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## A critical review on the nutrition role of arbuscular mycorrhizal fungi

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**Abstract**. Even though many factors influence the accession of mineral nutrients required for plant growth, arbuscular mycorrhizal-roots can greatly enhance the accession of mineral nutrients in host plants. The nutrients enhanced most by AM are those that are of low mobility or sparingly soluble. With other factors being equal in specific environments, AM may be the difference between whether plants will survive and/or have the ability to obtain the required mineral nutrients for sustainability. Although the most commonly reported mineral nutrient enhanced in host plants with AM-roots is P, accession of many other mineral nutrients (e.g., Zn, Cu, N, S, Ca, Mg, K) may be enhanced in plants by AM. Several reviews about accession of mineral nutrients in AM plants have been published fairly recently. Some of the concepts mentioned with P accession may be applicable to the other mineral nutrients. This review gives an overview on the role of mycorrhizae in nutrition.

Key words: arbuscular mycorrhizal (AM) fungi, nutrition, phosphorus, potassium, zinc, copper, iron, molybdenum, nitrogen.

**Introduction**. Mycorrhizal fungi are one of the soil organisms that create a direct connection between the soil mass and plant root systems (Alizadeh 2010). The root of mycorrhize was the continuation of the host plants root system and the constitutive of a big group of organisms which are in the microbe society of the soil (O'Keefe & Sylvia 1991). These fungi are of Glomales rank and belong to the Zygomycetes and maintained coexistent relationship with most palmary plants; in reality this coexistent counts as the most widespread type of coexistent on the planet earth. These fungi have an outstanding effect on the increase of food elements absorption, growth and adjustment of the host plant in environmental tension conditions. According to different researchers study the positive effect of mycorrhizal fungi on the increase of food element absorption such as phosphorus, potassium, zinc, copper and iron on mycorrhizal plants has been proved (Li et al 1991a, b, c).

The absorption of food elements by plant depends on the absorption capacity of those elements by the plant root and sending food elements to the root and soil solution. As a result the capacity of absorbing ions such as phosphorous, zinc and molybdenum which have low propagation in soil, is down to the density of root in the volume of soil. The effect of mycorrhize on the growth of plants could be direct or indirect. George et al (1992) reported that the direct effect of it is when the food elements are absorbed by the root and transferred to other plants and the indirect effect of it is when the root colonisation system causes morphological changes in the host plant through fungi. Wide range of researches has shown that the chains of VAM fungi are capable of absorbing elements that the roots are not capable of absorbing. From this the main duty of mycorrhize is more connection with soil to absorb food elements and increase of efficiency to absorb soil solution (Sieverding & Galvez 1988). In other words, mycorrhize fungi live with plant roots as coexistent and enter into cortex cells and at the same time by expanding their chains in the soil, increase food element absorption specially phosphorous which has very low movement, and in this way phosphorous that does not get absorbed in soil is turned to phosphorous that's usable for plant (Alizadeh & Namazi 2011). In reality these fungi create an extra effective root system. Elements such as Cu,

Zn, S, Ca, K, P, N, Sr are absorbed from the soil and transferred to the host plant by mycorrhizal fungi (Clark & Zeto 1996a, b). Elements can be absorbed by fungi chains and transferred to the mycorrhizal plant roots in distance more than 4cm from the nearest host plant root (Clark et al 1999). Barea et al (1993) estimated that arbuscular mycorrhizal (AM) fungi might increase the effective root surface absorption by ten times. In other words the absorption capacity of ions with low propagation in soil, such as phosphorous, zink, molybdenum and potassium to a certain level, sulphur and NH4 is dependent on the density of root in soil.

**Phosphorus**. As a result the main responsibility of mycorrhizal fungi is increase of accessible soil volume for food element absorption and also increase of foods element absorption efficiency from soil solution (Smith & Smith 1990; Alizadeh et al 2010). Alizadeh & Nadian (2010) addressed elements which absorb in plants root through propagation and their transportation speed in the soil towards the root surface is low, the presence of external mycelium of mycorrhizal fungi in soil cause increase in absorption and transporting these elements to the host plant and in this way the distance that these elements should travel through propagation in soil to the root surface, becomes shorter.

