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Significance of Mycorrhizae

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INTRODUCTION

Mycorrhiza is a mutualistic association between fungi and higher plants [1]. Different types of mycorrhizae occur, distinguished by their morphology and to a certain extent, in their physiology. These include the ectomycorrhizae and endomycorrhizae. The ectomycorrhizae characterized by an external sheath of fungal cells surrounding the root, often penetrates between the cells of epidermis and the first few cells of cortex and the fungal hyphae typically infect the roots of forest trees of the temperate region. While endomycorrhizae like vesicular arbuscular mycorrhizal (VA) fungi forms no sheath, the fungus infects the root system of most cultivated crops and usually it invades several layers of the outer root cortex. VA-fungal hyphae penetrate individual cells and form arbuscules within the cell and vesicles outside their host cells which led to their name [2].

Vesicular-arbuscular mycorrhizal (VA) fungi colonize plant roots and ramify into the surrounding bulk soil extending the root depletion zone around the root system. They transport water and mineral nutrients from the soil to the plant while the fungus is benefiting from the carbon compounds provided by the host plant. Therefore VA-fungi have a pervasive effect upon plant form and function [3]. Little is known about the natural ecology of these fungal-plant associations and the effects of certain soil amendments with natural waste products.

VA-fungi are associated with improved growth of many plant species due to increased nutrients uptake, production of growth promoting substances, tolerance to drought, salinity and transplant shock and synergistic interaction with other beneficial soil microorganisms such as N-fixers and P-solubilizer [4]. Symbiotic association of plant roots with VA-fungi often result in enhanced growth because of increased acquisition of phosphorus (P) and other low mobile mineral nutrients [5]. Effective nutrient acquisition by VA-fungi is generally attributed to the extensive hyphal growth beyond the nutrient depletion zone surrounding the root [2]. Although a lack in growth response to VA-fungi inoculation in unsterilized soil was also recorded, this result has been attributed to the fact that native VA-fungi may provide the potential benefit of this mutualistic association [6].

It was reported that one of the principal avoidance strategies of plants for adaptation to adverse soil conditions is an increase in root surface area via mycorrhizae [7]. A better understanding of the mycorrhizae of agronomic crops is needed because of their potential involvement in systems of sustainable agriculture [8].

SIGNIFICANCE OF VA MYCORRHIZAE

Mineral nutrition:

Phosphorus: The major role of VA-fungi is to supply infected plant roots with phosphorus, because phosphorus is an extremely immobile element in soils. Even if phosphorus was added to soil in soluble form soon, it becomes immobilized as organic phosphorus, calcium phosphates, or other fixed forms [9, 10]. VA-fungi are known to be effective in increasing nutrient uptake, particularly phosphorus and biomass accumulation of many crops in low phosphorus soil [11]. Several investigators indicated that there is a beneficial effect of VA-fungi inoculation on nutrient uptake and on plant growth especially in sterilized soils [1, 12-14].

In white clover (*Trifolium repens* L.), mycorrhizal inoculation doubled the concentration of phosphorus in shoots and roots of infected plants and increased their dry weight [15]. Also Al-Karaki *et al*., [16] indicated that shoot dry matter, shoot phosphorus and root dry matter were higher for mycorrhizal infected wheat (*Triticum aestivum* L.) plants than for non infected plants. On the other hand, mycorrhizal infection has been shown to

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depress plant growth in soils with optimum phosphorus availability, these effect were attributed to competition for carbon between the host plant and the mycorrhizal fungi [11].

Nitrogen and micronutrients: The enhanced effect of VA-fungi on the uptake of nitrogen and micronutrient uptake may be attributed to two situations. In the first one is mycorrhizal hyphae act as extension to plant root, increasing root surface area and exploring larger soil volume, which will increase the chance of more micronutrient uptake. Mycorrhizal association with plant root may also enhance translocation between root and shoot of the infected plant, hence enhancing the plant growth [11].

