



(REVIEW ARTICLE)



## Function of Arbuscular Mycorrhizal Fungus in Treatment of Plant Diseases (Review)

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### Abstract

Arbuscular mycorrhizal fungi (AMF) is a significant pathogen in the evolution and health of plants by establishing symbiotic relationships with most of the vascular plant species. Along with the traditional roles that AMF play in nutrient absorption and resistance to stress, there is also recent research that indicates that they guard plants against attacks by phytopathogens, and therefore provide an eco-friendly alternative approach to conventional systems of pesticide application. This review represents the analysis of the existing tendencies in the study of the biological and environmental nature of AMF with references to their multifunctional activity in the regulation of phytopathogens. They include competition with soil pathogens, changes in taxonomic besides functional variety and conformation of soil and root microbiomes, and plant immune responses via induced systemic resistance (ISR). The significance of arbuscular mycorrhizal fungi (AMF) to plant development can be explained by the fact that vascular plants are symbiotic to most arbuscular mycorrhizal fungi. In addition to their well-established roles in nutrient absorption and stress resistance, AMF has also been shown to protect plants against the attacks of phytopathogenic organisms, which has offered the economical solution to the conventional methods of pesticides to the environmentally friendly method. The present paper describes the recent advances in the knowledge regarding the biological and environmental qualities of AMF, and suggested focus on their multifunctional roles in the control of phytopathogens. These activities include competition against soil-borne pathogens, changes in taxonomic and practical diversity and structure of soil and root microbiomes, and changes in plant immune responses through made systemic resistance (ISR).

**Keywords:** Plant; AMF; Fungi; Control; Diseases

### 1. Introduction

Corporations like viruses, nematodes, fungus, bacteria and phytoplasmas continue to pose a threat to sustainable agriculture. Although chemical pesticides can be applied against a great number of phytopathogens, they pose a threat to the ecosystem, human healthiness, and biodiversity in soils (1). Besides, there is resistance to the use of numerous plant diseases, such as *Botrytis cinerea* multi-drug-resistant (2). Thus, the popularity of bio-oriented approaches to the treatment or a complex of phytopathogen control technologies based on maintainable farming increases. Most promising methods of opposing the phytopathogens is the use of the rhizosphere microbiome, in which there is a great level of variety of microorganisms, both detrimental and beneficial. The favorable atmosphere to plant growth can also be achieved with the assistance of different beneficial microorganisms that could accelerate the growth rate of plants and enhance defense systems of plants (3). Capability of arbuscular mycorrhizal fungi (AMF) to protect plants against a inclusive range of phytopathogens and improve nutrient uptake and resistance to stress was found to be one of the most interesting subjects in the recent years (4). It is also the case that AMF can be used to enhance the nutrition of plants and their resistance to abiotic stress factors like salinity, deficiency, and temperatures (5). It has been suggested in current literature that AMF can be used to directly inhibit infection by competing with it in rhizosphere and causing systemic resistance (6). In addition, AMF produces bioactive metabolites that facilitate the suppression of various phytopathogens among them the antifungal polyphenols and antibacterial molecule polymyxin B (7). Inoculation of

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rhizophagus irregularis has been reported to reduce the symptoms of Zucchini yellow mosaic virus in cucumbers through hormonal stability and antioxidant response alteration (8). In addition, AMF controls the structure of the plant roots rendering the root systems to be high resistant to the pathogen infiltrations (9). Specifically, AMF has a positive impact on the growth of roots that are particularly linked to a designated zone of the root, called the mycorrhizosphere (10). The suitability of bacterial, fungal, viral, and nematode pathogens in different agricultural systems is brought out by the fact that AMF make desirable biocontrol associates. However, to optimize the benefits of AMF symbiosis an ecological approach, which entails appropriate management of the soil, the nature of composed fertilizer application and increase of growth promoting microorganisms in soil is necessary.

