Vol. 5 Issue- 6, February 2025 (e-ISSN: 2582-8223)

Rooted in Harmony: How Plant-Soil-Microbe Interactions Sustain Wildlife Health

Gali Suresh[1] and Deepak Kher [2]
[1]Assistant Professor, School of Agriculture,
[2]Dean, School of Agriculture
Sanjeev Agrawal Global Educational University, Bhopal, M.P, 462022, India.

ARTICLE ID: 37

Abstract

Plant-soil-microbe interactions, particularly within the rhizosphere, are foundational to maintaining soil biodiversity and sustaining ecosystem dynamics. These interactions not only enhance soil nutrient cycling but also underpin food web stability, influencing wildlife health. This article delves into how rhizosphere-mediated processes, such as mycorrhizal associations, drive nutrient availability and contribute to the survival and well-being of herbivores and other wildlife species.

Introduction

The intricate relationships among plants, soil microbes, and wildlife form a dynamic network critical to ecosystem health. Plant roots serve as biochemical hubs, secreting exudates that shape microbial communities in the rhizosphere. In turn, these microbes facilitate nutrient cycling and organic matter decomposition, processes that directly or indirectly sustain wildlife through the food web (Jiang *et al*., 2022). Understanding these interactions provides insights into ecological resilience, especially in the context of habitat degradation and climate change.

Plant Roots and the Rhizosphere: A Biodiversity Hotspot

The rhizosphere, a narrow region of soil influenced by root exudates, is teeming with microbial life. Mycorrhizal fungi, a key component of this community, establish mutualistic relationships with plant roots. Arbuscular mycorrhizal fungi (AMF) enhance phosphorus uptake, while ectomycorrhizal fungi assist in decomposing complex organic matter, releasing essential nutrients (Smith & Read, 2020). These nutrient fluxes indirectly support herbivores, which depend on nutrient-rich plants for sustenance.

Case Study 1: Mycorrhizal Networks and Herbivore Health

Van der Heijden *et al*. (2021) highlighted the role of mycorrhizal networks in enhancing plant nutrient content, significantly benefiting herbivores in grassland ecosystems. The study

JUST AGRICULTURE
multidisciplinary e-Newsletter

demonstrated that mycorrhizal fungi improve the uptake of phosphorus and nitrogen, boosting the nutritional quality of grasses consumed by grazing animals. This increased nutrient density supports herbivore growth, reproduction, and resilience to environmental stressors, showcasing the cascading effects of rhizosphere interactions on food web stability.

Bennett and Classen (2020) investigated how mycorrhizal associations in temperate grasslands influence plant species composition and nutrient cycling. Their findings indicated that mycorrhizal fungi not only increase nutrient absorption but also enhance root biomass and soil structure, contributing to more resilient forage species. This, in turn, leads to higher grazing efficiency and better overall health in herbivore populations. Similarly, Avital *et al*. (2022) demonstrated that mycorrhizal inoculation in degraded grazing lands significantly improved forage yield and quality, which translated into higher body mass and reproductive success in livestock and wild herbivores.

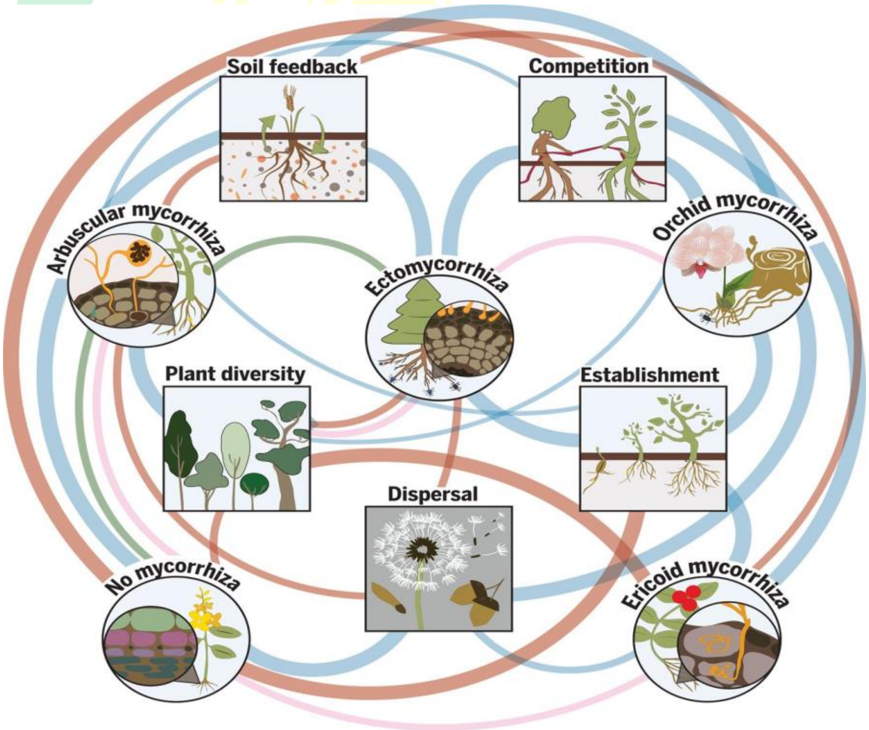

Figure: A diagram illustrating how various mycorrhizal types (represented by circles) affect plant population and community-level processes (depicted by squares). Blue lines indicate positive effects, red lines represent negative effects, green lines show the overlap of plant species among mycorrhizal types, and pink lines depict the overlap of fungal species across mycorrhizal types. The width of each line reflects the relative strength of the effect (Wu *et al*., 2023).

