International Journal Of

Recent Scientific Research

ISSN: 0976-3031

Volume: 7(4) April -2016

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THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 4, pp. 10267-10271, April, 2016

International Journal of Recent Scientific Research

Research Article

ASSOCIATION OF ARBUSCULAR MYCORRHIZAL FUNGI BENIFICIAL FOR CERTAIN MEDICINAL PLANTS: AN OVERVIEW

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ARTICLE INFO

Article History:

Received 15th January, 2016
Received in revised form 21st February, 2016
Accepted 06th March, 2016
Published online 28th April, 2016

Keywords:

Arbuscular mycorrhizal (AM) fungi, Medicinal plants, Photosynthesis, Secondary metabolites.

ABSTRACT

Medicinal plants have been identified and used throughout the human history. Arbuscular mycorrhizal (AM) fungi have been widely used in agriculture to improve the cultivation of many crops such as medicinal plants. They improve plant growth, secondary plant metabolites, antioxidants, photosynthesis, nutrient uptake, and promote plant diversity of medicinal plants. They also help in rehabilitation and reclamation of wasteland, biohardening, phytoremediation, soil aggregation and also help to control plant pathogens. They promote the accumulation of effective ingredients of medicinal plants, which have become a hot area of research. In this review we have assembled and summarized the effects of AM symbioses on secondary metabolites, antioxidant, photosynthesis, and mineral nutrition of medicinal plants. AM are associated with bryophytes, pteridophytes, gymnosperms, angiosperms, and in some floating and submerged aquatic plants. Mycelial networks of mycorrhizal fungi often connect plant root systems over broad areas.

INTRODUCTION

Role of Medicinal Plants

Medicinal plants have been identified and used throughout the human history. Plants have the the ability to synthesize a wide variety of chemical compounds that are used to perform important biological functions, and to depend against attack from predators such as insects, fungi, and herbivorous mammals. In plants chemical compounds mediate their effect on the humman body through processes identical to those already well understood for the chemical compounds in conventional drugs.

Herbal medicines donot differ greatly from conventional drugs in terms of how they work. The use of plants as medicines predates written human history. Ethnobotany, the syudy of traditional human uses of plants, is recogonised as an effective way to discover future medicines. Medicinal plants considered as rich resources of ingredients which can be used in drug development and synthesis. Besides that these plants play a critical role in the development of human cultures arround the while world. Some plants such as ginger, green tea, walnuts etc are considered as important soures of nutrition and as a result of that these plants are recommended for their therapeutic values.

Role of Arbuscular mycorrhizal (AM) fungi

Arbuscular mycorrhizal (AM) fungi play a key role in soil fertility and plant nutrition. They inhance the uptake and translocation of mineral nutrients – mainly P, N, S, K, Ca, Fe, Cu and Zn from soil of host plants (Smith *et al*., 2008, Giovannetti *et al*, 2002). Extensive belowground hyphal network develop from colonised root into the soil environment (Smith *et al*. 2008, Giovannetti *et al*. 2002). Mycorrhizal symbioses are essential for the sustainable management of agricultural ecosystem (Jeffries *et al* 2003, Barrios *et al*. 2007, Smith *et al*. 2007). AM fungi are known to provide phosphorus at very low concentration of host plants (Mehrvarz, *et al* 2008, Soleimanzadeh, *et al* 2010 and Alizadeh, *et al* 2012). AM fungi increase the effective absorbing surface of the host root by as much as ten times (Bieleski *et al*. 1973). Mycorrhizal fungi produce enzymes, auxin, cytokinin, vitamin, and other substances that increase rootlets size and longivity (Dixon *et al*. 1990). Mycorrhizal fungi have an ability to affect the plant community composition and productivity (Van- der *et al*. 1998, Klironomos *et al*. 2000). In soil AM fungi are known as the largest component (mycelia and spores) of the micribial biomass. According to Ames *et al*. (1983), Hawkins *et al*. (2000), Govindarajula *et al*. (2005), and Johansen *et al*.(1992) several studies have shown that AM also improves nitrogen acquistion. AM are associated with bryophytes, pteridophytes,

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gymnosperms and angiosperms.AM fungi also play an important role to help the plants to tolerate the stressed codition in the soils polluted with heavy metals, industrial effluents, acid rain and biocides, which affect the growth and establishment of plants (Dakession *et al*. 1986 ,Mosse *et al*. 1986).

