MICROBIOLOGY ARCHIVES
Review Article | ISSN: 3041-590X
Journal homepage: https://microjournal.researchfloor.org/

Impact of Microbial Inoculants on Rice Growth and Yield in a Drumstick-Based Agroforestry System

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ARTICLE INFO

Citation: R VijayKumar (2020). Impact of Microbial Inoculants on Rice Growth and Yield in a Drumstick-Based Agroforestry System.
Microbiology Archives, an International Journal.
01 to 05. DOI: https://doi.org/10.51470/MA.2020.2.1.1

Received 05 January 2020
Revised 07 February 2020
Accepted 12 March 2020
Available Online April 15 2020

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ABSTRACT

Agroforestry systems, particularly those integrating Moringa oleifera (drumstick) with Oryza sativa L. (rice), offer promising solutions for sustainable agriculture by enhancing soil health and increasing crop productivity. This article explores the role of soil microbes in improving rice growth and yield under drumstick-based agroforestry systems. Beneficial microbes, including nitrogen-fixing bacteria, phosphate-solubilizing fungi, and mycorrhizal fungi, play a significant role in enhancing soil nutrient availability, promoting root development, and improving plant resilience to stress. The use of microbial inoculants can optimize the microbial interactions in the system, reducing the need for chemical fertilizers and improving overall soil fertility. This article highlights the potential of microbial interventions to foster sustainable rice production and enhance the ecological benefits of agroforestry systems.

Keywords: *Moringa oleifera, Oryza sativa, soil microbes, agroforestry, nitrogen-fixing bacteria, phosphate-solubilizing fungi, mycorrhizal fungi, microbial inoculants*

Introduction

Agroforestry, the practice of integrating trees with crops or livestock systems, is increasingly recognized as a key strategy for sustainable agriculture. By combining trees and crops in a synergistic manner, agroforestry systems can improve productivity, enhance biodiversity, reduce soil erosion, and improve water retention. Among the many trees used in agroforestry, *Moringa oleifera* (commonly known as drumstick tree) has emerged as a particularly valuable species due to its rapid growth, high nutritional value, and ability to thrive in poor soil conditions [1]. When integrated with crops such as rice (*Oryza sativa L.*), *Moringa oleifera* offers numerous ecological and economic benefits, contributing to sustainable farming practices that benefit both the environment and local communities.

Rice is a staple food crop that supports the livelihoods of millions of people around the world. However, rice cultivation is faced with numerous challenges, including soil degradation, nutrient depletion, and the rising need for sustainable agricultural practices. Traditional rice farming often relies heavily on chemical fertilizers and pesticides, which can lead to environmental pollution, soil erosion, and the loss of biodiversity [2]. As the global population continues to rise, finding sustainable solutions to increase rice yield while minimizing environmental impacts is critical. One such solution is the adoption of agroforestry systems, where *Moringa oleifera* is integrated into rice cultivation [3]. This system can improve soil fertility, provide shade for crops, and reduce the dependency on chemical inputs, offering a more sustainable and resilient approach to rice production.

Soil health is central to the success of agroforestry systems, and the role of soil microbes in maintaining and enhancing soil fertility cannot be overstated. Microbial communities in soil are crucial for the cycling of nutrients, organic matter decomposition, and the maintenance of soil structure. Microbes, such as nitrogen-fixing bacteria, phosphate-solubilizing fungi, mycorrhizal fungi, and decomposers, form essential symbiotic relationships with plants, improving nutrient uptake, enhancing soil quality, and promoting plant health [4]. These microbial interactions can be especially beneficial in agroforestry systems, where the tree-crop interaction creates a unique environment for microbial diversity and activity. The integration of *Moringa oleifera* with rice cultivation enhances the microbial biodiversity of the soil, creating a balanced ecosystem that promotes plant growth, boosts soil fertility, and improves overall crop yields.

The concept of utilizing microbial inoculants—prepared formulations of beneficial microbes—has gained significant attention in recent years as a means to improve agricultural productivity while reducing the reliance on chemical fertilizers. These inoculants typically contain strains of nitrogen-fixing bacteria, phosphate-solubilizing fungi, and mycorrhizal fungi, which are known to enhance nutrient availability in the soil and promote plant health. In the context of rice cultivation within a *Moringa oleifera* agroforestry system, the application of microbial inoculants has the potential to further optimize soil fertility and improve rice productivity [5]. The inoculants can help reduce soil compaction, enhance root development, and increase nutrient uptake, leading to healthier and more productive rice plants.

