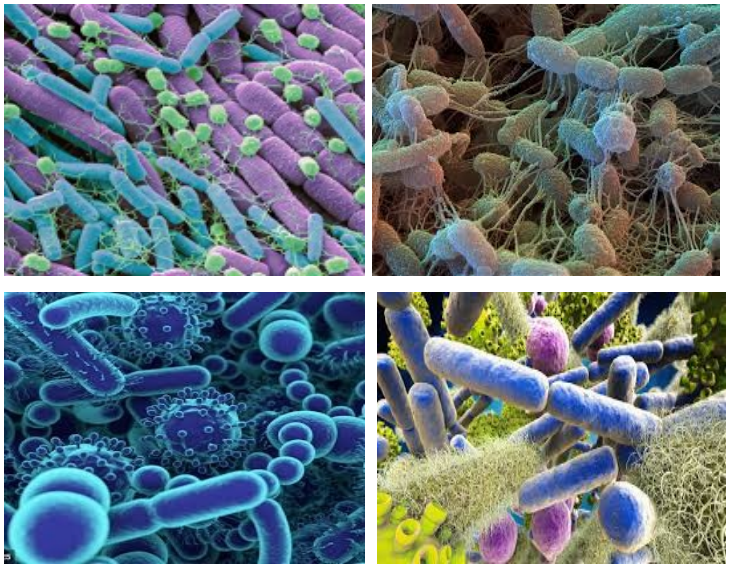
# Restoring Soil Fertility: The Role of Plant Growth Promoting Rhizobacteria in Salinity Management

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# Presentation Outline

- Introduction
- Salt affected soils
- Microbial approach
- Importance of PGPR
- Mechanism of PGPR
- Screening and application of PGPR
- Potential of PGPR under saline conditions
- Commercial use of PGPR
- Conclusion

- Soil salinity is one of the most significant challenges in agriculture, hindering crop growth and reducing productivity

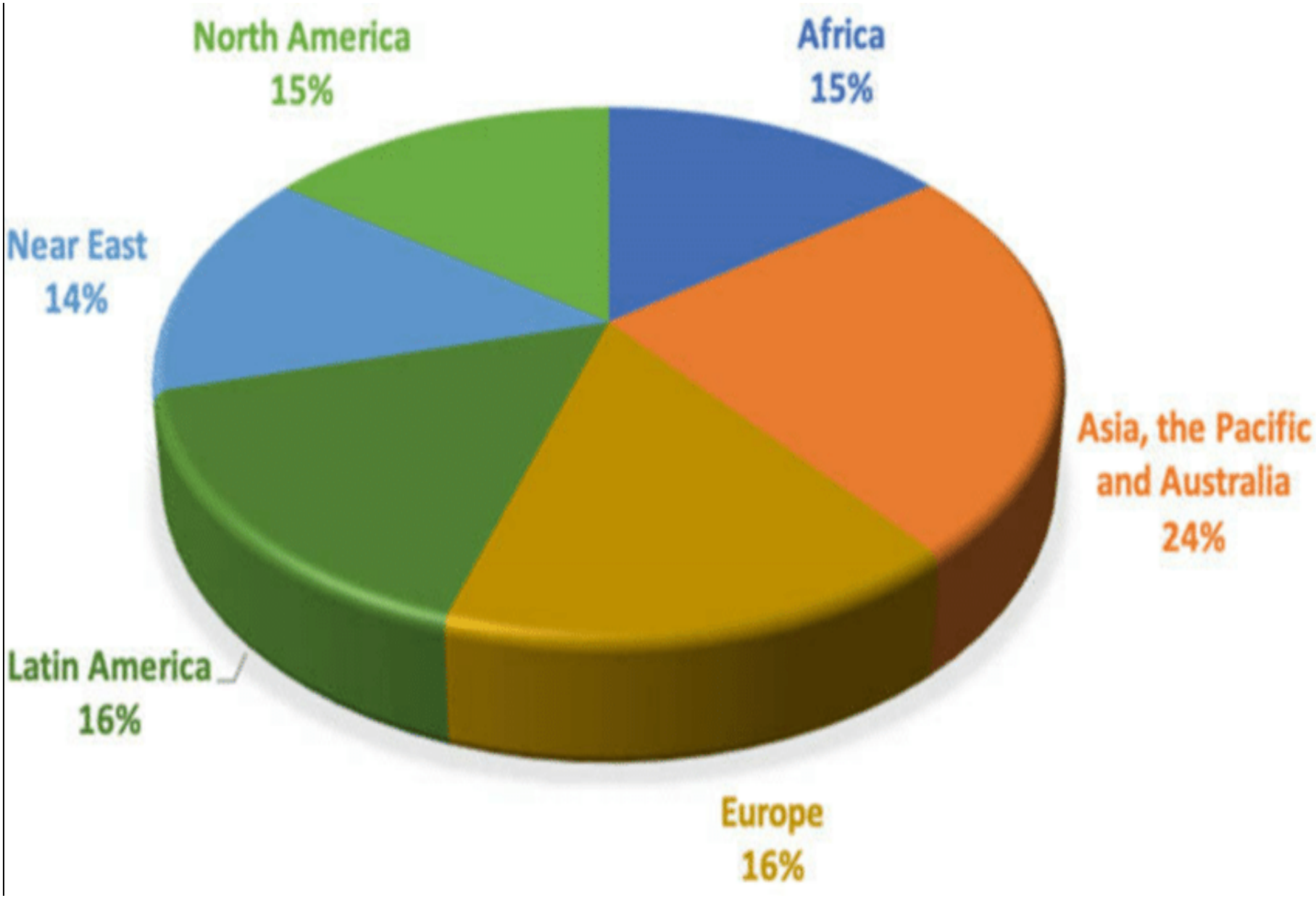
  (Singh & Singh, 2022)
- Salt-affected soils are widespread globally, particularly in arid and semi-arid regions, covering approximately one billion hectares

- Pakistan, situated in a semi-arid zone, faces severe soil salinization, with 25% of its irrigated land ($6 \times 10^6$ ha) affected equivalent to 3.9% of the world's total salt-affected soils

