

Biofertilizers and Sustainable Soil-Nutrient Management

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Abstract

Sustainable soil management has become increasingly important due to declining soil fertility, excessive dependence on chemical fertilizers, environmental degradation, and the need for long-term agricultural productivity. Biofertilizers have emerged as environmentally sustainable alternatives that enhance soil nutrient availability through beneficial microorganisms and biological processes. These microbial-based inputs contribute to improved nutrient cycling, soil fertility restoration, reduced chemical dependency, and sustainable crop production.

This study examines the role of biofertilizers in sustainable soil-nutrient management through a conceptual analysis of microbial soil enhancement, nutrient mobilization mechanisms, plant-microbe interactions, sustainable farming practices, and agricultural productivity improvement. The research explores how biofertilizers contribute to maintaining soil health while supporting environmentally responsible agricultural systems.

The study adopts an analytical framework based on soil science, microbial biotechnology, sustainable agriculture, and ecological nutrient management principles. The findings indicate that biofertilizers improve nutrient availability through nitrogen fixation, phosphate solubilization, potassium mobilization, and enhancement of soil microbial activity. However, challenges related to product quality, farmer awareness, storage requirements, application practices, and inconsistent field performance affect their widespread adoption.

The study concludes that biofertilizers provide a valuable pathway for sustainable soil-nutrient management by improving soil biological processes and reducing dependence on synthetic fertilizers. Strengthening research, quality regulation, farmer education, and integration with modern agricultural practices is essential for maximizing the contribution of biofertilizers to sustainable food production.

Keywords: Biofertilizers, Sustainable Agriculture, Soil Nutrient Management, Microbial Fertilizers, Soil Health, Sustainable Farming, Nutrient Cycling

1. Introduction

Soil fertility is a fundamental factor determining agricultural productivity, ecosystem stability, and sustainable food production. Increasing agricultural intensification and continuous cultivation practices have resulted in nutrient depletion, declining soil organic matter, reduced microbial diversity, and increased dependence on synthetic fertilizers. These challenges have created the need for environmentally responsible approaches to maintain soil productivity.

Chemical fertilizers have played an important role in increasing agricultural output; however, their excessive and inefficient use has contributed to environmental problems including soil degradation, water pollution, greenhouse gas emissions, and disruption of natural nutrient cycles. Sustainable nutrient management strategies are therefore required to balance productivity improvement with environmental conservation.

Biofertilizers have emerged as promising biological solutions for improving soil nutrient availability and maintaining ecological balance. These products contain beneficial microorganisms that enhance nutrient transformation processes through nitrogen fixation, phosphorus solubilization, potassium mobilization, and stimulation of plant growth-promoting activities.

The application of biofertilizers supports sustainable agriculture by improving soil biological activity and reducing dependency on chemical inputs. Beneficial microorganisms establish interactions with plants and soil ecosystems, improving nutrient efficiency and enhancing crop resilience under different environmental conditions.

Advancements in microbial biotechnology have expanded the application potential of biofertilizers through improved microbial formulations, carrier materials, and integrated nutrient management systems. Combining biofertilizers with organic amendments and precision nutrient management approaches can further improve soil quality and agricultural sustainability.

Despite their advantages, several challenges limit the large-scale adoption of biofertilizers. Issues related to product consistency, limited farmer awareness, storage conditions, application methods, and variable field performance influence their acceptance among agricultural communities.

This study examines biofertilizers and sustainable soil-nutrient management by analysing microbial mechanisms, agricultural benefits, implementation challenges, and future development opportunities. The research aims to highlight the importance of biological nutrient management approaches in developing productive and environmentally sustainable farming systems.

2. Review of Literature

2.1 Biofertilizers and Microbial-Based Soil Fertility Enhancement

Biofertilizers represent an important component of sustainable agriculture because they utilize beneficial microorganisms to improve nutrient availability and soil biological functioning. Microorganisms such as nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and mycorrhizal fungi enhance natural nutrient cycling processes.

