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Beneficial Effects of Arbuscular Mycorrhizal Fungi on Underground Modified Stem Propagule Plants

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ABSTRACT

Arbuscular mycorrhizal fungi (AMF) have mutualistic relationships with more than 80% of terrestrial plant species. Despite their abundance and wide range of relationship with plant species, AMF have shown low species diversity. AMF have high functional diversity because different combinations of host plants and AMF have different effects on the various aspects of symbiosis. Consequently, most of the research effort is concerned with mycorrhiza as a mutualistic association between the underground root of the host and soil fungi. However, there are reports that besides roots, these fungi can also associate mutualistically with underground modifications of stem like rhizomes, and other associated structures. Present study is therefore, based on a simple premise whether or not the AM fungi have any constitutive association with underground stem propagules which constitute the prime propagules for vegetative propagation and also being the parts of commercial utility and importance, and thereby assessing whether these have any substantive role in the health and productivity of these plants. This review provides a summary of recent studies of functional diversity of AMF and their roles in the underground stem modified plants like tuber, bulb and corm.

Key Words: AMF, stem modified plants, tuber, bulb, corm.

INTRODUCTION

Mycorrhiza is the mutualistic symbiosis between soil borne fungi with the roots of higher plants (Sieverding 1991). The term mycorrhiza was coined by German forest pathologist Frank in1885 and is derived from the combination of two words one Greek *mykes* (Mushroom/Fungus) and other Latin *rhiza* (roots), literally meaning root fungus (Allen 1991). The first report that root fungi may be beneficial to plants was observed on Indian pipe (Kamienski 1881). The partners in this association are members of fungi (Basidiomycetes, Ascomycetes, Zygomycetes) and most of the vascular plants (Brundrett 1991; Harley and Smith, 1983). Fitter and Moyersoen (1996) provided a succinct definition "a sustainable nonpathogenic biotropic interaction between a fungus and a root". In the mycorrhizal literature, the term symbiosis is used to describe a highly interdependent mutualistic relationship where the host plant receives mineral nutrients while the fungus obtains photosynthetically derived carbon atoms (Harley & Smith 1983;

Allen 1991). Most of the research effort is concerned with mycorrhiza as a mutualistic association between the underground root of the host and soil fungi. However, there are reports that besides roots, these fungi can also associate mutualistically with underground modifications of stem like rhizomes, and other associated structures. Taber & Trappe (1982) reported for the first time, the presence of AM fungi in the vascular system of rhizomatous tissue and the scale like leaves of *Zingiber officinale* L. Later Nasim (1990) reviewed the presence of AM fungi associated with the portions other than roots in twenty one angiosperms and some non-angiosperm species. Incidence of AM fungal colonization has been reported in scale leaves and leaf bases of *Curcuma longa* L. (Sampath & Sullia 1992), corms of *Amorphophallus commutatus* Engler (Rodrigues 1995) and tubers of *Pueraria tuberosa* (Willd.) DC (Rodrigues 1996). Arbuscular mycorrhizal fungi have been documented in tubers of *Colocasia esculenta* (L.) Schott (Bhatt and Kavreiappa 1997), garlic bulbs (Kunwar et al. 1999) and tubers of *Gloriosa superba* L. (Khade & Rodrigues 2003). On further perusal the availability of literature on such modified stem and AM fungi associations is scanty because of dominance of studies on root-fungi associations. Present study is therefore, based on a simple premise whether or not the AM fungi have any constitutive association with underground stem propagules which constitute the prime propagules for vegetative propagation and also being the parts of commercial utility and importance, and thereby assessing whether these have any substantive role in the health and productivity of these plants. This review provides a summary of recent studies of AMF on some stem modified plants.