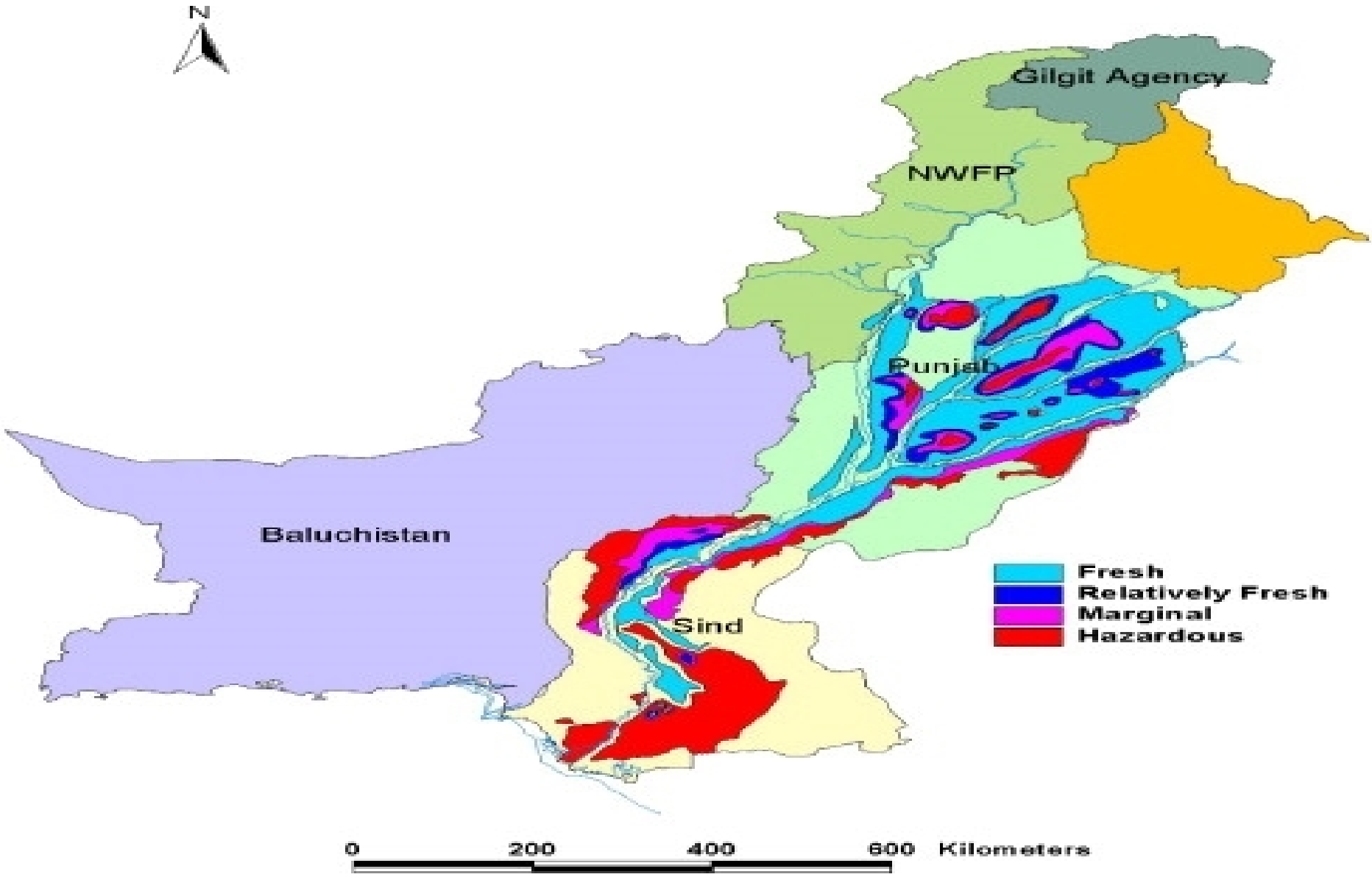
**Salt affected soils**

# The Extent of Soil Salinity

# Distribution of salt affected soils in the world



# Soil salinity in the Indus Basin of Pakistan



# Classification of salt-affected soils

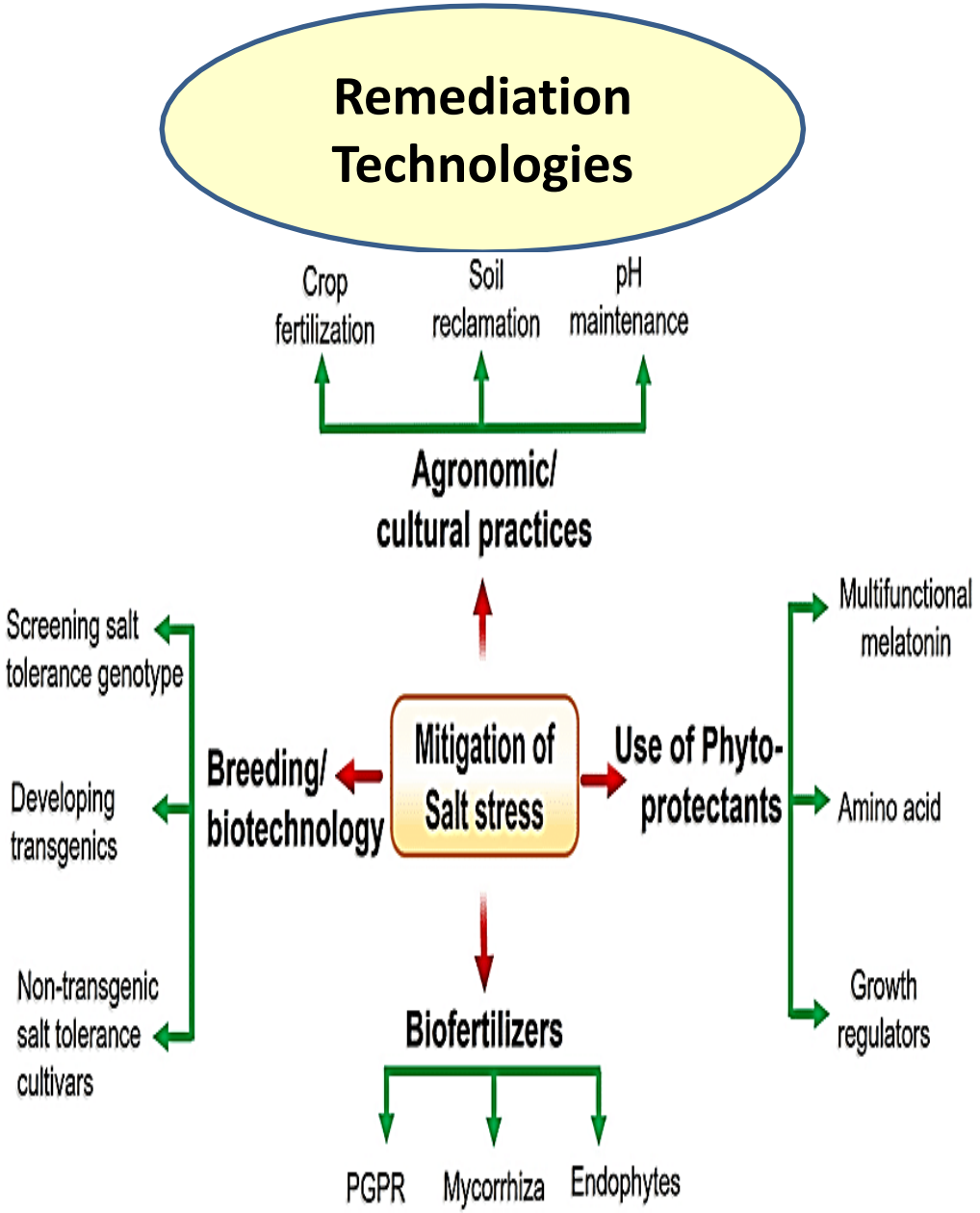
| Soil Salinity/Sodicity type | Electrical conductivity (EC) (dS $m^{-1}$) | Exchangeable sodium percentage (ESP) (%) | Sodium adsorption ratio (SAR)* | pH |
|---|---|---|---|---|
| Saline soil | > 4 | < 15 | < 13 | < 8.5 |
| Sodic-only soil | < 4 | >15 | >13 | >8.5 |
| Saline-sodic soil | > 4 | > 15 | > 13 | < 8.5 |

*SAR of the soil water extract

# Remediation of soil salinity

- To restore soil fertility, remediation strategies using chemical, physical, and biological methods are recommended.
- Numerous studies highlight the role of microorganisms in improving saline soils, particularly salt-tolerant bacterial strains naturally present in such environments

(Huang et al., 2025)



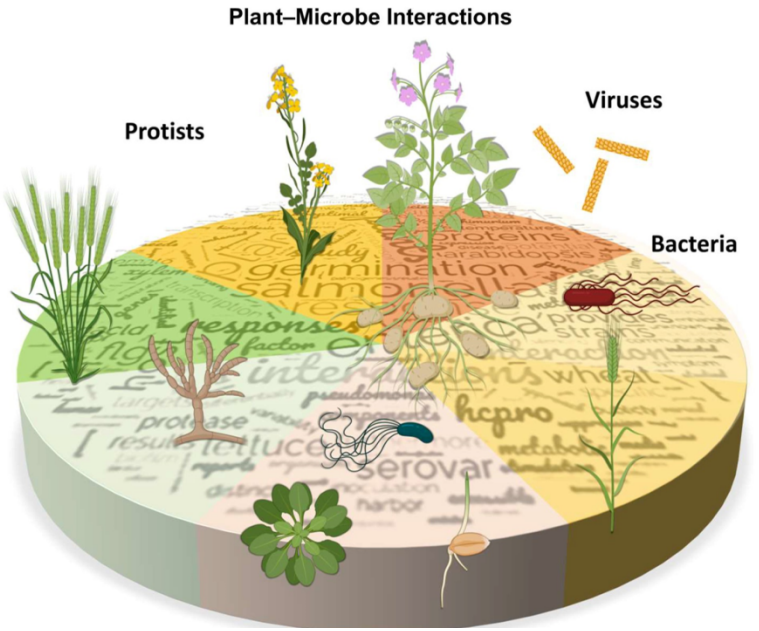
# Microbiota of soil

- Salinity is recognized as an important factor in determining bacterial communities in numerous ecosystems

- Healthy soils contain more diverse microbial populations in terms of species richness

