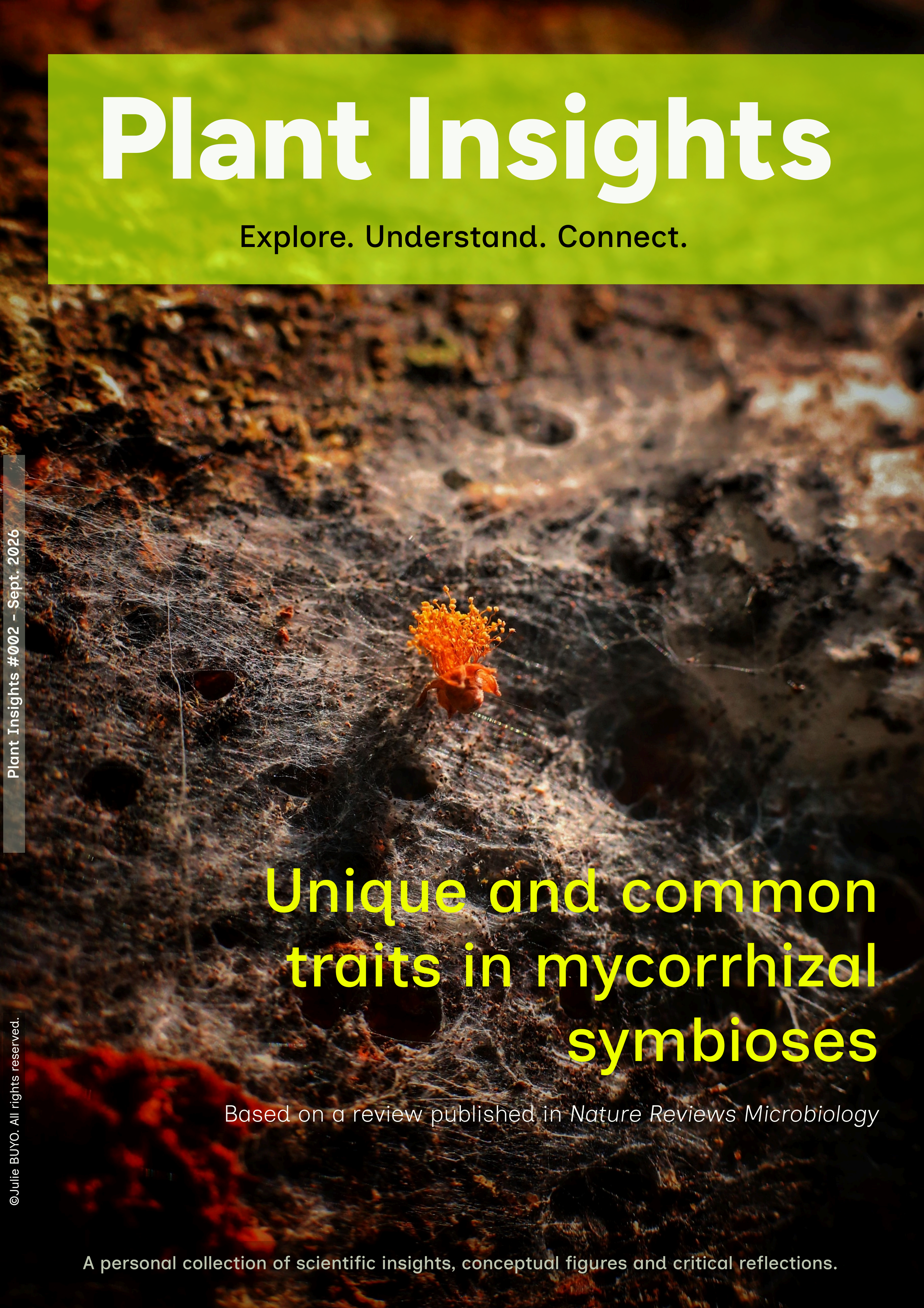

Plant Insights

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Plant Insights #002 - Sept. 2026

Unique and common traits in mycorrhizal symbioses

Based on a review published in *Nature Reviews Microbiology*

A personal collection of scientific insights, conceptual figures and critical reflections.

How have plant–fungus partnerships shaped plant evolution and ecosystem functioning for over 400 million years?

Why It Matters ?

Mycorrhizal symbioses are among the most widespread and influential biological interactions on Earth. They have shaped plant evolution for more than 400 million years, support nutrient cycling, improve plant nutrition and contribute to soil health and carbon sequestration. As agriculture faces increasing environmental challenges, understanding these ancient partnerships may provide new strategies to improve crop productivity while reducing dependence on chemical inputs.

Article Details

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Research area: Mycorrhizal symbiosis · Plant-fungus interactions · Evolution · Molecular signalling
Authors: Andrea Genre · Luisa Lanfranco · Silvia Perotto · Paola Bonfante
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KEY INSIGHTS

01. Mycorrhizas shaped plant evolution

The fossil record and phylogenomic data show that mycorrhizal symbioses are at least 400 million years old and were likely instrumental in the colonization of land by early plants. Over evolutionary time, these partnerships diversified into four major types-arbuscular, ecto-, orchid, and ericoid mycorrhizas-each reflecting specific host-fungus coevolutionary trajectories.

