Microbial Seed Coating for Drought Resilience in Cotton (Gossypium hirsutum L.): Potential Roles of Plant Growth-Promoting Bacteria

Kommineni Rama Rao*

Agricultural College, Bapatla-522101
Acharya N.G. Ranga Agricultural University, Lam, Andhra Pradesh

Corresponding Author
Kommineni Rama Rao
Email: ramaraok901@gmail.com

OPEN ACCESS

Keywords

Gossypium hirsutum; Drought Stress; Plant Growth-Promoting Bacteria; Microbial Seed Coating; ACC deaminase; Seed bacterization

How to cite this article:

Ramarao, K. 2026. Microbial Seed Coating for Drought Resilience in Cotton (Gossypium hirsutum L.): Potential Roles of Plant Growth-Promoting Bacteria. *Vigyan Varta* 7 (11): 66-69.

ABSTRACT

Drought increasingly threatens cotton (Gossypium hirsutum L.) production by restricting seedling establishment, root development, and reproductive growth. Microbial seed treatments offer a potential biological complement to drought-adapted cultivars and soil-water management because beneficial bacteria can be delivered close to emerging roots. Plant growth-promoting bacteria may influence drought responses through several mechanisms, including the moderation of stress-associated ethylene by 1-aminocyclopropane-1-carboxylate deaminase, production of exopolysaccharides, changes in root architecture, nutrient mobilization, and regulation of osmotic and antioxidant responses. Here, we synthesize the published evidence on cotton-associated bacteria and outline a framework for evaluating bacterial seed coating under defined water-deficit conditions. A published cotton study reported that selected phyllosphere isolates tolerated osmotic stress and that seed treatment with an Acinetobacter isolate was associated with improved germination and seedling vigor under the conditions tested. These findings support further investigation but do not establish that all strains or coating formulations produce consistent benefits. We propose evaluating inoculant identity, viable cell delivery, coating compatibility, root colonization, and plant responses in replicated experiments,

followed by multi-location field testing. Microbial seed coating could improve cotton establishment reliability in water-limited environments, provided that strain-specific effects, formulation stability, agronomic performance, and economic feasibility are demonstrated under realistic growing conditions.

INTRODUCTION:

Cotton is an economically important fiber crop; however, irregular rainfall and inadequate soil moisture can impair germination, seedling establishment, photosynthesis, and boll development in cotton plants. Water deficit may also induce oxidative stress and increase the shedding of reproductive structures. In addition to drought-adapted cultivars and soil moisture conservation, researchers have investigated beneficial microorganisms as biological tools to support crop performance under water limitation (Ngumbi, E., and Kloepper, J. 2016; Vurukonda *et al*., 2016). Plant growth-promoting bacteria (PGPB) can colonize plant surfaces or roots and influence growth by altering root development, nutrient availability, plant signaling, and stress physiology (Chieb, M., and Gachomo, E.W. 2023). Recent cotton research has also reported physiological and biochemical responses to rhizobacterial inoculation under water deficit, emphasizing the need for further validation under field conditions (Pereira *et al*., 2026). Seed coating may facilitate the delivery of inoculants near the emerging radicle; however, bacterial survival during storage and consistent establishment after sowing remain important considerations.

Materials and Methods

- **Isolation and characterization of PGPB:**

For future studies, cotton leaves and/or rhizosphere soil from drought-prone fields should be collected using aseptic techniques. Bacteria should be isolated and purified using serial dilution and plating, and colony characteristics, osmotic stress tolerance, and plant growth-promoting traits, including EPS, IAA, ACC deaminase, phosphate solubilization, and siderophore production, should be assessed. Promising isolates should be identified through 16S rRNA gene sequencing and preserved in authenticated cultures under appropriate laboratory biosafety procedures.

Sharath *et al*. (2021) reported 31 cotton phyllosphere bacterial isolates, of which 15 tolerated the highest osmotic stress. The five selected isolates were identified as Pseudomonas stutzeri, Acinetobacter sp., Bacillus mojavensis, Pseudomonas chlororaphis, and Enterobacter asburiae.

Evaluation of seed coating effects on cotton growth

- **Seed-coating formulation and application:**

Select authenticated PGPB isolates and prepare fresh cultures in a suitable growth medium. Harvest and wash the cells, as appropriate, and resuspend them in a compatible carrier at a quantified viable cell concentration. Apply a defined volume of suspension to cotton seeds using a validated, non-toxic binder, and mix to achieve uniform coverage. Dry the seeds under conditions that

maintain bacterial viability. Include untreated seeds and carrier-only-coated seeds as controls. Assess coating uniformity, seed germination, and viable cell counts immediately after coating and at defined storage intervals. Determine the appropriate inoculum concentration, carrier, and binder through preliminary compatibility and viability tests.

- **Greenhouse pot experiment and plant measurements:**

A replicated greenhouse experiment was conducted using a randomized factorial design to compare untreated, carrier-coated, and PGPB-treated seeds under well-watered and defined drought conditions. Uniform pots and characterized soil were used to maintain consistent plant density and monitor soil moisture. Seedling emergence, survival, plant height, leaf number, root length, biomass, and root-to-shoot ratio were recorded. Where facilities permitted, relative water content, chlorophyll, proline, malondialdehyde, and antioxidant enzyme activities (SOD, CAT, and peroxidase) were measured. Bacterial viability and root colonization were assessed to determine their association with plant responses. Bacterial consortia were included only after compatibility testing.

