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Association of am (arbuscular mycorrhizal) fungi in fruit crops production: A review

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Abstract
The exploitation of symbiotic feature of AM fungi is one of the efficient approaches to improve crop tolerance to unfavored environment. Generally, vascular plants have been considered as autonomous organisms especially when their performance has been interpreted at the genomic and cellular level. But in reality, vascular plants provide a unique ecological niche for diverse communities of cryptic symbiotic microbes which often contribute multiple benefits, such as enhanced photosynthetic efficiency, nutrient and water use and tolerance to stress. In fact, AM fungi are probably the most ubiquitous soil microbe that can colonize 80% of terrestrial plant species consisted of many fruit crops. Many beneficial effects from mycorrhizal colonization including increased seedling survival, enhanced growth, fruit yield and quality, uniformity of fruit crops, and earlier and increased flowering as well as induced resistance to abiotic and biotic stresses.

Keywords: Arbuscular mycorrhizal, fungi, fruit crops

Introduction
Arbuscular mycorrhizal fungi (AMF) penetrate the roots of plants to form a mutualistic symbiotic relationship. Mineral nutrients, mainly phosphorus, nitrogen and water are extracted from the soil via the extensive hyphal network and transferred to the plant. Organic carbon compounds are transferred to the AMF in return. They are known to improve plant nutrient uptake, protect plants from pathogens and buffer against adverse environmental conditions, especially drought. Arbuscular mycorrhizal fungi (AMF) can promote rapid increase in plant growth and contribute to better establishment of seedlings when transplanted to the field. In nursery, inoculation of these fungi can improve the plant growth, reducing the time for seedling production and protecting the plants against soil-borne pathogens. Contributing to increase the nutrient uptake and plant vigor, the AMF can act as biological control agents by direct or indirect mechanisms. The exploitation of symbiotic feature of AM fungi is one of the efficient approaches to improve crop tolerance to unfavored environment. In fact, AM fungi are probably the most ubiquitous soil microbe that can colonize 80% of terrestrial plant species consisted of many fruit crops. Many beneficial effects from mycorrhizal colonization including increased seedling survival, enhanced growth, fruit yield and quality, uniformity of fruit crops, and earlier and increased flowering as well as induced resistance to abiotic and biotic stresses.
The maintenance of a developed and diverse population of AMF and other soil micro-organisms is important in achieving sustainable agriculture thus reducing the requirement of such high levels of fertigation. However, products containing AMF are rarely used in commercial agriculture because of (a) difficulties in producing AMF inoculum in large quantities, (b) their variable beneficial effects, and (c) uncertainties in the benefits with added AMF in the presence of resident AMF populations. Substrates such as coir are usually devoid of beneficial microbes such as AMF; thus introducing them into substrate production is more likely to generate benefits.

Involvement of Am Fungi with Plant Development and Fruit Yield
Plant Development
Effect of Mycorrhizal Inoculation on Fruit Crops Beneficial effect of mycorrhizal inoculation found in fruit crops. The occurrence of AM fungi studied in Malaysia in two perennial fruits namely, durian (*Durio zibethinus*) and rambutan (*Nephelium lappaceum*). Higher spores were found in rambutan orchard. It is well known that AM inoculation at early stages of plant development performed better. The micropropagated banana plant inoculated at the beginning

of the weaning phase showed significant growth response (Grant *et al*., 2005) [14]. Various glasshouse and field experiments proved that inoculation with AMF enhanced the growth and ion uptake in citrus plants, and improved tolerance to drought and salt stress and also the quality of fruit (Wu *et al*., 2010) [54]. Moreover, it is reported that the symbiosis of AMF in trifoliate orange enhanced the soluble sugar and leaf chlorophyll content. However, onelayer mycorrhizal inoculation was the best for mycorrhization of trifoliate orange (Wu and Zou, 2012) [53]

The symbiotic association of arbuscular mycorrhizal fungi and plant roots is well known. AM fungi impart a variety of benefits upon their host including its increased growth and yield. AM improves plant growth through increased uptake of P, reduction of soil borne diseases, increased plant vigor and survival. Many fruit tree species are dependent on arbuscular mycorrhizal infection for survival and growth. Improved growth of mycorrhizal plants is often related to more efficient uptake of nutrients from soil. Depending on host plant-AM fungus combinations and pedoclimatic conditions, different amounts of P are necessary to obtain growth increments comparable to those observed in mycorrhizal plants.

The inoculation of *Glomus macrocarpum, G. coledonicum* and *Acaulospora* sp. resulted in increased plant height, stem diameter and biomass in trifoliate and troyer oranges (Vinayak and Bagyaraj, 1990; Souza and Souza, 2000) [50, 48]. Inoculation with *Gigaspora rosea* and *Glomus mosseae* increased the growth of different grape rootstocks and cultivars than uninoculated plants (Linderman and Davis, 2001) [22]. Renaldelli and Mancuso (1996) [38] reported maximum growth of shoots and leaves in olive plants when inoculated with *Glomus mosseae*. Vitagliano and Citernesi (1999) [51] also reported that the inoculation AM fungi in olive trees resulted in increased lateral root frequency, giving rise to plants with root system consisting of a greater proportion of higher older roots.