02. Different symbioses share a common molecular language

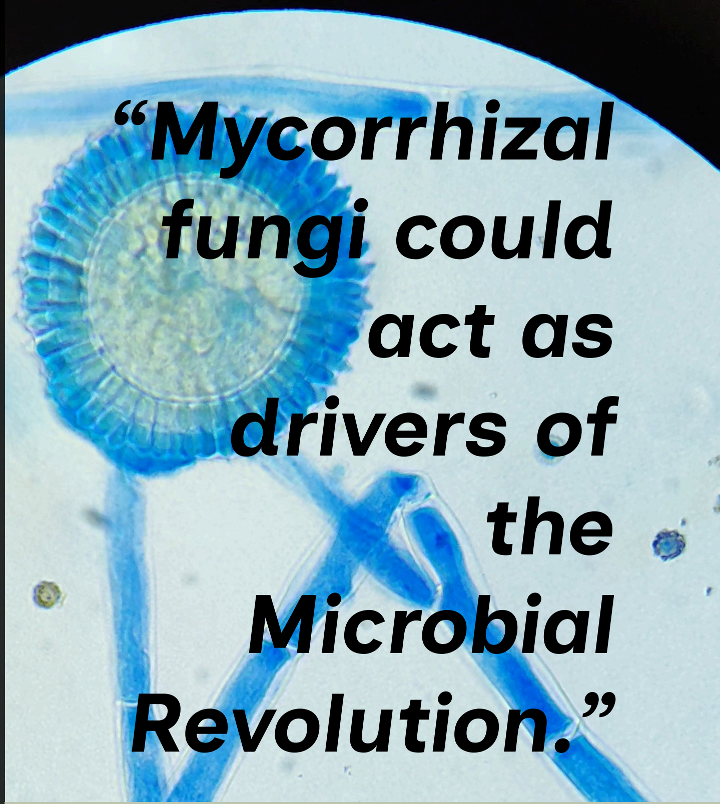
Despite the morphological and ecological diversity of mycorrhizal types, the underlying molecular dialogue is remarkably conserved. Plants possess a shared genetic toolkit, the common symbiotic signalling pathway (CSSP), that enables recognition and accommodation of fungal partners across the three endomycorrhizal types (AM, ERM, ORM).

03. A coordinated biological partnership

Mycorrhizas function as finely tuned biological exchanges: the plant supplies photosynthesis-derived carbon to the fungus, while the fungus provides soil-derived nutrients (phosphorus, nitrogen, sulfur) and water to the plant. This bidirectional transfer occurs through specialized cellular interfaces that maximize the efficiency of the exchange.

04. Ancient symbioses for future agriculture

Mycorrhizal fungi enhance plant productivity, improve stress tolerance, and contribute to soil health and carbon sequestration. As agriculture faces mounting environmental pressures-soil degradation, nutrient depletion, climate change-harnessing these ancient partnerships offers a pathway toward more sustainable and resilient food production systems.



"Mycorrhizal fungi could act as drivers of the Microbial Revolution."

TAKE-HOME MESSAGE

Mycorrhizal symbioses are not simply nutrient exchanges. They are ancient, highly coordinated biological partnerships that have shaped plant evolution, ecosystem functioning and hold great potential for the future of sustainable agriculture.

THE ROOT AS A SELECTIVE INTERFACE

How one molecular dialogue can lead to defence or symbiosis

RECIPROCAL CHEMICAL DIALOGUE

Plant roots release strigolactones. Fungal hyphae release Myc-factors such as short-chain chitin oligomers (COs) and lipo-chitooligosaccharides (LCOs). This chemical exchange between the two partners begins before any physical contact.

↓

CONTEXT DEPENDENT PERCEPTION

The same family of fungal molecules can trigger opposite responses. Short-chain chitin oligomers (tetra- and pentamers) and LCOs are potent elicitors of symbiotic signalling, whereas longer chains (such as chito-octamers) activate pattern-triggered immunity. Perception depends on the cohort of LysM receptors and co-receptors that discriminate between short and long chitin chains.

SIGNAL STRUCTURE + RECEPTOR CONTEXT + HOST STATE
= CELLULAR INTERPRETATION

TWO POSSIBLE CELLULAR OUTCOMES

DEFENCE RESPONSE

Longer chitin fragments activate pattern-triggered immunity: MAPK signalling, reactive oxygen species release, and defence gene expression. This early defensive activation is transient and decreases as the symbiosis matures. It also acts as a priming signal: it contributes to mycorrhiza-induced resistance (MIR), which raises the plant's protection against pathogens, nematodes, insects and viruses.

IMMUNITY IS TUNED, NOT SWITCHED OFF.