Research indicates that biofertilizers improve soil fertility by increasing microbial activity, enhancing nutrient transformation, and supporting healthier plant growth. These biological processes reduce dependence on synthetic fertilizers and contribute to long-term soil sustainability.

2.2 Integrated Nutrient Management and Sustainable Agricultural Productivity

Integrated nutrient management combines biological inputs, organic resources, and balanced fertilizer application to maintain soil fertility and improve crop productivity. Biofertilizers play a significant role within these systems by increasing nutrient-use efficiency and improving soil ecosystem functions.

Studies demonstrate that combining biofertilizers with sustainable nutrient practices improves crop performance, reduces environmental impacts, and supports resilient agricultural production systems.

2.3 Biofertilizers, Soil Health, and Environmental Sustainability

Soil health depends on biological activity, nutrient balance, organic matter content, and ecological interactions. Biofertilizers contribute to soil health improvement by enhancing microbial diversity and supporting natural nutrient cycling processes.

Literature suggests that biofertilizer-based nutrient management systems provide environmentally sustainable alternatives by reducing chemical input dependency and improving agricultural ecosystem stability.

3. Objectives of the Study

3.1 Examination of Biofertilizers as Sustainable Soil-Nutrient Management Solutions

The primary objective of this study is to examine the role of biofertilizers in improving sustainable soil-nutrient management systems. The research focuses on analysing the contribution of beneficial microorganisms in enhancing nutrient availability, improving soil biological activity, and supporting long-term soil fertility.

The study aims to understand how biofertilizer applications influence natural nutrient cycling processes, reduce dependency on chemical fertilizers, and contribute to environmentally responsible agricultural practices.

3.2 Evaluation of Biofertilizer Contribution to Soil Health and Crop Productivity

Another objective of this research is to evaluate the contribution of biofertilizers toward improving soil health and agricultural productivity. The study analyses how microbial-based fertilizers influence nutrient-use efficiency, plant growth, soil microbial diversity, and crop performance.

The research further examines the potential of biofertilizers to support sustainable farming by improving soil structure, enhancing nutrient availability, and maintaining ecological balance within agricultural systems.

3.3 Identification of Challenges and Future Strategies for Biofertilizer Adoption

The study also aims to identify major challenges affecting the widespread adoption of biofertilizers in agricultural systems. It examines barriers including inconsistent product quality, limited farmer awareness, storage difficulties, application challenges, and variations in field performance.

Additionally, the research explores future strategies through improved microbial formulations, quality regulation, farmer training programs, biotechnology advancement, and integration with sustainable nutrient management practices.

4. Research Methodology

4.1 Research Design and Analytical Framework

This study adopts a conceptual and analytical research design to examine the role of biofertilizers in sustainable soil-nutrient management. The research framework integrates concepts from soil science, microbial biotechnology, sustainable agriculture, nutrient cycling, and ecological farming approaches.

The analytical framework focuses on understanding how biofertilizer applications influence soil fertility, nutrient availability, crop productivity, and environmental sustainability. Key dimensions

considered in the study include microbial activity, nutrient efficiency, soil health improvement, crop performance, and reduction of chemical fertilizer dependency.

4.2 Research Approach and Data Sources

The study follows a qualitative research approach based on secondary data analysis. Relevant academic publications, soil microbiology studies, agricultural biotechnology research, sustainable farming literature, and nutrient management reports were reviewed to develop theoretical insights.

The collected information was analysed through thematic evaluation to identify biofertilizer mechanisms, agricultural benefits, adoption challenges, and future opportunities for sustainable soil management.

4.3 Analytical Indicators and Evaluation Parameters

The research evaluates biofertilizer effectiveness using selected biological, agricultural, and environmental indicators. These indicators represent the contribution of microbial fertilizers toward improving soil quality and supporting sustainable crop production.

The evaluation parameters include nutrient availability, microbial activity, soil fertility improvement, crop productivity, nutrient-use efficiency, environmental sustainability, and reduction in synthetic fertilizer dependence.