In the results that have been gained by Tarafdar & Marshner (1994a, b) planting wheat with the presence of mycorrhize fungi *Glomus mosseae*, causes the increase of potassium thickness and Magnesium of air figures and also causes increase in the amount of plants phosphorous and absorbing total phosphorous. Also according to the pervious researches, the colonisation of the plants root done by the VAM fungi increases the absorption of phosphorous and other low volubility elements such as zinc and copper (Alizadeh & Nadian 2010). On the other experimental results gained by Alizadeh & Namazi (2011) which was done on corn plant showed that the amount of phosphorous absorption in all plants that have been inoculated by *Glomus intraradices*, *G. mosseae* and *Glomus etunicatum* is more than the absorption speed of phosphorous by plants that have been mycorrhized by *G. intraradices* is more than the speed of absorbing phosphorous by inoculated corn plant with the two other types.

Overall the usage of fungi has caused increase in the usage of phosphorous absorption compared to lack of its usage. In annotation of this result it can be stated that through mycelium and chain divergence, fungi itself causes expansion of plant root and this way it causes the plant root to use rhizospher (Clark & Zeto 1996a, b). In another experiment mixing with AM fungi (Glomus types) phosphorous absorption has been increased by 54.5% compared to witness (without the mixture) (Manjunath & Habte 1988). In plant coexistent with mycorrhiza fungi, the level of absorbing food elements up to a high amount is under impact of their average thickness in soil (Khalil et al 1994).

The usage of phosphorous absorption by mycorrhizal plant has contrary relation with the amount of phosphorus. The opposite effect of fungi and phosphorous on the usage of corn phosphorous absorption has been significant. This shows that the effect of fungi on independent phosphorous absorption usage has not been from the phosphorous and has been put under its impact (Alizadeh & Namazi 2011). Comparison of the average effect of fungi and phosphorus on this demonstration showed that in both cases usage and lack of fungi usage, with increase in the amount of phosphorus, the usage of absorbing phosphorous by the plant is decreased. Also in every surface of phosphorous, using fungi has had a significant priority compared to not using it and this priority in the surface of zero phosphorous has reached its maximum level. Because increase of the amount of soils phosphorous causes decrease of fungi activity. So we can conclude that AM mycorrhizal fungi has a lot of importance in the increase of phosphorous absorption usage in plant especially in circumstances where the phosphorous in the soil is low (Alizadeh & Namazi 2011). Boln (1991) proved that transforming phosphorous to an absorbable form is done by plant, by realising hydrogen ions by external mycelium. Kothari et al (1990) mentioned that more increase of host plant, is a result of the mutual effects of mycorrhizal fungi and bacteria that dissolve phosphorous because of producing more herbal hormones and or vitamins from bacteria that dissolve phosphorous in soil.

**Nitrogen**. In addition to the enhanced P accession by AM plants so commonly reported, enhanced N uptake is also reported often for AM plants. The enhanced N in AM plants has been explained by high N demand because of enhanced P (Hamel & Smith 1991; George et al 1995).

Nevertheless, the research has indicated that N accession may be enhanced in AM plants even when plants have adequate P (Ames et al 1983).

Some researches indicated that N accession in legumes could be enhanced above that mediated by P nutrition and that AM may enhance N of host plants by not only indirect (improved nodulation and N<sub>2</sub>-fixation) but by direct (increased N uptake from soil) means as well. The AM helped alfa alfa acquire N from sources other than Ny-fixation, used available forms of N more efficiently, and/or obtained N from less available sources. Increased accessibility of plants to soil N pools has also been associated with AM (Barea et al 1993; Azcon & Barea 1992).

The AM hyphae have the capacity to take up and transport N from soil to roots (George et al 1992). Mycorrhizal fungi can also improve absorption of N from  $NH_4^+$  mineral fertilizers, transporting it to the host plant (Ames et al 1983; Johansen et al 1993). Itstransport and absorption can also increase biomass production in soils with low K, Ca and Mg (Liu et al 2002).

