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Review Article

Ecological importance of strigolactones hormone on arbuscular mycorrhizal fungi symbiosis in plant

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ABSTRACT

Strigolactones (SLs) are versatile compounds that have recently been identified as a special generation of plant hormones. They play a significant role as modulators of coordinated plant development in response to nutrient deficiency and defence, particularly by influencing plant root microbiome and mycorrhization. SLs act as signals molecules that help host communicate with their environment belowground, in addition to regulating root architecture and growth promotion. Alternatively, boosting the SLs hormone level or applying external SLs, SL synthetic analogs e.g. GR24, and SL mimics to plants, can improve the root architecture, and physiological changes, and controls biotic and abiotic parameters by activating regulatory genes and molecular changes. Interestingly, SLs perform a fundamental character in the establishment of arbuscular mycorrhiza fungi (AMF) symbiosis by eliciting mycorrhization in the plant, which allows for adequate phosphorus utilization. Due to various their multifunctional aspect, they have a wide range of possible agricultural and biotechnological applications. We should be able to comprehend the biological mechanisms operating below ground in plant systems and their significance in the ecosystem with greater clarity as more research is conducted into the necessary conditions for various SLs in various biological activities.

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1. Introduction

Arbuscular Mycorrhizal Fungi (AMF) are obligate biotrophic roots that exchange mutually beneficial effects with around 80% of plants^{1,2} and symbiotic relationship among plants and fungi from a long-gone phylum.^{3,4} AMF, which is established by the majority of territory plant species and fungi that are members of a monophyletic phylum called the Glomeromycota, is most likely the most widespread terrestrial symbiotic association.⁵⁻⁷ Interestingly, this mutualism relation helps host plants

develop vigorously in harsh circumstances by facilitating a series of complicated interactions among the fungus and plant that cause an increase in photosynthetic efficiency⁸ and additional gas exchange related attributes⁹ in addition to increase in water and soil nutrients absorption.^{3,10-12} AMF are recognized to tolerate high metal concentrations in the soil and it can reduce heavy-metal toxicity in the host plants reported by several investigators.¹³⁻¹⁶ The homeostasis of heavy metals depends heavily on metal transporters.¹⁷ *Glomus intraradices* has a Zn transporter, according to findings of Gonzalez-Guerrero et al.¹⁸ AMF closely links plants to the fungi's hyphal network,

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which can contain more than 100 meters of hyphae per cubic-centimeter of soil.¹⁹ This AMF hyphal-network has been specifically designed to absorb water and nutrients, primarily phosphate and others nutrients.²⁰ AMF enhance the soil-quality by changing the texture-structure of the soil, which benefits plant health.^{2,16,21} Organic matter in soil can decompose more quickly thanks to fungus hyphae. Additionally, by enhancing the "sink effect" and moving photon -assimilates from the aerial parts to the roots, mycorrhizal fungi may have an impact on how much atmospheric CO₂ fixation occurs by host plants.^{22,23}

Now a days, plants are constantly facing the challenges because of unfavourable environmental conditions, resulting in significant reductions in growth, yield, and physiological traits. Hormones have a major influence on the regulation in plant development, overall physiology, and shelf life. Strigolactones (SLs) were discovered to be in charge of altering fungal physiology and mitochondrial activity as well as inducing branching.²⁴ The parasitic plants *Striga* and *Orobanche* are known for using SLs as germination stimulants.²⁵ In some AMF, SLs can also promote sporulation.²⁶ It has been discovered that species of *Striga* take advantage of an ancient and conserved communication system between associated fungi and their host-plants.²⁷ The physiological functions and molecular signalling involved in root development are carried out by SLs involvement, which also serve as signals to attract the AMF for symbiosis.²⁸ SLs are new carotenoid-derived signaling molecules (hormones)²⁹ that developed as controllers of a simple developmental processes in very early plant lineages prior to actually bringing in unique roles to help land plants grow vigorously without any biological complexity²⁴ (Figure 1). Around 25 different types of naturally present SLs have been documented in various plant species, and they are divided into two groups classified on their chemical structures – (i) canonical and (ii) non-canonical SLs.³⁰ A butenolide ring (D ring) is joined to a tricyclic lactone (ABC rings) via an enol ether bridge in canonical SLs. The ABC ring is substituted with an irregular ring structure in non-canonical SLs. SL molecules in various forms may have diverse biological functions.³¹

