IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

An Overview of Salt-Tolerant Bacteria as Biofertilizers for Enhancing Saline-Sodic Soil Productivity.

SM. Titame[1*], BM. Gaykar[1], AA. Kulkarni[1] and BD. Takate[2]

[1]P.G. Department of Botany, Ahmednagar College, Ahmednagar (MH), India.

Savitribai Phule Pune University

[2]Dept. of Botany, Jijamata College of Science and Arts, Krushi Vigyan Farm, Loknete Marutirao Ghule Patil D.S.S.K. Ltd Bhende, Newasa, Ahmednagar (MH), India.

1. Abstract:

The review concluded that agriculture is the backbone of livelihood. However, imbalanced application of chemical fertilisers, outdated and heavy irrigation methods, and constant neglect of the specific health needs of agricultural soils have led to a significant increase in salinisation over time. Globally, this issue was first observed in agricultural regions of Iraq but has since become a prominent challenge in farming sectors worldwide, including India.

In India, the Green Revolution of 1968 revolutionised food production. However, the lack of proper agricultural guidance initially led to the emergence of this problem in states like Punjab, Haryana, and Uttar Pradesh, which has now extended across the country. Approximately 6.73 million hectares of Indian agricultural land are affected by salinity. This degradation is primarily due to the expansion of irrigated areas, over-reliance on chemical fertilisers, and inadequate incorporation of organic and biofertilizers. These practices have deteriorated soil structure, reduced organic carbon content, pH, electrical conductivity and inhibited beneficial microbial activities, creating significant challenges for sustainable agriculture.

Innovative research is essential to address this issue, and halotolerant bacteria offer a promising solution. Microbial species such as Bacillus and Pseudomonas thrive in saline soils, improving nutrient availability, regulating ion balance, enhancing plant resilience under salt stress, and promoting plant growth. Integrating these bacteria into agriculture through biofertilizer development and soil conservation techniques can significantly improve the productivity of salt-affected lands. With focused research and widespread adoption, these microbial strategies can pave the way for sustainable agriculture, ensuring resilience and productivity in salt-stressed regions.

Keywords: salinity, salt stress, halotolerant bacteria, biofertilizer, soil microbes.

2. Introduction:

Salt stress has been a concern throughout the world, as well as in India for many years, especially in regions with high soil salinity. Factors contributing to the problem include improper irrigation practices, imbalanced use of chemical fertilisers, poor drainage systems, and rising sea levels due to climate change, as well as industrialisation. In coastal areas of Gujarat, Tamil Nadu, Andhra Pradesh, and West Bengal, as well as in Maharashtra, Uttar Pradesh, Madhya Pradesh, Punjab, and many other states with large agricultural areas, this situation is generally increasing due to heavy use of irrigation practices and chemical fertilisers, particularly affecting crop production and agricultural productivity. Efforts to address salt stress in India include promoting salt-tolerant crop varieties, adopting improved irrigation and soil management practices, and implementing coastal zone management strategies to reduce the impact of rising sea levels on farmland. To compensate for the biological loss of the soil, it will be necessary to research and implement concrete solutions for using salt-tolerant bacterial fertilisers in the coming years.

The increasing prevalence of abiotic stresses, particularly salinity, significantly challenges global agricultural productivity. Halotolerant bacteria, capable of thriving in saline environments, have emerged as promising agents for enhancing plant growth and yield in salt-affected soils(Grover et al., 2011). Salinity stress adversely affects plant development and productivity in various crops worldwide, prompting the exploration of alternative solutions. Plant growth-promoting rhizobacteria (PGPR) have garnered attention for their potential to mitigate the detrimental effects of salinity on crop plants by enhancing stress tolerance and promoting growth(Alizadeh. et al., 2012). Salt-tolerant microbes, specifically salt-tolerant plant growth-promoting rhizobacteria (ST-PGPR), have the potential to enhance the productivity of saline agroecosystems and mitigate various biotic and abiotic stresses in plants, offering a sustainable solution for the reclamation of saline agroecosystems(Egamberdieva et al., 2019). Halotolerant plant growth-promoting rhizobacteria (HT-PGPR) secreted compounds that promoted plant growth and reduced the harmful effects of salinity stress by maintaining ion balance, increasing nutrient availability, and producing beneficial compounds, thus improving crop productivity and remediating degraded saline soils, presenting a key strategy for sustainable crop production in saline environments(Kumar et al., 2023).