Based on a study of Khalil et al (1994), coexistent of soybean plant with VAM fungus caused increase in total absorption of nitrogen, phosphorous, potassium, calcium, magnesium and zinc, but the thickness of nitrogen and calcium was reduced. Availability of good enough phosphorous is the vital condition for creation of stabilised knot of nitrogen and their activities. Because of the fact that mycorrhizal fungi can create satisfactory conditions in the limited phosphorous regime, their positive effects on stabilisation of nitrogen is associated in their role of providing part of plants need of phosphorous. Knot motivation through mycorrhizal fungi is possibly by the direct increase of knot activities or because of balancing the plants nourishment (Khalil et al 1994).

According to Azaizeh et al (1995), it was reported that nitrogen is absorbed by the chains of VAM fungus from  $NH_{4^+}$  mineral resources and the direct effect of VAM fungi on absorbing  $NO_3$  has not been confirmed. One of the reasons for the above conclusion is the propagation speed of the above ions in soil.

Bethlenfalvay et al (1991) found out that phosphorous nitrate can revive to nitrite via fungi (*G. mosseae*) spores. Such fungi that perform nitrate revival mostly contain enzymes that are related to NADP+ or contain revival activities related to NAD+. These enzymes mostly belong to supreme plants. In addition to this mycorrhizal fungi might enable the plant to plant transfer of nitrogen and the nitrogen realised from older plant roots will be absorbed by fungi chains and transferred to the rest of the plants (Bethlenfalvay et al 1991).On the other side mycorrhizal fungi are able to absorb nitrogen from mineral muck and transfer it to the plants (Hamel & Smith 1991).

Also according to the results that have been gained from the studies about nitrogen absorption, liquoring with VA mycorrhizal fungus (different types of *Glomus*), absorption of nitrogen in soybean, has increased by 98.3% compared to the one without liquoring (Khalil et al 1994) and also liquoring wheat with mycorrhizal fungi causes increase in the thickness of nitrogen to the one that's not liquored and this increase in composite liquoring with mycorrhizal fungi and nitrogen and bacteria was increased (Faber et al 1991).

**Other elements**. An enhanced <sup>35</sup>S accession was noted in *G. mosseae*-white clover, but not to the same extent as P (Cooper & Tinker 1978). In fact, hyphae may not have been highly involved in S transport Boron accession has been reported to be reduced, remain unaffected (Lu & Miller 1989), or enhanced (Kothari et al 1990) in shoots of AM plants. The information on accession of the macronutrient cat ions by AM plants has been relatively inconsistent in that increases, no effects, and decreases have been reported (Lambert et al 1979; Azcon & Barea 1992). Enhanced accession of Ca and Mg and usually K has been noted for various plants colonized with different AM isolates compared to non-AM plants (Sail 1987; Siqueira et al 1990).

In contrast to AM plants grown in acidic soil, those grown in neutral to alkaline soils generally have limited enhancement of K, Ca and Mg accession, and these nutrients are generally lower in AM than in non-AM plants (Bethlenfalvay et al 1989; Raju et al 1990; Hamel & Smith 1991; Khalil et al 1994; Bermudez & Azcon 1996). The enhancement of K, Ca and Mg in AM plants grown in alkaline soil also depends on AM isolate and plant species or type of plant. For example, when soybean was grown in a medium with arid, semi-arid, and mesic isolates of *G. mosseae*, only the arid isolate enhanced growth, improved activity of several physiological processes, and enhanced nutrient accession (Bethlenfalvay et al 1989).

The result of experiments has shown that myccorhizal fungi increase absorption of elements such as nitrogen, sulfur, potassium, calcium, magnesium, manganese and iron (Bolan 1991), copper and zinc (George et al 1994; Alizadeh et al 2010) in the vacated areas around the root. Also George et al (1994) reported that in coexistent plants with mycorrhizal fungi the amount of zinc and copper absorption increased, but in the experiment that was done by Buwalda et al (1983), it was shown that although the level of zinc in the plant millet increased by mycorrhizal colonisation, but in the plant cow pea with mycorrhizal colonisation, the level of zinc had a significant decrease. This was when in the plant sorghum, the level of plant zinc in the mycorrhizal and non mycorrhizal state was almost equal (Buwalda et al 1983).

