JUST AGRICULTURE
multidisciplinary e-Newsletter

Arbuscular Mycorrhizal Fungi in Plant Disease Management

SG Bhat[1], SD Somwanshi[2], SJ Magar[3] and SN Banne[4]
[1] PG Scholar, Department of Plant Pathology,
College of Agriculture, Latur-413512, Maharashtra, India
[2] Senior Scientist and Head,
Krishi Vigyan Kendra, Badnapur (Jalna 2)
[3] Associate Professor, Department of Plant Pathology,
College of Agriculture, Latur-413512, Maharashtra, India
[4] Assistant Professor, Department of Plant Pathology,
College of Agriculture, Pathri (Chh. Sambhajinagar)- 431111, Maharashtra, India

ARTICLE ID: 05

Introduction

Mycorrhiza is a type of endophytic, biotrophic, mutualistic symbiont prevalent in many cultivated and natural ecosystem. It is a bidirectional nutrient transferring symbiosis where plant provides sugar to fungi and in return fungi provides nutrients like phosphate and nitrate to plants. The term mycorrhiza was first coined by a German Botanist A. B. Frank in 1885, which means "Fungal root". AM fungi are known to promote plant growth by enhancing nutrient availability, alleviating water stress, metal toxicity, salt stress and other abiotic stresses. It is also reported that, AM fungi provides host plant resistance against biotic stress like diseases.

Application of AM fungi in disease management

- Mycorrhiza can be applied at any stage of the crop and can be directly applied to soil.
- Mycorrhiza promotes root system development and thus improves crop growth in water and nutrient deficient conditions.
- It promotes growth of beneficial microorganisms and suppresses the growth of pathogens in rhizosphere.
- Once inoculated to the field it will survive as chlamydospores and no requirement of repeated application.

Mechanism of host plant resistance

- AMF improves the rhizosphere environment by influencing the physical and chemical properties of soil.

JUST AGRICULTURE
multidisciplinary e-Newsletter

- It regulates the plant root morphological structures.
- It Improves plant nutrition.
- It regulates the synthesis of plant secondary metabolites.
- Regulates the microbial population in the rhizosphere of plants.
- It competes with the pathogenic microorganisms for invasive sites.
- It activates the host defense system.
- It promotes the synthesis of plant defense hormones.
- It induces the synthesis of plant signal substances.
- It regulates defense gene expression.
- It improves defense enzyme activity and induce PR synthesis.

AMF improves physical and chemical properties of soil

Mycorrhizae and their extra root hyphae penetrate through the tiny pores between soil particles and their secretions such as glomus associated proteins, organic acids and polyamines are used as adsorption agents for adhesion of soil particles, promote the formation of soil aggregate structures, improves soil pH, water stability, aeration and water permeability, further increase redox potential (Eh) and promote normal plant growth to resist disease invasion.

AMF regulate plant root morphological structure

- AMF symbiosis cause the root system of the host plant to grow, thicken and increase branching, accelerate the lignification of the cell wall, thicken the root tip epidermis and increase the number of cell layers there by effectively slows down the process of root infection by pathogens.
- AMF forms a mycelial network, callose and papillary structure stacked by non-esterified pectin in the root epidermis and endodermis of host plants, which hinders pathogen penetration into root cell and infection.
- AMF induces cell walls to produce hydroxyproline rich glycoprotein (HRGPs) that improves the strength of the host plant cell wall so that it cannot be decomposed by proteases, cellulases, hemicellulases, secreted during pathogen infection.

Improve plant nutrition

- AMF forms huge mycelial network, thereby expands the range of root system for water and nutrients, especially phosphate and nitrates.

JUST AGRICULTURE
multidisciplinary e-Newsletter

- AMF and pathogens compete for photosynthetic products from the root system of host plant and when photosynthetic products are first utilized by AMF, the opportunity for pathogen acquisition is reduced. Regulates the synthesis of secondary metabolites.
- AMF produces chemical substances such as phytochemicals, calloses, alkaloids and phenols on the surface of both inner and outer hyphae of root and these secondary metabolites are beneficial for plants, helps them to resist adverse conditions caused by diseases.
- Phytoprotictins are a class of resistant compounds produced during plant infection by pathogenic microorganisms and they accumulate around the infected cells and act as barriers to prevent further spread of pathogens.

Regulation of microbial populations in the rhizosphere of plants

- The exudates produced by plant roots symbiotic with AMF directly affect the growth, development and reproduction of other soil fungi, nematodes and bacteria.
- AMF promotes relationship with beneficial soil microorganisms, resulting in synergistic effect.
- It particularly stimulates the activity of microorganisms that are antagonistic to soil borne pathogens, increasing the number of beneficial microbes in the rhizosphere.
- PGPR can also strengthen the symbiotic relationship between AMF and plants. AMF compete with pathogenic microorganisms for invasion sites.
- As a biotrophic symbiotic microbe in the soil rhizosphere, AMF have same ecological niche and invasion site as soil borne pathogens.
- Therefore, in natural habitat conditions, AMF and pathogens have a spatially competitive relationship, and their biocontrol effect is mainly to reduce the initial infection and reinfection of root epidermal cells.
- AMF have a parasitic effect on nematodes.

AMF activate the host defense system

1. AMF promote the synthesis of plant defense hormones

- AMF directly induce the production of hormones such as, Auxin (IAA), cytokinin, gibberellic acid, brassinosteroids, jasmonic acid, salicylic acid, ethylene and abscisic acid which are involved in the establishment of AMF induced disease defense system.