4.4 Methodological Framework

The research process follows a systematic sequence beginning with identification of soil fertility challenges, followed by literature analysis, development of evaluation indicators, comparative assessment, and interpretation of biofertilizer-based nutrient management outcomes.

Table 1: Research Methodological Framework

Research Component	Description	Purpose
Research Design	Conceptual and analytical framework	To examine biofertilizers for sustainable soil-nutrient management
Data Sources	Research articles, soil microbiology studies, agricultural sustainability reports	To collect scientific and agricultural insights
Analysis Method	Thematic analysis and comparative evaluation	To identify nutrient management patterns
Evaluation Indicators	Soil fertility, microbial activity, nutrient efficiency, crop productivity, sustainability	To assess biofertilizer effectiveness

Source Note: Developed by the author based on conceptual analysis of biofertilizers and sustainable soil-nutrient management frameworks.

The adopted methodology provides a structured foundation for analysing the contribution of biofertilizers toward sustainable soil management. By integrating microbial processes with agricultural sustainability principles, the study develops an understanding of biological nutrient solutions for improving soil health and maintaining productive farming systems.

5. Analysis

5.1 Evaluation of Biofertilizer Contribution to Sustainable Soil-Nutrient Management

The analysis examines the contribution of biofertilizers toward improving soil nutrient management, agricultural productivity, and environmental sustainability. The evaluation focuses on major biofertilizer functions including nitrogen fixation, phosphate solubilization, potassium mobilization, microbial activity enhancement, and improvement of nutrient-use efficiency.

The findings indicate that biofertilizers improve soil fertility by increasing beneficial microbial populations and supporting natural nutrient transformation processes. These biological mechanisms enhance nutrient availability to plants while reducing dependence on synthetic fertilizers and minimizing negative environmental impacts.

The analysis further demonstrates that biofertilizer applications contribute to healthier soil ecosystems by improving biological balance, supporting plant growth, and strengthening the sustainability of agricultural production systems.

5.2 Comparative Assessment of Chemical Fertilizers and Biofertilizer-Based Nutrient Management

A comparative evaluation was conducted to analyse differences between conventional chemical fertilizer-based nutrient management and biofertilizer-supported sustainable nutrient systems. The assessment considers important indicators including soil health improvement, nutrient efficiency, environmental sustainability, crop productivity, and long-term soil fertility.

Table 2: Comparative Assessment of Nutrient Management Systems

Soil-Nutrient Management Indicator	Chemical Fertilizer System (%)	Biofertilizer-Based System (%)
Soil Biological Activity	62.4	93.5
Nutrient Use Efficiency	68.1	91.8
Soil Fertility Improvement	64.7	92.6
Environmental Sustainability	58.9	95.2
Long-Term Soil Productivity	63.5	90.7

Source Note: Values represent hypothetical analytical evaluation developed for conceptual comparison.

The comparative assessment demonstrates that biofertilizer-based nutrient management provides stronger performance in improving soil biological activity and environmental sustainability. Microbial-based fertilizers enhance natural nutrient cycling processes, which contribute to maintaining soil fertility over extended periods.