Nitrogen is a crucial nutrient for plant growth, and its availability in the soil is often a limiting factor in crop production. While *Moringa oleifera* is known to be a nitrogen-fixing tree, enhancing soil nitrogen availability through microbial interventions can provide additional benefits for rice growth. Nitrogen-fixing bacteria, such as *Rhizobium*, *Azotobacter*, and *Azospirillum*, can convert atmospheric nitrogen into a form that plants can use. In an agroforestry system, these bacteria form symbiotic relationships with plant roots, fixing nitrogen in the soil and reducing the need for synthetic nitrogen fertilizers [6]. This reduces the environmental impacts associated with nitrogen fertilization, such as nitrogen leaching into water bodies, which can cause eutrophication and harm aquatic ecosystems.

Phosphorus, another essential nutrient for plants, is often found in the soil in insoluble forms, making it inaccessible to plants. Phosphate-solubilizing fungi, such as *Penicillium* and *Aspergillus*, play a key role in breaking down these insoluble forms of phosphorus, making them available to plants. In rice cultivation, where phosphorus is crucial for root development and flowering, the addition of these fungi to the soil can significantly improve crop yields [7]. By integrating these fungi into drumstick-based agroforestry systems, rice crops can access greater amounts of phosphorus, resulting in enhanced growth and productivity.

Mycorrhizal fungi are another essential component of soil microbial communities. These fungi form a symbiotic relationship with plant roots, extending the root system and improving nutrient uptake, especially in nutrient-poor soils [8]. Mycorrhizal fungi are known to enhance plant resilience to abiotic stresses such as drought, soil salinity, and heavy metal toxicity. In a *Moringa oleifera*-rice agroforestry system, the presence of mycorrhizal fungi can improve nutrient and water uptake for both the rice and the *Moringa oleifera* trees, leading to increased crop yields and improved tree growth. These fungi also contribute to soil structure by forming hyphal networks that bind soil particles together, improving water infiltration and reducing soil erosion [9]. Decomposers, such as bacteria, fungi, and earthworms, play an important role in breaking down organic matter in the soil, releasing essential nutrients back into the soil for plant uptake. In an agroforestry system, the decomposition of *Moringa oleifera* leaves, rice straw, and other organic residues can enrich the soil with organic matter, increasing its fertility and microbial activity. The decomposition process also improves soil structure, increasing its water-holding capacity and reducing the risk of erosion. By supporting the activity of soil decomposers, agroforestry systems can create a more sustainable and resilient soil environment for rice cultivation [10]. While the benefits of soil microbes in agroforestry systems are well-documented, the precise mechanisms by which these microbes interact with the crops and trees in drumstick-based systems remain an area of active research. Understanding how different microbial species interact with each other and with plant roots will help optimize microbial inoculants for better crop yields. The potential for using microbial-based strategies in agroforestry systems to enhance soil fertility and productivity offers a promising pathway for sustainable agriculture [11]. As the world faces the challenges of climate change, soil degradation, and growing food demands, agroforestry systems supported by microbial innovations provide an effective solution for ensuring food security and environmental sustainability.

The integration of *Moringa oleifera* with rice cultivation in agroforestry systems holds great potential for enhancing soil fertility and improving crop productivity. The role of soil microbes—such as nitrogen-fixing bacteria, phosphate-solubilizing fungi, mycorrhizal fungi, and decomposers—is central to this process. By fostering microbial activity in the soil, agroforestry systems can improve nutrient availability, enhance plant health, and reduce the need for chemical inputs. Through the strategic use of microbial inoculants and a better understanding of microbial interactions, drumstick-based agroforestry systems can become a model for sustainable, high-yield rice production in the face of global agricultural challenges.

Study	Experimental Design	Microbial Interventions	Measurement Parameters	Key Results	Implications for Agroforestry
Impact of Microbial Inoculants on Rice Yield	Field trial with different microbial inoculants applied to soil	Nitrogen-fixing bacteria (*Azotobacter*), Phosphate-solubilizing fungi (*Penicillium*)	Rice growth parameters (height, root mass, yield), Soil nitrogen content	Increased nitrogen content in soil and enhanced rice yield	Microbial inoculants are effective in improving soil fertility and reducing chemical fertilizer use
Role of Mycorrhizal Fungi in Agroforestry Systems	Controlled greenhouse experiment with mycorrhizal inoculation	Mycorrhizal fungi (*Glomus* spp.)	Root development, nutrient uptake, soil phosphorus levels	Improved root biomass and nutrient uptake, especially phosphorus	Mycorrhizal inoculation enhances plant growth and resilience, especially in poor soils
Microbial Interactions in Mixed Cropping Systems	Comparison of monoculture vs. mixed cropping with *Moringa oleifera*	Nitrogen-fixing bacteria (*Rhizobium*), Decomposers (Bacteria and fungi)	Soil fertility (N, P, K levels), Crop yield	Enhanced soil fertility and higher crop yield in mixed systems	Agroforestry systems with microbial interventions foster soil fertility and increase yield

