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Effect of *Mycorrhiza* in Soil

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SUMMARY

Mycorrhiza (plural: mycorrhizae) refers to a symbiotic association between fungi and the roots of plants. This mutually beneficial relationship plays a crucial role in nutrient uptake and overall plant health. Mycorrhizal associations are essential for the majority of plants, and they are especially important in ecosystems with nutrient-poor soils. These symbiotic relationships have been integral to the success of plant life on Earth, facilitating nutrient cycling and contributing to the ecological balance of various ecosystems.

INTRODUCTION

The roots of the majority of land-dwelling plants engage in symbiotic relationships with fungi, forming widespread partnerships known as mycorrhizas. These symbiotic connections serve as channels facilitating the exchange of energy and nutrients between plants and the surrounding soil (Cardon and Whitbeck, 2007).This remarkable alliance, established over millions of years of evolution, has profound positive effects on both plant and fungal partners, as well as the broader environment. Mycorrhizal associations come in various forms, with *arbuscular mycorrhizae* (AM) and *ectomycorrhizae* (EM) being two primary types. The key to this symbiosis lies in the exchange of nutrients: while the fungi enhance the plant's ability to absorb essential elements from the soil, the plants reciprocate by providing the fungi with carbohydrates. This dynamic interaction not only contributes to the health and vitality of individual plants but also plays a crucial role in fostering resilient ecosystems. In this exploration of mycorrhiza and its positive effects, we delve into the fascinating mechanisms through which this symbiotic relationship promotes nutrient uptake, enhances plant growth, and ultimately sustains the delicate balance of nature.

Types of Mycorrhiza

There are several types of mycorrhizae, with the two main types being *Arbuscular Mycorrhizae* (AM) and *Ectomycorrhizae* (ECM).

Arbuscular Mycorrhizae (AM):

- AM is the most common type of mycorrhiza and involves fungi from the phylum Glomeromycota.
- The fungal hyphae penetrate the root cells of the plant, forming structures called arbuscules and vesicles.
- Arbuscular mycorrhizas, establishing symbiotic associations with a majority of plants, play a pivotal role in shaping plant community development, influencing nutrient absorption, regulating water relations, and enhancing above-ground productivity.
- Additionally, these mycorrhizas serve as protective agents against pathogens and harmful stresses, acting as bioprotective mechanisms (Heijden, 1998).

Ectomycorrhizae (ECM):

- ECM involves fungi from various phyla, including Basidiomycota and Ascomycota.
- Unlike AM, ECM does not penetrate the plant's cell walls but forms a dense network of hyphae around the outside of the root cells.
- This network, known as the Hartig net, enhances nutrient exchange and provides the plant with access to a larger volume of soil.

Effect of Mycorrhiza

This collaboration is known to improve plant resilience to a range of environmental stressors. Here are some key points on this interaction:

Nutrient Uptake and Exchange:

Mycorrhizal associations have a profound impact on nutrient uptake and exchange in plants. The primary types of mycorrhizae are arbuscular mycorrhizae (AM) and ectomycorrhizae (ECM), both of which play essential roles in enhancing a plant's ability to absorb and acquire nutrients from the soil.

Increased Nutrient Absorption Area:

Mycorrhizal fungi form a network of fine hyphae that extends into the soil beyond the plant root zone. This effectively increases the overall absorption surface area for nutrients. The hyphal network explores a larger volume of soil than plant roots alone, enhancing the plant's access to nutrients that might be present in localized patches.

Improved Phosphorus Uptake:

Phosphorus is often present in the soil in forms that are less accessible to plants. Mycorrhizal fungi can solubilize and mobilize phosphorus, making it more available for the plant. The fungal hyphae form structures called arbuscules that penetrate plant root cells, facilitating the transfer of phosphorus and other nutrients directly to the plant.

Enhanced Nitrogen Uptake:

Mycorrhizal associations can improve the plant's uptake of nitrogen, especially in nutrient-poor soils. The mycorrhizal fungi can acquire nitrogen from organic matter in the soil and convert it into forms that can be readily taken up by the plant.

Micronutrient Acquisition:

Mycorrhizal fungi are involved in the acquisition of micronutrients (such as copper, zinc, and iron) from the soil. The fungi can release organic acids and enzymes that help mobilize and chelate micronutrients, making them more available for uptake by plant roots.