Natural SLs' chemical synthesis is limited by their complicated structure and stereochemistry. GR24 is a generally applied synthetic SL analogue in science. Their adaptability is also demonstrated by the fact that, once released in the rhizosphere but it's extremely low amounts (10⁻⁷ to 10⁻¹⁵ M)^{24,32} or externally applied synthetic SLs analogs like GR24,^{33,34} they have been used as a signaling compounds for plant- networking organisms and plant growth development from various kingdoms.^{35,36}

Plants are regularly exposed to a variety of un-favourable environmental circumstances, resulting in abiotic stress and lower productivity. In this scenario, the microbiota of the rhizosphere must be improved by signalling molecules. New

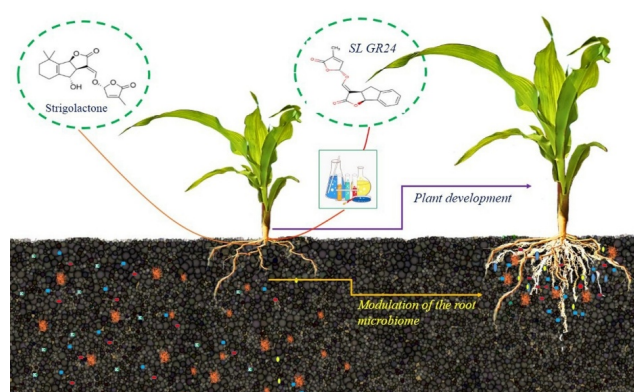


Fig. 1: SLs hormone in plant microbe's interaction and growth promoting

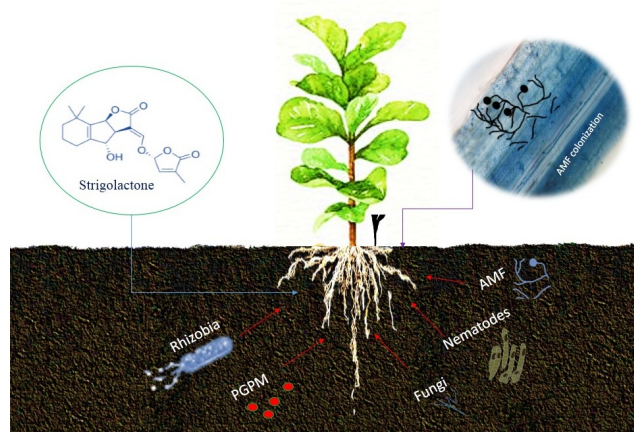


Fig. 2: SLs hormone role in plant interactions with beneficial root microbiome

phytohormones like SLs are important for regulating plant biological activities and assisting them in communicating with the outside microbial community (Figure 2).^{35–37} SLs also orchestrate resource distribution modifications by strategically altering plant growth, allowing plants to respond to nutrient availability. SL interacts with auxin, abscisic acid, ethylene, cytokinin, and other plant phytohormones to construct elaborate signalling networks, then instead of functioning independently.³⁷

Endogenous plant hormones, on the other hand, play crucial roles in modification to shifting environmental factors by mediating growth, development, nutrient dissemination, and source changes. Moreover, the hormonal interactions can modify how plants react to environmental cues like nutrient deficiency and canopy shade, as well as how plants are arranged. Since the initial discovery, there have been significant developments and fresh insights into the biosynthesis, signalling, and transport of SLs.^{38,39} We give a basic overview of SL in this review along with

a thorough discussion of how we currently understand their function in plants and how crucial they are to AMF symbiosis and plant growth.

2. Conclusion

Strigolactones (SLs) play a significant role in modulating coordinated plant development in response to nutrient deficiency and protection, especially by influencing plant mycorrhization and the root microbiome. In addition to controlling root architecture and promoting growth, SLs function as molecular signals that assist plants in interacting with their underground environment. They have a wide range of potential agricultural and biotechnological applications because of their multifunctional nature. We should be able to comprehend the biological mechanisms operating below ground in plant systems and their significance in the ecosystem with greater clarity as more research is conducted into the basic requirements for various SLs in various biological activities.

3. Source of Funding

None.

4. Conflict of Interest

We have no conflict of interest to declare.