Solanum tuberosum: (Tuber)

The potato (*Solanum tuberosum*) is a herbaceous annual plant that grows up to 100 cm tall and produces tubers – also called potato. Being rich in starch it ranks as the world's fourth most important food crop, after maize, wheat and rice. The potato belongs to the family Solanaceae or "nightshade" family of flowering plants, and shares the genus *Solanum* with at least 1000 other species, including such important vegetable crops like tomato, eggplant and chillies. Potato is a global crop planted in a wider range of altitude, and climatic conditions. Potato crop is at first number in its production of food energy and food value per unit area (Davies et al. 2005). Nutritionally potato is a healthy food in terms of vitamins, minerals, proteins, antioxidants, essential amino acids and carbohydrates (Andre et al. 2007). McArthur and Knowles (1993) observed that the growth response of potato was different in the presence of different AM fungi. In their study, inoculation with *Glomus intraradices* resulted in a stronger growth response of potato than did inoculation with *Glomus dimorphicum* or *Glomus mosseae*. Inoculation of micropropagated potato plants with AMF during the transfer from *in vitro* conditions may improve the viability of potato and their physiological state (McArthur & Knowles, 1992, 1993; Niemira et al. 1995). After dual inoculation with AMF and an appropriate bacterial partner, a synergistic effect on plant growth and nutrition can be observed in potato (Meyer & Lindermann, 1984; Barea & Azcón-Aguilar, 1986; Vosatka et al. 1992; Lone et al. 2015b). Previously, it was shown that arbuscular mycorrhization at potato microplant establishment improved microplant growth and significantly increased the yield of saleable potato minitubers in protected cropping (Duffy et al. 1999).

It has been reported that mycorrhizal fungi may increase tuberisation in solonaceous species (Bernard 1910; Lone et al. 2015b). Harley (1969) states that soil solution rich in soluble nutrients usually induce asymbiotic nutrient formation when potatoes are grown in artificial culture medium. AMF colonization in potato increase the growth, tuberisation and dry weight in the potato plants than the non-treated AMF potato plants (Graham et al. 1976; Lone et al. 2015b). AMF increases starch content, dry matter and specific gravity of tubers in potato (Sarikhant & Aliasgharzad 2012). McArthur and Knowles (1993) and Yao et al. (2002) reported that inoculation of two AMF species *G. etunicatum* and *G. intraradices* on two cultivators of potato showed increase of shoot fresh weight and dry weight of shoot respectively. AMF can enhance productivity of potatoes (Graham et al. 1976; Niemira et al. 1995). Puri and Adholeya (2012) developed a novel system using *Solanum tuberosum* for the co-cultivation of *Glomus intraradices* and its potential for mass spore production of AMF.

Gallou et al. (2011) induced resistance in potato plantlets by mycorrhiza inoculation against the late blight disease caused by *Phytophthora infestans*. Cesaro et al. (2008) reported in Italy that *Glomus intraradices* was much more frequent in potato roots than other *Glomus* species in arable soil of a potato farming area. Tissue culture raised potato shows that occurrence of AMF was highly variable. Endophytes like *Glomus mosseae* and *Glomus fasciculatum* were too abundant than those like *Acaulospora bireliculata*, *G. dimorphicum*, *G. macrocarpum* which were also had a fairly high presence (Nasim 2010).

Earlier studies reported that phosphate fertilization suppress AMF colonisation in potato (Black & Tinker 1977). AMF colonization increased with age in potato plant (Bhattarai & Mishra 1984; Shuab et al., 2014; Lone et al. 2015b). Potato plants have a low density (Purglove

& Sanders 1981) and high growth potential; thus AMF symbiosis may be of particular significance in coping with phosphorus deficiency stress in natural ecosystems. According to Sieverding (1991) reduction in phosphate fertilizer use can be achieved in potato by AMF inoculation. Adequate phosphorus nutrition is critical for tuber development and high photosynthetic rate maintenance during tuber bulking in potato. Phosphorus nutrition is also linked to the assimilation of other mineral nutrients and improvement of protein contents (Mishra et al. 2007). The potato has an inherently low root density and restricted ability to uptake fertilizer phosphorous. Phosphorous deficiency is usually a limiting factor in yield of commercial potato production (MacKay et al. 1988). Large amounts of chemical phosphorus fertilizers are to be added annually to cultivated soil and phosphorus is becoming uneconomical to extract and the supplies are to diminish with advancing time.