At low phosphorus-levels in soil, mycorrhizae substantially increases copper and zinc contents of the shoot. However, it was found in case of soybean (*Glysine max* L.), grown in high phosphorsu-levels soils, the mycorrhizae decreases copper and zink contents of infected plants [17]. Peanut (*Arachis hypogaea* L.) plants grown in sterilized soil without VA-fungi inoculation developed visible symptoms of phosphorus and zinc deficiency [18].

Water relationship: Although most of the work done with VA-fungi has concentrated on their effects in plant nutrition, there is an increasing interest also on drought resistance of mycorrhizal plants [19]. VA-fungi infection has been reported to increase nutrient uptake in water stressed plants [20], enable plant to use water more efficiently and to increase root hydraulic conductivity [21]. Few studies however are available on the effect of water-stress on the fungi themselves, displayed by the number of spores in the soil and the root infection percentage.

Protection against toxic metals and pathogen: Few investigations were made about the importance of endomycorrhizal and ectomycorrhizal fungi in protecting host plants from phytopathogens and mineral elements toxicity. Still it was indicated that ectomycorrhizal fungi protect trees from high concentrations of toxic heavy metals, because these tend to be accumulated and immobilized in the mycorrhizal sheath [9].

VA-MYCORRHIZAL ASSOCIATION WITH LEGUME CROPS

Legume crops are generally cultivated in poor environments, even recently bred cultivars are selected to grow in such a poor environment and associated with its Rhizobium and an associated microflora Legume crops have a high (P) requirement for nodule formation, nitrogen fixation and optimum growth. Mycorrhizal condition of legume crops found to increase its vegetative growth and seed yield in addition to improve nodulation on it's root system [17,18]. Nair *et al*., [22] reported that higher level of VA mycorrhizal infection was beneficial for plant growth of cowpea (*Vigna unguiculata* L.) under field condition.

Hamel and Smith [23] reported that mixture growth of both corn (*Zea mays* L.) and soybean plants was greatly enhanced when inoculated with mycorrhizal fungi. Although more N appeared to be transferred from soybean to corn when plants were mycorrhizal, growth enhancement was attributed mainly to a better phosphorus uptake by mycorrhizal plants. Jackson and Mason [9] found positive relationships among (P) availability, VA mycorrhizal infection and pod yield in groundnut (*Arachis hypogaea* L.). It was indicated that mycorrhizal colonization in several cowpea genotypes was host dependent and heritable [24]. Alloush [25] found that chickpea plants inoculated with mycorrhizal fungus *Glomus versiforme* had higher number of nodules, shoot phosphorus content, shoot dry weight and grain yield than uninoculated chickpea plants.

EFFECT OF SOIL AMENDMENT WITH ORGANIC WASTES ON MYCORRHIZAL COLONIZATION

The materials we refer as organic wastes are merely those which are not put to use in our existing technological system. Once we begin to use them, they will no longer be called wastes and if they are in demand, we may even seek to increase their production. Organic wastes are really resources out of place. Farmers historically have applied animal manure and human wastes to the land, both treated and untreated, for crop production. Animal and crop plant wastes are different in their chemical and biological composition depending on the source of the material. Kale *et al*., [26] found that mycorrhizae in roots of a summer crop was 2.85% in soil previously received chemical fertilizers compared to 10% in the soil with half the recommended dosage of chemical fertilizers and organic matter (OM) amendment. Inoculation with VA-fungus did not significantly affect seed yield of pea (*Pisum sativum* L.) plants in soil which is rich in OM and phosphorus. On the contrary, seed yield was significantly enhanced with VA-fungi inoculation in soil which is poor in OM and phosphorus [3].

In mycorrhizae treatments, sludge showed inhibition of the mycorrhizal infection. This inhibition was persistent and apparently due to suppression of mycorrhizal fungi by toxic levels of NH_4^+ [17]. Also, both VA mycorrhiza spore density and root colonization were found to be higher under wastewater irrigated oldfield soils than in non-irrigated [27].

