Arbuscular Mycorrhizal Fungi and Plant

Subjects: Plant Sciences

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This entry highlghts the role of Arbuscular Mycorrhizal Fungi (AMF) on plant nutrition and growth. AMFimproves plant nutrition and helps them to cope with environment stresses.

Keywords: AMF, Plant, Nutrition, stresses

1. Introduction

Arbuscular mycorrhizal fungi (AMF) are soil microorganisms that form a symbiotic relationship with 80–90% of vascular plant species and 90% of agricultural plants [1], including most agricultural crops, particularly cereals, vegetables, and horticultural plants. They have a ubiquitous distribution in global ecosystems that are primarily defined by the global distribution of known plant hosts [2][3]. AMF are classified as a member of subkingdom *Mucoromyceta* and the phylum *Glomeromycota* including three classes (*Glomeromycetes*, *Archaeosporomycetes*, and *Paraglomeromycetes* [4]). AMF belong to 11 families, 25 genera, and nearly 250 species [5][6]. *Glomeromycota* are obligate symbionts that rely on the carbon substrates provided by their host plants (up to 20% of plant-fixed carbon) to survive [7][8]. In return, the fungi improve the supply of water and nutrients, such as phosphate and nitrogen to the host plant through extraradical and intraradical hyphae, arbuscules, and the root apoplast interface [9]. Based on fossil records and molecular data, this symbiosis dates back to the first appearance of land plants, about 400 to 450 million years ago [1]. The Arbuscular mycorrhizal (AM) symbiosis is probably the most widespread beneficial interaction between plants and microorganisms [9]. Several studies have reported that they play a crucial role in plant nutrition and growth in stressed conditions and enhance a number of essential ecosystem processes [7][10].

2. Contribution of Arbuscular Mycorrhizal Fungi to Plant Nutrition and Growth

Among beneficial microbes, AMF are one of the most widespread symbiotic fungi colonizing the majority of agricultural plants [11]. The effects of AMF on plant growth and physiological elements contents have been widely studied in many species including relevant crops such as *Solanum lycopersicum* L. [12][13], *Sorghum bicolor* (L.) Moench [10][14], *Withania somnifera* (L.) Dunal [15] *Cucurbita maxima* Duchesne [16], *Piper longum* L. [17], *Phaseolus vulgaris* L. [18], *Panicum hemitomon* Schult [19], and some free fruits such as *Citrullus lanatus* (Thunb.) Matsum. & Nakai [20], *Musa acuminata* Colla [21], and *Prunus cerasifera* L. [22]. In all these species, AMF improved plant growth parameters [10][12][13][14][15][17] and the uptake of several major nutrients such as nitrogen and phosphorus in stressed conditions [23][24]. This growth stimulation is linked to the fact that AMF extends the absorbing network beyond the nutrient depletion zones of the rhizosphere, which allows access to a larger volume of soil [25]. Furthermore, fungal hyphae are much thinner than roots and are able to penetrate smaller pores and uptake more nutrients [26].

By extending the root absorbing area, AMF increases the total absorption surface of inoculated plants and thus improves plant access to nutrients, particularly those whose ionic forms have a poor mobility rate or those which are present in low concentration in the soil solution [1]. It is calculated that the rate of water transport from external hyphae to the root ranges from 0.1 [27] to 0.76 μL H_2O h^{-1} per hyphal infection point [28]. Furthermore, AMF contributes approximately 20% to total plant water uptake [29], highlighting the role of the symbiosis in the water status of host plants. AMF significantly improved *Cucurbita maxima* growth and metabolism, such as the concentrations of fat, crude protein, crude fiber, and carbohydrates in shoot and root systems of inoculated plants compared to control treatment [16]. Inoculation with this fungus significantly increased plant growth as well as phytochemical constituents such as sugar, protein, phenol, tannin, and flavonoid content [15]. In watermelon (*Citrullus lunatus* Thunb.), mycorrhizal colonization was found to improve not only the plant yield and water use efficiency but also the quality of the fruits [30]. Similar results were obtained in mycorrhizal tomato plants with an increase in the concentrations of sugars, organic acids, and vitamin C in fruits [12]. It has been demonstrated by [31] that AMF improved peach seedlings' performance under the potted conditions, and also significantly elevated K, Mg, Fe, and Zn concentrations in leaves and roots, Ca concentration in leaves, Cu and Mn concentrations in roots, which were obviously dependent on the AMF species. Compared to three AMF ([*Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler 2010, *Glomus versiforme* (P. Karst.) S.M. Berch 1983, and *Paraglomus occultum* (C. Walker) J.B. Morton & D. Redecker 2001), *F. mosseae* exhibited the best mycorrhizal efficiency on growth and nutrient acquisition of peach seedlings [31]. Compared to uninoculated plants, AMF inoculation had positive effects on the growth of carrot and sorghum [14]. In carrot, *Scutellospora heterogama* (T.H. Nicolson & Gerd.) C. Walker & F.E. Sanders 1986, *Acaulospora longula* Spain & N.C. Schenck 1984, and *F. mosseae* had a positive effect on the growth of the host, whereas AMF had only weak effects on the growth of red pepper and leek [14].