AM fungi improve the quality of medicinal plants

Many studies concerning AM fungi in medicinal plants emerged from late 1980s. The occurrence of AM association with medicinal plants have also been reported from China (Wei and Wang 1989) and Japan (Udea *et al*. 1992). An alternative strategy for improved plant survival and growth inoculation with AM fungi has become during an early stage of plant growth (Kothamasi *et al*. 2001). In soil AM fungal spore density had a strong positive correlation with soil pH and organic carbon arround medicinal plants but a negative correlation with soil phosphorus (Mathur *et al*. 2007). AM fungal spore density is higher in association with medicinal plants compared with cultivated species. Several studies have confirmed that mycorrhizal medicinal plants generally have greater nutrient contents and better than non- mycorrhizal plants (Karagiannidisa *et al*. 2011, Nisha and Rajeshkumar 2010). AM fungal associations improved the shoot height growth and root biomass *of Poncirus trifoliata, Piper longum, Salvia officinalis and Plectranthus amboinicus* (Geneva *et al*. 2010, Gogoi *et al*. 2011, Kumar *et al*. 2010, and Wang *et al*. 2006*). Datura metal* plants inoculated with AM fungi showed increased tolerance to heavy metals (Salvaraj *et al*. 2004)

Distribution of AM fungi

Table 1 includes the association of various types of AM fungi with certain medicinal plants. AM are the most widespread in their distribution. Almost all land plants including cereals, legumes, millets, plantations and horticultural crops ornamental and medicinal plants and forest trees are reported to be host of AM fungi (Chapin *et al*. 1980, Barea *et al*. 1983, and Chandra *et al*. 2006). AM fungi are found in almost every terrestrial ecosystem and are the second largest biomass component of many terrestrial ecosystems (Verma *et al*. 1995). AM fungi are predominant mycorrhizal types found in early stage of primary succession eg. Sand dunes (Corkidi *et al*. 1997 and Cakan *et al*. 2006), river floodplains (Jansen *et al*. 2005), and volcanic areas (Fujiyoshi *et al*. 2005, Fujiyoshi *et al*. 2006). A widespread occurrence of AM fungi association with medicinal and aromatic plants of western ghats, southern india has been well documented (Muthukumar *et al*. 2000 and Muthukumar *et al*. 2006).

AM fungi - root colonization

According to Bisleski (1973) AM fungi may increase the effectiveness of absorbing capability of surface host root as much as ten times. Harley and Smith (1983) recogonized that increase in plant growth resulting from AM symbiosis is usually associated with increased nutrient uptake by the hyphae from the soil. Root colonization by AM fungi can provide protection from parasitic fungi and nematodes (Duchesne *et al*. 1989, Grandmasson *et al*. 1993, Newsham *et al*. 1995, Little *et al*. 1996, Cordier *et al*. 1998, Morin *et al*. 1999). One of the important factors which may influence the assesment of species composition and richness is the depth of soil sampling.

Effect of AM fungi on medicinal composition

For pharmacological and therapeutical purposes secondary metabolites of medicinal plants are the critical resources in natural medicinal products. Three major groups of secondary plant metabolites such as Terpenoides, Phenolics and Alkaloids are essential for pharmacological and therapeutical purposes.

Photosynthesis

Rate of photosynthesis and storage of photosynthates are increased by the symbiosis of AM fungi (Auge *et al*. 2001). In plant photosynthic efficiency improved by improving phosphorus nutrition due to AM fungi association (Marschner *et al*. 1995). Rate of photosynthesis is higher in mycorrhizal plants than non – mycorrhizal plants. In *Citrus aurantium*, AM fungi enhanced the rate of photosynthesis. Photosynthetic activity was correlated with increased tissue, phosphorus and chlorophyll content, and ribulose -1, 5- bisphosphate carboxylase / oxygenase activity, RUBPCO.

Terpenoids

In recent years the effects of AM fungi on terpenoid concentration in medicinal plants have received more attention. AM fungi increase the cotent of essential oil and alternation in its composition, such as in medicinal basil (*O. basilicum*) (Copetta *et al*. 2006). *Andrographis paniculata,* commonly known as "King of bitters" has been used for centuries in Asia to treat gastrointestinal infection and several infectious diseases. *A. paniculata* is and rographolide, a colorless diterpine lactone with bitter taste. Radhika and Rodrigues (2011) showed that AM fungi can enhance the production of andrographolide a secondary metabolites in high concentration in the leaf extracts of *A. paniculata* when inoculated with *G. albida.*

Phenolic compound

Phenolic compounds include phytoalexin, wall bound phenol, flavonoids, and isoflavonoids and their derivatives. In *Bupleurum chinese, Ginkgo biloba* and *Astragalus membranaceus* content of flavonoids and in *Angelica daharica* total coumarin and imperatorin were significantly higher in mycorrhizal plants compared to non- mycorrhizal plants of the same species (Meng and He 2011).

