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Significance of VA Mycorrhiza and its response under varied soil conditions: An overview

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Abstract
One third of the land area of the world is dominated by arid and semi-arid climates and additionally human interference with the terrestrial ecosystem aiming at development and subsequent exploitation for increased agricultural production are many times responsible for stressed soil conditions. In India, about 20 million hectares of land is affected by salinity. Reclamation of such stressed and saline soil can possibly be done by aid of VAM/AM fungi. Vesicular arbuscular mycorrhizal fungi (VAM) or arbuscular mycorrhizal fungi (AM) are ubiquitous in their distribution. These are abundantly associated with nearly 80% of all terrestrial plant species in the form of symbiotic endomycorrhiza. Mycorrhizal association with the plants can help in restoration of the soil and make it arable.

Keywords: VAM, Mycorrhizal association, symbiotic endomycorrhiza, stressed soil

Introduction
Increasing human population requires increased agricultural production and hence, demands for better irrigation or land restoration. About two-third of the projected increase in arable soil is expected to come from expansion of irrigation. Irrigation plays a pivotal role in this increase in agricultural production, but in general, it has failed to sustain increased productivity, transforming land, with time, into being unproductive, saline fallow [15]. One of the approaches to reclaim all such stressed soils is sustainable agricultural practice such as exploiting VAM/ AM association. AMF are a normal and universal component of the rhizosphere microflora, and nearly 70- 90% of land plant species in all terrestrial ecosystems can become colonized by these fungi [46, 13, 20]. However, the distribution and function of VAM in natural ecosystem are not understood well and also the information on their prevalence and importance in natural ecosystem is limited and often contradictory [23].

VAM/AM Fungi
A mycorrhiza is a symbiotic association between a fungus and the roots of a vascular plant. The association of the fungus Glomeromycota colonizing the host plant's roots, either intracellular as in arbuscular mycorrhizal fungi or extracellularly as in ecto-mycorrhizal fungi has the widest distribution in the nature. The fungus colonizes the root cortex forming a mycelial network and characteristic vesicles (bladder-like structures) and arbuscules (branched finger-like hyphae). The mycelia are aseptate or septate ramifying intercellularly thus causing little damage to tissues. The arbuscules are the most characteristic structures, formed intracellularly and probably having an absorptive function. The vesicles are terminal swellings of hyphae formed inter and intracellularly having a storage function [1]. Soil characteristics, plant species, and climate are some of the factors that may regulate the arbuscular mycorrhizal fungi community. AM fungi inhabit a variety of ecosystems including agricultural lands, forests, grasslands and many stressed environments, and colonize the roots of most plants, including bryophyte, pteridophyte, gymnosperms and angiosperms [44]. Arbuscular mycorrhizal (AM) fungi are ubiquitous in soil habitats and form beneficial symbiosis with the roots of angiosperms and other plants [22]. This AM fungi belong to the family Endogonaceae, of the order Muccorales, of the class Zygomycetes [21]. The AM forming genera of the family includes *Acaulospora*, *Entrophospora*, *Gigaspora*, *Glomus*, *Sclerocystis* and *Scutellospora*. AMF have been separated from the Zygomycota and placed in a new monophyletic phylum, Glomeromycota composed of four orders with seven families and ten different genera [45]. There are more than 180 species of AMF [37]. They discovered two ancestral classes of AM fungal species from deeply divergent ribosomal DNA sequences and is classified into two new families Archaeosporaceae and Paraglomaceae.

Zhang *et al.*, reported that *Acaulospora* and *Glomus* were the dominant genera in the deforested and natural forest in sub-tropical region of Dujiangyan [50].