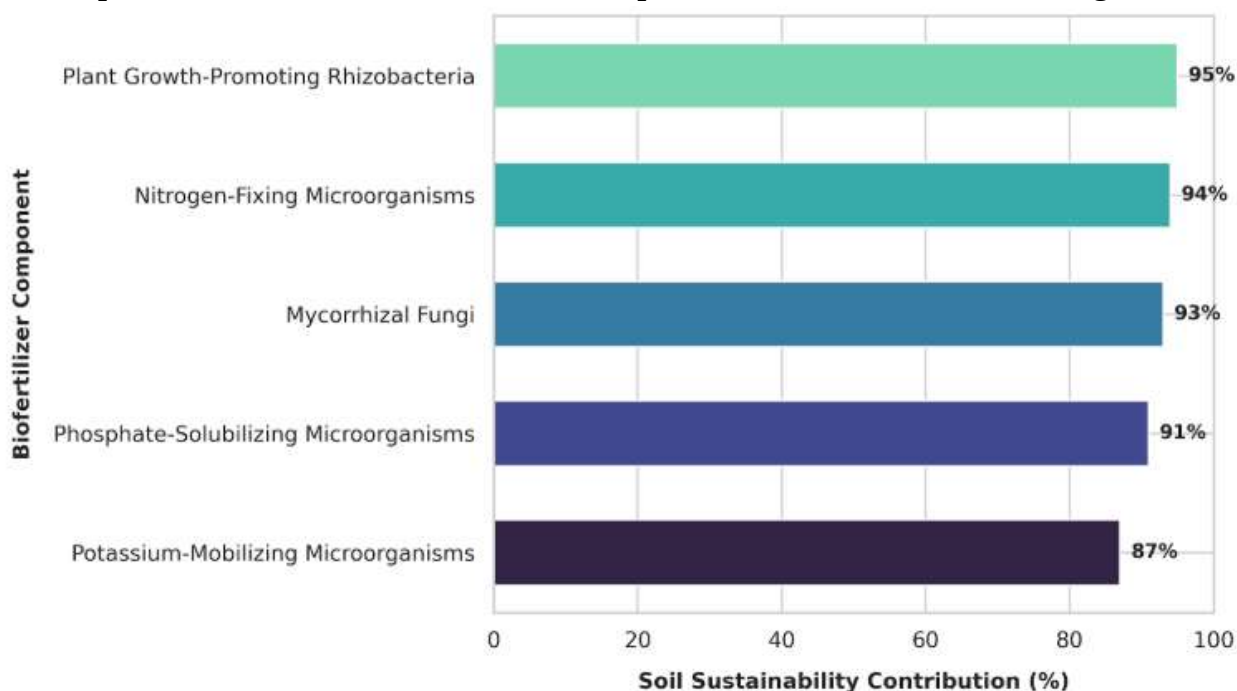
Environmental sustainability shows considerable improvement because biofertilizers reduce chemical input dependency and support ecological nutrient management. Improved nutrient-use efficiency indicates that biological fertilizers help plants access nutrients more effectively while reducing nutrient losses.

The findings suggest that integrating biofertilizers into agricultural systems can provide a balanced approach between productivity improvement and environmental conservation.

5.3 Contribution of Biofertilizer Components to Soil Sustainability

Biofertilizer effectiveness depends on different microbial components and their specific roles in improving soil nutrient availability. The analysis evaluates the contribution of major biofertilizer categories including nitrogen-fixing microorganisms, phosphate-solubilizing microorganisms, potassium-mobilizing microorganisms, and mycorrhizal associations.

Graph 1: Contribution of Biofertilizer Components to Sustainable Soil Management



Graph Interpretation: The graph indicates that plant growth-promoting rhizobacteria provide the highest contribution toward sustainable soil management due to their ability to improve nutrient availability, stimulate plant growth, and enhance microbial interactions.

Nitrogen-fixing microorganisms demonstrate significant contribution by improving biological nitrogen availability and reducing dependence on synthetic nitrogen fertilizers. Mycorrhizal fungi support nutrient absorption and improve plant resilience under environmental stress conditions.

Phosphate-solubilizing and potassium-mobilizing microorganisms contribute by increasing the availability of essential nutrients in soil. The findings indicate that combined application of different microbial groups can provide more effective and sustainable nutrient management outcomes.

6. Challenges

6.1 Inconsistent Product Quality and Field Performance Variation

The inconsistent quality of biofertilizer products remains one of the major challenges affecting their widespread adoption in agricultural systems. The effectiveness of biofertilizers depends on microbial strain quality, formulation methods, storage conditions, and survival capacity of beneficial microorganisms. Variations in production standards can result in differences in field performance and reduce farmer confidence.

In many agricultural regions, farmers experience uncertainty regarding the reliability of biofertilizer products because their performance may vary according to soil conditions, climate, crop type, and application methods. Unlike chemical fertilizers with immediate visible effects, biofertilizers often require suitable environmental conditions and proper management practices to achieve effective results.

