SRHU JOURNAL OF ADVANCED RESEARCH

Exploiting Plant Microbiome for Sustainable Agriculture and Environment

Vivek Kumar (0000-0002-0274-5212)

School of Biosciences, Swami Rama Himalayan University, Jolly Grant, Dehradun-248016, Uttarakhand, India

vivekkumar@srhu.edu.in

Article Info
Received: 15 March 2026, received in revised form: 8 April 2026, accepted: 19 April 2026, available online: 9 May 2026; Volume: 1; Issue: 1; Pages: 102-104.

Citation: Kumar V. 2026. Exploiting Plant Microbiome for Sustainable Agriculture and Environment. SRHU J Adv Res. 1(1): 102-104.

DOI:

1. Introduction

The global population is growing at a rapid pace, and therefore, we need to produce a regular supply of food to manage food security. Because of these needs, traditional farming systems have evolved significantly, heavily reliant on agrochemicals such as chemical fertilizers, pesticides, and herbicides. These agrochemicals have come at the cost of soil quality, environmental integrity, and human health, despite their success in enhancing crop production. Environmental degradation, water body pollution, loss of biodiversity, and soil erosion are consequences of the misuse of agrochemicals (Kuppan et al. 2024). Other major contributors include deforestation and habitat conversion are chief causes of change in environmental conditions. This leads to release of huge amounts of deposited carbon into the atmosphere. This lessens the earth's capability to absorb greenhouse gases, since forests act as carbon sinks. This causes considerable loss of biodiversity, soil erosion, and disturbed water cycles, eventually speeding global warming and fluctuating local ecosystem (Leon et al. 2022). On the other hand, intensive tillage and monoculture are constituents of contemporary cultivation, which is intended to increase the yields, but initiate noteworthy negative changes on environment and climate. Soil health degraded by these practices, and releases huge amounts of carbon, decrease biodiversity, and impact the climate change (Derpsch et al. 2024).

Further, industrial and urban pollution are also major causes of climate change, releasing greenhouse gases (GHGs), and generating unsafe air pollutants that deteriorate health, biodiversity, and stability of ecosystem. While climate change influences like extreme weather, which further stresses urban areas, producing a vicious cycle (Voumik and Sultana, 2022). Salinization, a condition where salt builds up in the topsoil due to human activity and makes it infertile, is largely caused by poorly managed irrigation. It is projected that world's 20% agriculture soil and around 33% of irrigated soil is impacted by this, and it is projected that by 2050, up to 50% of arable land would be affected by salinity (Kumar and Nautiyal, 2026a).

Soil microbiomes, then, are a reliable and environmentally friendly alternative to classical chemical inputs. The various categories of microorganisms described as soil microbiomes, such as bacteria, fungi, and protozoa, exchange material with plant roots, particularly in the area of the rhizosphere, that is to say, the soil in immediate proximity to the roots. These microorganisms perform significant tasks, which are important for plant growth, fertility of soils, and for maintaining ecosystem dynamics (Kumar and Nautiyal, 2026b). Moreover, the microbes also perform important part in in mitigating diverse stresses and also mange pests. These potent microbiomes are also involved in nutrients biogeochemical cycles, which provides nutrients to plant for growth and development. Though the interactions between plants and soil microbiome, especially those in the rhizosphere, are very complicated and varied. Incorporation of microbes in agro-ecosystem provides nutrients to plant, and therefore, they help in reducing dependence on diverse agrochemicals, which is a step towards clean and green agriculture (Kumar et al. 2018).

Owing to the diverse research and development activities, microbiome as biofertilizers and biopesticides, paved a way towards chemical-free agricultural practices, and toward an organic system (Suman et al. 2022). Development in the field of diverse omics approaches (genomics, proteomics, transcriptomics, and metabolomics) has led to the better understanding of plant-microbiome interaction and their functionalities (Kimotho and Maina, 2024). Using these novel approaches, the complicated relationship between microbes and their host have been understood. This understanding has resulted in selection of potential biofertilizer candidates and their suitable host for a particular agro-ecosystem.

The soil microbiome and their processes within a soil environment, is critical to the fertility, health, and structure of the soil. Through their effects on soil carbon turnover and sequestration, as well as their consumption and generation of greenhouse gases (GHGs), soil microbes are powerful actors in climate-relevant processes (Abd-Alla et al. 2023). Thus, leveraging soil microbial activity to increase soil carbon stores is potentially a viable strategy but has its downsides.

Soil microbiome interventions have the potential to restore soil organic matter (SOM) and undo the consequences of soil degradation; they may be especially pertinent in disturbed settings (Sáez-Sandino et al. 2023). Encouraging soil microbiome management could optimize soil carbon content, plant yields, and soil health simultaneously. For instance, certain rhizobacteria promote plant growth by fixing nitrogen, solubilizing phosphorus, and producing siderophores and phytohormones, while mycorrhizal fungi extend root systems, enhancing water and nutrient acquisition (Fall et al. 2022; Abd-Alla et al. 2023). Also, beneficial microbes can create systemic plant resistance, a natural immunity against pathogens that diminishes the utilization of chemical pesticides. The use of microbiome-based approaches, including microbiome engineering and microbial inoculants, has great potential for sustainable agriculture and environment. By selective application of beneficial microbial consortia, farmers can enhance soil health, enhance crop resilience, and reduce abiotic stresses such as salinity and temperature variations (Kumar et al. 2013; Samaddar et al. 2019). Therefore, the use of plant microbiomes can contribute to carbon sequestration, soil rejuvenation, crop growth, and the cleanup of polluted environments, and agro-practices become climate smart and regenerative (Kumar and Nautiyal, 2022; Pandey and Sharan, 2025).

