The Role of Arbuscular Mycorrhizal Fungi in Plant Nutrition

To determine how mycorrhizal fungi can benefit your production, consider applying these inoculants in your next growing cycle.

BY STEPHANIE GARCIA AND JOZSEF RACSKO

There are many factors that influence plant nutrition and yield. Besides plant genotype, environmental factors such as nutrient availability in the growing media, water availability and uptake, and the ability of the plant to properly utilize what is available in the soil all play an integral part in plant growth.

To help facilitate these processes, plants are able to form a mutually beneficial relationship with arbuscular mycorrhizal fungi, also known as AMF, VAM (vesicular arbuscular mycorrhizae) or endomycorrhizae. This group of soil fungi plays a major role in plant nutrition by facilitating nutrient and water uptake from the soil, and is able to form a mutualistic symbiotic relationship with more than 85 percent of plant species, including almost all major agricultural and horticultural crops.

The fossil evidence suggests that this symbiotic relationship dates back more than 400 million years and played a key role in allowing plants to migrate from the seas onto dry land and use terrestrial habitats. Without mycorrhizal fungi, today's crop plants would likely not exist, nor would life on land as we know it.

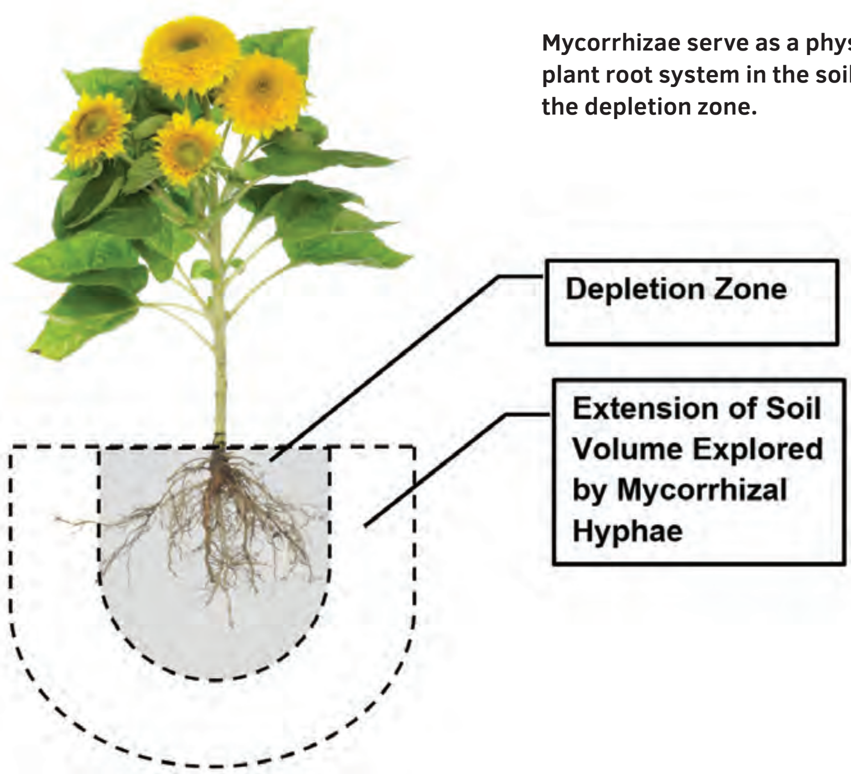
This relationship is initiated after mycelia are born via a spore (equivalent to seeds for plants) and stretches to meet a plant root. If the plant agrees the relationship is necessary, the fungus is invited in. Unique to AMF, these mycelia penetrate the cell membrane and stretch into the root cortex, thus bridging the gap between root and the soil biome. These fungi form specialized structures, namely arbuscules (which serve as the sites of nutrient exchange within the cell), and vesicles (which serve as storage sites).

In this symbiosis, the plant is provided better access to and uptake of nutrients and water from the soil. The fungi assist with these processes in exchange for photosynthetic carbons from the plant.