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## **2. Colonization of roots, symbiotic development.**

### **2.1. Formation symbiosis of AMF**

One of the most widespread and ancient mutualistic relationships is arbuscular mycorrhizal symbiosis which is more than 400 million years old. It is presumed to have helped the primitive plants move inland (11). The formation of symbiosis of AMF is a process that is highly controlled, and it is described by a complex of molecular interaction between the fungus and the plant. In case of nutritional deficiencies, in particular, phosphorus deficiency, plant roots produce strigolactones (SLs) to draw AMF spores and promote their germination and hygal growth (12). This communication is initiated before making contact with one another. As a result of these pre-symbiotic signals, AMF hyphae develop towards the direction of the root (13). As the hyphae approach each other, the fungus form lipo-chitooligosaccharide "Myc factors" which causes a symbiotic potential of the plant. To their surprise, prior to their identification, these Myc signals (in the form of CO<sub>2</sub> and CO<sub>2</sub> chitooligosaccharides) resemble pathogen-associated molecular patterns (MAMPs), yet induce symbiotic, as opposed to plant immunity (11). These signals are detected by plant receptors (e.g., the rice LysM receptor kinase OsCERK1), and trigger a cascade that changes the development of the roots to form symbiotic structures (e.g., the arbuscules formed in the root cortical cells) (14). The other crucial element is OsMYR1 Myc factor of rice receptor. It interacts with OsCERK1 and induces symbiosis and successful colonization by AMF (15).

### **2.2. Root colonization procedure and intracellular mycelium development**

The interdependent association between AMF and roots is complicated, and is arranged intensely. The process of correlation starts with the identification of the plants and goes on with a series of steps which are strictly controlled resulting in the development of certain structures. Other than the assistance in the transport of nutrients, these structures have significant role in increasing the well being and capability of plants to withstand both biotic and abiotic pressures. The AMF hyphae adhere to epidermal cells on the root surface and propagate into appressoria whereby the fungus gets the chance to enter through root tissues a critical step in symbiosis development (16). Plant-based signaling molecules such as flavonoids and phytohormones that induce hypertrophy in hyphae towards the root cortex also induce the generation of appressoria which is aroused by the attachment of fungal adhesins to root surface receptors (17). After the appressorium formation, the fungus infiltrates the root epidermis and enters through the mechanical force into the cortex and releases enzymes that break down cell walls such as laccases, chitinases, and glucanases (18). The invasive hyphae are enclosed in a periarbuscular membrane by the plant and this inhibits the excessive invasion of fungi (19).

### **2.3. Development of symbiosis structure**

Arbuscules are highly dynamic forms that are frequently recreated as per the requirements of both the plant and the fungus in the changing environment or during varying phases of plant development (20). Their expounding is a great way of ensuring growth of host plant specially in a case of shortage of nutrients. The fungus relies on these specific structures as a reservoir to store the energy reserves in lipid metabolites during periods of nutrient shortage. Moreover, the vesicles can also promote asexual reproduction of fungi that promotes growth of the organism in roots. In special environments where water supply fluctuates, they made mycorrhizal symbiosis persist and stabilize in the long term (21). The functional importance of extraradical hyphae: Outside the host root, extraradical hyphae establish a fine net within the soil around them, in this way increasing significantly the surface on which nutrient and water can be absorbed. These hyphae are fundamental in the absorption of the plant of numerous weakly mobile nutrients, like P and trace elements. They also endorse consumption of water as this is important in keeping the plants alive during dry periods. Besides, extraradical hygapes contribute to the aggregation of the particles, which enhances the porosity of the soil and its capacity to hold water and makes a significant contribution to soil structure stabilization (22).

### **3. Manipulating factors on colonization of AMF roots**

#### **3.1. Abiotic and Biotic components**

Environmental variables, soil type and nutrition of plants have a significant effect on the establishment of mycorrhizal interactions in plant roots. The physical environment the fungal hyphae are formed and penetrated is based on soil texture and structure. To illustrate, the AMF colonization may be mandated to a higher level to promote the optimum nutrient absorption in the sandy soils because they lack capacity to contain nutrients (23). Conversely, resistant soils, which are not open to the growth of AMF mycelium, are compressed and not aerated (24). The availability of nutrients especially P that is essential in this symbiosis interaction is one of the main factors in the acquisition of symbiosis with AMF. In fact, such fungi facilitate uptake of weakly transportable nutrients in exchange with carbon produced by the process of photosynthesis (25). The example of wheat subjected to salinity stress was used in (26) where the amount of AMF colonization decreased by 35 percent. In the same case, the growth and absorption of the nutrients and hence the alleviation of stress by AMF was found to be increased in AMF-colonized plants. Another important microorganism community of significance to the AMF root colonization is the rhizosphere microbial community. Other microbes of the soil such as nematodes, bacteria and fungi can either activate or repress this symbiotic relationship (27). The success of the AMF colonization may be affected by many microorganisms competing with AMF colonization by getting root space immunological response of the plant. It has also been established that there are some bacteria in the soil that generate compounds that stimulate the growth of the AMF mycelia (26).