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References

- Berruti A, Borriello R, Orgiazzi A, Barbera AC, Lumini E, Bianciotto V. Biodiversity: the dynamic balance of the planet. In: Arbuscular mycorrhizal fungi and their value for ecosystem management. Rijeka, Croatia: InTech; 2014. p. 159–91.
- Berruti A, Lumini E, Balestrini R, Bianciotto V. Arbuscular mycorrhizal fungi as natural biofertilizers: let's benefit from past successes. *Front Microbiol.* 2016;doi:10.3389/fmicb.2015.01559.
- Begum N. Role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance. *Front Plant Sci.* 2019;10:1068. doi:10.3389/fpls.2019.01068.
- Panneerselvam P, Kumar U, Sugitha TCK, Parameswaran C, Sahoo S, Binodh AK, et al. Arbuscular mycorrhizal fungi (AMF) for sustainable rice production. In: *Advances in Soil Microbiology: Recent Trends and Future Prospects.* Singapore: Springer; 2017. p. 99–126.
- Mitra D, Panneerselvam P, Ganeshamurt AN, Jain D, Uniyal N, Senapati A, et al. Role of mycorrhiza and its associated bacteria on plant growth promotion and nutrient management in sustainable agriculture. *Int J Life Sci Appl Sci.* 2019;1(1):1–10.
- Schüßler A, Walker C. Evolution of the 'Plant-Symbiotic' Fungal Phylum, Glomeromycota. In: *Evolution of fungi and fungal-like organisms.* Berlin, Heidelberg: Springer; 2011. p. 163–85.
- Wang FY, Shi ZY. Biodiversity of arbuscular mycorrhizal fungi in China: a review. *Adv Environ Biol.* 2008;2(1):31–9.
- Borde M, Dudhane M, Jite PK. AM fungi influences the photosynthetic activity, growth and antioxidant enzymes in *Allium sativum* L. under salinity condition. *Note Sci Biol.* 2010;2(4):64–71.
- Panneerselvam P, Kumar U, Senapati A, Parameswaran C, Anandan A, Kumar A, et al. Influence of elevated CO₂ on arbuscular mycorrhizal fungal community elucidated using Illumina MiSeq platform in sub-humid tropical paddy soil. *Appl Soil Ecol.* 2020;145:103344. doi:10.1016/j.apsoil.2019.08.006.
- Sahoo, Panneerselvam P, Chowdhury T, Kumar A, Kumar U, Jahan A, et al. Understanding the AM fungal association in flooded rice under elevated CO₂ condition. *ORYZA-An Int J Rice.* 2017;54(3):290–7.
- Mitra D, Djebaili R, Pellegrinic M, Sarker A, Chaudhary P, Khoshru B. Arbuscular mycorrhizal symbiosis: plant growth improvement and induction of resistance under stressful conditions. *J Plant Nutr.* 2021;44(13):1993–2028.
- Nichols KA. Indirect contributions of AM fungi and soil aggregation to plant growth and protection. In: *Mycorrhizae: sustainable agriculture and forestry.* Dordrecht: Springer; 2008. p. 177–94.
- Mitra D, Saritha B, Janeesha E, Gusain P, Khoshru B, Nouh FAA, et al. Arbuscular mycorrhizal fungal association boosted the arsenic resistance in crops with special responsiveness to rice plant. *Environ Exp Bot.* 2022;193:104681.
- Riaz M, Kamran M, Fang Y, Wang Q, Cao H, Yang G, et al. Arbuscular mycorrhizal fungi-induced mitigation of heavy metal phytotoxicity in metal contaminated soils: A critical review. *J Hazardous Mat.* 2021;402:123919.
- Atakan A, Erdogan O, Ozgonen H. Effects of arbuscular mycorrhizal fungi (AMF) on heavy metal and salt stress. *Turk J Agr Food Sci Technol.* 2018;6(11):1569–74.
- Panneerselvam P, Mohandas S, Saritha B, Upreti KK, Poovarasan, Monnappa A, et al. Glomus mosseae associated bacteria and their influence on stimulation of mycorrhizal colonization, sporulation, and growth promotion in guava (*Psidium guajava* L.) seedlings. *Biol Agr Hortic.* 2012;28(4):267–74.
- González-Guerrero M, Escudero V, Saéz A, Tejada-Jiménez M. Transition metal transport in plants and associated endosymbionts: arbuscular mycorrhizal fungi and rhizobia. *Front Plant Sci.* 2016;7:1088.
- Gonzalez-Guerrero M. Ultrastructural localization of heavy metals in the extraradical mycelium and spores of the arbuscular mycorrhizal fungus *Glomus intraradices*. *Can J Microbiol.* 2008;54(2):103–10.
- Giovannetti M. Functional significance of anastomosis in arbuscular mycorrhizal networks. In: *Mycorrhizal networks.* Dordrecht: Springer; 2015. p. 41–67.
- Cavagnaro TR, Smith FA, Smith SE, Jakobsen I. Functional diversity in arbuscular mycorrhizas: exploitation of soil patches with different phosphate enrichment differs among fungal species. *Plant Cell Environ.* 2005;28(5):642–50. doi:10.1111/j.1365-3040.2005.01310.x.
- Panneerselvam P, Saritha B, Mohandas S, Upreti KK, Poovarasan S, Panneerselvam P. Effect of mycorrhiza-associated bacteria on enhancing colonization and sporulation of *Glomus mosseae* and growth promotion in sapota (*Manilkara achras* (Mill) Forsberg) seedlings. *Biol Agr Hortic.* 2013;29(2):118–31.
- Goicoechea N, Baslam M, Erice G, Irigoyen JJ. Increased photosynthetic acclimation in alfalfa associated with arbuscular mycorrhizal fungi (AMF) and cultivated in greenhouse under elevated CO₂. *J Plant Physiol.* 2014;171(18):1774–81.
- Jajoo A, Mathur S. Role of arbuscular mycorrhizal fungi as an underground saviour for protecting plants from abiotic stresses. *Physiol Mol Biol Plants.* 2021;27(11):2589–2603.
- Lanfranco L, Fiorilli V, Venice F, Bonfante P. Strigolactones cross the kingdoms: plants, fungi, and bacteria in the arbuscular mycorrhizal symbiosis. *J Exp Bot.* 2018;69(9):2175–8.
- Yoneyama K, Awad AA, Yoneyama K, Ayman A, Xie X, Yoneyama K. Strigolactones as germination stimulants for root parasitic plants. *Plant Cell Physiol.* 2010;51(7):1095–1103.
- Hossain A. Arbuscular Mycorrhizal Fungi: the natural biotechnological tools for sustainable crop production under saline soils in the modern era of climate change. In: *Plant Growth Regulators.* Cham: Springer; 2021. p. 373–401.