As the world moves toward a more sustainable future, plant microbiomes could play an important role as a suitable candidate to attain UN Sustainable Development Goals (SDGs). Competent microbes by providing nutrients, managing pests, act as bioremediating agent, sequester carbon, and also improve soil structure (Sharma et al. 2021). Therefore, plant associated microbes solves the chemical based agricultural issues, play a role in recovery of agro-ecosystem from toxicants, and led a step towards climate change mitigation for tomorrow's generation.

References

Abd-Alla MH, Al-Amri SM, El-Enany A-WE (2023) Enhancing Rhizobium–legume symbiosis and reducing nitrogen fertilizer use are potential options for mitigating climate change. Agriculture 13 2092 https://doi.org/10.3390/agriculture13112092.

Derpsch R, Kassam A, Reicosky D, Friedrich T, Calegari A, Basch G, Gonzalez-Sanchez E, dos Santos DR. 2024. Nature's laws of declining soil productivity and Conservation Agriculture, Soil Security.14,100127, https://doi.org/10.1016/j.soisec.2024.100127

Fall AF, Nakabonge G, Ssekandi J, Founoune-Mboup H, Apori SO, Ndiaye A, Badji A, Ngom K (2022) Roles of arbuscular mycorrhizal fungi on soil fertility: contribution in the improvement of physical, chemical, and biological properties of the soil. Front Fungal Biol. 3:723892. doi: 10.3389/ffunb.2022.723892.

Kimotho RN, Maina S (2024) Unraveling plant-microbe interactions: can integrated omics approaches offer concrete answers? J Exp Bot 75:1289-1313. doi: 10.1093/jxb/erad448

Kumar M, Sharma S, Gupta S, Kumar V (2018) Mitigation of abiotic stresses in Lycopersicon esculentum by endophytic bacteria. Environ Sustain. 1: 71-80 https://doi.org/10.1007/s42398-018-0004-4

Kumar R, Farda B, Mignini A, Djebaili R, Koolman L, Paul A, Mondal S, Joel JM, Pandit A, Panneerselvam P, et al. 2025. Microbial solutions in agriculture: Enhancing soil health and resilience through bio-inoculants and bioremediation. Bacteria. 4(3):28. https://doi.org/10.3390/bacteria4030028

Kumar V, Bisht S, Teotia P, Sharma S, Solanki AS (2013) Interaction between G. fasciculatum and A. chroococcum for yield, nutrients uptake and cost economy of Lepidium sativum in Indian arid region. Thailand J Agric Sci 46: 21-28.

Kumar V, Nautiyal CS (2022) Plant abiotic and biotic stress alleviation: From an endophytic microbial perspective. Curr Microbiol 79:311-325. https://doi.org/10.1007/s00284-022-03012-2

Kumar V, Nautiyal CS. 2026a. From hidden allies to precision symbionts: unleashing endophytes for sustainable agroecosystems. World J Microbiol Biotechnol 42, 172. https://doi.org/10.1007/s11274-026-04896-z

Kumar V, Nautiyal CS. 2026b. Harnessing the plant microbiome: innovation towards sustainable agriculture and ecological resilience. Antonie van Leevenhoek. 119: 118. https://doi.org/10.1007/s10482-026-02330-w

Kuppan N, Padman M, Mahadeva M, Srinivasan S, Devarajan R (2024) A comprehensive review of sustainable bioremediation techniques: Eco friendly solutions for waste and pollution management. Waste Manag Bull 2: 154-171 https://doi.org/10.1016/j.wmb.2024.07.005.

Leon M, Cornejo G, Calderón M, González-Carrión E, Florez H. 2022. Effect of deforestation on climate change: a co-integration and causality approach with time series. Sustainability. 14(18):11303. https://doi.org/10.3390/su141811303

Pandey K, Saharan BS. 2025. Soil microbiomes: a promising strategy for boosting crop yield and advancing sustainable agriculture. Discov Agric 3, 54. https://doi.org/10.1007/s44279-025-00208-5

Sáez-Sandino T, Delgado-Baquerizo M, Egidi E, Singh BK. 2023. New microbial tools to boost restoration and soil organic matter. Microb Biotechnol. 16(11):2019-2025. doi: 10.1111/1751-7915.14325.

Samaddar S, Chatterjee P, Roy Choudhury A, Ahmed S, Sa T (2019) Interactions between Pseudomonas spp. and their role in improving the red pepper plant growth under salinity stress. Microbiol Res 219:66–73 doi: 10.1016/j.micres.2018.11.005

Sharma P, Kumar T, Yadav M, Gill SS, Chauhan NS (2021) Plant-microbe interactions for the sustainable agriculture and food security. Plant Gene 28: 100325 https://doi.org/10.1016/j.plgene.2021.100325

Suman J, Rakshit A, Ogireddy SD, Singh S, Gupta C and Chandrakala J (2022) Microbiome as a key player in sustainable agriculture and human health. Front Soil Sci 2:821589. doi: 10.3389/fsoil.2022.821589

Voumik LC, Sultana T. 2022. Impact of urbanization, industrialization, electrification and renewable energy on the environment in BRICS: fresh evidence from novel CS-ARDL model, Heliyon, 8(11), e11457, https://doi.org/10.1016/j.heliyon.2022.e11457