Improved water uptake

Mycorrhizal associations play a crucial role in improving water uptake for plants, particularly in conditions of water stress or low water availability. The mechanisms by which mycorrhizae enhance water uptake include:

Extended Root System:

Mycorrhizal fungi extend the effective root zone of the plant. The fungal hyphae form a dense network in the soil, reaching areas that plant roots alone might not access. This extended network effectively increases the surface area for water absorption, allowing the plant to explore a larger volume of soil.

Improved Soil Structure:

Mycorrhizal fungi can contribute to soil aggregation, creating stable soil structures. Well-aggregated soils have better water infiltration and retention properties, as they allow water to penetrate the soil more easily and resist evaporation.

Hyphal Exploration in Soil Pores:

The fine hyphae of mycorrhizal fungi can navigate through small soil pores that may be inaccessible to plant roots. This exploration increases the chances of encountering water pockets in the soil, especially in dry or compacted conditions.

Increased Water Absorption Efficiency:

Mycorrhizal associations improve the efficiency of water absorption by the plant roots. The fungal hyphae can take up water directly from the soil, and this water is then transferred to the plant. This can be particularly beneficial under conditions where water is limited.

Water Redistribution within the Plant:

Mycorrhizae contribute to a more efficient internal water transport system within the plant. The enhanced nutrient uptake facilitated by mycorrhizal associations supports the plant in maintaining turgor pressure and overall water balance.

Induction of Plant Defense Mechanisms

Mycorrhizal associations can have a significant impact on the induction of plant defense mechanisms, contributing to the plant's ability to defend itself against various biotic stresses, including pathogens.

Priming the Immune System:

Mycorrhizal fungi can act as "biological signals" that prime the plant's immune system for a more rapid and effective response to pathogen attacks. This priming involves the activation of defense-related genes and the production of secondary metabolites even before an actual pathogenic threat occurs.

Systemic Resistance:

Mycorrhizal associations can induce systemic resistance in plants, a phenomenon known as mycorrhiza-induced resistance (MIR) or mycorrhiza-induced systemic resistance (MISR). Systemic resistance involves the plant's ability to mount a defense response not only at the site of infection but also in other parts of the plant that are remote from the initial attack.

Production of Defense Compounds:

Mycorrhizal fungi can stimulate the production of secondary metabolites and defense compounds in plants. These compounds, such as phytoalexins and pathogenesis-related (PR) proteins, play crucial roles in deterring or inhibiting the growth of pathogens.

Enhanced Antioxidant Systems:

Mycorrhizae can enhance the plant's antioxidant defense systems, helping to neutralize reactive oxygen species (ROS) produced during stress or pathogen attack. Improved antioxidant capacity contributes to reduced oxidative damage and supports the plant's overall defense response.

Activation of Signaling Pathways:

Mycorrhizal associations can activate specific signaling pathways in the plant that are associated with defense responses. These pathways often involve the recognition of signals from the mycorrhizal fungi, leading to the activation of defense-related genes and the synthesis of defense proteins.

Improved Pathogen Recognition:

Mycorrhizal fungi can enhance the plant's ability to recognize and respond to pathogens. This improved pathogen recognition is a result of the complex signaling interactions between the plant and the mycorrhizal fungi, leading to a more effective defense response.

Modulation of Jasmonic Acid and Salicylic Acid Pathways:

Mycorrhizae can modulate the balance between the jasmonic acid (JA) and salicylic acid (SA) signaling pathways. These pathways are associated with different types of plant defenses, and the modulation helps tailor the defense response to the specific type of pathogen challenge.

Enhanced Tolerance to Abiotic Stresses

Mycorrhizal associations play a significant role in enhancing a plant's tolerance to various abiotic stresses, which are non-living factors that can negatively affect plant growth and development.

Enhanced Water Uptake and Drought Tolerance:

Mycorrhizal associations improve water uptake by extending the effective root zone through the fungal hyphal network. The enhanced water absorption can help plants cope with drought stress by exploring a larger soil volume and improving water use efficiency.