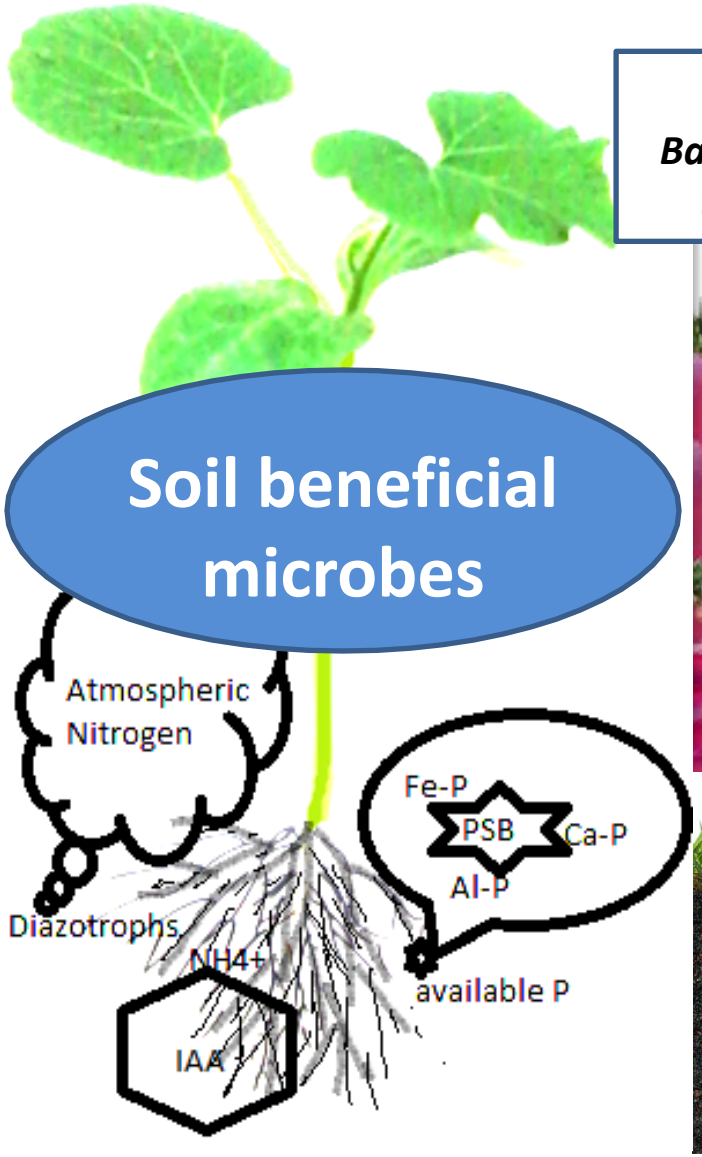
- One gram of medium contains $10^8$ to $10^9$ bacterial cells, $10^7$ to $10^8$ actinomycete cells, $10^5$ to $10^6$ fungal cells, and thousands of other species

**(Microbes et al., 2022)**



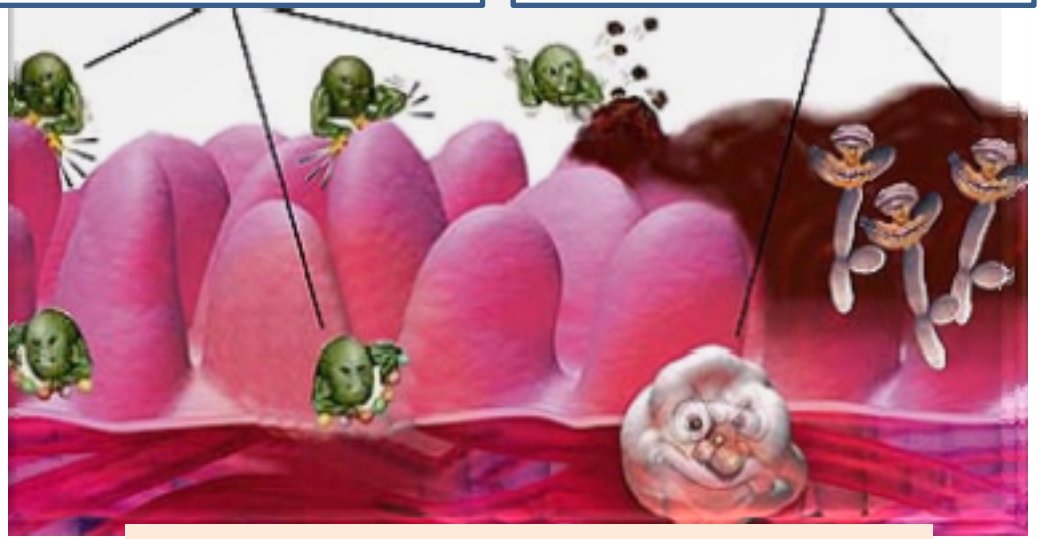

**(Microbes in soil**

# Microbial association with plants

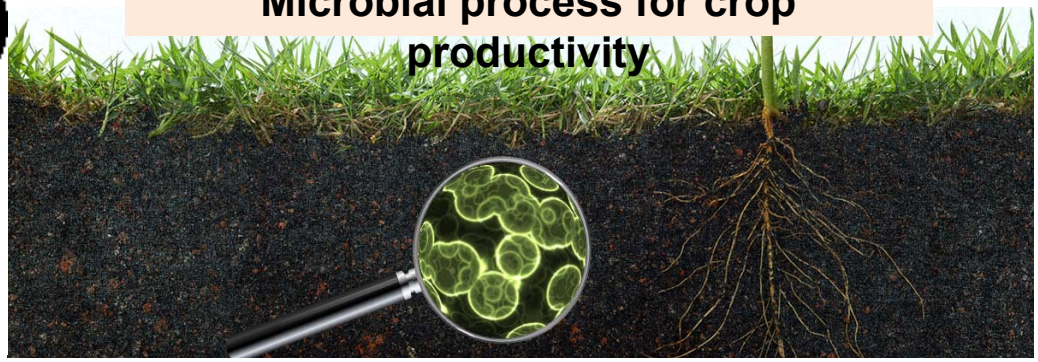



**Friendly microbes**
***Bacillus* sp., *Pseudomonas* sp., *Rhizobium* sp. etc**

**Unfriendly microbes**
**Pathogenic bacteria & fungi e.g. *Rhizoctonia sp.***



**Microbial process for crop productivity**



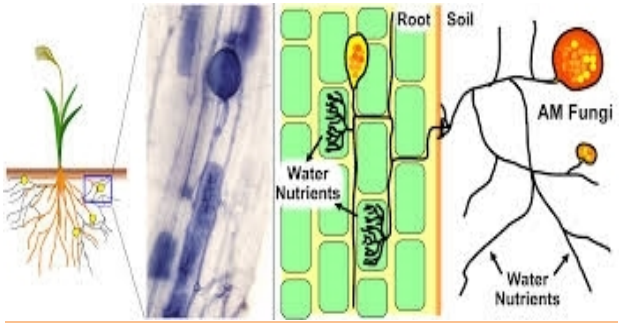
- Various microbial groups, including halophilic bacteria, arbuscular mycorrhizal fungi, cyanobacteria, and plant growth-promoting rhizobacteria (PGPR), have been shown to enhance plant growth under salt stress condition

- PGPR can also fix nitrogen and solubilize phosphorus, making nutrients more available to plants

- Incorporating salt-tolerant microbes into soil inoculation practices can significantly boost crop yields

(Wu et al., 2024)

Halophilic PGPR




Arbuscular mycorrhizal fungi

Cyanobacteria

- Several plant growth promoting rhizobacteria (PGPR) are very useful for high crop yields

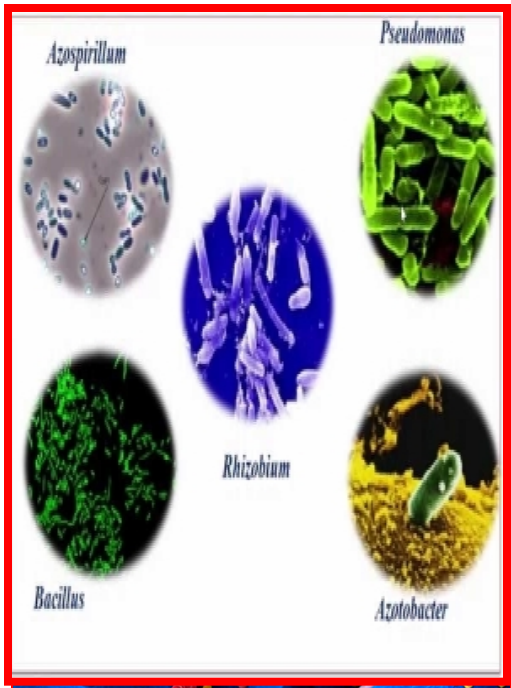
(Panhwar et al., 2014)

- In addition, PGPR can be a new approach for sustainable crop production

(Panhwar et al., 2017)

- The judicious use of chemical fertilizers with microbes can be a supplement source for crop production under stress conditions

(Dobrei et al., 2001)




PGPR

- Several PGPR including *Pseudomonas, Bacillus, Enterobacter, Agrobacterium, Streptomyces, Klebsiella*, and *Ochromobacter* have demonstrated the ability to enhance crop productivity under saline stress conditions

- PGPR exhibit beneficial traits that allow them to mitigate the toxic effects caused by high salt concentrations and improve plant growth

- Salt-tolerant PGPR have improved crop yields in soils with salinity levels ranging from 4–8% NaCl

(Panhwar et al., 2024)

- The development and application of halophilic plant growth-promoting rhizobacteria offer a promising strategy for sustainable agriculture in salt-affected regions.