The first mycorrhiza-specific plant P transporter gene StPT3 was identified from potato (Rausch et al. 2001), and it has been shown that this gene is highly expressed in root cells harboring various mycorrhizal structures (Karandashov et al. 2004). Different AMF taxa are known to contain different P-transporter genes and genetic variations in P uptake pathways could therefore, potentially explain why different AMF provide different amounts of phosphorous to plants (Harrison 2005).

The AMF symbionts could stimulate leaf growth and expansion (McArthur & Knowles 1993), increases shoot fresh weight, root dry weight and the number of tubers produced per potato plant (Graham et al. 1976; Yao et al. 2002; Lone et al. 2015b). AMF inoculants promoted the number of minitubers per plant and weight per minituber (Vosatka & Grynder 2000). Thus the AMF inoculation is potentially useful to post-vitro transplanted plants in microtuber seed production systems. However, one consideration is that appropriate microbe isolation should be selected for a particular host genotype. When the micro plants of potato were inoculated with three commercial AMF inoculants in the glasshouse (Duffy & Cassells 2000), the yield quality of potato micro plants mainly depended on the mycorrhizal isolate and host plant genotype. In field studies, inoculation with commercial inoculants containing AMF *Glomus intraradices* resulted in higher yields and larger tubers than treatments using conventional chemical fertilizers over two growing seasons (Douds et al. 2007).

The factors that determine the tuber yield and tuber size distribution in potato are more complex than previously thought. The AMF enhance potato tuber production partly due to the increased nutrient uptake, particularly P uptake (McArthur & Knowles 1993), and enhanced disease resistance (Niemira et al. 1996).

AMF and phosphorus solubilizing bacteria (PSB) play a role in the suppression of crop pests and diseases (Asok & Jisha 2006), including pathogenic nematodes (Hol & Cook 2005), herbivores (Gange et al. 2002) and particularly soil-borne fungal diseases (Borowicz 2001). Some potato-associated endophytes were found to antagonize fungal or bacterial pathogens by increasing the production of active compounds including enzymes, antibiotics, siderophores, and the plant hormone indole-1,3-acetic acid (Sessitsch et al. 2004). AMF and antagonistic bacteria utilization, through inoculation of crops or stimulation of naturally occurring populations, could be a promising approach to control the development of potato diseases. Niemira et al. (1996) indicated that the fungus *Glomus intraradices* can suppress the development of potato dry rot, a post-harvest disease caused by the fungus *Fusarium sambucinum*, but the efficiency sometimes relied on species specificity of inoculants (Niemira et al. 1996). But when AMF used as biocontrol agents of potato in greenhouse and field trials, it can reduce soilborne disease stem canker and black scurf by 17–28 percent (Larkin 2008). One interesting phenomena is that highly diseases resistant potato cultivars showed an earlier establishment and more rapid development of AMF colonization than highly susceptible cultivars (Bhattarai & Mishra 1984; Yao et al. 2002). The mechanism however, is not clear.

The establishment of AMF in plant roots can reduce the damage caused by soil-borne plant pathogens, with an enhancement of plant resistance/tolerance in mycorrhizal plants (Harrier & Watson 2004). In nematode control studies, inoculation of potato plants with AMF delayed nematode hatching (Ryan et al. 2000). Root leachates from AMF-inoculated potato plants have multiple effects on the production of nematode hatching factors (Deliopoulos et al. 2007). Microbes such as AMFs were considered promising biocontrol agents to manage pathogens and potato nematode. To some extent, biocontrol effects of microbes depend on the AMF species, the substrate, and the host plant involved (Borowicz 2001; Whipps 2004). By screening effective rhizospheric soils as inoculum from 12 different plant species grown as monocultures at a field site in northern Sweden, the AMF propagules from the hosts *Festuca ovina* and *Leucanthemum vulgare* were considered to be highly effective inoculants for potato cultivation (Bharadwaj et al. 2007). The most efficient bacteria and fungi for potato growth isolated from 15 different crop plants were *Penicillium* sp., *Pseudomonas* sp., *Bacillus* sp., and *Glomus mosseae* (Asok & Jisha 2006; Davies et al. 2005). But *G. intraradices* was the most abundant fungus in potato roots (Cesaro et al. 2008). Sixteen AMF morphotypes were identified in potato under field conditions in India, and they proved that dark septate endophytes (DSE) and AMF colonization progressed synchronously with the dominance of *Glomus tortuosum* (Das and Kayang 2010).