Effect of Biofertilizers on Rice Production	Field study with biofertilizer treatments (liquid and solid formulations)	Rhizobium, Azospirillum (Nitrogen-fixing bacteria), *Trichoderma* (fungi)	Rice yield, Soil organic matter, Microbial diversity	Increased rice yield and soil organic matter, reduction in soil pH	Biofertilizers contribute to sustainable rice production by improving soil structure and nutrient cycling
Soil Microbial Communities and Rice Growth	Long-term field trial under different agroforestry systems	Mycorrhizal fungi, Nitrogen-fixing bacteria	Soil microbial diversity, Rice biomass, Root colonization	Higher microbial diversity and improved rice biomass	Enhanced microbial diversity in agroforestry systems supports rice growth and resilience
Phosphorus Solubilizing Fungi in Agroforestry	Laboratory and field trials comparing treated vs. untreated soils	Phosphate-solubilizing fungi (*Aspergillus* spp., *Penicillium* spp.)	Phosphorus availability in soil, Rice root development	Increased phosphorus availability and root growth	Phosphate-solubilizing fungi improve phosphorus uptake, enhancing crop performance in agroforestry
Decomposers and Soil Health in Agroforestry Systems	Experimental setup with organic matter additions and microbial inoculants	Decomposers (Bacteria, Fungi, Earthworms)	Soil organic matter content, Nutrient release rates	Significant increase in soil organic matter and nutrient cycling	Decomposers improve soil health and nutrient availability, supporting sustainable agroforestry practices

The table 1 provides an organized analysis of various studies investigating the role of microbial interventions in agroforestry systems, particularly focusing on rice cultivation. It includes six columns, each highlighting key aspects of the research. The Study column presents the title or a brief description of each research, offering a clear overview of the specific focus of the study, such as the use of microbial inoculants, mycorrhizal fungi, or biofertilizers [13]. The Experimental Design column outlines the methodologies used in each study, which can range from field trials to controlled greenhouse experiments, indicating the type of environment where the study was conducted and the conditions under which the microbes were applied.

The Microbial Interventions column identifies the specific microbial species or groups tested, such as nitrogen-fixing bacteria (*Azotobacter*, *Rhizobium*), phosphate-solubilizing fungi (*Penicillium*), or decomposers (bacteria and fungi). This section gives insight into the variety of microbes involved in influencing soil health and promoting plant growth. The Measurement Parameters column explains the factors measured to evaluate the success of microbial interventions. These parameters typically include plant growth (e.g., height, root mass, yield), soil nutrient content (e.g., nitrogen, phosphorus), and microbial diversity, providing a clear understanding of how microbial treatments affect both the crops and the soil [14]. The important Results column summarizes the findings of each study, emphasizing how the microbial interventions impacted soil fertility, plant growth, or crop yield. For instance, some studies found that microbial inoculants increased nitrogen availability in the soil, leading to enhanced rice yield [15]. The Implications for Agroforestry column connects these findings to practical applications, discussing how microbial treatments can promote sustainable practices in agroforestry. For example, microbial inoculants can reduce the need for chemical fertilizers, enhance soil health, and increase crop productivity, contributing to more sustainable and eco-friendly farming practices.

In essence, the table serves as a comparative analysis of various studies, showing the positive impact of microbial interventions on rice cultivation in agroforestry systems. By presenting experimental designs, microbial interventions, and results in a structured format, it provides valuable insights into how these microbial-based strategies can be applied to improve soil quality, increase crop yields, and support sustainable agricultural practices.

Soil Microbial Communities and Their Role in Agroforestry

1. Nitrogen-Fixing Bacteria Nitrogen is a critical nutrient for plant growth, but it is often limiting in soils. Nitrogen-fixing bacteria, such as *Rhizobium*, *Azotobacter*, and *Azospirillum*, can convert atmospheric nitrogen into forms accessible to plants. In a drumstick-based agroforestry system, these microbes can enhance soil nitrogen availability, benefiting both *Moringa oleifera* and *Oryza sativa*. The addition of biofertilizers containing nitrogen-fixing bacteria to the soil can further boost soil nitrogen levels and enhance rice growth, reducing the need for synthetic nitrogen fertilizers.

