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The Hidden Network: Mycorrhizal Fungi and Rangeland Resilience

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Healthy soil is the foundation for productive rangelands (Fig. 1). Not only does soil provide a growth medium and nutrient source for plants, but it also plays a role in nutrient cycling and water filtration and storage. When soil is "healthy," it functions in a way that supports ecological processes like decomposition and buffering against drought and erosion. In turn, these processes sustain livestock, wildlife, people, and numerous ecosystem processes.

Effective restoration and conservation efforts include giving attention to the living components of the soil. Soil microorganisms—which include bacteria, fungi, and other tiny life forms—are the foundation of healthy soil. These microbes break down organic matter, recycle nutrients, and influence how water moves through the soil. Together, they form an underground community that maintains essential ecological functions. Among these organisms, mycorrhizal fungi, in particular, drive underground processes that support healthy rangeland ecosystems. Even in semi-arid and arid rangelands, where annual rainfall may be less than 10 inches, mycorrhizal fungi play a critical role in helping plants survive by enhancing access to moisture and nutrients that are scarce.

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Figure 1. Desert grasslands of the Trans-Pecos Rangelands.

What are mycorrhizal fungi?

Mycorrhizal fungi are beneficial soil fungi that form symbiotic relationships with plants and their roots. "Symbiotic" means that both the fungi and the plants benefit from their interaction: the fungi help plants absorb water and nutrients in exchange for carbohydrates created through the plant's photosynthetic process. Around 95 percent of terrestrial plants are capable of forming relationships with mycorrhizal fungi, but the actual level of colonization can vary depending on environmental conditions. This partnership has shaped how plants grow, compete, and survive in diverse ecosystems.

There are two main types of mycorrhizal fungi: ectomycorrhizal and endomycorrhizal. Ectomycorrhizal fungi (Fig. 2) form sheaths outside and around the plant's roots and do not penetrate the root cells. Because of the hosts' larger and

thicker root systems, ectomycorrhizae are more common in forests on trees such as the ponderosa pine. On the other hand, endomycorrhizal fungi (Fig. 3) penetrate the root cells of the fibrous roots of grasses, such as sideoats grama, and herbaceous plants such as butterfly milkweed. Therefore, endomycorrhizae, specifically arbuscular mycorrhizal fungi, are the most dominant type of mycorrhizae in grasslands and rangelands. This type of teamwork between rangeland plants and endomycorrhizae allows for a more efficient exchange of nutrients and water in arid and semi-arid ecosystems.

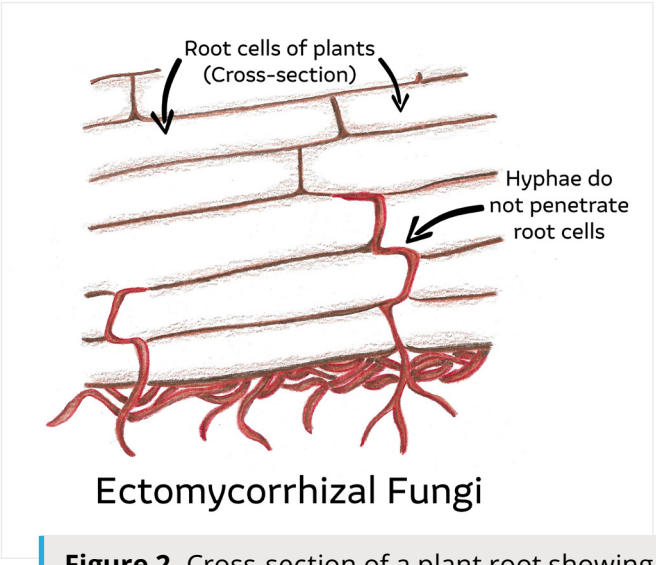

Figure 2. Cross-section of a plant root showing the presence of ectomycorrhizal fungi.

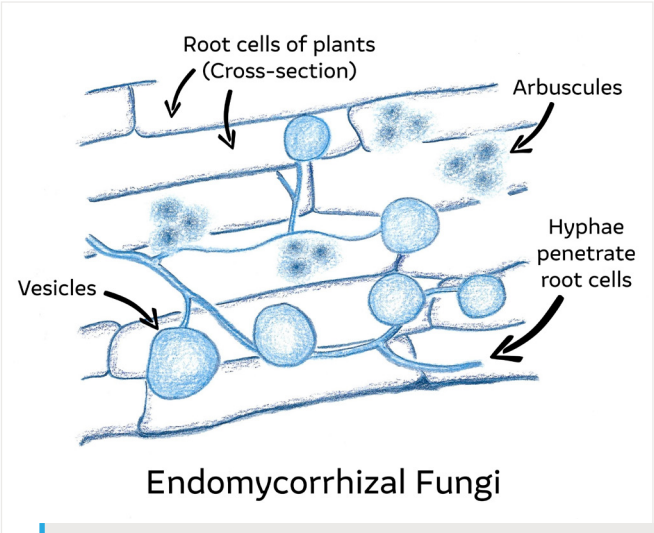

Figure 3. Cross-section of a plant root showing the presence of endomycorrhizal fungi.

How do mycorrhizal fungi work?

Mycorrhizal fungi begin their relationship with plants by colonizing their roots. Once the fungi are established, either outside or inside the root, they form specialized structures that allow them to interact directly with plant cells. From there, the fungus grows outward into the soil, forming extensive networks of thread-like structures called hyphae.