Allium cepa: (Bulb)

Onion is a biennial herb with a superficial root system, a very short flattened stem at the base, which increases in diameter as it grows. The onion is probably native to southwestern Asia but is now grown throughout the world, chiefly in the temperate climates. The plant belongs to the family Alliaceae; however, some earlier classifications place it in the family Liliaceae. Most members of both families have an underground storage system, such as a bulb or tuber. Other members of this family include ornamental plants such as the tulip, hyacinth, and lily-of-the-valley and edible plants such as the leek, garlic, and chive.

The common onion has one or more leafless flower stalks that reach a height of 0.75–1.8 m (2.5–6 feet), terminating in a cluster of small greenish white flowers. The leaf bases of the developing plant swell to form the underground bulb that is the mature, edible onion. Most commercially cultivated onions are grown from the plant's small black seed, which is sown directly in the field, but onions may also be grown from small bulbs or from transplants. Onions are among the hardiest of all garden vegetable plants. These vary in size, shape, colour, and pungency. Warmer climates produce onions with a milder, sweeter flavour than do other climates.

Onions may be grown from seed or more commonly today, from sets started from seed the previous year. Onion sets are produced by sowing seed very thickly one year, resulting in stunted plants that produce very small bulbs. These bulbs are very easy to set out and grow into mature bulbs the following year, but they have the reputation of producing a less durable bulb than onions grown directly from seed and thinned. Seed-bearing onions are day-length sensitive; their bulbs begin growing only after the number of daylight hours has surpassed some minimal quantity.

Onion contains high amounts of a variety of antioxidants, mainly of flavonoid character (quercetin, luteolin, kaempferol, etc.), of which quercetin glycosides represent the highest portion (Miean & Mohamed 2001). Onion is, therefore, considered a fundamental vegetable that has been valued for its medicinal qualities since ancient times. Studies have revealed that onion possesses antibiotic, anticarcinogenic, anti-inflammatory, and antioxidative properties (Corzo-Martinez et al. 2007). Biotests suggest that a diet including onion may be beneficial for the elderly as a means of improving antioxidant status (Park et al. 2007). Onion extracts have been reported to be effective in treating cardiovascular diseases due to their hypocholesterolemic, hypolipidemic, antihypertensive, antidiabetic, antithrombotic, and antihyperhomocysteinemia effects (Vazquez-Prieto & Miatello 2010).

Onion (*Allium cepa* L.) is one of the leading vegetable crops worldwide. In the Middle East, onion is used as bulbs or harvested earlier and consumed as green leaves. It constitutes a major part of daily diet as it is included in almost all recipes. Due to its superficial root system that is rarely branched and lacks root hairs, onion is very inefficient in the uptake of water and nutrients. As a result, large amounts of chemical fertilizers are usually used in onion cultivation. The use of chemical fertilizers, however, has its negative side. In general, chemical fertilizers are expensive, produce short-term benefits and above all, their use may contribute to environmental pollution. Therefore, attempts have been directed towards minimizing dependence on chemical fertilizers and, one way to do so would be the use of AM fungi. Previous research indicated that onion is highly responsive to several AM fungi, which tend to associate with onion roots leading to improved plant growth and nutrient uptake as well as, increased tolerance to soil salinity and water stress (Mahaveer & Alok 2000; Bolandnazar et al. 2007; Shuab et al. 2014: Lone et al., 2005b). However, results of these studies were variable depending on AM species, soil fertility and experimental conditions.