Therefore, it is important to mention that the extent to which a host plant benefits vary with the AMF species used [14]; and macro and micro-nutrients uptake could depend partly not only on the fungal partner but also on the host plant [32]. A study carried out by [33] indicates that the contribution of the mycorrhizal pathway to nutrient acquisition also depends on fungal effects on the activity of the plant pathway and on the efficiency with which both partners interact and exchange nutrients across the mycorrhizal interface [34]. For various crops such as sweet potato [35] or pepper plant [17], the beneficial effect on plant nutrient content has also been shown to be dependent on fungal diversity.

A similar positive effect was reported in sorghum with an enhancement of plant height, the number of leaves, biomass, total nitrogen, phophorus and potassium uptake [10]. Although, among some species of native AMF tested (*Glomus aggregatum* N.C. Schenck & G.S. Sm 1982, *F. mosseae*, *Acaulospora longula*, and *Acaulospora scrobiculata* Trappe 1977) some species like *Acaulospora scrobiculata* are more efficient for improvement of all these parameters in sorghum [10]. The effect of an AMF, *F. mosseae* was examined regarding the morphological and biochemical properties of different genotypes of the medicinal plant *W. somnifera*, commonly called Ashwagandha [15]. In addition, several studies reported that the responses of plants to colonization by AMF vary depending on inoculum composition, and a combination of mycorrhizal fungi is more effective than a monospecific inoculum [10][14][17][18].

AMF colonization by *F. mosseae* or *R. intraradices* (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüßler 2010) increased both the survival and growth (by over 100%) of micropropagated transplants of *Prunus cerasifera* L., compared with either uninoculated controls or transplants inoculated with the ericoid mycorrhizal species *Hymenoscyphus ericae* (D.J. Read) Korf & Kernan 1983 [22]. Thus, inoculation of woody species' seedlings under nursery conditions is a valuable strategy to produce seedlings with good vigor, which would translate into high survival and growth at the field [36][37][38].

AMF play an important role in biofortification [39][40]. AMF inoculation may affect selenium uptake from soil and the level of antioxidant compounds in vegetable crops such as the green asparagus *Asparagus officinalis* L. Research carried out by [41][42] showed increasing selenium (Se) content in wheat grain through inoculation. It has been found by [43] that AMF modifies the concentration and distribution of nutrients within wheat and barley grain. Inoculation with AMF improves the grain nutritional content in protein, Fe, and Zn [44]. Under distinct environmental conditions, [45] concluded that AMF symbiosis positively affected the Zn concentration in various crop plant tissues. AMF can contribute substantially to the Zn nutrition of cereal crops such as bread wheat and barley but the role played by AMF on Zn uptake depends on the functional compatibility between AMF isolate and inoculated cereal species [40].

It is well-known that AMF symbiosis specifically induces the expression of transporters such as the plant aquaporin (AQ) genes, Pi transporters (PT), ammonium transporter (AMT), nitrate transporter (NT), sulfur (S) transporter, Zn transporter, carbon transporter, protein transporter etc. [46][47][48][49][50]. In wheat plants treated with *F. mosseae* and *R. intraradices* Zn concentration is 1.13–2.76 times higher than non-inoculated plants observed [51]. Further, it has been demonstrated that fungal form a network called mycorrhizal networks (MNs) that improve nutrients transfer between plants through the extension of fungal mycelium [52][53]. Also called common mycorrhizal networks, these MNs can integrate multiple plant species and multiple fungal species that interact, provide feedback, and adapt, which comprise a complex adaptive social network [52]. Results obtained by [54] confirm the role of AMF in driving biological interactions among neighboring plants.

3. Conclusions

AMF play an important role in improving the adaptation to biotic and abiotic plant stresses and to alleviate the effects of these stress on plants. Their role in increasing plant growth and yield, disease resistance, biotic and abiotic tolerance provides an environmentally friendly solution to reduce the use of hazardous pesticides and industrial fertilizers. However, more research is needed to test in the field the results obtained in the laboratory and in the greenhouse. The application of this knowledge in real environments and according to biogeographical zones becomes essential in order to promote their industrial production for a large scale used and increase their impact to ensure enough food for every human being on the planet now and in the future. As an ecofriendly method, some work must be done by researchers, private and public sectors, to promote the use of AMF by increasing their production, particularly in developing countries where AMF inocula are not accessible and not affordable.

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