Statistical analysis

Analyze seed treatment and moisture regime using two-way ANOVA, including their interaction, where assumptions are met. Apply Tukey's HSD for multiple comparisons when appropriate. Check residual normality and variance homogeneity using suitable transformations or alternative models, if necessary. Report replicate numbers, means, standard errors, confidence intervals, p-values, and effect sizes. Treat the pot as the experimental unit, unless the design justifies otherwise. These proposed methods should be adapted to the final experimental design and dataset.

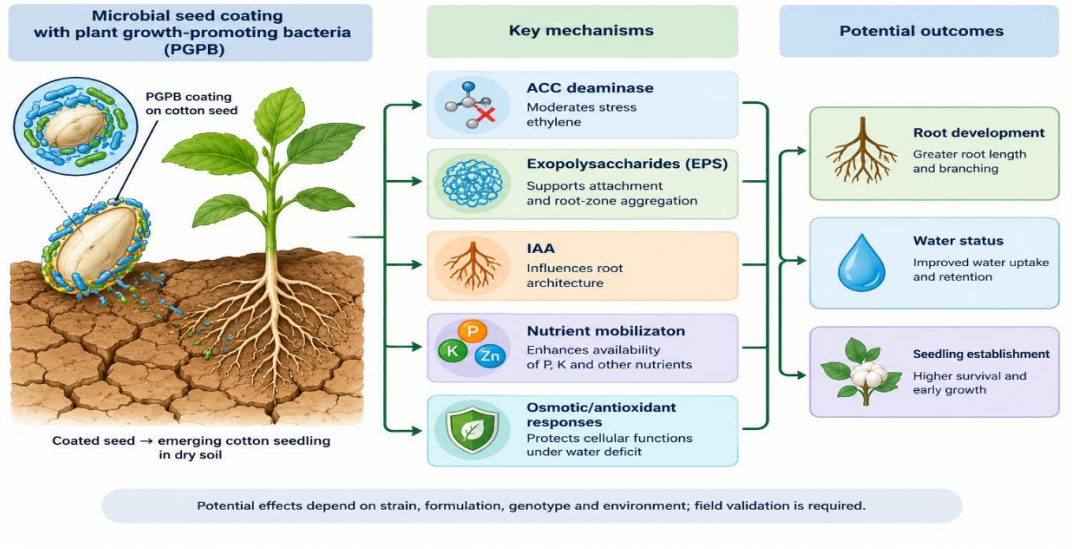
Results and Discussion

- **Effects of PGPB on Cotton under Drought Stress:**

Sharath *et al*. (2021) reported that Acinetobacter sp.-treated cotton seeds achieved the highest germination percentage (76.67%) among the tested treatments, along with improvements in seedling vigor and health. This study also reported changes in root length, fresh weight, proline content, and number of bolls. Pereira *et al*. (2026) found that Leifsonia sp. CR132 and Enterobacter sp. CR14 influenced cotton growth and physiological responses, including antioxidant enzyme activity, under different water availability conditions, including severe water stress.

Potential mechanisms include ACC deaminase-mediated regulation of stress ethylene, EPS-associated bacterial attachment, IAA-induced root development, nutrient mobilization, and antioxidant responses (Ngumbi, E., and Kloepper, J. 2016; Vurukonda *et al*., 2016; Chieb, M., and Gachomo, E.W. 2023). However, these effects depend on the bacterial strain, cotton genotype, soil conditions, and drought severity. Further field validation is necessary before recommending specific microbial seed-coating formulations for commercial use.

Figure 1. Proposed mechanisms through which PGPB may influence drought-stressed cotton



Research limitations and future directions

Microbial seed coating efficacy depends on bacterial survival, formulation compatibility, soil conditions, cotton genotype, and drought severity. Multi-location field trials are required to validate controlled-environment results. Future research should focus on strain authentication, formulation stability, shelf life, dose optimization, consortium compatibility, inoculant viability, root colonization, and economic feasibility. Biosafety assessment is also essential before agricultural applications.

CONCLUSION

Microbial seed coating with selected PGPB is a promising complementary strategy for supporting cotton establishment and potentially mitigating the effects of drought. Its reliable application requires well-characterized strains, compatible formulations, adequate bacterial viability at sowing, and a replicated evaluation under defined water-deficit conditions. Findings from controlled studies should be followed by multi-location field trials and economic assessments before recommendations are made. Microbial treatments should complement, rather than replace, drought-adapted cultivars and sound soil-water and nutrient management.

REFERENCES

Chieb, M., & Gachomo, E. W. (2023). The role of plant growth-promoting rhizobacteria in plant drought stress responses. BMC Plant Biology, 23, Article 407 https://doi.org/10.1186/ s12870-023-04403-8

Ngumbi, E., & Kloepper, J. (2016). Bacterial-mediated drought tolerance: Current and future prospects. Applied Soil Ecology, 105, 109–125. https://doi.org/10.1016/ j.apsoil.2016.04.009

Pereira, E. J., de Souza, V., da Silva Braulio, C., *et al*. (2026). Leifsonia sp. and Enterobacter sp. improve physiological and biochemical adjustments in cotton under water deficit. BMC Microbiology. https://doi.org/10. 1186/s12866-026-05545-z

Sharath, S., Triveni, S., Nagaraju, Y., Latha, P. C., & Vidyasagar, B. (2021). The role of phyllosphere bacteria in improving cotton growth and yield under drought conditions. Frontiers in Agronomy, 3, Article 680466. https://doi.org/10.3389/ fagro.2021.680466

Vurukonda, S. S. K. P., Vardharajula, S., Shrivastava, M., & SkZ, A. (2016). Enhancement of drought stress tolerance in crops by plant growth-promoting rhizobacteria. Microbiological Research, 184, 13–24. https://doi.org/10.1016/j. micres. 2015.12.003.