Onion (*Allium cepa*) has a sparse rooting system without root hairs which makes the crop dependent for water and nutrient acquisition on AMF (De Melo 2003; Stribley 1990; Mengel & Kirby 2001). This dependency is especially true in case of cultivation under nutrient-poor condition. Research on *Allium* species and their interactions with AMF has a long history that dates back to 1884 when Mollberg described hyphae and structures in roots of *Allium scorodoprasum* what we currently known as AMF (Koide & Mosse, 2004). *Allium* species, and in particular onion, are excellent models for mycorrhizal research because they have a simple rooting system, slow growth, and high response to AMF. The knowledge on *Allium*–AMF interactions benefited greatly from the work of Mosse and co-workers, who presented detailed analyses of AMF functioning under field conditions (Hayman & Mosse 1971; Mosse & Hayman 1971; Mosse 1973; Owusu-Bennoah & Mosse 1979).

Onion is highly responsive to several AM fungi, which tend to associate with onion roots leading to improved plant growth and nutrient uptake under normal as well as stressed conditions (Mahaveer & Adholeya 2000; Boladnazar et al. 2007; Jamie et al. 2008; Goussous & Mohammad 2009; Galvan et al. 2009, Koul et al. 2012; Shuab et al. 2014; Lone et al. 2015b). Inoculation of onion plants with AM fungi can significantly increase bulb diameter, bulb yield, shoot dry and fresh weight and phosphorous content (Mahaveer and Adholeya 2000; Shuab et al. 2014; Lone et al., 2015b). In onion plants higher Zn as a result of AM inoculation was reported (Mahaveer & Adholeya 2000, Ward et al. 2001; Lone et al. 2015). Smith et al. (1985) studied the effect of mycorrhization and phosphate fertilization on the expression of glutamate sythetase (GS) and glutamate dehydrogenase (GDH) in roots and shoots of *Trijolum subterraneun* and *Allium cepa.*

Wang et al. (2011) reported that inoculation with arbuscular mycorrhizal fungi increases vegetable yield in carrot and green onion plant. Pyruvic acid and sulphur nutritional statuses of spring onion were significantly enhanced by mycorrhizal colonisation (Guo et al. 2007; Lone et al. 2015). AMF mediated growth promoting effects have been shown previously in pot experiments (Tawaraya et al. 1999, 2001). Experiments showed that mycorrhizal fungi tend to affect the pungency of *Allium cepa* and *Allium fistulosum* (Guo et al. 2006). Shinde et al. (2013) reported that fresh and dry biomass is more in AMF inoculated *Allium cepa* plant than non-inoculated under salt stress conditions. Tawaraya et al. (2012) showed that inoculation of AM fungi increases shoot phosphorous uptake and growth of *Allium fistulosum*. Biomass of mycorrhizal plants of *Allium* species were significantly correlated than non mycorrhizal species (Galvan et al. 2011). Hayman & Mosse (1971) found that the weight of *A. cepa* AMF plants increases 18 fold than that of non-mycorrhizal plants. Similarly plant growth of 27 *Allium fistulosum* cultivars was enhanced by AMF and increases upto 20 times that of the non mycorrhizal control in an extremely responsive cultivar (Tawaraya et al. 2001). Among cultivated species onion and leek (*A. porrum*) are regarded highly responsive to AMF (Miller et al. 1986; Plenchette et al. 1983). Such very high responsiveness of *Allium* species to mycorrhizal implies that these plants are unable to complete their life cycle in the absence of AMF due to insufficient phosphorous uptake and hence insufficient growth, this means that *Allium* species can be regarded as highly obligate mycorrhizal plants (Deressa & Schenk 2008; Galvan et al. 2011). The inability to grow in the absence of AMF was discussed previously for onion (Charron et al. 2001) and for *Allium fistulosum* (Tawaraya et al. 2001). AMF *Glomus intraradices* showed positive effectiveness in suppressing *Allium* white rot on onions in organic soils (Jaime et al. 2008). Mahaveer & Alok (2000) showed that the inoculation of onion plants with AMF can significantly increase bulb diameter, bulb yields, shoot dry and fresh weight and shoot phosphorous content.