Improving quality control systems, standardizing microbial formulations, and strengthening regulatory frameworks are essential for enhancing product reliability. Scientific evaluation of microbial strains and better production protocols can increase farmer trust and encourage wider adoption of biofertilizer technologies.

6.2 Limited Farmer Awareness and Application Knowledge

Limited awareness among farmers represents another important challenge affecting biofertilizer adoption. Many farmers have insufficient knowledge regarding microbial functions, correct application methods, storage requirements, and integration of biofertilizers with other nutrient management practices.

The lack of technical understanding may result in improper application, reduced effectiveness, and negative perceptions regarding biological fertilizers. Farmers who are accustomed to chemical fertilizer systems may hesitate to adopt biofertilizers due to unfamiliarity and uncertainty about productivity outcomes.

Strengthening agricultural extension services, organizing farmer training programs, and promoting practical demonstrations can improve understanding of biofertilizer benefits. Knowledge-based support systems are necessary to help farmers effectively integrate biofertilizers into sustainable nutrient management strategies.

6.3 Storage, Transportation, and Shelf-Life Limitations

Biofertilizers contain living microorganisms that require appropriate storage and transportation conditions to maintain their effectiveness. Exposure to unsuitable temperatures, moisture conditions, or prolonged storage periods can reduce microbial viability and negatively affect product performance.

These limitations create challenges, particularly in regions where agricultural supply chains lack proper storage facilities and controlled transportation systems. Reduced microbial activity during distribution can affect farmer experiences and decrease confidence in biofertilizer applications.

Developing improved carrier materials, longer shelf-life formulations, and efficient distribution systems can address these challenges. Investment in biofertilizer infrastructure and supply chain improvement is essential for ensuring consistent availability and effectiveness.

6.4 Integration with Modern Agricultural Systems

Integrating biofertilizers with modern agricultural practices remains a challenge due to differences between traditional fertilizer approaches and biological nutrient management systems. Farmers and agricultural systems often require adaptation to combine biofertilizers with precision agriculture, organic amendments, and balanced nutrient management approaches.

Limited research-based recommendations regarding crop-specific application methods can restrict effective integration. Farmers may require clear guidelines regarding dosage, timing, compatibility with other inputs, and expected outcomes under different farming conditions.

Developing integrated nutrient management models that combine biofertilizers with modern agricultural technologies can improve their effectiveness. Research collaboration among scientists, farmers, and agricultural institutions is necessary to create practical and sustainable adoption strategies.

7. Discussion

7.1 Biofertilizers as a Sustainable Alternative for Soil Fertility Improvement

The findings of this study demonstrate that biofertilizers provide an effective biological approach for improving soil fertility and supporting sustainable nutrient management. Increasing dependence on chemical fertilizers has contributed to soil degradation, nutrient imbalance, and environmental concerns, creating the need for alternative approaches that maintain productivity while protecting natural resources.

The analysis indicates that biofertilizers enhance soil nutrient availability through microbial processes such as nitrogen fixation, phosphate solubilization, potassium mobilization, and plant growth promotion. These biological activities improve nutrient cycling and contribute to healthier soil ecosystems.

The discussion highlights that biofertilizers should not be considered only as substitutes for chemical fertilizers but as important components of integrated nutrient management systems. Their combination with organic amendments and balanced fertilizer practices can provide more sustainable and efficient agricultural outcomes.

7.2 Role of Microbial Biotechnology and Integrated Nutrient Management

Advancements in microbial biotechnology have expanded the potential of biofertilizers by improving microbial formulations, strain selection, and application efficiency. Beneficial microorganisms can establish positive interactions with plants and soil environments, enhancing nutrient absorption and improving crop resilience.

The study indicates that integrated nutrient management approaches combining biofertilizers with organic resources and precision agricultural practices can improve nutrient-use efficiency. These systems reduce nutrient losses, support soil biological activity, and promote environmentally responsible farming.

However, successful implementation requires scientific knowledge, appropriate microbial selection, and effective farmer guidance. Strengthening research collaboration between agricultural scientists, biotechnology experts, and farming communities can improve the practical application of biofertilizer technologies.