#### **3.2. Host plant factors and microbial community of the soil**

The host plant species, physiological conditions and root secretions play an important role in the colonization of AMF. Diffusion of AMF in the colonization of different species of plants varies and some species develop stronger symbiosis compared to others (28). The success of colonization also regards the physiological state of the plant which combines the aspects of the root vitality, and metabolic machinery. Plants can thus generate a certain amount of root exudates which will draw or push AMF depending on the type of stress that the plants will be exposed to (29). The development of the mycelial development and the formation of the symbiotic structures depend on the chemical signals, to which the root secretions, especially flavonoids and SLs, depend in order to coordinate the correlation between AMF and the host plant. In addition, the effect of these secretion products on AMF colonization can be influenced by the effect they have on the rhizosphere microbiota (19). Moreover, the relationship AMF has with other rhizosphere fungi may or may not promote this symbiotic relationship. It is therefore clear that fungi like *Trichoderma* spp. can increase the activity of AMF in terms of root colonization (30). However, it is also known that other types of fungi may also be a rival of AMF when it comes to nutrients or places where root tissues are attached to, which may determine the success of the establishment of this symbiotic relationship (31).

#### **3.3. Properties of AMF on the microbiota of the soil.**

The interactions of AMF with roots and rhizosphere can transform composition of interaction of AMF and soil microbiota is essential in responding to stress. Further increases in plant tolerance to biotic and abiotic stress factors require the integration of AMF and soil microbial community. AMF is capable of altering the rhizosphere microbiota to enhance plant resilience in cases of either high salinity or drought water conditions. As an example, through enhancing water and nutrient access, the association between AMF and drought-resistant bacteria can be used to support plant development (32). AMF also has the capacity to help eliminate several of the soil-borne diseases, as it has the capacity to stimulate the defensive capabilities of the plants and attract beneficial microorganisms, which outcompete the pathogens according to their available resources and space (33).

#### **3.4. Induced systemic resistance that is induced (ISR)**

The production of pathogenesis connected (PR) proteins and antioxidant enzymes having antimicrobial possessions is an accumulation of ISR activation (34). Different systemic learned resistance (SAR), ISR is activated by favorable colonization of microbes and does not often require on salicylic acid (SA) signaling, but the latter pathogen infection does (35). Colonization of AMF enhances chitoooligosaccharides that are prerequisite in the induction of ISR (36). Also, the exudates enhance the symbiosis of microbes and induce the production of defensive related compounds like phenolics, terpenoids, and flavonoids that enhance plant immunity (19). In addition, phytoalexins, antimicrobial polypeptides, and proteinase inhibitors that inhibit the multiplication of pathogens are generated due to the stimulation of ISR (37). The impact of ISR is not simply the prevention of the pathogenic infiltration. It also elevates the level of abiotic stressors, including salt, drought, and dangerous heavy metal concentration, which makes the plants more resilient (44). Another feature of ISR is production of volatile organic compounds (VOCs), which prevent attack by herbivores and prevent the transmission of pathogens (38). As terpenes, green leaf volatiles, and methyl assonate

among others, these volatile organic compounds (VOCs) are used to signal other plants and activate them to more vigorous defenses (39). In addition, the complex of environmental factors like complexity of the soil microbiomes, availability of nutrients, and stage of development of plant affect the ISR process (40). Revisions have indicated that ISR is especially upgraded in soils with in elevation readings of organic substance and microbial cover that synergistic communication between AMF and plant development-growing rhizobacteria (PGPR) and *Trichoderma* species is enhanced (41).