Alkaloids

Antineoplastic alkaloids (eg., vinblastine) are extracted from Vinca (*Catharanthus roseus*). A positive correlation was found between mycorrhizal colonization and castanospermine content in field – grown *Castanospermum australe* seeds and in greenhouse – leaves in inoculated plants (Abu- Zeyad *et al*. 1999). Freitas *et al*. (2004) also observed that inoculation with AM fungi led to an increase of 89% in the essentionl oil and menthol content of *Mentha arvensis* plants.

Antioxidant enzyme

AM symbiosis induces information changes in enzymatic activities of superoxide dismutase and catalase (Ruiz- Lozano *et al*. 1996 and Marin, *et al*. 2002).

Table 1 List of some commonly used medicinal plants and associated AM fungal species.

Plant family	Plant species	AM fungal species	Source
Acanthaceae	*Andrographis paniculata*	*Acaulospora scrobiculata, Glomus aggregatum*	Radhika and Rodrigues (2010)
Asteraceae	*Arnica montana*	*G. geosporum, G. constrictum, G. intraradices*	Jurkiewiez et al. (2010) and Chaudhary et al. (2008)
amaranthaceae	*Amaranthus spinosus*	*A. denticulata, A. scrobiculata, G. monosporum*	Yang et al.(2002)
Compositae	*Carthamus tinctorius*	*A . rehmii, G. claroideum*	Zhao (2006)
Compositae	*Xanthium sibirlcum*	*G. claroideum, G. mosseae*	Zho(2006), Zhang and Tang (2006)
Ginkgoaceae	*Ginkgo biloba*	*G. mosseae, G. aggregatum, G. versiforme*	Chen and Hen (1999)
Labiatae	*Salvia miltiorrhiza*	*A . bireticulata, G. aggregatum, G. mosseae*	He et al. (2010)
Labiatae	*Scutellaria baicalensis*	*G. geosporum, G. versiforme*	Zhang and Tang (2006)
Leguminosae	*Prosopis cineraria*	*G. fasciculatum, G. aggregatum*	Verma et al. (2008)
Liliaceae	*Allium macrostemon*	*G. caledonium*	Gai et al (2000)
Liliaceae	*Aloe vera*	*G. maculosum, G. multicaule, G. geosporum*	Radhika and Rodrigues (2010)
Fabaceae	*Cajanus cajan*		
Apocynaceae	*Calotropis procera*		
Euphorbiaceae	*Croton sparciflorus*	Unidentified and Unpublished data.	
Fabaceae	*Leucaena leucocephala*		Kumari and Jha.
Asteraceae	Parthenium hysterophorus		
Poaceae	*Zea mays*		

Minzenberger *et al*. (1997) and Reis *et al*. (2011) recogonized that production and activity of antioxidants including (eg. Superoxidedismutase, catalase and peroxidase) or phenolic compound might be increased in plant roots and/ or mycelia.

CONCLUSION

Medicinal plants are used as traditional herbal medicines and are increasingly used by people for primary health care system. The benificial role of rhizosphere AM fungi is to enhance the tolerance to various biotic and abiotic stresses, thereby increase the growth of medicinal plants. In this paper, we have tried to provide a comprehensive review of information available about research on AM and secondary metabolites of medicinal plants in order to set a basis for future work.

Research in detail is needed in future on the following aspects:

1. Identification of fungal species associated with medicinal plants.
2. One or more than one fungal species are associated or not.
3. Is there any competition among fungal species for association to specific host medicinal plants.
4. To quantify how much the efficiency of medicinal plants are improved by specific association of fungal species.
5. How much fungal species improves the production of various types of secondary metabolitesin medicinal plants.
6. The growth development and those physiological processes which are positively affected by fungi of medicinal plants, should be quantified.

Acknowledgements

Authors are thankful to the Head Department of Botany, Jai Parkash University Chapra for providing the support during compilation of this review paper.

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TSSN 0976-3031