SYMBIOTIC ACCOMODATION

Short-chain COs and LCOs activate the plant common symbiotic signalling pathway (CSSP), nuclear Ca2+ spiking, and symbiosis-supporting genes. This prepares the root for fungal colonization, and mycorrhizal fungi can additionally modulate plant immunity through secreted effector proteins.

A CONTROLLED INTERFACE IS BUILT

In a functional symbiosis, the fungal hypha is accommodated within a host-defined interface. The hypha stays in the apoplast and never enters the plant cytoplasm: it remains separated from it by a plant-derived membrane and interface compartment. This boundary allows communication and exchange while preserving cellular control.

EXCHANGE BECOMES FUNCTIONAL

THE INTERFACE IS THE FUNCTIONAL CORE OF THE SYMBIOSIS.

FUNGUS TO PLANT

Mineral nutrients such as phosphorus and nitrogen, collected by the fungal network, are transferred to the plant.

PLANT TO FUNGUS

Photosynthetically fixed carbon, including fatty acids synthesized by the host, is delivered to the fungal partner.

SAME SIGNAL FAMILY
→ DIFFERENT INTERPRETATION
→ DIFFERENT CELLULAR OUTCOME

Symbiosis begins when the plant can accommodate the fungus without abandoning defence.

Figure Legend

Figure 1. From signal perception to a functional symbiotic interface. Mycorrhizal symbiosis begins with a reciprocal chemical dialogue: roots release strigolactones and fungi release Myc-factors, including short-chain chitin oligomers and LCOs. Read by LysM receptors and co-receptors, these signals trigger either transient immunity or symbiotic signalling that tunes defence without switching it off and allows controlled colonization. The fungal hypha then develops in the apoplast, separated from the plant cytoplasm by a plant-derived membrane that forms the functional interface for nutrient exchange. Together, these steps show how one family of microbial signals can lead to defence or accommodation depending on context. **Conceptual figure: Julie BUYO. Based on Genre et al. (2020).**

Connecting research findings to broader scientific perspectives.

Scientific Implications_

Mycorrhizas as a route to drought resilience

Arbuscular mycorrhizal fungi improve nutrient acquisition and influence root development, two processes central to plant performance under water limitation. By linking fungal nutrient exchange with root plasticity, mycorrhizas offer a biological route toward more drought-resilient crops.
Their effects remain context-dependent, shaped by plant genotype, fungal identity, nutrient availability and environment. This makes them relevant to efforts to maintain crop growth as water becomes scarce.

Broader Perspectives_

From root symbiosis to sustainable agronomy

Mycorrhizal partnerships extend this research from molecular biology to sustainable agronomy. In crops, they can support nutrient acquisition, productivity, soil aggregation and organic matter accumulation while reducing nutrient losses. This opens a path toward field agriculture, greenhouse production and soil restoration.
The challenge is to identify where these partnerships remain effective under real water limitation.

Research Outlook_

From mechanism to field application

The next step is to test whether mycorrhizal fungi can help crops remain productive under drought. This requires selecting compatible plant-fungus combinations, optimizing inoculation, and comparing outcomes across soils, crops and management systems. Field validation will determine whether benefits observed in controlled conditions can support reliable, lower-input agriculture under fluctuating conditions.

CONNECTIONS_

From mycorrhizas to drought-resilient crops

Water scarcity is becoming an agronomic challenge, not only a problem of plant physiology. Mycorrhizal fungi improve mineral nutrient acquisition, influence root development, and can increase plant tolerance to abiotic stress. This places the symbiosis at the intersection of soil ecology, root biology, and the search for crops that remain productive under drought.
Research on drought responses shows that resilience depends on coordinated changes in root architecture, hormone signalling, and water acquisition (1). Genetic studies highlight ABA, auxin, and root-development pathways, while epigenetic studies reveal distinct drought-responsive regulation in tolerant and sensitive crop lines (1, 2). Mycorrhizas add a microbial layer to this framework by influencing the root environment in which these responses unfold (3).
Could linking symbiotic, physiological, and genetic levels help design crops that respond dynamically to water limitation? The goal is not to present mycorrhizal inoculation as a universal solution, but to identify plant-fungus combinations that support growth under specific drought conditions. Future agronomy may move beyond isolated resistance traits toward resilient roots, where genetics, physiology, and beneficial microbes work together. Under a variable climate, crop performance may depend as much on coordinated adaptation as on resistance.

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(2) MA, L., XING, L., LI, Z. et JIANG, D. *Epigenetic control of plant abiotic stress responses*. Journal of Genetics and Genomics. 2024, vol. 52, no 2, p. 129–144. DOI 10.1016/j.jgg.2024.09.008.
(3) HECK, Carolin, KUHN, Hannah, HEIDT, Sven, WALTER, Stefanie, RIEGER, Nina et REQUENA, Natalia. *Symbiotic fungi control plant root cortex development through the novel GRAS transcription factor MIG1*. Current Biology. 2016, vol. 26, no 20, p. 2770–2778. DOI 10.1016/j.cub.2016.07.059.

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