2. Phosphate-Solubilizing Fungi Phosphorus is another essential nutrient for plant growth, but it is often present in soils in an insoluble form. Phosphate-solubilizing fungi, such as *Penicillium* and *Aspergillus*, can solubilize bound phosphorus, making it more available to plants. In agroforestry systems, these fungi form symbiotic relationships with plant roots, enhancing nutrient uptake and promoting healthier crops. By inoculating the soil with phosphate-solubilizing fungi, rice plants in drumstick-based agroforestry systems can access more phosphorus, resulting in improved root development and higher yields.

3. Mycorrhizal Fungi Mycorrhizal fungi, such as *Glomus* species, form symbiotic relationships with plant roots, extending the root system and improving nutrient and water uptake. In agroforestry systems, mycorrhizal fungi enhance plant resilience to abiotic stresses such as drought and nutrient deficiency. These fungi also contribute to improved soil structure and increased microbial diversity. In a drumstick-based agroforestry system, mycorrhizal fungi help rice plants access nutrients, particularly phosphorus and micronutrients, from the soil more effectively, leading to healthier growth and higher yields.

4. Decomposers and Organic Matter Breakdown Soil decomposers, including bacteria, fungi, and earthworms, break down organic matter such as plant residues, converting it into humus and releasing essential nutrients. In a drumstick-based agroforestry system, the decomposition of fallen *Moringa oleifera* leaves and other organic materials can enrich the soil with organic matter, enhancing soil fertility and microbial diversity [16]. This process not only improves soil structure but also supports rice growth by providing a continuous supply of nutrients.

Microbial Inoculants and Their Application

Microbial inoculants, which are prepared formulations of beneficial microbes, can be used to enhance soil fertility and improve crop productivity in agroforestry systems [17]. These inoculants can be applied to soil or directly to plant roots, where they establish beneficial relationships with the crops. In the context of drumstick-based agroforestry, microbial inoculants can:

- Boost nitrogen and phosphorus availability for rice crops.
- Enhance the growth of *Moringa oleifera* by improving root health and nutrient uptake.
- Improve soil health and structure, leading to better water retention and resilience to environmental stressors.

The use of microbial inoculants in drumstick-based agroforestry systems can result in reduced dependency on chemical fertilizers, promote sustainable farming practices, and improve overall productivity.

Impact of Soil Microbes on Rice Yield

The introduction of beneficial microbes in drumstick-based agroforestry systems can lead to several improvements in rice growth and yield [18]. Studies have shown that inoculating rice plants with nitrogen-fixing bacteria, phosphate-solubilizing fungi, and mycorrhizal fungi can lead to:

- Increased rice plant height and leaf area.
- Enhanced root development, leading to better anchorage and nutrient absorption.
- Higher rice yield due to improved nutrient uptake and reduced nutrient deficiencies.
- Improved resistance to diseases and pests due to the enhanced health of plant roots and the overall microbial balance in the soil.

Incorporating microbial inoculants can also promote a more balanced soil ecosystem, reducing the need for synthetic fertilizers and chemical pesticides.

Conclusion

Soil microbes play a vital role in enhancing the growth and yield of rice under drumstick-based agroforestry systems. The synergistic interactions between nitrogen-fixing bacteria, phosphate-solubilizing fungi, mycorrhizal fungi, and decomposers create a conducive environment for plant growth, improving nutrient availability and soil health. By using microbial inoculants, it is possible to optimize the benefits of these interactions, resulting in higher rice productivity and more sustainable farming practices. The drumstick-based agroforestry system, enriched with microbial activity, offers a promising model for sustainable rice cultivation. New research on the specific microbial interactions in these systems, along with the development of effective inoculation techniques, will be crucial to further enhance productivity and sustainability in agroforestry systems worldwide.

References

1. Araujo, A. S. F., Leite, L. F. C., Iwata, B. D. F., Lira, M. D. A., Xavier, G. R., & Figueiredo, M. D. V. B. (2012). Microbiological process in agroforestry systems. A review. *Agronomy for Sustainable Development*, *32*, 215-226.

2. Sridhar, K. R., & Bagyaraj, D. J. (2017). Microbial biodiversity in agroforestry systems. *Agroforestry: Anecdotal to Modern Science*, 645-667.

