JUST AGRICULTURE
multidisciplinary e-Newsletter

Mycorrhizal Association with Litchi Production

P. K. Nimbolkar[1], Srishtty Kashyap[1*] and Sunita Dhar[2] and Ajaykumara K. M.
College of Horticulture and Forestry, Pasighat, Arunachal Pradesh

ARTICLE ID: 30

Mycorrhiza is a symbiotic mutualistic association between special soil fungi and fine plant roots. The fungus may invade host plant roots in a mycorrhizal relationship, either intercellularly or extracellularly. The fungi play an important role in plant health by improving nutrient and water uptake by their host plant and providing protection against soil-borne pathogens (Ryan and Graham, 2002). In return, the fungi receive carbohydrates and growth factors from the host plant.

Litchi is an important evergreen, subtropical fruit crop in India and is relished by people all across the world irrespective of its short period of availability in the market. In India, litchi is cultivated over an area of approximately 99,000 hectares, with a production of 7.37 lakh metric tons and a productivity of 7.43 tons/ha (Pathak *et al.*, 2023). Bihar followed by West Bengal and Uttar Pradesh are the main litchi producing states in the country. The heart to oval-shaped fruits is well known for their exquisite flavor, aroma, and nutritive values. The fruits are highly perishable and available for 45-50 days in the market in an entire year. The roots of litchi exhibit a mycorrhizal association with Arbuscular Mycorrhizal Fungi (AMF) which in turn aids in increasing the yield of the plant. This chapter focuses on understanding how the interaction of AMF with the litchi rhizosphere helps to enhance the potential productivity of the litchi.

Classification of Mycorrhizae

Albert Bernard Frank coined the term mycorrhiza in 1885 and it originated from the Greek words mycos, meaning ‘fungus’, and rhiza, meaning ‘roots’. Based on morphological and anatomical features mycorrhizae are classified into:

1. **Ectomycorrhizae**: The ectomycorrhizae consist of a hyphal sheath covering the root apex and a Hartig hyphal network that surrounds the plant cells in the root cortex. They form symbiotic relationships with approximately 10% of the plant families characteristic of conifers.

JUST AGRICULTURE
multidisciplinary e-Newsletter

2. **Endomycorrhizae**: The mycorrhizae that grow intercellularly and form structures within the cortical cells of the roots are called endomycorrhizae. In the contact area between the fungus and the plant, the membranes of the fungus and the plant are in direct contact with each other. They form symbiotic relationships in almost 80 percent of plant families. There are several types of endomycorrhizae, the most well-known being Arbuscular Mycorrhizae (AM).
3. **Ectendomycorrhizae:** They share the characteristic features of both ectomycorrhizae and endomycorrhizae and have a poorly developed Hyphal coat. They are usually associated with *Eucalyptus* sp. and *Salix* sp. as host plants.

Table 1: Difference between ectomycorrhiza and endomycorrhiza

ECTOMYCORRHIZAE	ENDOMYCORRHIZAE
1. The fungal hyphae do not penetrate the cortical cells of the plant root	1. The fungal hyphae penetrate the cortical cells of the plant root
2. Produces a Hartig Net between the cells in the root cortex	2. Produces branched hyphae called arbuscules inside the cells in plant roots
3. Forms extracellular colonization	3. Forms intracellular colonization
4. Hyphal Mantle present	4. Hyphal Mantle absent
5. Less prevalent	5. More prevalent