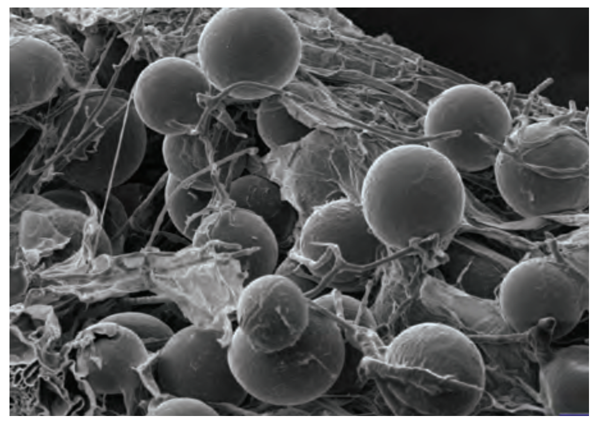
These two coreopsis were grown in identical conditions with a standard commercial nutrient regime, and then subjected to drought stress, with no watering for approximately 48 hours. The coreopsis on the left was inoculated with mycorrhizal fungi at the plug stage, the plant on the right was not. In this trial (conducted at the 2017 California Spring Trials), the mycorrhizal plants resisted wilt for 36 to 48 hours longer than non-treated plants.

These two coreopsis were grown in identical conditions with a standard commercial nutrient regime at the 2017 California Spring Trials (in greenhouse conditions at American Takii). Even with the same fertilizer load (Osmocote slow-release fertilizer), the plants that were treated with mycorrhizae showed improved top growth and root system development (mycorrhizal plant on left).

Experiment conducted with geranium, where plants were grown on a commercial nutrient regime (left) and plants were grown with the same nutrient supply but were additionally inoculated with mycorrhizal fungi (right). Mycorrhizal fungi provided better nutrient and water uptake and use efficiency.



Mycorrhizae serve as a physical extension of the plant root system in the soil by reaching out of the depletion zone.



Scanning electronmicroscopy image of mycorrhizal hyphae and spores.

In this nearly ubiquitous symbiotic relationship between plant roots and mycorrhizal fungi, the latter have been shown to help plants allocate mineral nutrients from the soil, especially immobile elements such as phosphorus, zinc and copper but under certain conditions also more mobile ions such as sulfur, calcium, sodium, potassium, iron, magnesium, manganese, chlorine, bromine and nitrogen.

Mycorrhizal fungi increase efficiency of mineral uptake in soils or growing media where such elements may be deficient or otherwise less available. These fungi have also been shown to moderate certain nutrient uptake in soils that contain high levels of minerals, preventing plant toxicity. Both of these mechanisms result in enhanced plant growth and/or increased yield.

The beneficial growth responses to mycorrhizal fungi are attributed to these mechanisms:

1. INCREASED PHYSICAL EXPLORATION OF THE SOIL

The increase in absorption of various mineral nutrients, including phosphorus, by mycorrhizal plants has been attributed to increases in surface area for nutrient absorption. Plant roots function as the primary absorbing organ of mineral nutrients and water.

Within the soil, plant roots are limited to a small area for absorption of nutrients, while hyphae of arbuscular mycorrhizal fungi grow out beyond the depletion zone, where the plant roots have already removed the available nutrients and water. It has been reported that the root absorptive surface area can increase up to 50 times in mycorrhizal plants compared with that of non-mycorrhizal plants. Fungal hyphae can reach beyond the root zone by 4 to more than 20 cm.

2. INCREASED NUTRIENT AVAILABILITY WITHIN GROWING MEDIA

A number of studies have demonstrated the ability of arbuscular mycorrhizal fungi to solubilize otherwise insoluble nutrients. The mycorrhizal phosphatase enzyme activity

In a closer look of the roots (30 to 40 times magnification), a network of mycorrhizal hyphae and spores can be detected.

converts phosphate into soluble forms and enables mycorrhizal plants to take up more phosphorus than non-mycorrhizal plants. It has been demonstrated that the extraradical hyphae of *Glomus intraradices* were readily capable of hydrolyzing exogenously supplied organic phosphorus sources and transferring significant quantities of phosphorus to roots.