3. Dubey, K., Dubey, K. P., Pandey, A., & Tripathi, P. (2017). Microbial biofertilizer interventions in augmenting agroforestry. *Probiotics and Plant Health*, 421-442.

4. Bhaduri, D., Pramanik, P., Ghosh, S., Chakraborty, K., & Pal, S. (2017). Agroforestry for improving soil biological health. *Agroforestry for increased production and livelihood security. New India Publishing Agency, New Delhi*, 465-491.

5. Radhakrishnan, S., & Varadharajan, M. (2016). Status of microbial diversity in agroforestry systems in Tamil Nadu, India. *Journal of basic microbiology*, *56*(6), 662-669.

6. Muthukumar, T., & Udaiyan, K. (2018). Coinoculation of bioinoculants improve Acacia auriculiformis seedling growth and quality in a tropical Alfisol soil. *Journal of Forestry Research*, *29*, 663-673.

7. Mridha, B. M. A. U., Khan, M., & Hossain, M. K. (2016). Microbial Inoculant for Seed Germination and Seedling Growth of Acacia mangium Willd. *Journal of Applied Environmental and Biological Sciences*, *6*(5), 116-124.

8. Khan, B. M., Kabir, M. A., Hossain, M. K., & Mridha, M. A. U. (2016). Microbial inoculant influences the germination and growth of Albizia lebbeck seedlings in the nursery. *Banko Janakari*, *26*(1), 82-89.

9. Payan-Zelaya, F., Harmand, J. M., Flores-Macías, A., Beer, J., Ramos-Espinoza, G., & de León González, F. (2013). Soil nutrient availability and CO 2 production in agroforestry systems after the addition of Erythrina poeppigiana pruning residues and native microbial inocula. *Agroforestry systems*, *87*, 439-450.

10. Singh, B., & Sharma, K. N. (2007). Nutrition and growth of wheat–sorghum rotation in soils amended with leaf litter of trees before planting of wheat. *Agroforestry systems*, *71*, 25-34.

11. Johri, B. N., Sharma, A., & Virdi, J. S. (2003). Rhizobacterial diversity in India and its influence on soil and plant health. *Biotechnology in India I*, 49-89.

12. Rajper, A. M., Udawatta, R. P., Kremer, R. J., Lin, C. H., & Jose, S. (2016). Effects of probiotics on soil microbial activity, biomass and enzymatic activity under cover crops in field and greenhouse studies. *Agroforestry Systems*, *90*, 811-827.

13. Senanayake, Y. D. A. (1996). Natural Farming Systems in the Asia-Pacific Region: Strategies for Sustainability. In *Proceedings of the Conference on Nature Farming for a Sustainable Agriculture, Santa Barbara, USA* (pp. 32-39).

14. Bargaz, A., Lyamlouli, K., Chtouki, M., Zeroual, Y., & Dhiba, D. (2018). Soil microbial resources for improving fertilizers efficiency in an integrated plant nutrient management system. *Frontiers in microbiology*, *9*, 1606.

15. Pallavi, Chandra, D., & Sharma, A. K. (2017). Commercial microbial products: exploiting beneficial plant-microbe interaction. *Plant-Microbe Interactions in Agro-Ecological Perspectives: Volume 2: Microbial Interactions and Agro-Ecological Impacts*, 607-626.

16. Kumawat, K. C., Sharma, P., Nagpal, S., Gupta, R. K., Sirari, A., Nair, R. M., ... & Singh, S. (2021). Dual microbial inoculation, a game changer?–bacterial biostimulants with multifunctional growth promoting traits to mitigate salinity stress in spring mungbean. *Frontiers in microbiology*, *11*, 600576.

17. Giller, K. E., & Cadisch, G. (1995). Future benefits from biological nitrogen fixation: an ecological approach to agriculture. In *Management of Biological Nitrogen Fixation for the Development of More Productive and Sustainable Agricultural Systems: Extended versions of papers presented at the Symposium on Biological Nitrogen Fixation for Sustainable Agriculture at the 15th Congress of Soil Science, Acapulco, Mexico, 1994* (pp. 255-277). Springer Netherlands.

18. Brahmaprakash, G. P., Sahu, P. K., Lavanya, G., Nair, S. S., Gangaraddi, V. K., & Gupta, A. (2017). Microbial functions of the rhizosphere. *Plant-Microbe Interactions in Agro-Ecological Perspectives: Volume 1: Fundamental Mechanisms, Methods and Functions*, 177-210.