The inoculation with *Glomus macrocarpum* increased plant height, root length, number of leaves and dry matter of peach seedlings (Awad, 1999) [3]. Sharma and Bhutani (1998) [40] also obtained better growth of apple grown in sterilized soils inoculated with endomycorrhizae (AM). Inoculation of glass house grown apple seedlings with AM species increased leaf area, biomass and chlorophyll content. Mortin *et al*. (1994) [29] reported that apple seedlings inoculated with different *Glomus* spp. produced tall plants and more biomass than uninoculated plants.

Lovato *et al*. (1994) [23] reported that increased stem diameter and plant height in cherry. In strawberry, the combined application of AM fungi at different rates of P had increased total shoot dry weight, fresh weight, leaf area and leaf number compared with application of P alone (Khanizadeh *et al*., 1995) [19].

Bettio *et al*. (2009) [6] reported that AM fungi positively influenced vegetative growth and nutrients content of peach cv. Aldgrighi. The effect of pre-inoculation with AM fungi on post-transplant growth of peach seedlings in replant and non-replant soils was also studied (Kipkoriony and Fusao, 2006) [20]. The AM fungi inoculation has been reported to improve plant growth and dry matter production are also the cause to increase in leaf area and chlorophyll content of peach (Awasti *et al*., 1998) [4].

In pear seedlings, plant height, stem diameter and dry weight of shoot increased significantly with AM inoculation (Gardiner and Christensen, 1991) [13]. AM fungal root colonization were significantly increased seedlings growth of apple tree (Wang *et al*., 2001) [52].

Joolka *et al*. (2004) [16] also observed highest linear and radial growth, internodal length, leaf number, dry weight of shoot, root/shoot ratio and highest rate of photosynthesis in AM treated pecan seedlings. *Glomus fasciculatum* was significantly increased the height of banana cvs. Dwarf Cavendish and Robusta. The plants inoculated with AM fungi had greener and larger leaves, greater bunch weight and number of fruits per bunch than non-inoculated plants (Eswarappa *et al*., 2002) [11].

Mazzitelli and Schubert (1990) [27] observed increased growth in grape vines inoculated with *Glomus caledonium*. Lakshmipathy *et al*. (2002) [21] evaluated the effect of nine different species of AM fungi and reported that *Acaulospora laveis* and *Glomus mosseae* significantly increased plant height, stem girth and total biomass of cashew rootstock compared to uninoculated plants.

Porras *et al*. (2002) [33] observed that the growth of roots and aerial parts of olive was maximum in inoculated plants than un-inoculated plants. Inoculation with *Glomus intraradices* significantly increased growth of banana tree as compared to non-mycorrhizal plants in promoting plant growth by improving nutrition (Pinochet *et al*., 1997) [32]. Banana plants inoculated with *G. mosseae* and *G. macrocarpum* had maximum shoot dry weight than non-inoculated plants (Declerckut *et al*., 1995) [7].

The studies also revealed that the correlation between AM spore populations and shoot extension growth, leaf area and fruit yield. It has been observed that AM spore population and per cent root colonization was positively and significantly correlated with shoot extension growth, leaf area and yield in apple tree (Sharma *et al*., 2002) [41]. A highly significant correlation between AM fungi and growth of mandarin orange was observed (Panja and Chaudhuri, 2004) [31]. Reena and Bagyaraj (1990) [37] reported that soil inoculation with arbuscular mycorrhizal fungi increased the number of AM spores, external hypha and root colonization in *Tamarindus indica.*

Biofertilizers are ready to use live formulates of such beneficial microorganisms, which on application have nitrogen-fixing, phosphorus solubilizing and potassium solubilizing abilities, which facilitate the absorption and utilization of mineral nutrition, leading to promotion of plant growth in rhizosphere of pine tree (Lu and Huang, 2010) [24]. The highest value of shoot length (95.3cm) in guava trees was recorded when fertilized with dual inoculation of AM fungi + *Bacillus megaterium* over control (Ibrahim *et al*., 2010) [15]. Similarly, Esitken *et al*. (2006) [10] reported that bacterial treatments including *Pseudomonas* sp. significantly increased shoot length of sweet cherry. Karlidag *et al*. (2007) [18] reported that root inoculation of plant growth promoting rhizobacteria strains significantly increased shoot length (16.4-29.6%) in apple as compared to control.

The application of phosphate solubilizing bacteria (PSB) significantly increased shoot length in 'Le-Conte' pear (Fawzi *et al*., 2010) [12]. Whereas, the application of *Pseudomonas* sp. increased shoot extension growth in apple (Aslantas *et al*., 2007) [2]. Sharma *et al*. (2005) [43] reported that the frequency of occurrence and degree of colonization of endomycorrhizae have a direct effect on shoot extension growth of apple tree.