Several mycorrhizal plants including marigold, wheat, onion and corn can increase acid phosphatase activity in roots, and thus hydrolysis of organic phosphorus. For instance, a study with marigold revealed that the increase in acid phosphatase activity in the arbuscular mycorrhizal fungi association was regulated at the gene expression level. This provides clear evidence that molecular changes caused by arbuscular mycorrhizal fungi in the roots increase the capability of the plants to convert insoluble organic P into bioavailable forms of P.

In addition to their roles in phosphorus nutrition, AMF play a major role in uptake and the conversion of insoluble nitrogen to bioavailable forms. AMF increase decomposition and subsequent capture of inorganic nitrogen from complex organic materials such as plant litter. AMF can enhance the degradation of organic residues and nitrogen uptake by the host plant. It has also been reported that arbuscular mycorrhizal fungi species enhanced nitrogen mineralization from organic residues to different levels, e.g., *Glomus clarum* hyphae recovered and translocated up to 25 phosphorus of mineralized nitrogen to Russian wild rye.

3. INCREASED UPTAKE OF NUTRIENTS

The rate of uptake by plant roots colonized by arbuscular mycorrhizal fungi is normally faster than that by non-mycorrhizal roots. Mycorrhizal fungal hyphae have higher affinity for mineral ions and lower threshold concentration for absorption than do plant roots.

Furthermore, the finest absorptive arbuscular mycorrhizal hyphae in soil are typically 2 µm in diameter, compared with root-hair diameters of 10 to 20 µm and fine-root diameters of 100 to 500 µm. Therefore, hyphae are approximately 10 times more efficient than that of root hairs and about 100 times more efficient than that of roots.

4. ACCESS TO STORAGE RESERVES OF ABSORBED MINERALS.

AM fungi form structures called vesicles. These structures act as storage sites within the plant roots and store absorbed minerals and lipids. These stored nutrients act as reserves and become accessible by the host plant when their supply is limited.

5. DECREASED UPTAKE OF SALTS AND TOXIC MINERALS.

Mycorrhizal fungi have shown to protect plants from saline conditions and heavy metal uptake, helping the plant avoid nutrient lockout conditions.

Mycorrhizal fungi have been shown to mitigate uptake of salts, balancing the toxic ion uptake of Na^+ and Cl^-, thus allowing the plant to uptake other ions, such as K^+, Ca^{2+} Mn^{2+}. Plants colonized by AMF also have been shown to possess a buffer between the plant and heavy metals, preventing the uptake of elements like copper, zinc, arsenic and aluminum. Accumulation of these heavy metals in plants can cause various symptoms, including: slow growth, chlorosis, browning of roots and death. This heavy metal resistance has been found to occur via sequestration of these metals in the fungal tissue and also by improved phosphorus nutrition of the plant.

To summarize: the use of mycorrhizal fungi in greenhouse production is a no-brainer. Through the hyphal mass and plant-root connection, these fungi help increase water absorption, increase uptake of nutrients, increase availability of nutrients that are unavailable to the plant's roots, and protect the plant from excess salts or harmful minerals. These fungi can extend farther into the soil than any plant root and they possess several mechanisms to ensure your plants will receive the TLC they deserve. This is a truly beneficial relationship for the plant and for the container grower.

Mycorrhizal fungi have shown to protect plants from saline conditions and heavy metal uptake.

To determine how mycorrhizal fungi can benefit in your operation, consider applying these inoculants in your next growing cycle, or at least running a comparison trial to see how inputs can be reduced and plant performance can increase using this technology. These fungi will be rooting for you! gpn

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