- Therefore, the importance of these beneficial microbes has been increased recently due to their prospective use

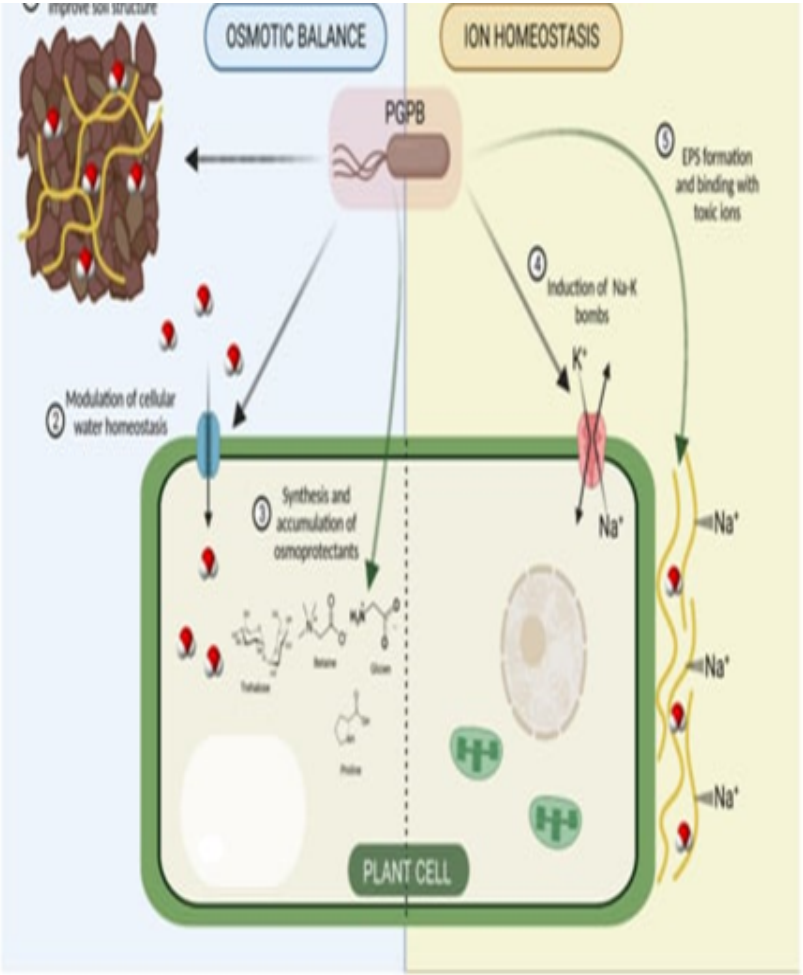
(Panhwar et al., 2020)

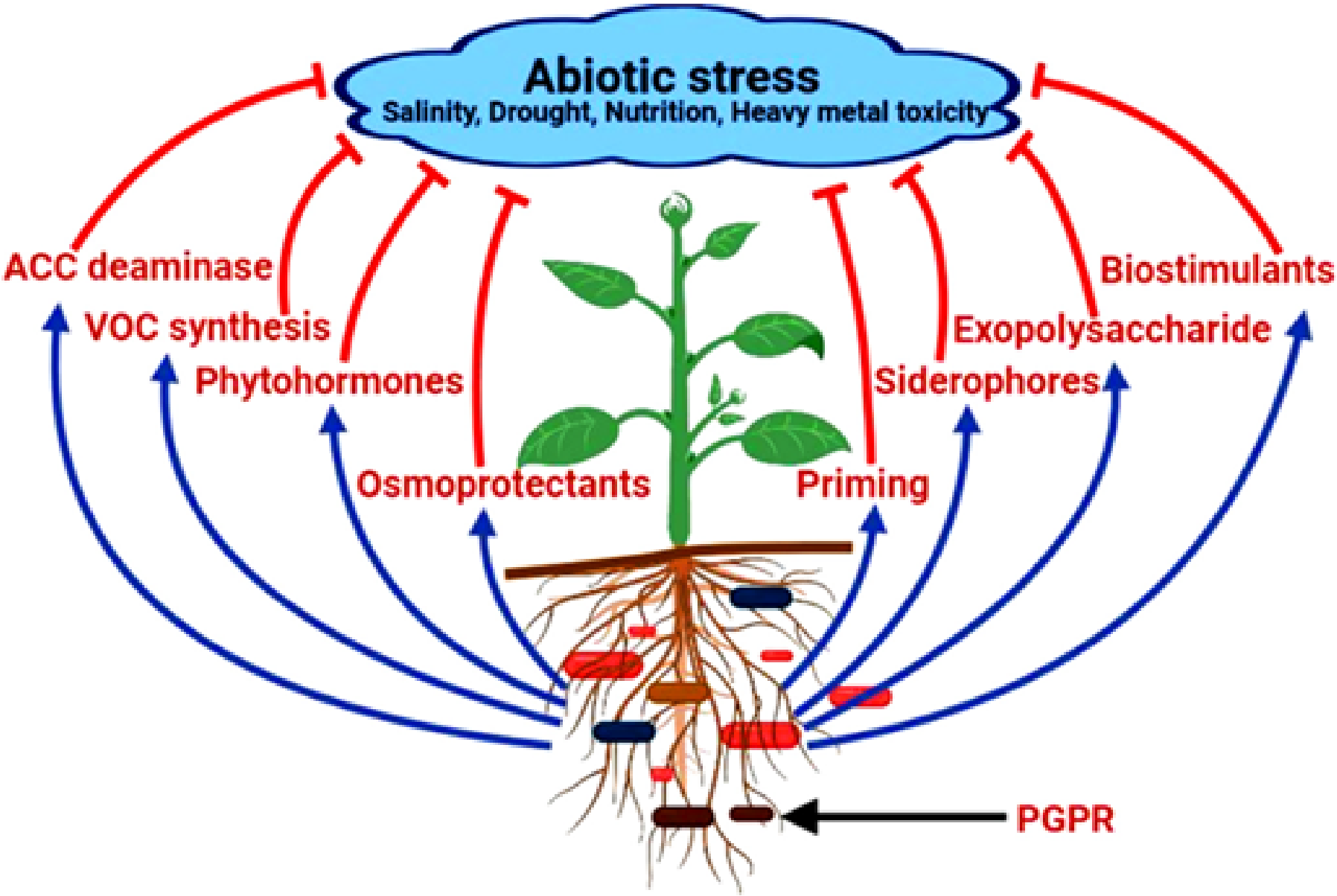
# Mechanism of salinity tolerance induced by PGPR