3. Salt-tolerant bacteria:

Studies have highlighted the beneficial effects of specific salt-tolerant bacteria, such as *Bacillus pumilus* and *Bacillus subtilis,* in promoting plant growth and development under saline-sodic soil conditions. These bacteria exhibit multiple plant growth-promoting traits and demonstrate tolerance to high salt concentrations, making them valuable allies in sustainable agriculture(Damodaran et al., 2013). The potential of halotolerant bacteria, including *Planococcus rifietoensis,* to alleviate the toxic effects of salinity and enhance the growth and yield of crops like wheat has been demonstrated. These bacteria offer a viable solution for improving crop productivity under saline-stress conditions, thereby contributing to food security(Rajput et al., 2013). The pivotal role of plant growth-promoting rhizobacteria (PGPR) in enhancing crop resilience to salinity stress. By exploiting the unique properties of halotolerant PGPR strains, such as Pseudomonas strains PF1 and TDK1, significant improvements in plant growth and development have been achieved even under saline conditions, offering promising prospects for sustainable agriculture(Sen & Chandrasekhar, 2014). Halophilic bacteria strain, *Lelliottia amnigena*, exhibited plant growth-promoting rhizobacteria (PGPR) traits and notably enhanced wheat growth parameters and nutrient uptake while reducing sodium levels in plant tissues, offering a sustainable solution for alleviating salt stress and improving wheat production(El-Akhdar et al., 2020). Halophilic bacteria, such as *Pseudomonas spp*., *Azotobacter spp*., and *Bacillus spp*., showed promise in addressing challenges posed by sodic soils in agriculture by promoting plant growth, enhancing crop yields, and improving nutrient uptake, offering a sustainable solution to increase agricultural productivity in sodic soil-affected areas(Sonawane et al., 2021).

4. Effect of Salt-Tolerant Bacteria on the yield of crops:

Plant Growth-Promoting Rhizobacteria (PGPR) have shown promise in enhancing salinity stress resistance in crop plants, offering eco-friendly biofertilizers to improve growth and yield quality under saline conditions(Khan et al., 2019). Plant growth-promoting halophilic bacteria from saline soil exhibited various growth-promoting traits, including indole acetic acid production, phosphate solubilization, and nitrogen fixation, suggesting their potential for bioremediation of salt-affected soils(Mahamuni, 2020). Salt-tolerant plant growth-promoting rhizobacteria (PGPR) strains enhanced the physiological and biochemical properties of rice plants, demonstrating their effectiveness in alleviating salinity stress and improving crop performance. *Bacillus tequilensis*, *Bacillus aryabhattai*, and *Providencia stuartii* strains are identified for their positive impact on rice physiology and biochemistry(Rakiba et al., 2020). Salt-tolerant plant growth-promoting rhizobacteria (PGPR) isolated from saline soils showed significant potential for improving crop productivity, highlighting their role in sustainable agriculture practices(Sharma et al., 2021).

Halophilic bacteria, such as *Pseudomonas spp*., *Azotobacter spp*., and *Bacillus spp*., aided in soil reclamation by promoting plant growth, enhancing crop yields, and improving nutrient uptake in sodic soils, offering a sustainable solution for increasing agricultural productivity(Sonawane et al., 2021). Sodic-tolerant bacteria isolated from sodic soils improved rice dry matter production under sodic stress, highlighting their potential for sustainable agriculture and soil reclamation efforts(Gunasekaran et al., 2022). Phosphate-solubilising salt-tolerant bacteria isolated from the soybean rhizosphere significantly mitigated salt stress and improved soybean growth on saline soils, suggesting the potential for developing inoculants to enhance crop productivity under saline conditions(Smirnova et al., 2024).