Mycorrhizal onions had greater bulbing ratio than control Bolandnazar (2009), implying the bulb initiation and bulbing process occurred earlier and faster in mycorrhizal plants than non mycorrhizal ones (Shuab et al. 2014). In onions plants, bulbing ratio index exceeds two in mycorrhizal plants than in control plants wherein bulbing also occurred 10-15 days later (Brewster 1994; Lone et al., 2015b). Charron et al. (2001) also reported that mycorrhizal onion can reach to marketable size 2- 3 weeks earlier than non-mycorrhizal onion.

Crocus sativus: (Corm)

Saffron Plant (*Crocus sativus*), is an important cash crop of Jammu and Kashmir and therefore, India. From Vedic times the saffron finds its reference to Kashmir and in Sanskrit is known as “Kashmir Janama” (Koul 1980)

The genus *Crocus* includes about 80 species distributed primarily in the Mediterranean and south-western Asia (Gresta et al. 2008). Among these, saffron is *Crocus sativus* whose stigmas are economically most important. Because of colouring and aromatic properties of its dried stigmas. saffron is one of the most expensive spices in the world (Winterhalter & Straubinger 2000; Fernandez 2004). The four major bioactive compounds in saffron stigma are crocin, crocetin, picrocrocin and safranal, together contribute not only to the sensory profile due saffron of colour, taste and aroma but also to the medicinal properties. The name saffron is derived from the Arab word for yellow, the ‘Zaffran’. Both lipophilic carotenoids and hydrophilic carotenoids have been identified in saffron (Alonso et al. 2001). Crocin, typically deep red in colour, quickly dissolves in water to form an orange coloured solution thereby making crocin widely used as a natural food colourant. In addition, crocin also acts as an antioxidant by quenching free radicals, protecting cells and tissues against oxidation (Assimopoulou et al. 2005; Papandreou et al. 2006; Soeda et al. 2007). The actual taste of saffron is derived primarily from picrocrocin which is the second most abundant component, accounting maximally upto 13 percent of saffron's dry matter (Alonso et al. 2001). Natural de-glycosylation of picrocrocin yields another important chemical component, safranal, which is mainly responsible for the aroma.

An increasing interest has been established in the biological effects of component of saffron and their cytotoxic, anti-carcinogenic and anti-tumour properties (Abdullaev & Frenkel 1999; Ashrafi et al. 2005). Extracts of saffron have been reported to inhibit cell growth of human tumour cells. Crocin, the water-soluble carotenoids of saffron, are the most promising components of the spice to be assayed as a cancer therapeutic agent (Escribano et al. 1996). Although, the other components like picrocrocin, crocetin and safranal also show antitumour potential but are not as good as crocin (Johri & Jyoti 1995; Souret & Weathers 1999). Saffron also acts as an agent for anti-depression, anti-tussive, anti-oxidant and for neuroprotection (Noorbala et al. 2005; Chatterjee et al. 2005; Ahmad et al. 2005). Studies report that saffron is also beneficial in learning and memory process (Pitsikas & Sakellaridis 2006).

For a long time, saffron was neglected by researchers and farmers since it was considered a minor crop used only for agricultural diversification. However, in the recent years, it is gaining importance in low-input agricultural systems and as an alternative crop. Today, besides Kashmir in India saffron is cultivated in several other countries of the world which include Iran, Greece, Morocco, Spain, Italy, Turkey, France, Switzerland, Israel, Pakistan, Azerbaijan, China, Egypt, UAE, Japan and recently in Australia (Tasmania).