VAM as biofertilizer

Biofertilizers are the organic substances that contain living microorganisms such as bacteria, cyanobacteria, fungi etc. or latent cells of the same. They increase the nutrients available to the plants, and pathogen protection, in exchange for photosynthetic products through symbiosis with the host or by colonizing the rhizosphere of the plants. Among all the sources of biofertilizers, mycorrhiza is an important one with respect to cultivation of most of the crops. They are an important component of soil life and soil chemistry contributing to its fertility. Due to the growing interest in reducing phosphorus inputs using AMF inocula, these fungi have assumed a primary role in the development of a sustainable agriculture, which is based fundamentally on the limitation and partial replacement of chemical fertilizers and pesticides mediated by the respect of natural microbiological balances [12]. These primary biotic soil components which, when missing or impoverished, can lead to a less efficient ecosystem functioning [11]. The AM fungi are important to their hosts as they enhance the ability of plants to absorb phosphorus from soil, which is relatively inaccessible to the plants [34, 36]. Under phosphorus-limited conditions, mycorrhizal association improves phosphorus supply to the infected roots of host plants [14]. For example, Pi uptake rate was markedly improved in the AMF-colonized maize plants [19]. Additionally, it has been suggested that some AM associations are able to mobilize organically bound nitrogen, which the plants are unable to absorb [27]. The P depletion zone around a non-mycorrhizal root extends to only 1-2 mm whereas extra radical hyphae of VAM fungi extend up to 8 cm or more beyond the root making the P available to the host [43]. The beneficial microorganisms like antagonistic bacteria and fungi compete with plant pathogens for nutrients and space, by producing antibiotics, by parasitizing pathogens, or by inducing resistance in the host plants, these microbes have been used for biocontrol of pathogens [10]. In this regards it has been suggested that AM fungi increase host tolerance of pathogen attack by compensating for the loss of root biomass or function caused by pathogens [33]. Mycorrhizae are known to increase the root growth of infected plants [25]. Species of AM fungi can either directly or indirectly increase plant growth by improving soil conditions [31].

VAM in arid soil

The great challenge for the coming decades will be the task of ever-increasing food production with less water, particularly in countries with limited water and land resources [3]. Critical water shortages are developing in the arid and semi-arid regions as existing water resources are entirely exploited [7]. Vesicular- arbuscular mycorrhizae (VAM) are critical components of arid ecosystems and all arid plant species are capable of forming mycorrhizal associations except a limited suite of annual weeds [6]. Plants in arid environment are specifically challenged in both (a) accessing nutrients and water from limited and immobile resources, and (b) making these resources available when conditions are favourable for performing vital functions such as growth or flowering [9]. They found that VAM in many plants growing in desert rarely produced arbuscules. Arbuscules are the principal exchange site for P and carbon between the host and VAM fungi [24]. The AM fungal species of *Glomus mosseae* was the most efficient for its ability to increase plant growth, soil nutrient and level of active arbuscular formation [39]. They reported that the cumulative effect increases the soil quality and growth performance of the mycorrhizal inoculated plants compare to non-mycorrhizal under barren soil condition. AM fungi improve their host plants ability to grow under conditions of deficiency of water or in mineral deficient soils [29].

VAM under saline soil conditions

Soil salinity is a common and serious environmental problem with over 800 million hectares of the land surface worldwide are affected by excessive salt [38, 42]. Arbuscular mycorrhizal fungi (AMF) are considered as bio-ameliorators of soil salinity tolerance in plants and improve the growth of the plants. Improvement in the plant growth is attributed to enhanced uptake of mineral nutrients with low mobility, like P, Zn, Cu and Fe [4, 40] and reduced Na^+ uptake [5]. Am fungi may protect the shoot system, mainly leaves from Na^+ toxicity either by regulating Na^+ uptake or by accumulating it in the root subsequently delaying its translocation into shoot system [41, 49]. Not all VAM fungi can improve plant growth in saline soils. In some cases *Glomus fasciculatus* appeared to be most efficient at reducing the negative effects of salinity [16, 26], while in others *G. mosseae* was a better option to reduce salt stress [18]. Thus the introduction of mycorrhizal fungi in barren land is a key tool to improve the quality of soil and plant growth.

SOIL pH and VAM

The distribution of certain VAM fungal species has been related to soil pH, phosphorus level, salinity, soil disturbance [2], vegetation [30], or hydrologic condition of the soil [28, 35]. In general terms, increase in soil pH is related to a decrease in VAM root colonisation or spore density [47]. However, many chemical properties of soil vary with changes in pH, hence, interpreting the effect of pH on the germination of VAM fungal spores is difficult [8]. Daniels & Trappe, reported that optimum germination of *Glomus epigaeum* occurred at pH 7 [17]. Wang *et al*., had reported that percentage colonization and crop yield were little affected by soil pH ranging from 4.5 to 7.5 [48]. Khade, 2009 reported enhanced K and P uptake VAM fungi inoculated *Carica papaya* plants in acidic soil [32].

Conclusion

The significance of VAM in augmenting food production and multidimensional importance of mycorrhizae in horticulture, forestry etc. is well documented. Mycorrhizae may be used to enhance the ability of the plants to cope with water stress situations associated to nutrient deficiency and physiological draught. The use of VAM infected plants could reduce the amount of fertilizers needed for optimal agricultural production. They can play a vital role in soil restoration or bioremediation of as they are able to colonise unproductive, polluted soil and stressed soil of varied degrees.

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