5. Mechanism of action of salt-tolerant bacteria:

Discusses the traits possessed by halotolerant microorganisms, such as exopolysaccharide production, ACC deaminase activity, and osmolyte production, which contribute to promoting plant growth in saline environments (Zahir et al., 2019). Investigated the effects of plant growth-promoting rhizobacteria (PGPR) producing ACC deaminase enzymes on wheat growth and yield under salinity stress, highlighting the role of these enzymes in mitigating stress by converting ACC to less harmful substances(Zafar-Ul-Hye et al., 2020). The potential of halotolerant plant growth-promoting rhizobacteria (HT-PGPR) in remedying soil salinity issues. These bacteria promote plant growth and mitigate the harmful effects of salinity stress through various mechanisms, including maintaining ion balance and enhancing nutrient availability (Kumar et al., 2023). This study identifies halotolerant bacteria associated with halophytic plants and their potential to promote crop growth under saline conditions. It highlights the ability of these bacteria to establish themselves as endophytes within plant roots, suggesting their role as sustainable bio-stimulants(Kearl et al., 2019). Halophilic bacteria from saline soil and their plant growth-promoting traits, such as indole acetic acid production, phosphate solubilization, and nitrogen fixation, indicate their potential for bioremediation of salt-affected soils and improving crop production(Mahamuni, 2020). The use of sodic-tolerant bacteria (EPS-STB) to alleviate sodic stress in rice. It identifies bacterial candidates like *Bacillus rugosus* and *Pseudomonas sp*., showcasing biofilm formation, plant growth promotion, and osmolyte accumulation abilities under sodic stress, thus improving rice dry matter production(Gunasekaran et al., 2022). The potential of halotolerant bacteria, specifically *Bacillus megaterium,* in mitigating the effects of salinity stress on crop growth. The study identifies isolate-07 as exhibiting both high salt tolerance and plant growth-promoting activities, offering a solution for agriculture in saline environments(Sreelakshmi & Sujatha, 2022). Isolation of salt-tolerant *Azotobacter spp*. and phosphate-solubilising bacteria from Egyptian soils. These bacteria, identified as *Azotobacter salinistris* and *Bacillus amyloliquefaciens*, respectively, show significant potential in nitrogen fixation, phosphate solubilization, and indole acetic acid production, offering eco-friendly solutions for mitigating salinity stress in plants(Abdelsattar et al., 2022). The role of bacterial endophytes in mitigating the negative effects of salinity stress on plants. The study highlights the mechanisms through which endophytic bacteria promote plant growth and balance stress hormones, offering insights into their potential application in improving salt tolerance and food crop production(Slama et al., 2023). They isolated phosphate-solubilising salt-tolerant bacteria from the soybean rhizosphere to enhance soybean growth on saline soils. The study identifies strains of Pseudomonas and Bacillus species exhibiting promising abilities in phosphate solubilization and indole-3-acetic acid production under salt stress, leading to improved soybean growth and ecological adaptation(Smirnova et al., 2024).

6. Future perspective and scope in Agriculture:

The increasing prevalence of salt stress in agriculture necessitates innovative solutions to enhance crop productivity sustainably. Salt-tolerant bacteria offer a promising avenue for addressing this challenge. Studies have showcased the efficacy of various halotolerant bacteria, such as Bacillus spp. and Pseudomonas spp., in promoting plant growth and mitigating the adverse effects of salinity stress. These bacteria possess traits like exopolysaccharide production, ACC deaminase activity, and osmolyte synthesis, enabling them to thrive in saline environments and aid in plant growth. By improving ion balance, increasing nutrient availability, and producing beneficial compounds, salt-tolerant bacteria contribute to enhancing crop productivity and remediating degraded saline soils.

The scope of utilising salt-tolerant bacteria in agriculture is vast. From promoting salt-tolerant crop varieties to adopting improved soil management practices, integrating these bacteria into agricultural systems offers sustainable solutions. Furthermore, their potential for soil reclamation in sodic and saline soils can significantly contribute to increasing agricultural productivity and ensuring food security. Research and implementation of concrete solutions for the use of salt-tolerant bacterial fertilisers hold promise for mitigating salt stress and enhancing crop resilience, thus fostering sustainable agricultural practices in salt-affected regions worldwide. With ongoing advancements in biotechnology and microbiology, harnessing the capabilities of salt-tolerant bacteria presents a compelling strategy to address the challenges posed by salinity stress and pave the way for a more resilient and productive agricultural future.

7. Conclusion:

Addressing the growing challenge of salt stress in agriculture requires sustainable and innovative solutions. *Bacillus spp*., *Pseudomonas spp*., and other salt-tolerant bacteria are increasingly recognised as valuable partners in this effort. These microorganisms not only thrive in saline conditions but also promote plant growth and mitigate the adverse effects of salt stress. The research highlighted in this article emphasises the promising potential of salt-tolerant bacteria in agriculture. From supporting the development of salt-tolerant crop varieties to the reclamation of sodic and saline soils, these bacteria contribute significantly to various aspects of the agricultural sector.

They are crucial for enhancing agricultural sustainability and ensuring food security. Their role in reducing salt stress and improving crop tolerance is vital in addressing global agricultural challenges. Coordinated efforts in research and implementation are necessary to fully harness the benefits of salt-tolerant bacteria in farming. By integrating these bacteria into agricultural systems and exploring innovative applications like biofertilizers (bacterial fertilisers), it is possible to pave the way for more sustainable and productive farming in salt-affected regions.

With continuous advancements in biotechnology and microbiology, enhancing the potential of salt-tolerant bacteria emerges as a promising strategy for reducing salt stress in agriculture and promoting sustainable farming practices.