Total world saffron production is estimated at about 205 tons per year (Fernandez 2004). Iran produces 80 per cent of global production and in recent years saffron production in Iran has increased significantly (Ahmad et al. 2011). Besides Iran, the main producer countries are Spain, India and Greece. Annual production of saffron in Kashmir ranges between 8 to 10 tons. The major saffron-importing countries are Germany, Italy, USA, Switzerland, the United Kingdom and France (International Trade Centre 2006). Spain imports large quantities of saffron as well, especially from Iran, Greece and Morocco for re-export and for its internal market needs.

Saffron grows on a wide range of soils. Skrubis (1990) reported that the best growth is achieved on well-drained clay-calcareous and deep soils. Fernandez (2004) suggested that clay is a good soil for saffron, while Sampathu et al. (1984) reported that saffron requires a well-ploughed sandy-loamy soil or a well-drained clay soil. Saffron is also cultivated on sandy soil in Azerbaijan (Azizbekova & Milyaeva 1999). Tammaro (1999) suggested that the humus-clay soil of Navelli guarantees good water storage for saffron. Saffron grows well in salty soil, where a limiting factor could be calcium carbonate deficiency (Mollafilabi 2004). Good soil pH ranges from neutral to slightly alkaline. Conflicting information is reported with regard to nutrient requirements of saffron (Goliaris 1999; Tammaro 1999; Skrubis 1990). Mounira & Cantrell (2009) cultivated saffron in experimental plots in different zones of Morocco varying in altitudes, soil and climate, and used HPLC to quantify the most important saffron components, namely crocin, picrocrocin, and safranal. On the basis of this, saffron was proposed as a sustainable substitute crop with high added value in some Moroccan agricultural areas with low and erratic rainfalls. Azizbekova & Milyaeva (1999) discussed the distribution, adaptation and cultural practices of cultivation of *Crocus sativus* in Azerbaijan and reported that the treatment of saffron corms with gibberellins promoted formation of flower buds from undifferentiated meristems, thereby increasing stigma yield. Sampathu et al. (1984) reviewed the available literature on saffron and covered in detail a number of aspects, such as cultivation, world trade, uses, harvesting, processing, yield, chemistry of the constituents, including pigments and volatiles, variations in the chemical constituents, saffron adulterants, methods for their detection, and official standards and purity requirements.

Literature about the nature of rhizsospheric microbial diversity of saffron and its role in growth, yield and quality of saffron is very scarce however, Kianmehr (1981) examined the arbuscular mycorrhizas associated with saffron in some regions of Iran and found seasonal variation in spore density in its rhizosphere; with highest spore populations in January and lowest in July, and highest AMF presence in April. The spores of *Glomus macrocarpus*, recovered from soils, when used as inoculum on *Crocus* had a positive effect on growth and yield, hence indicative of strong benefit from AM association. Zare et al. (2000) worked out the mycorrhizal symbiosis of saffron in Irano-Turannian region and selected three cultivars of this crop from the most predominant growing regions to investigate their mycorrhizal status *in-situ*. AMF association was observed in all the cultivars and *Acaulospora morrowiae* and *Glomus coronatum* were found to be dominant AMF species. Moreover, they suggested that application of mycorrhizal inocula in saffron fields could improve its yield and could make possible growing of saffron in more stressful habitats.

Studies carried out at national level in India on soil microbe-saffron interaction are limited, mainly due to restriction of the crop to some specific regions of northern part of the country, especially Kashmir. Amongst various districts of J&K where saffron cultivation is undertaken, district Pulwama is the leading one. There is hardly any literature available about soil microbial spectrum of saffron rhizosphere, this is despite the fact that potentially strong impact of soil symbionts on growth and yield as has been reported in large number of crops world over (Saharan & Nehra 2011:Shuab et al., 2014; Lone et al., 2015a; Lone et al., 2015b).

CONCLUSION

The present review has been envisaged with an aim to provide some insight into the influence of AMF on underground stem propagated plants. All the three underground modifications of the stem are in someway or the other affected by the presence of AMF association.

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