Salinity Tolerance:

Mycorrhizae contribute to salinity tolerance by improving the absorption of essential nutrients like phosphorus, which can be challenging for plants in saline soils. The symbiotic relationship helps maintain ion homeostasis within plant cells, preventing the toxic effects of excess salts.

Heavy Metal Tolerance:

Mycorrhizal associations can enhance the tolerance of plants to heavy metal contamination in the soil. Mycorrhizal fungi may immobilize or sequester heavy metals, reducing their uptake by plant roots and mitigating their toxic effects on the plant.

Temperature Stress Tolerance:

Mycorrhizae can contribute to improved tolerance to temperature extremes, including both cold and heat stress. The symbiotic relationship supports the plant's ability to withstand temperature fluctuations by enhancing nutrient uptake and promoting overall plant health.

Alleviation of Oxidative Stress:

Mycorrhizal associations help alleviate oxidative stress caused by various abiotic factors, such as high light intensity, pollutants, or drought. The symbiotic relationship enhances the plant's antioxidant defense systems, reducing damage caused by reactive oxygen species (ROS).

Regulation of Abscisic Acid (ABA) Levels:

Mycorrhizae may influence the plant's response to abiotic stresses by regulating the levels of abscisic acid (ABA), a plant hormone associated with stress responses.
A balanced ABA response can help the plant modulate water use and manage stress conditions more effectively.

Induction of Stress-Responsive Genes:

Mycorrhizal associations can induce the expression of stress-responsive genes in plants, preparing them to respond more effectively to abiotic stressors.

Interactions with Plant Growth-Promoting Microbes:

Mycorrhizal associations interact with other plant growth-promoting microbes in the rhizosphere (the soil region surrounding plant roots). These interactions are essential for promoting plant health, nutrient cycling, and overall ecosystem functioning.

Enhanced Nutrient Availability:

Mycorrhizal fungi can form symbiotic relationships with nitrogen-fixing bacteria, such as rhizobia or free-living nitrogen-fixing bacteria. These nitrogen-fixing bacteria convert atmospheric nitrogen into a form that is readily available to plants. The mycorrhizal network facilitates the transfer of fixed nitrogen to the plant, enhancing overall nutrient availability.

Increased Phosphorus Mobilization:

Mycorrhizal fungi release organic acids and enzymes that help mobilize and solubilize phosphorus in the soil. This enhanced phosphorus availability benefits not only the plant but also other microbes in the rhizosphere that may rely on phosphorus for their growth and activities.

Facilitation of Microbial Consortia:

Mycorrhizal associations create a complex microbial community in the rhizosphere by providing a network for the exchange of nutrients and signaling compounds. This microbial consortia can include various bacteria, fungi, and other microorganisms that contribute to nutrient cycling, disease suppression, and overall soil health.

Induction of Plant Defense Mechanisms:

Mycorrhizal associations can stimulate the plant's defense mechanisms, and this signaling may extend to other beneficial microbes in the rhizosphere. The presence of mycorrhizae can create an environment conducive to the proliferation of beneficial microorganisms that contribute to plant protection against pathogens.

Biocontrol of Soilborne Pathogens:

Mycorrhizal fungi can form associations with certain rhizosphere bacteria and fungi that have biocontrol properties against soilborne pathogens. These biocontrol agents help suppress the growth and activity of pathogenic microorganisms, contributing to plant health.

Enhanced Plant Growth-Promoting Rhizobacteria (PGPR) Activities:

Mycorrhizal associations can positively influence the activities of PGPR, such as nitrogen-fixing bacteria and phosphate-solubilizing bacteria. These PGPR contribute to nutrient availability, disease suppression, and overall plant growth promotion.

CONCLUSION

In conclusion, mycorrhiza emerges as a cornerstone of ecological resilience and plant health, showcasing the intricate dance between plants and fungi beneath the soil's surface. As we reflect on the positive effects of mycorrhizal associations, it becomes evident that this symbiotic relationship is not merely a biological occurrence but a vital force shaping the vitality of ecosystems. The enhanced nutrient uptake, improved water absorption, and increased disease resistance facilitated by mycorrhiza contribute to the sustainability and stability of plant communities. Understanding and appreciating the positive impacts of mycorrhiza is not just a scientific pursuit but a call to recognize the interconnectedness and interdependence that defines the beauty of our natural world.

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