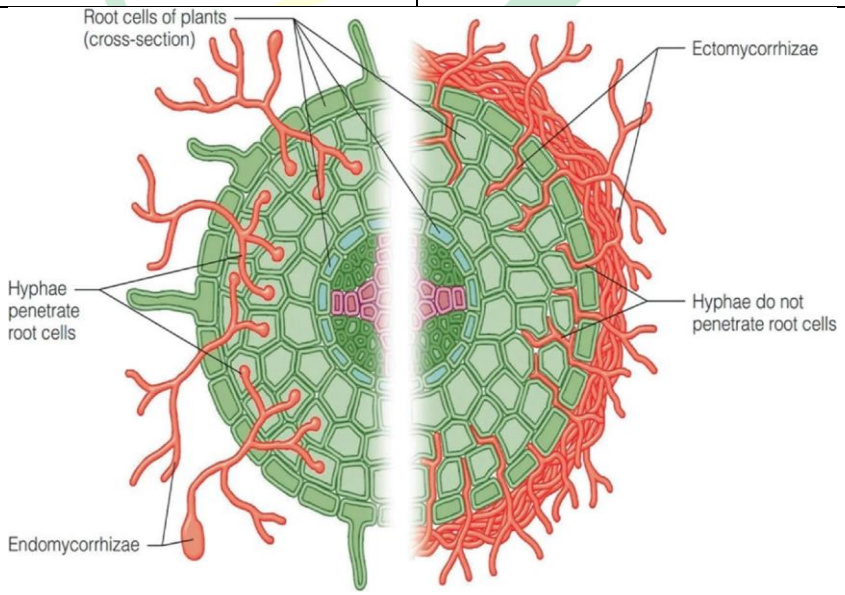

Figure 1: Hypae of Endomycorrizae and Ectomycorrhizae invading root cells

JUST AGRICULTURE
multidisciplinary e-Newsletter

Arbuscular Mycorrhizae

They are endomycorrhizae whose hyphae invade plant cells and produce either balloon-like structures called vesicles or bifurcate invaginations called arbuscules to exchange nutrients such as phosphorus, carbon, and water. Fungal hyphae do not penetrate the protoplast but rather penetrate the cell membrane. The arbuscule structure significantly increases the contact area between hyphae and cytoplasm, facilitating nutrient transfer between hyphae and cytoplasm.

Presence of Mycorrhizae In Litchi Rhizosphere

Litchi (*Litchi chinensis* Sonn) is an important subtropical fruit crop native to the subtropics of China. It is known as queen of fruits due to its attractive deep pink to red colours and fragrant aril. Litchi usually prefers growing in slightly acidic to neutral well-drained soil with a pH ranging from 6 to 6.5. The roots of litchi trees are found to have a symbiotic association with mycorrhizal fungi which improves the nutrient uptake and availability in the root zone.

Role of Mycorrhizae in Litchi Production

Litchi is an important fruit crop and the nation demands quality and quantity production from its orchards. However modern agricultural practices avoid the use of chemical fertilizers and promote bio-fertilizers. This growing trend of biological fertilizers leads to the exploitation of the microbial association of mycorrhiza in Litchi's rhizosphere. This association is recognized as Vesicular Arbuscular Mycorrhizae (VAM). Mycorrhizal fungi are advantageous for plant growth because they facilitate the uptake of nutrients and minerals by plants as well as the conveyance of water. Coville was the first to report the presence of AMF in the cortical cells of litchi roots. AMF results in root infections that are characterized by strongly branching arbuscules that grow inside the host's cortical cells, as well as intercellular hyphae and vesicles (Dohroo *et al*., 2013). The primary role of the vesicles is to store food for the fungus, and the nutrients are transported by the arbuscules. These Arbuscular mycorrhizal fungi (AMF) express a high affinity for phosphorous uptake which helps plants absorb large amounts of phosphorous with ease.

a) **AMF's Impact on the Soil's Phosphorus Content:** Plants absorb phosphorus in the form of orthophosphates, a mineral form of the element that is scarce in the soil. As a result of the soil's low mobility and delayed Phosphorous delivery, huge depletion zones rapidly form around roots. Therefore, the reservoir of phosphorus needs to be

JUST AGRICULTURE
multidisciplinary e-Newsletter

hydrolyzed before plants can absorb it from the soil. Arbuscular Mycorrhizal fungi plays a major role in improving the availability of Phosphorus in the soil. However, AMF cannot release phosphatases into the soil (Zhang *et al*., 2016) and hence they recruit Phosphate Solubilising Bacteria (PSB) that produce phosphatase, which mineralizes the organic P provides for a function that the AMF lacks (Zhang *et al*., 2018; Etesami and Jeong, 2021). PSB and AMF interact to mineralize insoluble phosphate in the soil and liberate soluble phosphate that is readily absorbed by plants (Wei *et al.*, 2017). According to this association, AMF mycelia enhance plant absorption of soluble phosphorus, while PSB is responsible for producing organic acids, including gluconic acid, keto gluconic acid, siderophores, protons, and acid phosphatases, which are involved in the mineralization of organic phosphorus in soil.

b) **Contribution of AMF on Soil Nitrogen Availability**: The AMF mycelium can absorb nitrogen in the form of ammonium ions, in the form of nitrates, and in the form of amino acids

c) **Contribution of AMF on Soil Trace Elements Transfer:** AMF plays a key role in making essential elements like Ferrous and Zinc available to the plants due to which mycorrhizal plants exhibit twice the amount of Zn, Fe, and Mn as compared to non-mycorrhizal plants (Krishna and Bagyaraj, 1984).