### 3.5. Opposition against pathogenic microorganisms

The AMF have ability to develop massive systems of hyphae cover rhizosphere also root surfaces as a defense mechanism of the plant. This facilitates good competition with the soil pathogens in terms of nutritional and spatial resources (42). Many pathogenic microorganisms with a long known track of being a spartan root cause in a range of harvest species which include *Phytophthora*, *Fusarium*, *Rhizoctonia*, and *Pythium* have a small ecological niche through this competitive exclusion process (43). Besides its ability to boost the efficiency of nutrient uptake and provide a physical obstruction to pathogen settlement on root tissue, the highly complex mycorrhizal hyphal network helps to enhance plant vigor and resilience (44). AMF can affect structure of rhizosphere microbiome to a considerable degree by creating various bioactive complexes, as well as organic acids, secondary metabolites, in addition signals (26). In the lab experiments, AMF-stimulated root exudates convert pH and chelate minerals essential and create an undesirable situation against convinced pathogens due to the antibacterial effect (45). *P. fluorescens* and *B. subtilis* together by AMF cause a significant reduction in occurrence of root diseases in yields including legumes, cereals, and solanaceous crops by inhibiting direct antagonistic activities of *F. oxysporum* and *Rhizoctonia solani*, and systemically inducing resistance (46). According to the recent study that utilizes metagenomic and transcriptomic analysis, AMF can affect the microbial communities dynamics by preferring the shift towards antagonistic microbial communities and, at the same time, inhibiting the pathogenic strains (55). Moreover, AMF are known to have the ability to manipulate the soil suppressiveness and the ability to provide long term defense against soilborne diseases by establishing disease-repressive microbial consortia that survive in pathogen-infested soils (47).

### 3.6. Manufacture of antimicrobial composites

It has been demonstrated that colonisation of AMF leads to significant metabolic alteration in the host enhancing a number of antimicrobial compounds. The metabolite contains phenolic acids, terpenes, flavonoids and antimicrobial phytoalexins (48). There is also a higher accumulation of some flavonoid such as kaempferol and quercetin in AMF-inoculated plants (49). Direct effects on the balance of signaling and microorganisms of the rhizosphere are also created by these biostimulants, in addition to direct effects of the killing of bacteria (50). It is also linked with the degradation of pathogenic microbial biofilms, which are linked with increased phenolic exudation of mycorrhizal plant roots and this reduces stage coordinated infections. It is also important in specific cases of *Pectobacterium carotovorum* and *Ralstonia solanacearum* which are soilborne infections that actively regulate pathogenicity by quorum sensing, subsequently reducing the success of infection (52). One of the best-investigated substances is Glomalin. It is a protein that initiates synergism in microbes, and hardening of the soil (53). Other researchers have found out that glomalin interferes with microbial competition by inhibiting fungi growth that causes diseases but promoting the growth of non-pathogenic microbes such as *P. fluorescens* and *Trichoderma* spp. (54). It has also been observed that AMF produces lytic proteins, chitinolytic proteins, and antimicrobial peptides especially when it comes to bacterial and fungal infections (55). To be more exact, the fungal pathogens *F. oxysporum* and *R. solani* have a large chitin content of their cell walls and can be broken down by chitinases produced by AMF because the disease frequency becomes practically decreased in plants colonized in this way (56). Recently, AMF was found to synthesize the terpenoids as a common antimicrobial agent especially in dealing with soilborne include oomycete pathogens that include *Phytophthora infestans* besides *Pythium ultimum* (57).

### 3.7. Improvement of immunological reactions in plants

In many different ways, AMF provision plants by attractive their overall and numerous aspects of natural immunity against pathogens. These connections for a long time up to disease resistance improve general plant health by repelling harmful organisms. Mainly it boosts plant immunity by means of alteration in structure so that structural defenses against infections can be better organized. This is done by more deposition of cell wall material, and content of lignin as well as callose, and cuticle layer strength on which pathogen penetration and inside multiplication in plant tissues are restricted. Such expansions have been reported in various crops excluding vegetable and cereal harvests in which symbiosis with AMF has controlled to impressive reduction in incursion by pathogens (58). Besides essential defense, AMF moreover plays a role in ROS stabilities in plants (26). Controlled ROS buildup is one of the key immunological signaling molecules that stimulate the defense-related pathways and have direct antimicrobial effects on invasive infections (59). The oxidative stress cannot negatively impact the plant metabolism in case it is excessive because the

concentration of the ROS is fine-tuned by AMF (60). AMF directive of these hormones safeguards a perfectly stable defense response by avoiding over stimulation of defense that might result in the diversion of resources to the plant development and production (61). Studies show that the process of AMF colonization can induce the overexpression of the ISR protection genes as well as Systemic Acquired Resistance (SAR), which leads to resistance of plants to a wide variety of pathogens, such as bacterial, viral, and fungal diseases (62). Also, AMF has been linked to the stimulation of secondary metabolites, which enhance the defense system of plants. These metabolites comprise of alkaloids, terpenoids, and flavonoids that are antimicrobials and are essential elements in plant defense (63). In addition, AMF exposed to enhance the accretion of pathogenesis related (PR) proteins, that enhance resistance to biotrophic and necrotrophic diseases (56).

