

Biological Inputs for Future Agriculture: Impact of *Glomus* on Soybean Performance

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Abstract

The transition toward sustainable and climate resilient agriculture necessitates the integration of biological inputs that enhance nutrient efficiency, soil health, and crop productivity. Among beneficial soil microorganisms, arbuscular mycorrhizal fungi (AMF), particularly species of the genus *Glomus*, have emerged as pivotal bio-inoculants for leguminous crops. Soybean (*Glycine max* L. Merr.), a globally important oilseed and protein crop, exhibits strong mycorrhizal dependency, especially under nutrient-limited conditions. This chapter synthesizes current advances in the biology, ecology, and functional mechanisms of *Glomus* and critically evaluates its impact on soybean growth, nutrient uptake, nodulation, stress tolerance, and yield performance. Mechanistic insights into phosphorus solubilization, hyphal-mediated nutrient transport, hormonal modulation, and synergistic interactions with *Rhizobium* are discussed. Empirical evidence from field and controlled experiments demonstrates significant improvements in root colonization, biomass accumulation, chlorophyll content, pod number, and seed yield following *Glomus* inoculation. Furthermore, the role of *Glomus* in mitigating abiotic stresses such as drought and salinity is examined in the context of climate smart agriculture. The chapter concludes with future prospects for integrating *Glomus* based biofertilizers into sustainable soybean production systems and highlights research gaps in molecular interactions and large-scale application strategies.

Keywords: Arbuscular mycorrhizal fungi, *Glomus*, Soybean, Biological inputs, Sustainable agriculture, Nutrient uptake.

Introduction

Global agriculture faces serious challenges due to soil degradation, excessive fertilizer dependency, and climate variability. Sustainable intensification strategies increasingly emphasize biological inputs as eco-friendly alternatives to synthetic agrochemicals (Berruti et al., 2016).

Arbuscular mycorrhizal fungi (AMF), belonging to the phylum Glomeromycota, form mutualistic associations with nearly 80% of terrestrial plants (Brundrett, 2009). The genus *Glomus* is one of the most widely distributed and agriculturally significant AMF groups (Smith & Read, 2008). Its symbiotic relationship with soybean (*Glycine max* L. Merr.) is particularly relevant due to soybean's high phosphorus demand and its global importance as an oilseed and protein crop. The integration of *Glomus*-based inoculants into soybean cultivation systems represents a promising strategy for enhancing nutrient use efficiency and reducing chemical fertilizer inputs (Berruti et al., 2016).

Biology and Functional Attributes of *Glomus*

- **Taxonomy and Morphology**

Glomus species form arbuscules, vesicles, and extensive extraradical hyphal networks. Arbuscules are the primary sites for nutrient exchange between fungus and host plant (Smith & Smith, 2011). Vesicles function as storage organs, while hyphal networks extend beyond root depletion zones, enhancing nutrient absorption efficiency (Smith & Read, 2008).

- **Life Cycle**

The life cycle includes spore germination, hyphal growth, root penetration, arbuscule development, and sporulation (Brundrett, 2009). Host root exudates initiate signaling pathways that facilitate fungal colonization and symbiosis establishment.

Mechanisms of *Glomus*-Mediated Enhancement in Soybean

- **Improved Phosphorus Uptake**

Phosphorus (P) is relatively immobile in soil. *Glomus* hyphae access distant phosphate pools and transport them to the host plant via specialized phosphate transporters (Chen et al., 2018). Mycorrhizal associations significantly enhance P-use efficiency (Smith & Smith, 2011).

- **Enhanced Nitrogen Fixation and Nodulation**

Soybean establishes symbiosis with nitrogen-fixing bacteria such as *Bradyrhizobium japonicum*. Dual inoculation with AMF enhances nodulation and nitrogenase activity due to improved phosphorus availability and metabolic coordination (Smith & Read, 2008).

- **Hormonal and Physiological Modulation**

Mycorrhizal colonization influences phytohormone regulation, enhancing auxins, cytokinins, and gibberellins while modulating stress-related hormones. These physiological changes improve chlorophyll synthesis and photosynthetic

efficiency (Smith & Smith, 2011).

- **Improved Water Relations and Stress Tolerance**

Under drought stress, AMF-colonized soybean plants exhibit improved osmotic adjustment, stomatal conductance, and relative water content (Begum et al., 2019). Earlier research also demonstrated the protective role of vesicular-arbuscular mycorrhizae under environmental stress conditions (Sylvia & Williams, 1992).

Impact on Growth and Yield Parameters

Experimental studies report significant improvements in plant height, root length, biomass accumulation, chlorophyll content, pod number, and seed yield following *Glomus* inoculation (Berruti et al., 2016; Smith & Read, 2008).

Field studies under semi-arid tropical conditions show yield increases ranging from 15–35% in low-phosphorus soils due to enhanced nutrient acquisition and physiological performance (Smith & Smith, 2011).

Role in Soil Health and Sustainability

- **Soil Structure and Aggregation**

Extraradical hyphae produce glomalin-related soil proteins that improve soil aggregation and carbon sequestration (Giovannetti et al., 2010). Improved aggregation enhances porosity, aeration, and root penetration capacity.

- **Reduction in Chemical Fertilizer Dependency**

AMF-based biofertilizers can reduce phosphorus fertilizer inputs by 25–50% without compromising yield (Berruti et al., 2016), contributing to cost reduction and environmental protection.

Molecular Insights and Emerging Research

Transcriptomic analyses reveal upregulation of phosphate transporter genes in mycorrhizal roots (Chen et al., 2018). Symbiotic signaling pathways involving Myc factors and SYM genes regulate fungal colonization and nutrient exchange (Smith & Smith, 2011). However, genotype-specific responses require further investigation.

Constraints and Challenges

Field variability, soil-specific performance, cultivar compatibility, inoculum formulation issues, and limited farmer awareness constrain large-scale adoption (Berruti et al., 2016).

Future Prospects

Future agricultural systems must integrate biological inputs such as *Glomus* within precision nutrient management frameworks (Smith & Read, 2008).

Development of multi-strain consortia and improved formulations will enhance field reliability.

Conclusion

Glomus represents a cornerstone biological input for sustainable soybean production. Through enhanced nutrient uptake, improved nodulation, stress tolerance, and soil health restoration, it significantly contributes to sustainable intensification (Smith & Smith, 2011; Begum et al., 2019). Successful implementation requires standardized inoculum production and interdisciplinary research.

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