AMF association in litchi orchards are reported to increase drought and heat tolerances in the plants as well as increase resistance to several detrimental diseases. AMF assists the plants in tide over various abiotic and biotic stresses. Yao *et al.* (2005) reported that the AMF *Gigaspora margarita* and *Glomus intraradices* when injected into *Litchi chinensis* seedlings seemed to increase the quantities of isopentenyl adenosine and indole-3-acetic acid (IAA) in the shoots and roots.

The inoculation of the litchi plant with AMF resulted in the enhancement of the plant's growth (Yao *et al*., 2005) and also showed a significant impact on the root system morphology of the plant (Kaldorf and Muller, 2000). According to a study by Yao *et al.* (2005), litchi plants inoculated with two VAM species—*Gigaspora margarita* and *Glomus intraradices*—show a significant increase in lateral root length. Sharma *et al.* (2009) also reported that dual inoculation of litchi with *Glomus fasciculatum* and *Azotobacter* species

JUST AGRICULTURE
multidisciplinary e-Newsletter

resulted in enhanced root length. It was reported previously that inoculation of litchi plants with AMF enhanced growth and development after propagation by air layering.

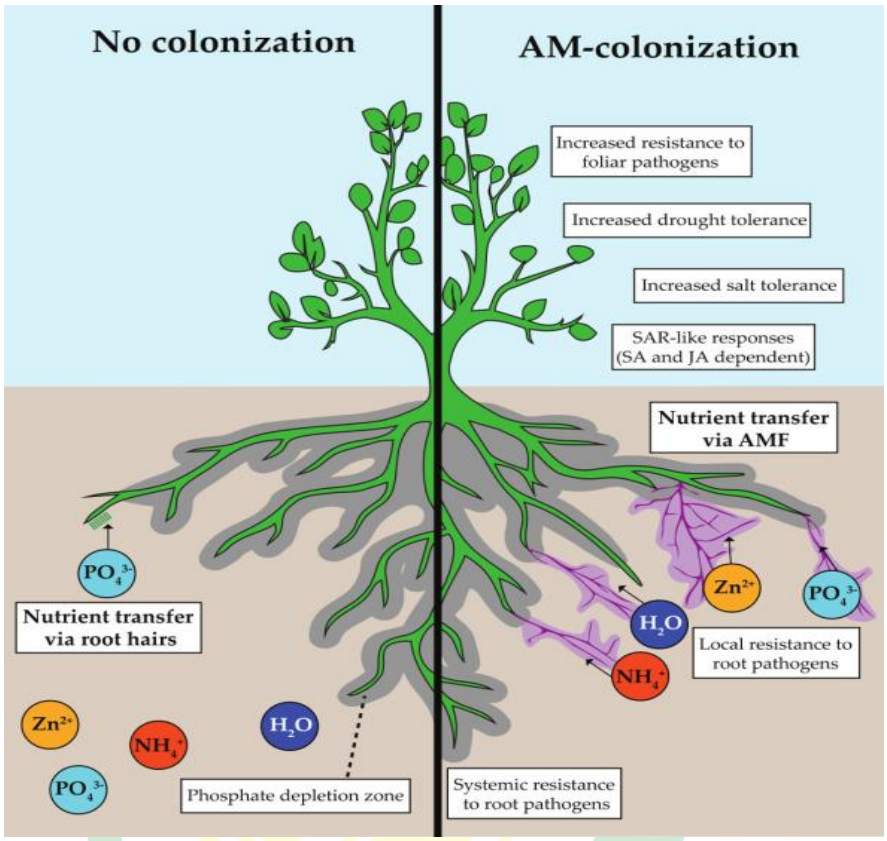

Figure 3: Benefits of AM fungi colonization

It has consistently been shown that the inoculation of litchi with mycorrhizal fungus promotes plant development. Since the beginning of time, litchi trees have been heavily dependent on AM fungus. The reason might be that the soil of older, more established litchi trees is used to inoculate the newly planted seedlings.