**PGPR can increase plant development in a salt environment in two ways:**

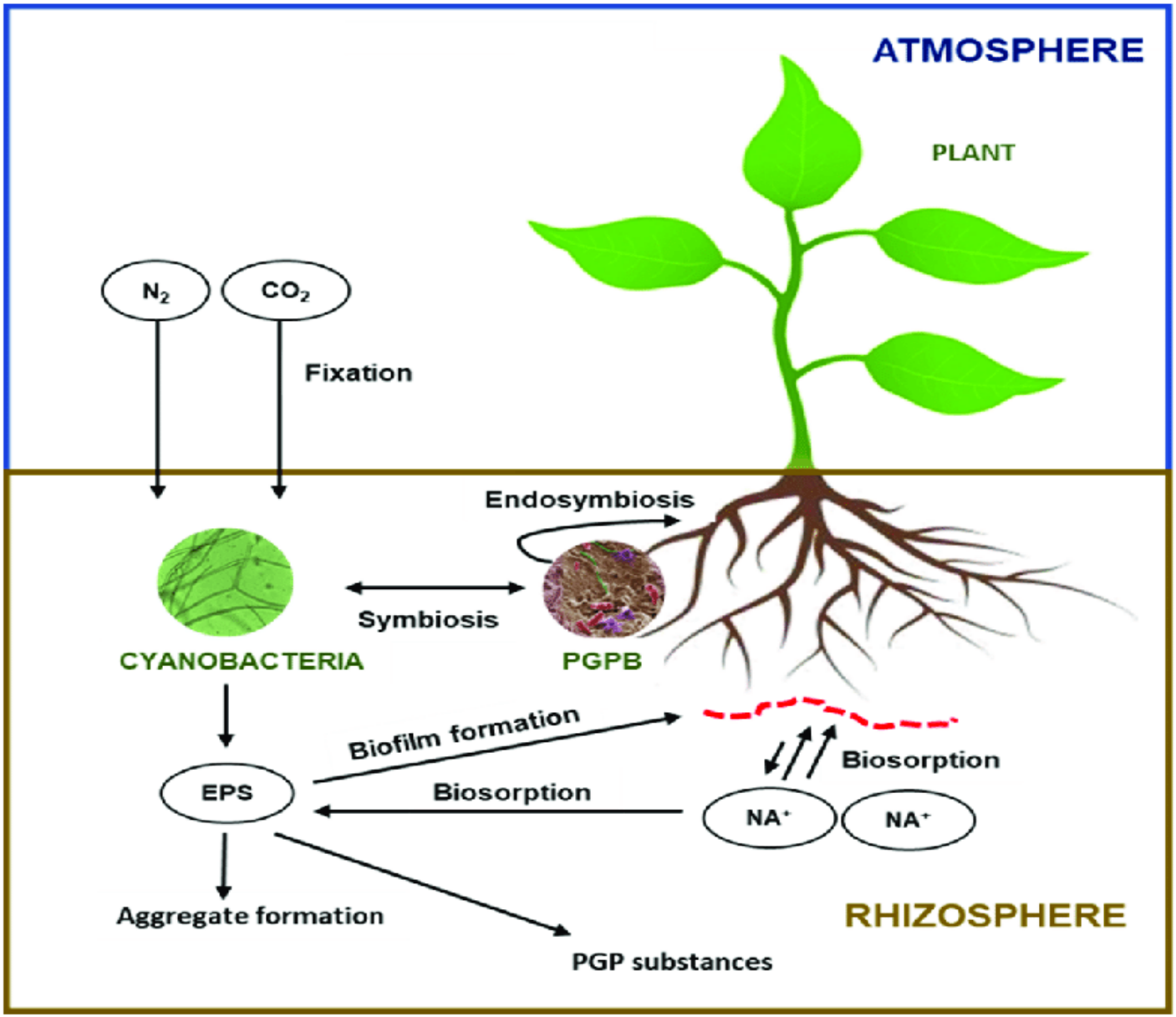
(i) **Activating or regulating plant response systems during salt exposure**, and

**(ii) Manufacturing anti-stress molecules** and resistance of plants exposed to salinity, the processes include improving nutrient uptake e.g., $N_2$ fixation, P-solubilization etc