27. Crosino A, Genre A. Peace talks: symbiotic signaling molecules in arbuscular mycorrhizas and their potential application. *J Plant Interact.* 2022;17(1):824–39.
28. Hull R, Choi J, Paszkowski U. Conditioning plants for arbuscular mycorrhizal symbiosis through DWARF14-LIKE signalling. *Curr Opin Plant Biol.* 2021;62:102071.
29. Al-Babili S, Bouwmeester HJ. Strigolactones, a novel carotenoid-derived plant hormone. *Annu Rev Plant Biol.* 2015;66:161–86.
30. Jamil M, Kountche BA, Haider I, Guo X, Ntui V, Jia KP. Methyl phenlactonoates are efficient strigolactone analogs with simple structure. *J Exp Bot.* 2018;69(9):2319–31.
31. Yoneyama K, Xie X, Yoneyama K, Kisugi T, Nomura T, Nakatani Y. Which are the major players, canonical or non-canonical strigolactones? *J Exp Bot.* 2018;69(9):2231–9.
32. Andreo-Jimenez B, Ruyter-Spira C, Bouwmeester HJ, Lopez-Raez JA. Ecological relevance of strigolactones in nutrient uptake and other abiotic stresses, and in plant-microbe interactions below-ground. *Plant and Soil.* 2015;394(1):1–19.
33. Dor E, Joel DM, Kapulnik Y, Koltai H, Hershenhorn J. The synthetic strigolactone GR24 influences the growth pattern of phytopathogenic fungi. *Planta.* 2011;234(2):419–27.
34. Elhiti M, Mira MM, So KKY, Stasolla C, Hebelstrup KH. Synthetic Strigolactone GR24 Improves Arabidopsis Somatic Embryogenesis through. *Plants (Basel).* 2021;10(12):2720.
35. Mitra D. Impacts of arbuscular mycorrhizal fungi on rice growth, development, and stress management with a particular emphasis on strigolactone effects on root development. *Commun Soil Sci Plant Anal.* 2021;52(14):1591–21.
36. Mitra D, Rad K, Chaudhary P, Ruparelia J. Involvement of strigolactone hormone in root development, influence and interaction with mycorrhizal fungi in plant: mini-review. *Curr Res Microb Sci.* 2021;2:100026. doi:10.1016/j.crmicr.2021.100026.
37. Wu F, Gao Y, Yang W, Sui N, Zhu J. Biological functions of strigolactones and their crosstalk with other phytohormones. *Front Plant Sci.* 2022;13:821563. doi:10.3389/fpls.2022.821563.
38. Saeed W, Naseem S, Ali Z. Strigolactones biosynthesis and their role in abiotic stress resilience in plants: a critical review. *Front Plant Sci.* 2017;8:1487. doi:10.3389/fpls.2017.01487.
39. Kapulnik Y, Koltai H. Strigolactone involvement in root development, response to abiotic stress, and interactions with the biotic soil environment. *Plant Physiol.* 2014;166(2):560–9.

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