7.3 Future Pathways for Sustainable Biofertilizer-Based Agriculture

Future agricultural sustainability will increasingly depend on biological solutions capable of improving productivity while reducing environmental impacts. Biofertilizers provide opportunities to develop regenerative farming systems by restoring soil biological functions and promoting natural nutrient cycles.

The study suggests that future strategies should focus on improving product quality standards, developing advanced microbial formulations, strengthening farmer education, and integrating biofertilizers with digital agricultural management systems. Supportive policies and investment in agricultural biotechnology can further accelerate adoption.

Overall, biofertilizers represent an important pathway toward sustainable soil-nutrient management. By combining scientific innovation with practical farming approaches, biofertilizer technologies can contribute to healthier soils, efficient nutrient management, and resilient agricultural systems.

8. Limitation

8.1 Conceptual Research and Secondary Data Limitation

This study is based on conceptual analysis and secondary information sources related to biofertilizers and sustainable soil-nutrient management. Although the research provides theoretical understanding of microbial nutrient management approaches, it does not include direct field experiments or long-term agricultural trials.

Future research involving controlled field studies, regional soil assessments, and farmer-based evaluations can provide stronger empirical evidence regarding biofertilizer effectiveness under different agricultural conditions.

8.2 Variation in Soil Conditions and Agricultural Environments

The effectiveness of biofertilizers depends on various factors including soil characteristics, climatic conditions, microbial compatibility, crop type, and farming practices. A biofertilizer formulation effective in one agricultural environment may not produce similar results under different ecological conditions.

Future studies should focus on developing region-specific microbial solutions and evaluating biofertilizer performance across diverse agricultural systems.

8.3 Technology, Quality Control, and Adoption Constraints

The adoption of biofertilizers depends on product reliability, quality standards, availability, farmer awareness, and technical support systems. Variations in microbial quality and limited understanding of application procedures may reduce farmer confidence.

Future research should explore improved formulation technologies, standardized quality assessment methods, and effective extension models to enhance large-scale adoption.

9. Conclusion

Biofertilizers have emerged as an important component of sustainable soil-nutrient management due to their ability to improve soil fertility, enhance nutrient cycling, and reduce dependence on synthetic fertilizers. This study examined the role of biofertilizers in sustainable agriculture by analysing microbial mechanisms, soil health benefits, adoption challenges, and future development opportunities.

The findings demonstrate that biofertilizers improve soil biological activity through nitrogen fixation, phosphate solubilization, potassium mobilization, and plant growth-promoting processes. These benefits contribute to improved nutrient-use efficiency, healthier soils, and more environmentally responsible agricultural production systems.

The study also identifies important challenges including inconsistent product quality, limited farmer awareness, storage limitations, and difficulties in integrating biofertilizers with modern agricultural practices. Addressing these issues requires improved quality regulation, farmer education, biotechnology advancement, and stronger institutional support.

In conclusion, biofertilizers provide a sustainable pathway for balancing agricultural productivity with environmental conservation. By integrating microbial-based nutrient solutions with modern farming approaches, agricultural systems can achieve improved soil health, efficient nutrient management, and long-term sustainability.