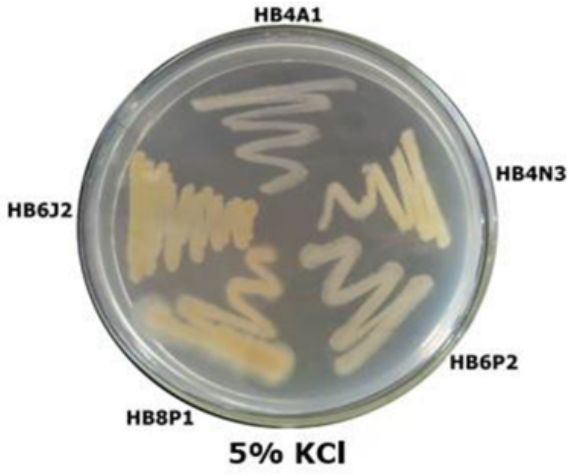

# PGPR: Mechanisms to Alleviate Abiotic Stresses



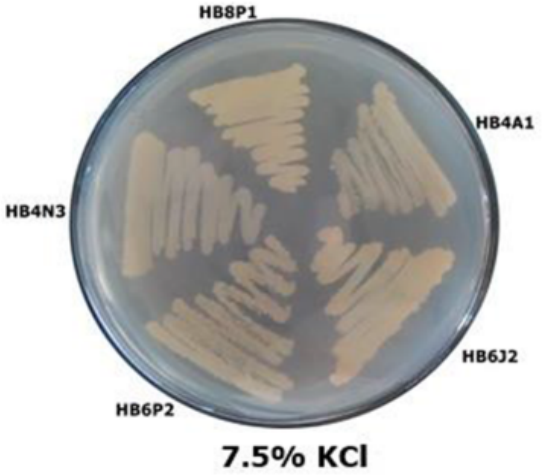

# Mechanisms of salt-affected soils remediation by bacteria

# Screening and Applications of PGPR in Saline Soils

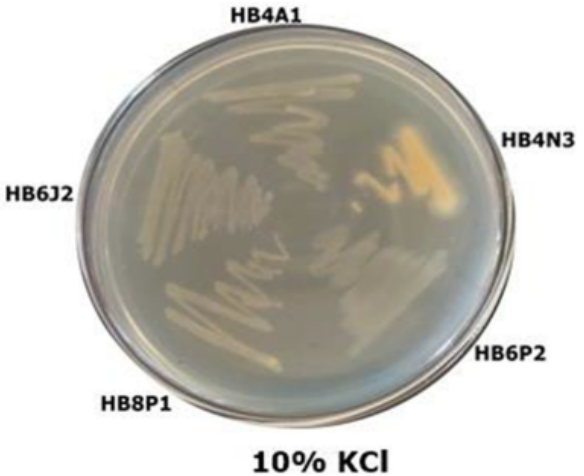
# Screening of salt tolerance PGPR



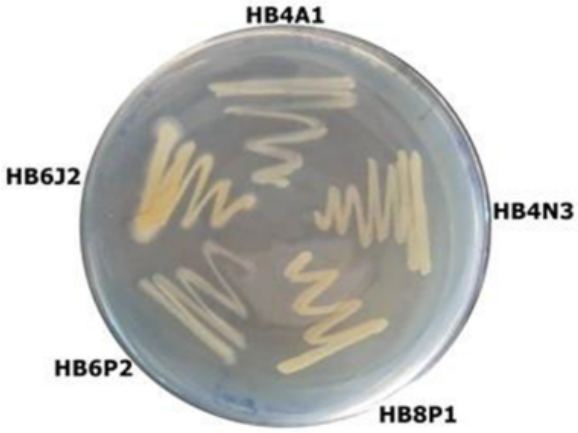
5% KCl



7.5% KCl

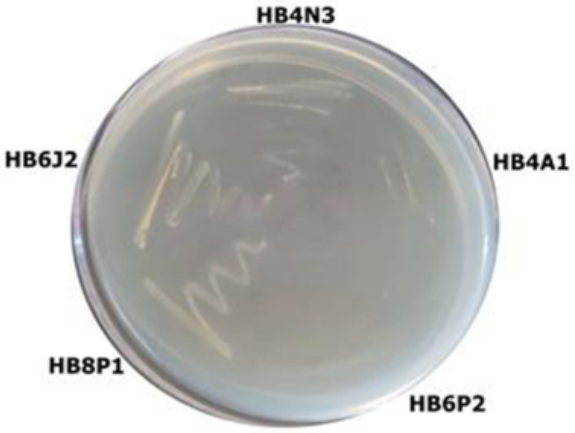


10% KCl

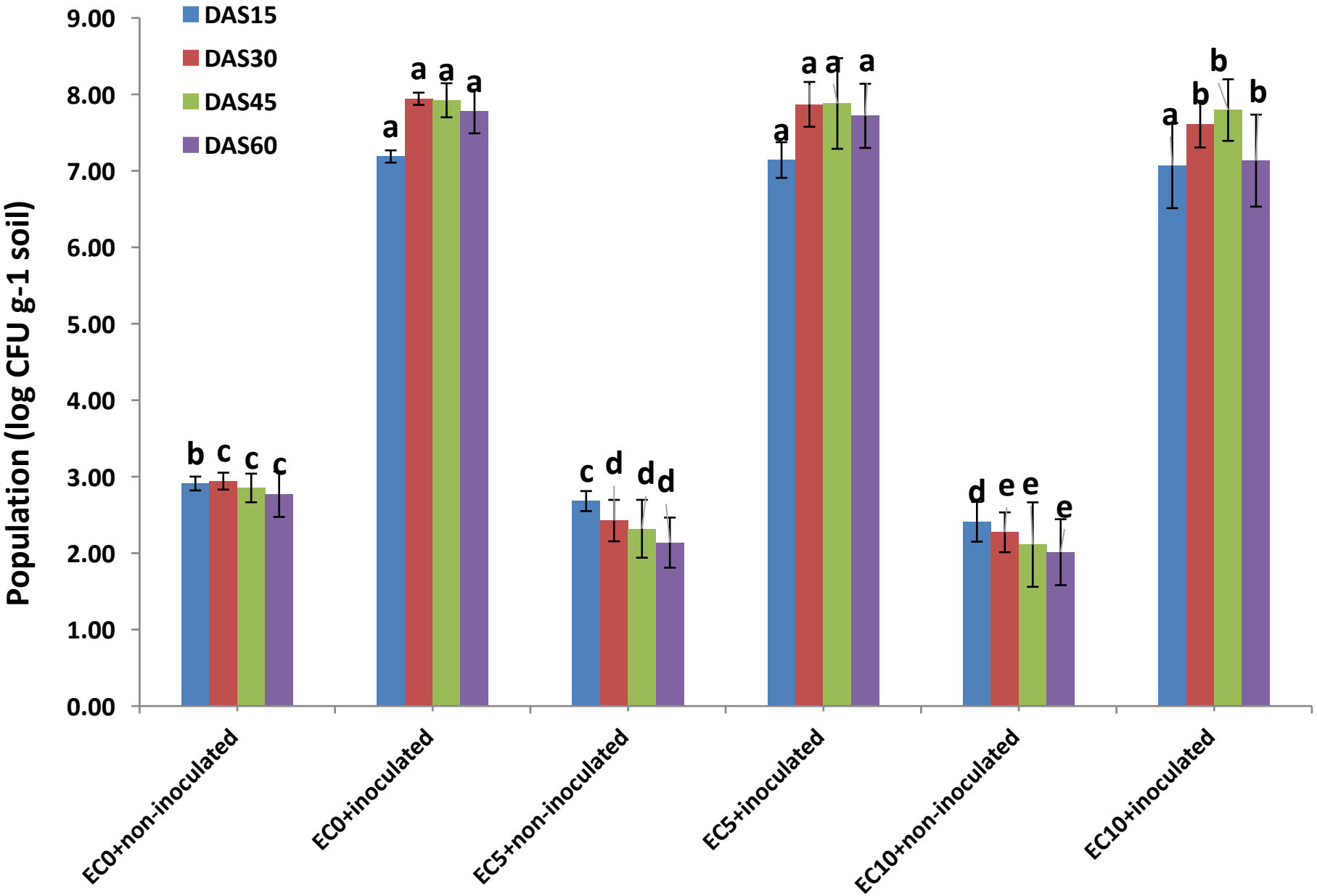


5% NaCl

7.5% NaCl



10% NaCl

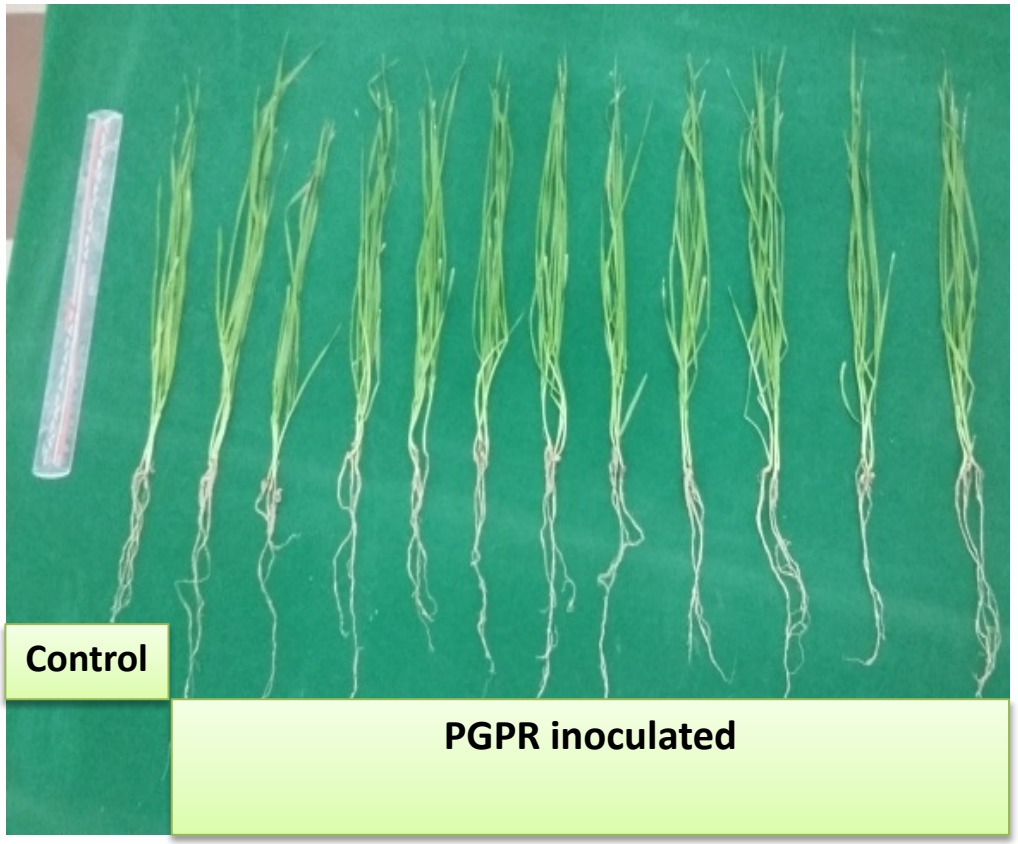



# Total bacterial counts at different salinity levels

# Screening of salt tolerant PGPR inoculated with wheat and rice plants

Control

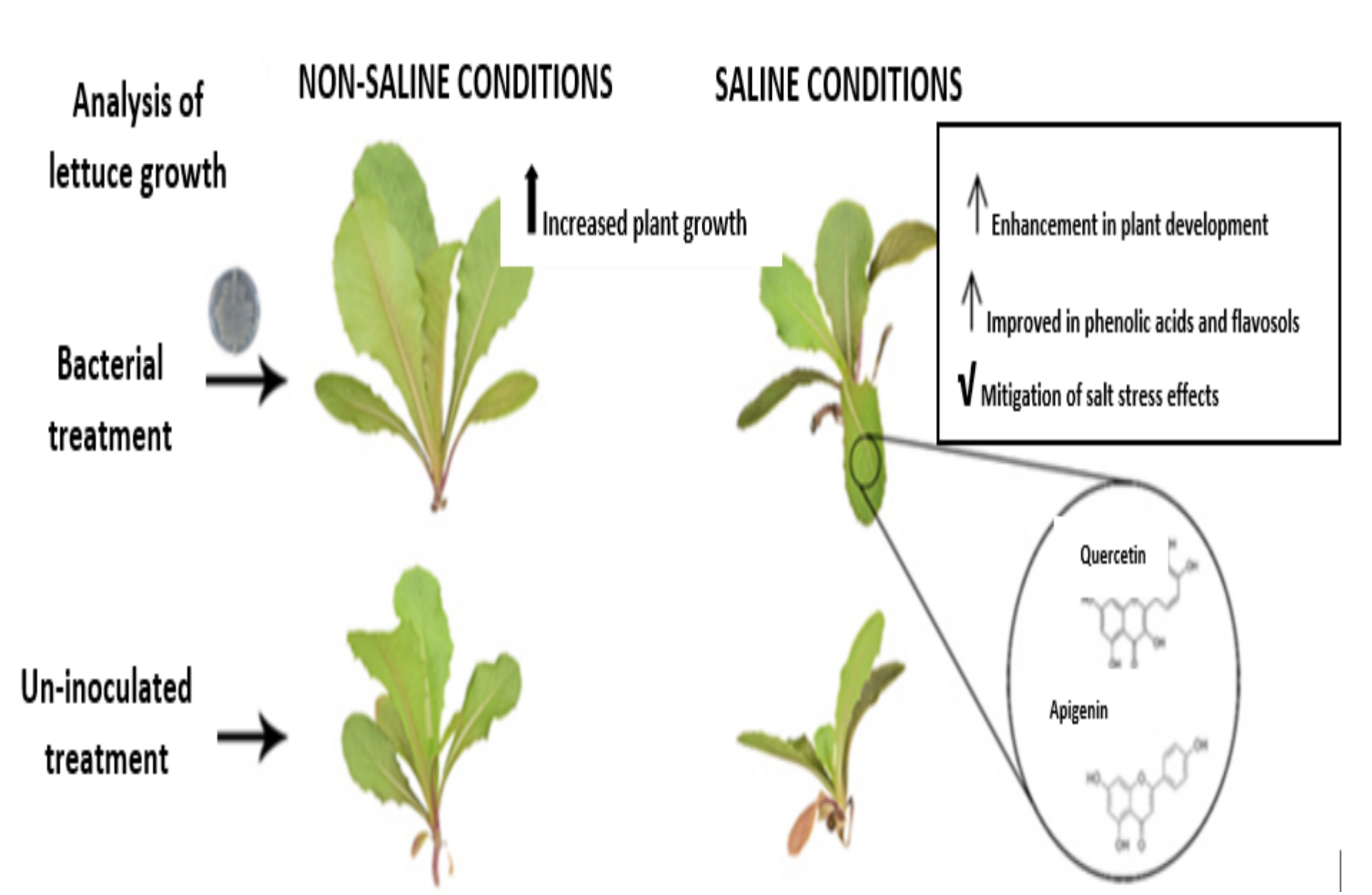
PGPR inoculated



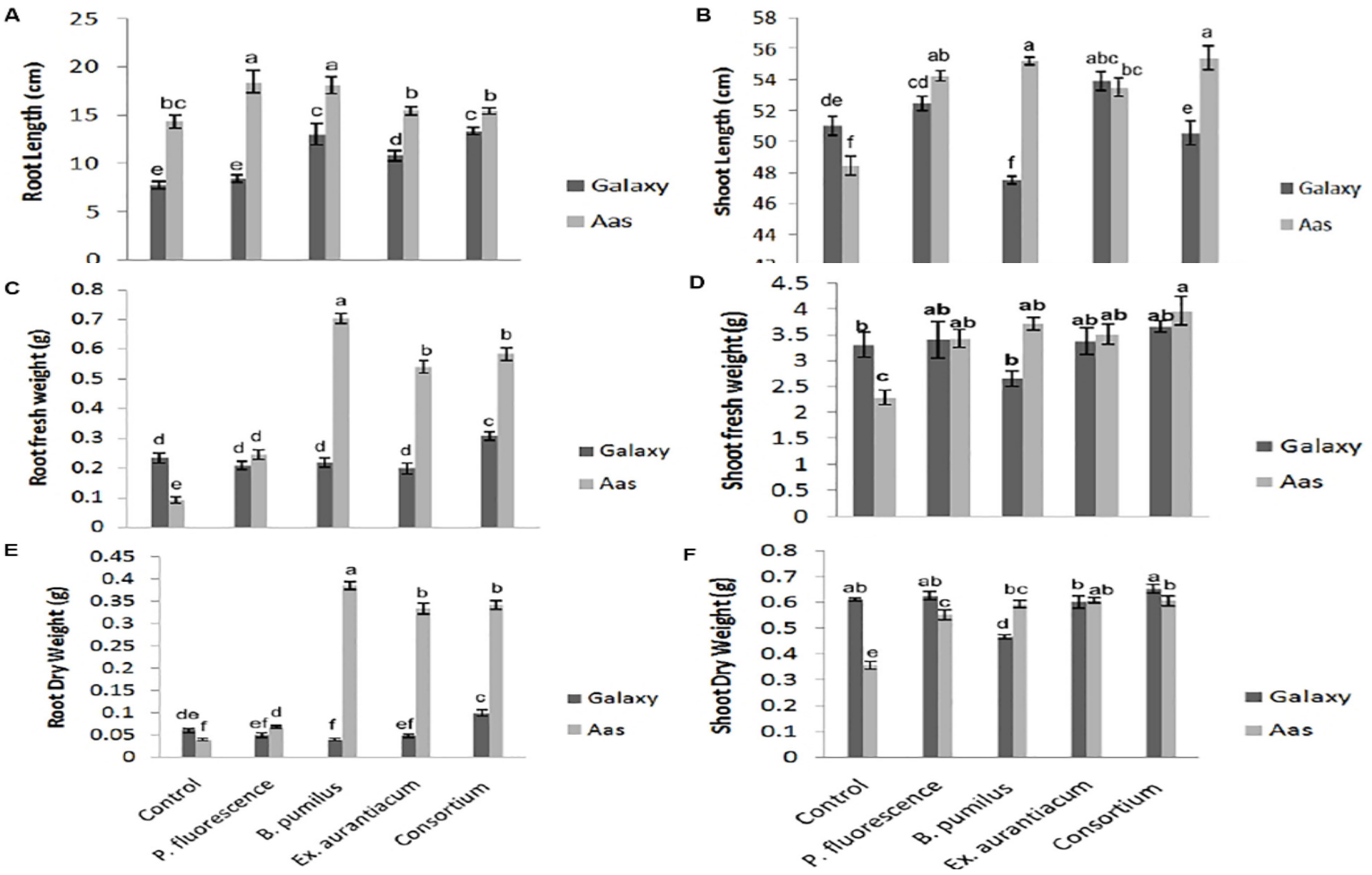
# Salt tolerance efficiency of bacterial strains isolated from various locations of spinach grown area

| No. | Strain | Salt concentration (%) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.5 | 1 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4 | 5 | 7.5 | 10 | 12.5 | 15 |
| 1 | SP-1 | +++ | +++ | +++ | + | + | + | + | + | + | + | + | + | - | - |
| 2 | SP-2 | +++ | +++ | + | + | + | + | + | + | + | + | + | - | - | - |
| 3 | SP-3 | +++ | +++ | + | + | + | + | + | + | + | + | - | - | - | - |