The uptake of both Zn and Cu is enhanced in AM plants (Cooper & Tinker 1978; Lambert et al 1979; Gildon & Tinker 1983; Pacovsky 1986) but in considerably smaller quantities than P (Cooper & Tinker 1978). These micronutrients may not be as readily translocated from roots to shoots as P (Manjunath & Habte 1988), and distribution in roots and shoots depends on soil P level (Lambert et al 1979). Enhanced accession of Zn and Cu in shoots was reduced when P was increased in soil (Lambert et al 1979), although an enhanced accession of these nutrients occurred even at high levels of soil P (Raju et al 1990).

The AM plants generally have lower Mn accession compared to non-AM plants (Lambert et al 1979; Kothari et al 1990; Azaizeh et al 1995), although enhanced Mn has been reported for some AM plants (Medeiros et al 1994; Clark & Zeto 1996b; Al-Karaki et al 1998). Manganese is more soluble in acidic compared to alkaline conditions, and enhanced Mn acquisition has been noted for plants grown in acidic soil.

In the experiment done by Buwalda et al (1983), it was clarified that by increasing the thickness of phosphorous in soil, its' amount in the plants' tissue was increased, but the thickness of zinc, calcium and magnesium decreased. It was also clarified that by using phosphorous and mycorrhizal colonisation at the same time, the amount of zinc in the sorghum plant is less than the case of using phosphorous and lack of colonisation (Buwalda et al 1983).

Coexistent of plant with mycorrhize usually reduces the thickness of plants' potassium or has no effect on absorbing potassium and the amount of absorption is increased only when the soil is extremely poor (Bethlenfalvay et al 1991). Also transferring sulphur and calcium was examined in an experiment and the amount of sulphur in the root and stems of three types of plant was measured, the result of the examinations was precisely declaring that the effect of mycorrhizal colonisation in absorbing sulphur was more by the plant. Transferring calcium and transferring phosphorous were comparable, but transferring calcium was lesser amount then transferring phosphorous. Potassium and magnesium usually have more thickness in mycorrhizal plants compared to none mycorrhizal plants; these elements are more active in soil solution rather than phosphorous. Transferring potassium and magnesium directly using VAM fungi roots has not been confirmed therefore in this case absorbing these elements actively by mycorrhizal plants is possibly indirectly confirming the removal of lack of phosphorous by VAM fungus. In any case the result of experiments shows that in soils with lack of potassium, absorption of potassium by types of VAM fungi will be improved and this shows that there's a possibility that potassium is transferred by the chains of VAM fungi (Sieverding & Galvez 1988).

**Conclusion**. So as a result AM funguses have an important effect in nutrient element absorption by increase of rizosphere. One centimetre of mycorrhizal hairy roots will engage 1-2 square centimetre from the mass of the soil, but this mass reaches to about 200 square centimetres by roots that contain fungi chains (Sieverding & Galvez 1988).

The fungi with uptake of P and other mobile elements such as Cu and Zn in corn, soybeans and sorghum will increase the growth of these plants (Johansson et al 2004). Some farm operations, such as uncontrolled use of chemical fertilizers, fungicides and pesticides have a negative impact on survival and spread of this fungus. It can be said for most of intensive agricultural systems are deprived of the benefits of this symbiosis. Since the mechanical method is not efficient and economical use of biological methods to reduce soil compaction, which is environmentally friendly and economically both useful sustainable farming practices are leading to a system (Bouwman & Arts 2000; Passioura 2002). The fungus can absorb the toxic elements in soil, raising electrical conductivity in the soil and prevent their absorption and other elements, also worthy to mention (Pardo et al 2000). The AM can enhance mineral nutrient accession in host plants. Phosphorus, N, Zn and Cu accession are most commonly reported to be enhanced by AM plants, but accession of oilier minerals required for plant growth may be enhanced, especially when plants are grown in soils or conditions where these minerals are limiting. For example, AM plants often have increased levels of Ca, Mg, and K and reduced Mn and Al relative to non-AM plants when grown in acidic (pH<5) conditions. Water relations of AM plants are improved over non-AM plants, but evidence for direct contribution of hyphae in water transport is limited. Plants receive considerable benefit from AM when grown under harsh conditions, especially where mineral deficiency/toxicity and water stress conditions prevail.

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