These hyphal networks extend far beyond the root zone, expanding the plant's access to key nutrients, including phosphorus, nitrogen, and various micronutrients. Hyphae also offer improved water uptake and protection against soil pathogens. In return, the fungi receive a steady supply of carbohydrates, which they cannot produce on their own. This relationship enhances plant growth and resilience to stress when water or nutrients are scarce, while also promoting healthy soils.

Why are mycorrhizal fungi important in rangelands?

Mycorrhizal fungi play a role in maintaining the resilience of rangeland ecosystems. Their benefits extend from the soil to the plants and the broader landscape.

Soil benefits

Mycorrhizal fungi enhance soil structure by binding soil particles into stable aggregates through their hyphae and by producing glomalin. These processes support the soil health principles of minimizing disturbance and maintaining continuous living roots by strengthening soil structure. Some additional benefits include:

- Prolonged water retention;
- Improved infiltration;
- Reduced erosion; and
- Supporting soil health by increasing organic matter.

Plant benefits

Mycorrhizal fungi enhance access to water and essential nutrients. Other notable benefits are:

- Increased plant biomass;
- Increased root biomass; and
- Improved drought tolerance.

Ecosystem benefits

Mycorrhizae contribute to plant community diversity, as well as:

- Increase ecosystem resilience, especially in periods of stress from drought or fire, and disturbances such as herbivory; and
- Improve recovery in degraded areas due to enhanced early plant establishment.

Maintaining mycorrhizae in different ecosystems is essential for several reasons, including their universal role in plant health, soil structure and stability, ecosystem resilience, and biodiversity. Mycorrhizal fungi may be more critical in arid and semi-arid ecosystems compared to wetter environments. In dry soils with low nutrient availability, mycorrhizal symbiosis helps plants survive under these extreme conditions. In sandy soils, where particles are loose and erosion-prone, mycorrhizal fungi help form soil aggregates by binding particles together with glomalin, which acts like glue. This aggregation improves soil stability and increases water and nutrient retention. Maintaining healthy fungal communities in these landscapes is crucial for long-term productivity, forage stability, and successful restoration.

What factors affect mycorrhizal fungi on rangelands?

Several environmental and management factors influence the presence and effectiveness of mycorrhizal fungi in rangelands. Understanding what helps or harms these fungi is necessary for maintaining healthy soil-plant relationships.

Soil condition

- Compacted soils can limit air and water flow, making it harder for fungi to spread and colonize.
- Maintaining ground vegetative cover is crucial to prevent soil loss through wind and water erosion.
- Excessive fertilizer use can reduce plant reliance on mycorrhizal fungi and suppress colonization.
- Bare ground exposes soil to erosion, extreme temperatures, and reduces organic matter inputs, creating a harsh environment for fungal growth.

Invasive species

- Some invasive plants do not form mycorrhizal associations or form poor-quality relationships, disrupting native fungal networks.
- Invasive species can alter soil biology and reduce the abundance of fungi that support native plants.
- Heavy termite disturbance or mound formation may disrupt fungal networks and root connections.

Disturbance

- Overgrazing can degrade soil structure, reduce plant cover, and limit the diversity of mycorrhizal fungi.
- Allowing forage to rest and recover after disturbances and maintaining diverse vegetation can promote healthy fungal communities.
- Minimizing disturbance severity allows fungi to reestablish networks and support long-term rangeland productivity.

Supporting mycorrhizal fungi on rangeland

Maintaining healthy mycorrhizal fungi is an integral part of land stewardship. By supporting this symbiotic relationship, landowners can improve soil health, increase forage productivity, and build long-term forage resilience.

Ways to support mycorrhizal fungi

- Minimize soil disturbance by avoiding overgrazing, excessive tilling, compaction, and erosion that disrupts fungal networks.
- Incorporate forage rest and recovery periods to promote healthy root systems and fungal colonization.
- Maintain diverse native plant communities to support diverse and resilient mycorrhizal communities.
- Use low-impact organic soil amendments, such as compost, instead of synthetic fertilizers to enhance soil biology without suppressing beneficial fungi.
- Consider microbial or fungal inoculants in areas where the native fungal community has been lost, such as in compacted or eroded areas, or on newly seeded sites.

Fun fact: **In some cases, mycorrhizal fungi can decrease the fitness of invasive or introduced plant species. This is the case of the barbwire Russian thistle (*Salsola paulsenii* Litv.)—introducing mycorrhizal fungi into the roots of barbwire Russian thistle decreases its fitness, while increasing the mycorrhizal fungi population. This, in turn, facilitates the germination, growth, and survival of native vegetation (Meshkov et al., 2015).**

Glossary

Ectomycorrhizal fungi: Mycorrhizal fungi that grow on the outside of plant roots; common in forests

Endomycorrhizal fungi: Mycorrhizal fungi that penetrate the root cells of plants; common in grasslands

Glomalin: Soil protein that helps soil aggregates stick together

Hyphae: Thread-like fungal structures

Microorganisms: A life form that can only be seen with a microscope

Symbiotic: A relationship between two organisms that benefits both

References

Meshkov, V. V., Kolesnichenko, Y. S., & Borisenko, E. V. (2015). Study interaction of plants and fungi in drained bed of Aral Sea in Kazakhstan (pp. 134–136). In V. G. Storozhenko & V. B. Zviagintsev (Eds), *Problems of forest phytopathology and mycology. Materials of the IX International Conference.* Minsk – Moscow – Petrozavodsk.