| 4 | SP-4 | +++ | +++ | + | + | + | + | + | + | + | + | - | - | - | - |
| 5 | SP-5 | +++ | +++ | +++ | +++ | +++ | ++ | ++ | ++ | ++ | + | + | + | + | - |
| 6 | SP-6 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | ++ | ++ | + | - |
| 7 | SP-7 | +++ | +++ | +++ | +++ | ++ | + | + | + | + | + | + | + | - | - |
| 8 | SP-8 | +++ | +++ | ++ | ++ | ++ | ++ | + | + | + | + | + | + | + | - |
| 9 | SP-9 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | ++ | + | + | - |
| 10 | SP-10 | +++ | +++ | +++ | +++ | ++ | ++ | ++ | ++ | ++ | + | + | + | - | - |
| 11 | SP-11 | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | +++ | ++ | ++ | + | - |
| 12 | SP-12 | +++ | +++ | ++ | ++ | + | + | + | + | + | + | + | - | - | - |
| 13 | SP-13 | +++ | +++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | - |
| 14 | SP-14 | +++ | +++ | ++ | ++ | ++ | ++ | + | + | + | + | + | + | - | - |
| 15 | SP-15 | +++ | +++ | ++ | ++ | + | + | + | + | + | + | + | + | - | - |
| 16 | SP-16 | +++ | +++ | ++ | ++ | ++ | ++ | + | + | + | + | + | + | - | - |
| 17 | SP-17 | +++ | +++ | +++ | ++ | + | + | + | + | + | + | - | - | - | - |

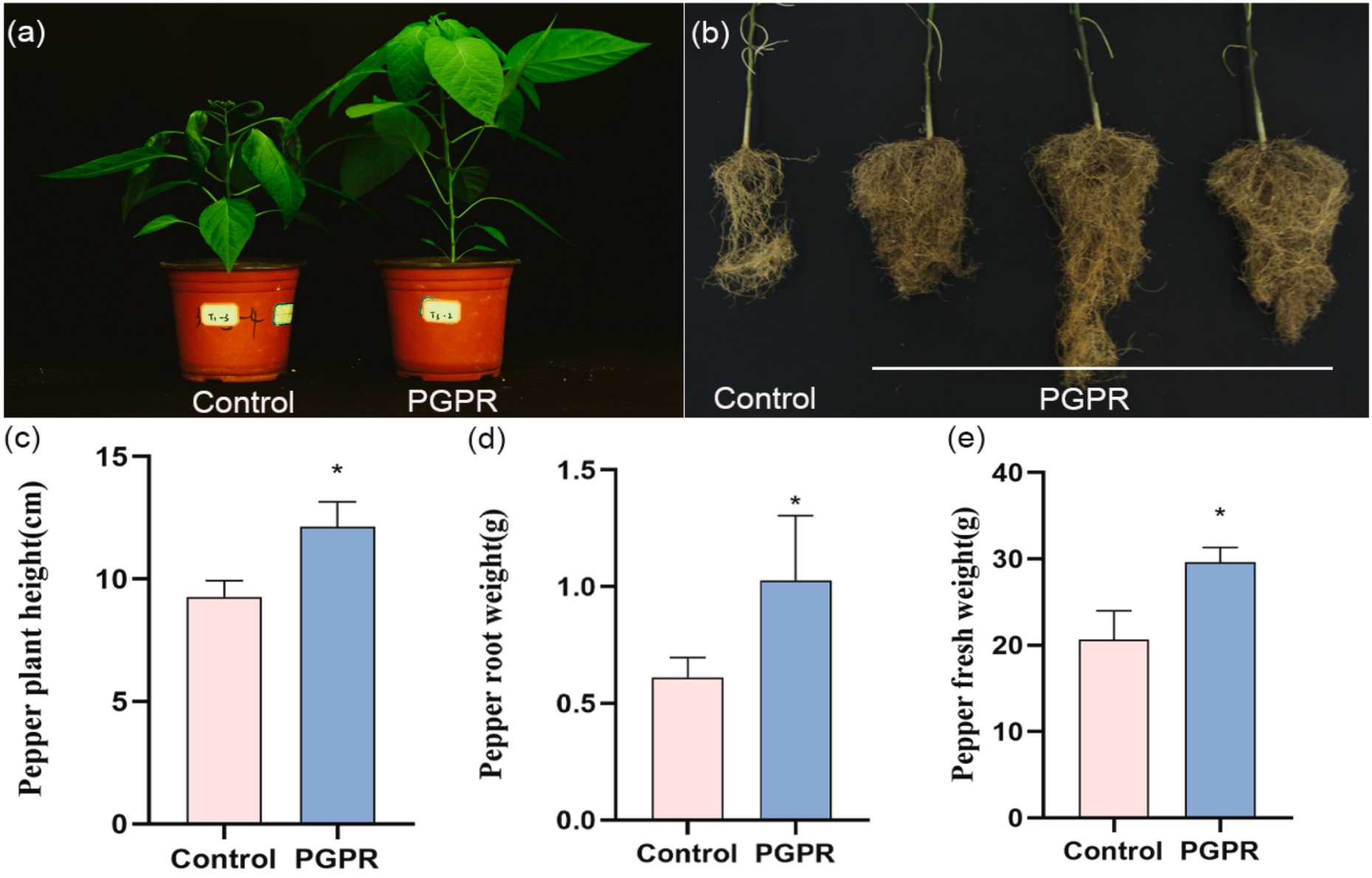
**Note: - Sensitive, + Slightly tolerant, ++ Moderately Tolerant, +++ Tolerant**