Large quantities of olive mill by-products are obtained when oils are extracted after mechanical and chemical treatments of olive yields [28]. The olive milling industry by-products; solid portion known as (Jift) or the liquids called (Zebar) could be used as soil OM amendment as Jift material is a nitrogen rich organic waste [29]. Although there are high levels of phytotoxic compounds found in fresh Jift which may inhibit seed germination or reduce plant growth, it contains no chemical contaminates like heavy metals [30]. On the other hand, Al Sakit and Al-Momani [31] found a positive relationship between fresh Jift amendment, olive seedling growth and association with mycorrhizae. There are no previous reports about the influence of the olive mill by-products, jift and zebar on the VA-fungi and its ecology and significance to commercial legume crops.

EFFECT OF SOIL STERILIZATION AND FUNGICIDE TREATMENTS ON MYCORRHIZAL INFECTION

Although large number of experiments studied the effect of different sterilization methods on soil pathogenic fungi, little information were reported about their effect on useful soil fungi.

Fungicide treatment: The effects of biocide use on non target organisms, such as VA-fungi, are of interest to agriculture, since inhibition of beneficial organisms may counteract benefits derived from pest and disease control.

Most of the fungicides which have been used to study their effect on VA mycorrhizal fungi were found to be deleterious, but some were quite compatible with VA mycorrhizal fungi. Sreenivasa and Bagyaraj [4] were studied the effect of nine fungicides on root colonization with VA mycorrhizal fungi and indicated that reduction from 10 to 20% of root infection percentages were recorded when the recommended level of fungicides were used. While some fungicides were significantly increased the percentage root colonization at half the recommended level.

In an experiment studied the effect of different fungicides on VA-fungi infection and population, it was concluded that application of fungicide to soil reduced sporulation and the root length colonized by VA-fungus, although interaction of VA-fungi and fungicide were observed to be highly variable depending on fungus-fungicide combination and on environmental conditions.

Solarization treatment: Soil solarization was shown to be cost reducing, compatible with other pest management tactics, readily integrated into standard production systems and a valid alternative to preplant fumigation with methyl bromide [32]. It also reported that soil solarization induced better growth response in plants even when no pathogen is present in the soil [33].

In field experiment, it was reported that solarization of soil by covering it with transparent plastic sheets resulted in reduction or complete elimination of soil pathogens between 0 and 25 cm depth in soil covered for 30-60 days [34]. In other experiment it was observed that covering the soil with a clear plastic sheet resulted in complete elimination of endomycorrhizal fungi at 10 and 20 cm soil depths [35]. It was also reported that root nodulation, infection by mycorrhizal fungi and yield of cowpea were higher in plants grown in solarized soil when compared to control treatment without solarization [22]. Stapleton and DeVay [33] indicated that the beneficial response of plant growth to soil solarization might have resulted from the effects of better root nodulation, enhanced VA mycorrhizal association and the increased availability of some of the macro and micro nutrients in soil solution due to solarization.

Methyl bromide treatment: Although there was a grave environmental concern about the application of methyl bromide and it's toxicity to mammals, it is still recommended for soil disinfection. Great reduction or complete elimination of all living organisms in the soil after methyl bromide gas fumigation of soil is well documented [25, 32]. Soil disinfection by methyl bromide fumigation or steam is often used to eliminate soil-borne plant pathogens, but such treatments can reduce VA mycorrhizal fungi as well [1]. Several studies have indicated that plant stunting following soil fumigation treatments may be due to elimination of VA mycorrhizae [36, 37].

EFFECT OF SOIL FERTILITY ON MYCORRHIZAL INFECTION

Most authors report extensive colonization to occur mainly in plants growing in soils of low fertility [8, 38]. Field and greenhouse studies demonstrated that crops growing in nutrient-poor soils had higher levels of mycorrhizal colonization than crops growing in better

soils [38]. Vesicular- arbuscular mycorrhiza inoculation in combination with phosphorus increased dry and fresh shoot weight, leaf area and leaf number of strawberry compared to application of phosphorus alone [39].

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