Conclusion

This article highlights the role of AMF in litchi plantations. Moreover, Arbuscular Mycorrhizal Fungi prove to be a suitable candidate for the production of sustainably produced. It also adds to the cost-effective cultivation of litchi as AM fungi reduce the application of chemical fertilizers to a great extent. In the Future, studies on the chemistry of exogenous and endogenous factors in AMF are required; in particular, how nutrients affect symbiotic signaling and the cellular programming that follows in the litchi rhizosphere.

References:

JUST AGRICULTURE
multidisciplinary e-Newsletter

Dohroo, A., Sharma, D. R., & Dohroo, N. P. (2013). Occurrence of arbuscular mycorrhizae in rhizospheric soils of different crops and agroclimatic zones of Himachal Pradesh, India. *Indian Journal of Agricultural Research*, *47*(4), 373-376.

Etesami, H., Jeong, B. R., & Glick, B. R. (2021). Contribution of arbuscular mycorrhizal fungi, phosphate–solubilizing bacteria, and silicon to P uptake by plant. *Frontiers in Plant Science*, *12*, 699618.

Jacott, C., Murray, J., & Ridout, C. (2017). Trade-Offs in Arbuscular Mycorrhizal Symbiosis: Disease Resistance, Growth Responses and Perspectives for Crop Breeding. *Agronomy*, *7*(4), 75. https://doi.org/10.3390/agronomy7040075

Kaldorf, M., & Muller, L. J. (2000). AM fungi might affect the root morphology of maize by increasing indole-3-butyric acid biosynthesis. *Physiologia Plantarum*, *109*, 58-64.

Krishna, K. R., & Bagyaraj, D. J. (1984). Growth and nutrient uptake of peanut inoculated with the mycorrhizal fungus Glomus fasciculatum compared with non-inoculated ones. *Plant and soil*, *77*, 405-408.

Pathak, H., Chandrakar, M. R., Choudhary, V. K., Singh, S., Thakur, S. K., & Langangmeilu, G. (2023). Growth Rate of Area Production and Productivity of Litchi Fruit in Jashpur District of Chhattisgarh, India. *International Journal of Environment and Climate Change*, *13*(9), 1173-1182.

Ryan, M. H., & Graham, J. H. (2002). Is there a role for arbuscular mycorrhizal fungi in production agriculture?. *Plant and soil*, *244*, 263-271.

Sharma, S. D., Kumar, P., Raj, H., & Bhardwaj, S. K. (2009). Isolation of arbuscular mycorrhizal fungi and Azotobacter chroococcum from local litchi orchards and evaluation of their activity in the air-layers system. *Scientia Horticulturae*, *123*(1), 117-123.

Smith, R. L., Smith, T. M., Hickman, G. C., & Hickman, S. M. (1998). *Elements of ecology* (No. 577 S6E5 1998). Menlo Parie, CA: Benjamin Cummings.

Wei, Y., Zhao, Y., Fan, Y., Lu, Q., Li, M., Wei, Q., et al. (2017). Impact of phosphate-solubilizing bacteria inoculation methods on phosphorus transformation and long-term utilization in composting. *Bioresource Technology*, 241, 134–141.

Yao, Q., Zhu, H. H., & Chen, J. Z. (2005). Growth responses and endogenous IAA and iPAs changes in litchi (*Litchi chinensis* Sonn) seedling induced by arbuscular mycorrhizal fungal inoculation. *Scientia Horticulturae*, *105*, 145-151.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Zhang, L., Shi, N., Fan, J., Wang, F., George, T. S., & Feng, G. (2018). Arbuscular mycorrhizal fungi stimulate organic phosphate mobilization associated with changing bacterial community structure under field conditions. *Environmental Microbiology*, *20*(7), 2639-2651.

Zhang, L., Xu, M., Liu, Y., Zhang, F., Hodge, A., & Feng, G. (2016). Carbon and phosphorus exchange may enable cooperation between an arbuscular mycorrhizal fungus and a phosphate-solubilizing bacterium. *New Phytologist*, *210*(3), 1022-1032.