The increasing salinisation of soils, rendering them infertile, poses long-term consequences for human life and livelihoods. Immediate awareness and action are necessary to address this issue. Initiatives such as social awareness campaigns, the promotion of biofertilizers and biopesticides, and coordinated efforts by governments, social organisations, and educational institutions are crucial. Region-specific strategies, based on geographic conditions, must include proper fertiliser management, understanding the impact of chemical fertilisers and pesticides on human health, seasonal water management, and crop-specific strategies, saving economy with low cost.

Farmer training programs can play a key role in raising awareness and implementing these solutions effectively. Research suggests that instilling these concepts and practices can contribute to sustainable soil management, thereby reducing the impact of salinity on agriculture and human health.

8. Acknowledgement:

The Authors are thankful to the Honourable Chairman, Dr. R.J. Barnabas, Respected Principal Dr. Noel Parge and the Department of Botany of B.P.H.E Society's Ahmednagar College, Ahmednagar. Grateful to the Honourable Chairman, MLA Dr. Narendra Ghule Patil, Hon. MLA Chandrashekhar Ghule Patil, Dr. Kshitij Ghule Patil, Vice Chairman Abhang Saheb and the board of directors, Managing Director Anil P. Shewale, Secretary R.N. Mote (Loknete Marutrao Ghule Patil DSSK Ltd. Bhende Bk). Thank you for the guidance from Dr. Adinath Takate (Soil Scientist, Mahatma Phule Agricultural University, Rahuri, Ahmednagar) and Mrs. Sudha Ghodke (Head of Microbiology Department, Vasant Dada Sugar Institute, Manjari, Pune).

9. References:

Abdelsattar, M., El-Sawah, A., El-Kady, S., & Hauka, F. (2022). Evaluation of Plant Growth Promoting of Salt-tolerant Rhizobacteria Isolated from Egyptian Saline Soils. *Journal of Agricultural Chemistry and Biotechnology*, *13*(10), 95–100. https://doi.org/10.21608/jacb.2022.163494.1033

Alizadeh., Shahram., & H., A. (2012). *1-the Effect of Pgpr on Salinity.Pdf* (pp. 1–8). Asian Journal of Plant Science.

Damodaran, T., Sah, V., Rai, R. B., Sharma, D. K., Mishra, V. K., Jha, S. K., & Kannan, R. (2013). Isolation of salt tolerant endophytic and rhizospheric bacteria by natural selection and screening for promising plant growth-promoting rhizobacteria (PGPR) and growth vigour in tomato under sodic environment. *African Journal of Microbiology Research*, *7*(44), 5082–5089. https://doi.org/10.5897/AJMR2013.6003

Egamberdieva, D., Wirth, S., Bellingrath-Kimura, S. D., Mishra, J., & Arora, N. K. (2019). Salt-Tolerant Plant Growth Promoting Rhizobacteria for Enhancing Crop Productivity of Saline Soils. *Frontiers in Microbiology*, *10*(December), 1–18. https://doi.org/10.3389/fmicb.2019.02791

El-Akhdar, I., Elsakhawy, T., & Abo-Koura, H. A. (2020). Alleviation of Salt Stress on Wheat (Triticum aestivum L.) by Plant Growth Promoting Bacteria strains Bacillus halotolerans MSR-H4 and Lelliottia amnigena MSR-M49. *Journal of Advances in Microbiology*, *20*(1), 44–58. https://doi.org/10.9734/jamb/2020/v20i130208

Grover, M., Ali, S. Z., Sandhya, V., Rasul, A., & Venkateswarlu, B. (2011). Role of microorganisms in adaptation of agriculture crops to abiotic stresses. *World Journal of Microbiology and Biotechnology*, *27*(5), 1231–1240. https://doi.org/10.1007/s11274-010-0572-7

Gunasekaran, Y., Thiyageshwari, S., Ariyan, M., Roy Choudhury, A., Park, J. H., Selvi, D., Chithra, L., & Anandham, R. (2022). Alleviation of Sodic Stress in Rice by Exploring the Exopolysaccharide-Producing Sodic-Tolerant Bacteria. *Agriculture (Switzerland)*, *12*(9), 1–20. https://doi.org/10.3390/agriculture12091451

Kearl, J., McNary, C., Lowman, J. S., Mei, C., Aanderud, Z. T., Smith, S. T., West, J., Colton, E., Hamson, M., & Nielsen, B. L. (2019). Salt-tolerant halophyte rhizosphere bacteria stimulate growth of alfalfa in salty soil. *Frontiers in Microbiology*, *10*(AUG). https://doi.org/10.3389/fmicb.2019.01849