JUST AGRICULTURE
multidisciplinary e-Newsletter

- AMF promotes plant growth and indirectly enhances disease resistance by affecting the content of endogenous plant hormones and the balance between them. Plant hormones may promote gene expression under stress, which can induce the expression of many new genes and protein synthesis.

2. AMF induce the synthesis of plant signal substances

- AMF induces the synthesis of various signalling substances such as nitric oxide (NO), JA, SA, ET, hydrogen peroxide (H2O2), ABA, Ca2+ signal, and sugar signal.
- Studies have shown that JA and ET are generally resistant to saprophytic pathogens, whereas SA as an inhibitory effect on biotrophic pathogens.
- JA and ET are associated with plant systemic induced resistance (SIR), and SA with plant systemic acquired resistance (SAR) when plants are infected by pathogens signalling molecule.
- NO is involved in signalling and gene expression processes related to plant defense systems.

3. AMF regulate defense gene expression

- AMF can enhance the disease resistance of host plants by inducing the expression of genes related to plant defense responses, such as PAL5 and chitinase gene Chib l, or by regulating the expression and specific expression of various disease resistance genes.
- The defense response in the mycorrhizal plants was more rapid and intense. AOS, PR2a and PAL genes related to disease resistance and BX9, a key gene in the synthesis pathway of 2, 4-dihydroxy-7-methoxy-2h-1, 4-benzoxazin-3 (4h)-one, and DIMBOA, were strongly induced and expressed in two maize leaves.
- The key enzymes involved in JA synthesis are produced in the process of establishing a mutualistic symbiotic relationship between AMF and plants, which can effectively catalyze the synthesis of JA. The expression of cDNAs of allene oxide cyclase (AOC), the main synthase of JA in mycorrhizal *Medicago truncatula* roots, was enhanced, and the accumulated endogenous JA content increased.

4.AMF improve defense enzyme activity and induce PR Synthesis

- In the process of AMF forming symbiosis with host plants, it can activate many defensive enzymes, such as polyphenol oxidase (PPO) and peroxidase (POD) involved

JUST AGRICULTURE
multidisciplinary e-Newsletter

in the metabolism of phenolic substances; chalcone isomerase (CHI) is involved in the metabolism of phytoalexin, lignin, and flavonoid/isoflavone biosynthesis.

- Chalcone Synthase (CHS) is involved in flavonoid synthesis; phenylalanine ammonia lyase (PAL) is involved in the metabolism of phenylpropanes, and some defensive proteins associated with disease resistance (such as pathogenesis-related protein, PR protein) were also expressed specifically.
- PAL activity can be used as a physiological indicator of disease resistance in plants.
- Enhanced superoxide dismutase (SOD) activity and 1,1-Diphenyl-2-picrylhydrazyl (DPPH) free-radical-scavenging activity was observed in strawberry plants inoculated with *Glomus mosseae*.
- Recent studies have found that *G. rhizogenes* can secrete a defense protein, sp7, that can interact with the disease process-related protein transcription factor ERF19 in the nucleus. The expression of sp7 can alleviate the symptoms of root rot caused by *Magnaporthe oryzae*.

Limitations of AM fungi

- AMF cannot be industrialized and mass produced through fermentation, and the limitations of their cultivation methods limit their application.
- Numerous studies have shown that AMF not only promote plant growth and improve plant health, but also enhance plant resistance to biotic and abiotic stresses. Due to differences in test materials, conditions, sampling sites, and measurement time in the study, the results of different researchers are inconsistent, or even contradict with each other.
- The biocontrol effect of AMF is affected by many biotic and abiotic factors; therefore, the regulatory factors that can maximize the benefit of plants, such as the optimal inoculation period, inoculation dose, ecological conditions, farming methods, and fertilization amount, should be studied in depth to establish a scientific and effective AMF biocontrol effect evaluation standard and provide a theoretical basis for the use of AMF to carry out biocontrol work.
- There are many possible mechanisms for AMF to improve plant disease resistance, but it is still unclear which mechanisms play a major role, a secondary role, or do not play a role.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Conclusion

Numerous studies have shown that AMF not only promote plant growth and improve plant health, but also enhance plant resistance to biotic and abiotic stresses. The application of AMF in plant disease control is bound to become a feasible and ecosystem-friendly solution to reduce the occurrence of pathogens and achieve green and sustainable development. Breaking through the technical bottleneck to realize rapid cultivation of AMF is also a future research priority. Attention should be paid to the safety evaluation of microbial biocontrol, particularly the impact of biocontrol microorganisms on the diversity of other microorganisms in the soil.

References

Wahab, A.; Muhammad, M.; Munir, A.; Abdi, G.; Zaman, W.; Ayaz, A.; Khizar, C.; Reddy, S.P.P. (2023). Role of Arbuscular Mycorrhizal Fungi in Regulating Growth, Enhancing Productivity, and Potentially Influencing Ecosystems under Abiotic and Biotic Stresses. *Plants*. 12, 3102.

Weng, W.; Yan, J.; Zhou, M.; Yao, X.; Gao, A.; Ma, C.; Cheng, J.; Ruan, J. (2022). Roles of Arbuscular mycorrhizal Fungi as a Biocontrol Agent in the Control of Plant Diseases. *Microorganisms*. 10, 1266.