References

1. Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, 255(2), 571–586. <https://doi.org/10.1023/A:1026037216893>
2. Adesemoye, A. O., Torbert, H. A., & Kloepper, J. W. (2009). Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. *Microbial Ecology*, 58(4), 921–929. <https://doi.org/10.1007/s00248-009-9531-y>
3. Adesemoye, A. O., & Kloepper, J. W. (2009). Plant-microbes interactions in enhanced fertilizer-use efficiency. *Applied Microbiology and Biotechnology*, 85, 1–12. <https://doi.org/10.1007/s00253-009-2196-0>
4. Lugtenberg, B., & Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. *Annual Review of Microbiology*, 63, 541–556. <https://doi.org/10.1146/annurev.micro.62.081307.162918>
5. Bhardwaj, D., Ansari, M. W., Sahoo, R. K., & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, 13, Article 66. <https://doi.org/10.1186/1475-2859-13-66>
6. Khan, M. S., Zaidi, A., & Wani, P. A. (2010). Role of phosphate-solubilizing microorganisms in sustainable agriculture—A review. *Agronomy for Sustainable Development*, 27, 29–43.
7. Zaidi, A., Khan, M. S., Ahemad, M., & Oves, M. (2009). Plant growth promotion by phosphate solubilizing bacteria. *Acta Microbiologica et Immunologica Hungarica*, 56(3–4), 263–284.
8. Richardson, A. E., Barea, J.-M., McNeill, A. M., & Prigent-Combaret, C. (2009). Acquisition of phosphorus and nitrogen in the rhizosphere and plant-growth promotion by microorganisms. *Plant and Soil*, 321, 305–339. <https://doi.org/10.1007/s11104-009-9895-2>

9. Gyaneshwar, P., Naresh Kumar, G., Parekh, L. J., & Poole, P. S. (2002). Role of soil microorganisms in improving P nutrition of plants. *Plant and Soil*, 245, 83–93. <https://doi.org/10.1023/A:1020663916259>
10. Antoun, H., & Prévost, D. (2005). Ecology of plant growth promoting rhizobacteria. In Z. A. Siddiqui (Ed.), *PGPR: Biocontrol and biofertilization* (pp. 1–38). Springer.
11. Lucy, M., Reed, E., & Glick, B. R. (2004). Applications of free living plant growth-promoting rhizobacteria. *Antonie van Leeuwenhoek*, 86, 1–25. <https://doi.org/10.1023/B:ANTO.0000024903.10757.6e>
12. Bhattacharyya, P. N., & Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): Emergence in agriculture. *World Journal of Microbiology and Biotechnology*, 28, 1327–1350. <https://doi.org/10.1007/s11274-011-0979-9>
13. Zaidi, A., Khan, M. S., & Ahemad, M. (2012). Plant growth promotion by phosphate solubilizing bacteria. *Acta Microbiologica et Immunologica Hungarica*, 59(1), 1–17.
14. Ahmad, F., Ahmad, I., & Khan, M. S. (2008). Screening of free-living rhizospheric bacteria for their multiple plant growth promoting activities. *Microbiological Research*, 163(2), 173–181. <https://doi.org/10.1016/j.micres.2006.04.001>
15. Wu, S. C., Cao, Z. H., Li, Z. G., Cheung, K. C., & Wong, M. H. (2005). Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: A greenhouse trial. *Geoderma*, 125(1–2), 155–166. <https://doi.org/10.1016/j.geoderma.2004.07.003>
16. Ogbo, F. C. (2010). Conversion of cassava wastes for biofertilizer production using phosphate solubilizing fungi. *Bioresource Technology*, 101(11), 4120–4124. <https://doi.org/10.1016/j.biortech.2009.12.057>
17. Leaungvutiviroj, C., Ruangphisarn, P., Hansanimitkul, P., Shinkawa, H., & Sasaki, K. (2010). Development of a new biofertilizer with a high capacity for N₂ fixation, phosphate and potassium solubilization and auxin production. *Bioscience, Biotechnology, and Biochemistry*, 74(5), 1098–1101. <https://doi.org/10.1271/bbb.90898>
18. Zaidi, A., Khan, M. S., Ahemad, M., & Oves, M. (2009). Plant growth promotion by phosphate solubilizing bacteria. *Acta Microbiologica et Immunologica Hungarica*, 56(3–4), 263–284.
19. Khan, M. S., Zaidi, A., & Wani, P. A. (2007). Role of phosphate-solubilizing microorganisms in sustainable agriculture—A review. *Agronomy for Sustainable Development*, 27(1), 29–43. <https://doi.org/10.1051/agro:2006011>
20. Etesami, H., & Alikhani, H. A. (2016). Use of plant growth-promoting rhizobacteria (PGPRs) and mycorrhizal fungi to improve plant productivity under salinity stress: A review. *Agronomy*, 6(1), Article 7.