### 3.8. Environmental factors and synergistic interactions on AMF mediated pathogen reduction

Preventing proliferation of pathogens by AMF is not merely due to direct contact of AMF to soil suppressivity through generation of bioactive products like glomalin adding to the direct removal of phytopathogenic microorganisms. Glomalin is antimicrobial in nature by inhibiting the adherence of repugnant microorganisms on the root surfaces, altering their dynamics, although its initial activities are soil aggregation and carbon sequestration. This shows the diversity of AMF in soil structure and reduction of attack on phytoplankton. Ecological conditions are also major factors affecting the AMF in inhibiting the disease. Soil salinity, pH, organic substance content, besides nutrient obtainability are among factors that have a great effect on the level of AMF colonization and strength of persuaded defenses in plants (37). More specifically, soils with a high microbial diversity have a high ISR. It is due to such connections between AMF and PGPR additional useful fungi like *Trichoderma* sp. that increased plant pliability is observed in such soils (64). To enhance application of AMF in environmental farming, and increase resistance of plants to infections, such complicated interactions require an understanding of their nature. AMF play a critical role in the prevention of soil-borne diseases since they occupy soil and establish symbiotic interaction with the plant roots (65). They have been shown to play a significant role as biocontrol agents by a number of different mechanisms including rhizosphere niche competition, systemic introduction of plant defenses, and the control of crowd biochemical pathways (56). The colonization of the root system by AMF limits the growth of the pathogens by occupying their space and nutrients along with additional pathogens like *Alternaria* sp., *Fusarium* sp., and *Phytophthora* sp. (66). The synergistic effect of *Glomus fasciculatum* and *F. mosseae* in combination also minimized the harshness of the *Fusarium* wilt, by 40-60%, in tomatoes by augmenting the P metabolism and antioxidant activity (67). The main determinants of the effectiveness of AMF mediated defense are the host pathogen specificity, ecological factors, and symbiotic compatibility (46). Flax AMF colonization reduced growth of *F. oxysporum* by 55% since it glutathione reductase and induced catalase which served to protect oxidative damage and maintain redox homeostasis (68). Of particular interest are how *Claroideoglomus etunicatum* and *Glomus macrocarpum* regulate the actions of the *Macrophomina phaseolina* and *R. solani* in soybean and peanuts, showing their beneficial effects in diverse agroecosystems (69).

### 3.9. Apparent for biocontrol in numerous agricultural systems

The AMF possesses the biological control role which depends on cropping system, existing ecological circumstances, nature of crop and soil type. The disease pressure in culture could be lowered by AMF through the enhancement of nutrient uptake, through the change of chemical makeup of root exudation, and the maximization of the impact and action of antagonistic microbes (66). They do better in more diversified systems like agroforestry and intercropping where the wider array of microbial habitats and root exudates can be used to help condition a more balanced microbiome in soil (70). In addition, there is also development of AMF variety that is related to these systems (71). Potatoes and legume agricultural systems have also received a Mycorrhizal fungi introduction to enhance nutrient uptake, resilience of the plant, and production (72). AMF has found itself handy in management of various polyphagous diseases in a number of trials which result in significant losses in terms of crops. Indicatively, research has shown that *Fusarium* and *Verticillium* species induced infections can be treated using AMF (73). Use of AMF has dramatically decreased the rate and extent of bacterial wilt in apple and tomato crop; many infectious crop diseases which may accompany the rise in nutrient uptake of AMF has decreased considerably in frequency as well as severity. Recent researches(74) show that AMF contributes significantly to the regulation of the plant-pathogen relationships of even invasive crops. Taking the example, the adverse effects of *R. solani* infecting *Alternanthera philoxeroides* were suppressed when used along with the application of *Glomus etunicatum*. Invasive plant AMF was also linked to a significant proportion of aerial components growth and optimization of resources allocation on biomass which enhanced resistance of the plants against the biotic stress (75).