Raj and Sharma (2009) [34] reported that different treatment combinations of Arbuscular-mycorrhizal and *Azotobacter chrococcum* resulted in increased shoot length of apple seedlings of solarized soil in comparison to untreated plots. Mia *et al*. (2010) [28] reported that micropropagated banana plant inoculated with mycorrhizae and rhizobacteria either alone or in combination had significantly higher shoot extension growth than the non-treated control plants.

Fruit Yield

There has been a tendency for intensification of fruit tree cultivation, mainly in order to obtain the higher yield per unit area. One such possibility for high yield is the use of mycorrhizal fungi by introducing inoculums into a plant root system. It is well documented that AM symbiosis can increase plant gowth and nutrient uptake, improve fruit yield and quality and enhance several abiotic stresses such as low temperature stress, drought, salt stress, etc. The use of biofertilizers in enhancing plant growth and yield has gained momentum in recent years because of higher cost and hazardous effect of chemical fertilizers. Rana and Srivastva (1984) [35] reported a positive correlation between mycorrhizal spore population with fruit yield and root colonization in litchi trees. Fruit number, mean fruit weight and yield of papaya are also positively correlated (Manjunatha *et al*., 2002) [26].

The positive influence of mycorrhizal fungi on the growth and yield of plum trees was estimated (Slawomir and Aleksander, 2010) [47]. Shresta *et al*. (1996) [44] reported that satsuma mandarin tree inoculated with different species of AM fungi have shown an increase in fruit size which culminate into higher yields.

Awasthi *et al*. (1999) [5] reported that a positive correlation between per cent root colonization and AM spore number with fruit yield in Peach orchards of Himachal Pradesh. Spore population and root colonization is also negatively correlated with soil P in apple trees, whereas in peach trees, a positive correlation was found between vesicle number and leaf P content (Karagiannidis and velimis, 2000) [17].

Rana and Chandel (2003) [36] obtained maximum yield, as well as number of runners per plant in *Azotobacter* inoculated plants. The higher yields in biofertilizers inoculated plants was due to more number of fruits per plant with better fruit size and weights as compared to un-inoculated plants in strawberry. Eswarappa *et al*. (2002) [11] observed that AM fungi treated plants had greater bunch weight. Obtained maximum number of fruits/plants, highest weight of fruits/plant and maximum fruit size in tomato when inoculated with *Azotobacter* sp.

Arbuscular mycorrhizal fungi influenced the yield and productivity of apple trees (Sharma *et al*., 1998, 2005) [40]. However, the results were significantly better in relation to fruit yield when guava plants were inoculated with AM fungi (Singh and Singh, 2004) [45]. Dey *et al*. (2005) [8] also reported similar results with the inoculation of *Azotobacter* and arbuscular mycorrhizae in guava. Aslantas *et al*. (2007) [2] reported that the fruit yield of apple crop was significantly higher when plants were inoculated with the *Pseudomonas BA*-8 and *Bacillus OSU*-142 of phosphate solubilizing bacteria.

A significant improvement in fruit yield was evident in 5-year old pomegranate plants in field conditions when dual inoculation with *Azotobacter chrococcum* and *Glomus mosseae* (Aseri *et al*., 2008) [1]. Fruit yield was also significantly increased with sole inoculation of *Azotobacter chrococcum* in strawberry seedlings (Umar *et al*., 2008) [49]. Recorded an increased yield of banana trees with *Azotobacter* inoculation.

Promotive effects of phosphate solubilizing bacteria (PSB) were found in fruits of olive cv. Chemalali (Maksoud *et al*., 2009) [25]. Shamseldin *et al*. (2010) [39] reported that inoculation with *Pseudomonas fluorescence* -843 resulted in significant increase in fruit yield of Washington Navel orange. Singh *et al*. (2010) reported that multi-inoculation with *Azotobacter* + PSB + AM fungi recorded maximum berry yield which was significantly higher over control in strawberry. Osman and El-Rahman (2010) [30] also recorded significant increase in yield with the application of *Azotobacter* along with poultry manure in fig trees (*Ficus carica* L). Biofertilization of guava plants with AM fungi + *Bacillus megaterium* (PSB) recorded maximum fruit yield (kg/ha) (Ibrahim *et al*., 2010) [15]. Whereas, Dutta *et al.* (2010) [9] also recorded significant increase in fruit yield of litchi trees when treated with 150g *Azotobacter* + 100g AM fungi/tree along with farm yard manure (FYM).

Conclusion

Current levels of high intensity agriculture are no longer sustainable primarily due to energy costs of N fertilizers and the decreasing supplies of P, along with a decreasing armory of pesticides (due to legislation) and water limitation. Various studies are needed to improve our knowledge of how best to apply and use these beneficial organisms to successfully incorporate them into sustainable commercial cropping systems for fruit crops. With a greater understanding of the application and benefits of these beneficial microbes there is a real possibility for their use in aiding sustainable crop production.

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