Khan, M. A., Asaf, S., Khan, A. L., Adhikari, A., Jan, R., Ali, S., Imran, M., Kim, K. M., & Lee, I. J. (2019). Halotolerant Rhizobacterial Strains Mitigate the Adverse Effects of NaCl Stress in Soybean Seedlings. *BioMed Research International*, *2019*. https://doi.org/10.1155/2019/9530963

Kumar, V., Raghuvanshi, N., Pandey, A. K., Kumar, A., Thoday-Kennedy, E., & Kant, S. (2023). Role of Halotolerant Plant Growth-Promoting Rhizobacteria in Mitigating Salinity Stress: Recent Advances and Possibilities. *Agriculture (Switzerland)*, *13*(1), 1–22. https://doi.org/10.3390/agriculture13010168

Mahamuni, S. V. (2020). Attributes of Prospective Plant Growth Promoting Halophilic Bacteria (Pgphb) Screened from Saline Soils of Baramati Tehsil of Maharashtra State (India). *Journal of Microbiology, Biotechnology and Food Sciences*, *10*(1), 117–121. https://doi.org/10.15414/jmbfs.2020.10.1.117-121

Rajput, L., Imran, A., Mubeen, F., & Hafeez, F. Y. (2013). Salt-tolerant PGPR strain Planococcus rifietoensis promotes the growth and yield of wheat (Triticum aestivum L.) cultivated in saline soil. *Pakistan Journal of Botany*, *45*(6), 1955–1962.

Rakiba, S., Zuan, A. T. K., Yusop, M. R., Saud, H. M., & Ayanda., A. F. (2020). E ff ect of Salt-Tolerant Bacterial Inoculations on Rice Seedlings Di ff ering in Salt-Tolerance under Saline. *Agronomy*, *10*(1030), 1–22.

Sen, S., & Chandrasekhar, C. N. (2014). Effect of PGPR on growth promotion of rice (Oryza sativa L .) under salt stress. *Asian Journal of Plant Science and Research*, *4*(5), 62–67.

Sharma, A., Dev, K., Sourirajan, A., & Choudhary, M. (2021). Isolation and characterization of salt-tolerant bacteria with plant growth-promoting activities from saline agricultural fields of Haryana, India. *Journal of Genetic Engineering and Biotechnology*, *19*(1). https://doi.org/10.1186/s43141-021-00186-3

Slama, H. Ben, Chenari Bouket, A., Alenezi, F. N., Luptakova, L., Baranov, O., Ahadi, R., & Belbahri, L. (2023). Impacts of Salt Stress on the Rhizosphere and Endophytic Bacterial Role in Plant Salt Alleviation. *International Journal of Plant Biology*, *14*(2), 361–376. https://doi.org/10.3390/ijpb14020030

Smirnova, I., Sadanov, A., Baimakhanova, G., Faizulina, E., & Tatarkina, L. (2024). Phosphate-Solubilizing Salt-Tolerant Bacteria to Support Soybean Growth (Glycine max (L.) Merr.) On Saline Soils. *OnLine Journal of Biological Sciences*, *24*(1), 9–18. https://doi.org/10.3844/ojbsci.2024.9.18

Sonawane, R., Patole, A., Gaikwad, A., & Navale, R. (2021). Isolation, Characterization and Identification of Salt Tolerant Bacterial isolates from Sodic Soil of Ahmednagar, Maharashtra. *International Journal of Current Microbiology and Applied Sciences*, *10*(5), 52–58. https://doi.org/10.20546/ijcmas.2021.1005.009

Sreelakshmi, B., & Sujatha, B. (2022). Isolation and Characterization of Plant Growth Promoting Halotolerant Bacteria From Saline Rhizospheric Environments. *International Journal of Advanced Research*, *10*(06), 185–190. https://doi.org/10.21474/ijar01/14873

Zafar-Ul-Hye, M., Zahra, M. B., Danish, S., Abbas, M., Rehim, A., Akbar, M. N., Iftikhar, A., Gul, M., Nazir, I., Abid, M., Tahzeeb-Ul-Hassan, M., & Murtaza, M. (2020). Multi-strain inoculation with pgpr producing acc deaminase is more effective than single-strain inoculation to improve wheat (Triticum aestivum) growth and yield. *Phyton*, *89*(2), 405–413. https://doi.org/10.32604/phyton.2020.08918

Zahir, Z. A., Nadeem, S., Khan, M. Y., & Binyamin, R. (2019). Saline Soil-based Agriculture by Halotolerant Microorganisms. In *Saline Soil-based Agriculture by Halotolerant Microorganisms* (Issue August 2020). https://doi.org/10.1007/978-981-13-8335-9