The arbuscular mycorrhizal fungi are also significant to the organic farming systems because they improve the well being of the soil besides, they cause a variety of soil born diseases in several ways. This is promoted by their exposure to compost, organic additives and proper rotation. The system of farming and activity and richness affect mycorrhizal communities. The high AMF diversity and abundance is encouraged by organic farming through the use of organic

fertilizers and limited use of chemicals. Organic management practices that promote AMF growing and multiplying in the soil include minimum tillage, application of chemical fertilizers among others (76). AMF have been demonstrated to be highly symbiosis in environments, so use of organic alterations has been shown to increase fungal mass and retain high fungal diversity in the soil as compared to use of chemical composts and adds to the long-term effects of AMF suppression of soil-borne pathogens. In that respect, AMF has been reported to have a great antagonistic activity in low-latitude areas, soils with P-deficiency, dry and semi-arid areas, and more mixed cropping systems (77). In such circumstances, AMF is useful in enhancing the P uptake then systemic plant protection in the fit bio-systems in order to augment the disease suppression strategies (78). The release of nutrients progressively and the improvement of soil structure have been observed as an effect of the organic amendments to stimulate the colonization of AMF soils. This in conclusion results in a favorable environment, where there is mutualistic interaction such as in AMF-plant symbiosis. Plants, in their turn, lose their reliance on AMF-mediated acceptance of nutrients and are exposed to overabundance of nutrients, the vast majority of them being P (79). Availability of readily accessible nutrients can constrain molecular mechanisms of AMF root colonization, and decrease symbiosis advantages of enhanced plant health and resistance to diseases. The application of AMF and compost has been established to enhance long-term biomass of carob trees and the resistance of water stress (80). Moreover, AMF targets with organic bio stimulants like humid compounds and seaweed excerpts to improve the growth of plants and their reaction to stress without necessitating the application of artificial chemical inputs (81). In order to recover long period soil status and increase the food safety, (82) point out the need of incorporating mycorrhizal fungus as part of the organic farming. This is in view of the increased awareness of the mycorrhizal fungi as biofertilizers that have the potential to reduce the environmental degradation brought about by harmful agricultural activities through either reducing or replacing use of chemical composts (83).

### 3.10. Merging biofertilizers & biocontrol agents

AMF when used in combination by biological control agents and biofertilizers meaningfully enhances the yield of crops and eliminates diseases. AMF could be used along with other biological agents like *Bacillus* spp., *Pseudomonas* spp., and *Trichoderma* spp. in management of a wide variety of diseases. Microorganisms are reported to generate metabolites also antifungal molecules, which assistance plants to combat large number of phytopathogens in their resistance mechanisms. This mixture, thus, optimizes the activity of the plant and makes it more resistant to diseases (84). Microbes that optimize the availability of nutrients such as PGPR and AMF enhance the ability of vital nutrients like N and P that improves the nutritional state of plants and by extension, various plant-based metabolic processes such as defense responses (85). The anti-pathogenic and secondary metabolites of PGPR have a direct inhibitory effect on the pathogen infection. These bacteria cause systemic resistance in plants as well as increase the activity of defense related enzymes (86). AMF can regulate the health of the plants by expressing defensive related genes against the pathogenic attacks and at the same time support the uptake of nutrients by the plants (87). AMF is also helpful in managing oxidative stress by the induction of antioxidant enzymes in the host plant (88). Combination of the effect of PGPR and AMF has been described to enhance crop confrontation to biotic and abiotic stresses. These applications can increase photosynthetic activities, improve nutrient and water uptake, and decrease oxidative stress as a result of dehydration. As the production of antimicrobial metabolites causes the repulsion of the pathogens by releasing the PGPR, the AMF restricts the development of the pathogens under biotic stress conditions through nutritional competition. This can indicate that there are other mechanisms of the synergy effects in the system of inoculation that is not currently known (85). Such integrated systems require the balance of antagonistic and synergistic interactions of the injected bacteria to be healthy. Modest exclusion and synthesis of inhibitory compounds can be listed among the factors that can decrease efficiency of AMF colonization. Moreover, these conditions have the potential of weakening general performance of microbial consortium.

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## 4. Conclusion

Arbuscular mycorrhizal fungi are the organic sustainable plants that are used as a disease control measure. These ensure that the plant absorbs the nutrients in the agriculture production systems, promotes resistance to the stressors and mechanisms of defense controls during disease management. The various mechanisms by which AMF inhibit plant diseases that were highlighted in this paper are the activation of induced systemic resistance, competition against pathogens, production of antimicrobial compounds, and overall elevation of the plant immunity. The effect of AMF on the soil microbiome ecology will qualify it among integrated disease management programs because AMF results in soil fertility and soil structure improvement in addition to being a biocontrol agent. Nonetheless, despite this potential, the AMF performance variation is very problematic in the context of scaling between laboratory and greenhouse to the field implementation. The results ought to be used in designing technologies based on scalability of AMF bioproducts with different cropping systems and their interactions with other biocontrol agents.

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