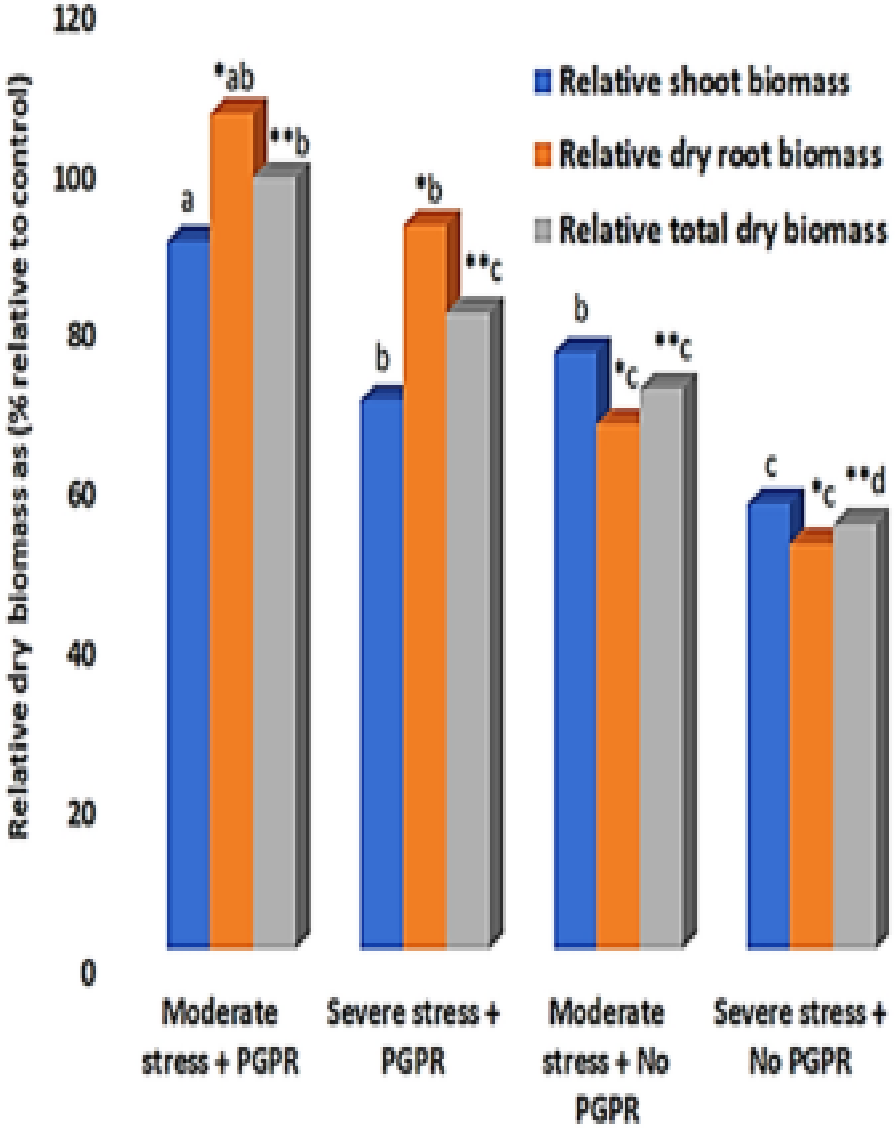

# Effect of PGPR under saline conditions

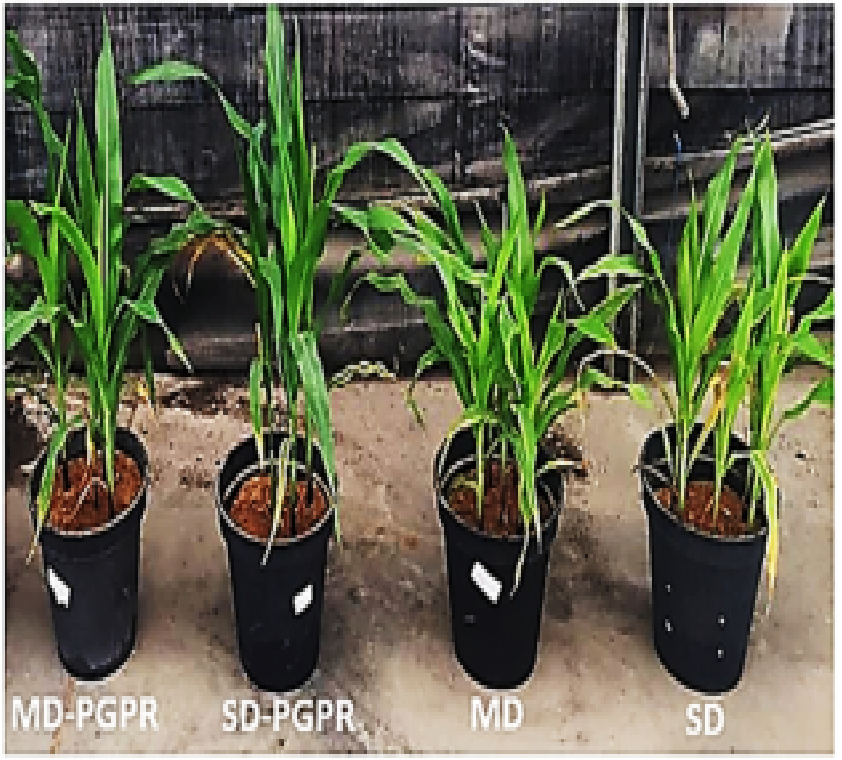



# Effect of salt tolerant PGPR on growth attributes of wheat varieties under saline condition




**Plant growth-promoting rhizobacteria (PGPR) improve the growth and quality of pepper plant**




**Effect of PGPR protect the maize plants from salt stress**


**Effect of PGPR to improve plum plant growth under salt stress**


**Application of microbes floating treatment wetland for the remediation of swage wastewater of Faisalabad city**

# PGPR Based Commercial Products used for Saline Soils







# Commercial PGPR based bio-fertilizers used in Pakistan





# PGPR used as bio-control agents against insects and diseases


Bio-insecticide


Bio-fungicide


Bio-insecticide product in Pakistan

# NIA-BIOBOOSTER (Patent Product)


# CONCLUSION

- **Soil salinity is a worldwide issue that impacts the soil's health, crop productivity and environment**

- **The microbial-based approaches can mitigate soil salinity, enhance soil fertility, and improve crop productivity, making them a viable solution for long-term agricultural sustainability**

- **PGPR supports higher crop productivity through natural processes like $N_2$ fixation, phytohormone production, and stress alleviation, making them an eco-friendly alternative to chemical inputs in agriculture**

- **The potential PGPR strains could be a substitute nutrient source (bio-fertilizer) to reduce mineral fertilizer application for sustainable crop cultivation and mitigating soil salinity**


Thank you