Case Study 2: Soil Microbes: The Invisible Engineers of the Food Web

Zhou *et al*. (2023) explored the role of nitrogen-fixing bacteria like *Rhizobium* in enhancing soil fertility and supporting plant growth, ultimately benefiting herbivorous insects and mammals. This microbial activity triggers a bottom-up effect, enriching the food web from primary producers to higher trophic levels. Their findings revealed that the increased nitrogen content in leguminous plants resulted in greater biomass production, supporting populations of grasshoppers, deer, and other herbivores.

Delgado-Baquerizo *et al*. (2021) studied microbial-driven decomposition processes and their influence on nutrient cycling in dryland ecosystems. The research demonstrated that microbial diversity accelerates organic matter decomposition, improving soil nutrient availability. This directly affects the abundance and diversity of primary producers, creating a reliable food source for herbivores and indirectly supporting predator populations. Additionally, Wang *et al*. (2022) found that symbiotic relationships between plants and rhizobacteria enhanced root growth and nutrient uptake, leading to higher crop yields and increased food resources for local wildlife.

Case Study 3: Rhizosphere-Driven Impacts on Wildlife Health

Tedersoo *et al*. (2020) underscored how mycorrhizal fungi improve tree resilience to drought and pathogens in forest ecosystems, ensuring a stable habitat for birds, mammals, and insects. The study demonstrated that trees with well-established ectomycorrhizal associations showed reduced mortality during dry seasons, contributing to sustained wildlife populations that rely on foliage, seeds, and shelter.

Frąc *et al*. (2022) investigated the role of microbial diversity in maintaining plant community health in mixed forests. Their findings highlighted that a richer microbial community in the rhizosphere promoted higher plant species richness, providing diverse food and habitat resources for wildlife. Similarly, Martínez-García *et al*. (2021) demonstrated that soil microbial inoculation in reforestation projects increased sapling survival rates, accelerating the recovery of wildlife corridors and enhancing biodiversity.

Challenges and Future Prospectives

Bender *et al*. (2023) emphasized the urgent need to restore rhizosphere diversity through regenerative agricultural practices and habitat conservation. Their review suggested that mycorrhizal inoculation, cover cropping, and reduced tillage could revitalize soil biodiversity, mitigating the negative impacts of climate change and intensive farming.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Rodrigues *et al*. (2024) highlighted the importance of rewilding projects that focus on restoring native plant species and soil microbial communities. These efforts not only improve soil structure and nutrient cycling but also enhance wildlife habitats, promoting ecosystem resilience. De Vries *et al*. (2023) pointed to the need for global policy shifts to protect soil biodiversity as a critical component of wildlife conservation strategies.

Conclusion

Plant-soil-microbe interactions within the rhizosphere are a cornerstone of ecosystem health, influencing nutrient cycling, food web stability, and wildlife health. Protecting and restoring these interactions is essential for maintaining biodiversity and ecological resilience in the face of global environmental challenges.

References

Avital, Y., Gross, A., & Shelef, O. (2022). Mycorrhizal inoculation enhances forage yield and quality in semi-arid grazing lands. *Agriculture, Ecosystems & Environment, 322*, 107681.

Bender, S. F., Wagg, C., & van der Heijden, M. G. A. (2023). Soil biodiversity and ecosystem function. *Nature Reviews Earth & Environment, 4*(1), 50–63.

Bennett, J. A., & Classen, A. T. (2020). Climate change influences mycorrhizal fungal communities that may accelerate grassland carbon cycling. *Ecology Letters, 23*(7), 1261–1271.

de Vries, F. T., Wall, D. H., & Bardgett, R. D. (2023). Global perspectives on soil biodiversity and conservation. *Nature Sustainability, 6*(4), 345–356.

Delgado-Baquerizo, M., Reich, P. B., Trivedi, C., Eldridge, D. J., & Singh, B. K. (2021). Multiple elements of soil biodiversity drive ecosystem functions across biomes. *Nature Ecology & Evolution, 5*(6), 507–518.

Frąc, M., Hannula, S. E., Bełka, M., & Jędryczka, M. (2022). Fungal biodiversity and their role in soil health. *Frontiers in Microbiology, 13*, 805275.

Martínez-García, L. B., Richardson, S. J., & Tibbett, M. (2021). Microbial inoculation accelerates forest restoration by enhancing tree growth and survival. *Journal of Applied Ecology, 58*(4), 848–859.

Rodrigues, L. M., Pereira, P., & Loureiro, C. (2024). Rewilding and soil biodiversity: A pathway to ecosystem recovery. *Ecological Applications, 34*(1), e2915.

Tedersoo, L., Bahram, M., & Zobel, M. (2020). How mycorrhizal associations drive plant population and community biology. *Science, 367*(6480), eaba1223.

van der Heijden, M. G. A., Martin, F. M., Selosse, M. A., & Sanders, I. R. (2021). Mycorrhizal ecology and evolution: The past, the present, and the future. *New Phytologist, 231*(3), 1123–1136.

Wang, Y., Wang, R., & Liu, H. (2022). Plant growth-promoting rhizobacteria enhance crop yield and soil health under sustainable agricultural practices. *Agronomy Journal, 114*(9), 3124–3135.

Wu, L., Weston, L. A., Zhu, S., & Zhou, X. (2023). Editorial: Rhizosphere interactions: root exudates and the rhizosphere microbiome. *Frontiers in Plant Science, 14*.

Zhou, Z., Wang, C., & Luo, Y. (2023). Meta-analysis of the effects of plant-soil feedback on plant growth and soil microbiome. *Nature Ecology & Evolution, 7*(3), 450–460.