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The Role of Mycorrhizal Fungi in Pepper *(Capsicum annuum)* Production

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Abstract

The term 'mycorrhiza' comes from Greek – mycos meaning fungus and rhiza meaning roots and it is simply means fungus root. It is broadly classified as endo-mycorrhizae, (penetrating the root skin cellforming swollen vesicles or branching invaginations (arbuscules) and ectomycorrizae (the fungal hyphae form a sheath around the plant root but do not penetrate the root extensively). of the host plant. The roots of almost all plants form mutualistic associations with mycorrhizaefungi, which serve them to enhance the uptake of water and mineral nutrients, especially phosphate, by the plants. In addition to nutrient uptake mycorrhizal fungi also helps the plant to tolerate different stress conditions like salt stress and diseases occurrence. In pepper production inoculation with arbuscularmycorrhizal fungi had agreat role in increasing economic yield, and improving maturity by improving nutrient uptake, reducing salinity effect anddiseases tolerance.

Keywords: Mycorrhiza; Arbuscularmycorrhizal; Pepper Mycorrhizal association;

Introduction

Plants associate with other life forms (animals, bacteria or fungi) to complete their life cycle, to fight against pathogens or to thrive in adverse environments. The plant root and its associated living organisms are together called 'rhizosphere', and it is the region of mycorrhizal association. Mycorrhiza is one of the best examples of symbiotic association between plants and fungi. The term 'mycorrhiza' comes from Greek – mycos meaning fungus and rhiza meaning roots. In nature, more than eighty percent of angiosperms, and almost all gymnosperms are known to have mycorrhizal associations. Arbuscularmycorrhizal (AM) fungi are soil fungi that form a symbiosis with the majority of crop and horticultural plants. Among the benefits to the host plant ascribed to the symbiosis are enhanced uptakes of immobile mineral nutrients.[1].

AM associations occur in a wide spectrum of tropical and temperate tree species. They are known not to occur only in a few plants, namely members of the families Amaranthaceae, Pinaceae, Betulaceae, Cruciferae, Chenopodiaceae, Cyperaceae, Juncaceae, Proteaceae, and Polygonaceae. The ectomycorrhizas, on the other hand, occur primarily in temperate forest species, although they have been reported to colonize a limited number of tropical tree species. [2].

Different literatures show that the symbiosis association with mycorrhizal fungi assists plant growth by different mechanisms. The fungi enhance immobile nutrient uptake by increasing the absorptive surfaces of the root[2] and improve plants tolerance adverse environmental stress. The plant pepper (*Capsicum annuum)*is very important vegetable which is the member of *solanaceae* family. Different researches were conducted on the relation of mycorrhizae and pepper. So the objective of this paper is to review and summarize the role of mycorrhizal fungi on production of pepper.

1.1. Mycorrhizal fungi

'Mycorrhiza' literally means fungus-root', a term coined by German mycologist AB Frank in 1885 when he was searching for a way to cultivate truffles. It describes the intimate association between the roots of plants and a range of different fungi. Only about 3% of the higher plants, mainly forest trees in the *Fagaceae*, *BetulaceaePinaceae*, *Eucalyptus*, and some woody legumes, form ectomycorrhiza. The fungi involved are mostly higher *Basidiomycetes* and *Ascomycetes* which colonize the cortical, root tissue which lacks intracellular penetrations and develops a sheath or mantle around the feeder roots. The other types of mycorrhiza can be grouped as endomycorrhiza, in which the fungus can colonize the root cortex intracellularly. One of these is restricted to some species in the *Ericaceae* ('ericoid' mycorrhiza), the second to the *Orchidaceae* ('orchid' mycorrhiza), and the third, the arbuscularmycorrhizas, which is by far the most widespread type. There is also other group which is called the ectendomycorrhiza, composed of plant species in families other than *Ericaceae* but in the *Ericales*, and in the *Monotropaceae*. They have sheaths and produce intracellular penetrations ('arbutoid' and 'monotropoid' mycorrhiza)[4].

But in broad classification mycorrhizal associations can be grouped in two major categories. One kind is ectomycorrhizae, typically formed between *basidiomycetes* and the roots of woody plants. In ectomycorrhizal associations the fungal hyphae form a sheath around the plant root but do not penetrate the root extensively. A second kind is endomycorrhizae, which form between *glomeromycete* fungi and many herbaceous (nonwoody) plants. In endomycorrhizae the fungal hyphae embed deeply in the plant root tissue, forming swollen vesicles or branching invaginations (arbuscules) [5].

ArbuscularMycorrhizae are endomycirrhizal fungi which classifide in the family of *Glomeromycota* under phylum zygomycota. The word "arbuscular" means "little tree. Allor most species are obligate plantmutualists. AM colonizemore than 85% of all terrestrial plants, including most grasslandspecies and many crop species[6]. It also forms association with the solanaceae family Pepper (*Capsicum annuum*) and therefore it is the main focus of this review.

2. The role of mycorrhizal fungi for plant growth

Over 80% of all land plants have a mutualistic relationship with one or more mycorrhizal fungi, and these mycorrhizal fungi have different roles on plant growth. They have been shown to be capable of making nutrients available to plants and providing a better transplant performance by offering higher shoot fresh weight, high shoot/root ratio, higher root biomass and higher root growth rate. In addition, protection from diseases caused by root pathogens is a major benefitthat AM fungi could offer in both containerized and hydroponicproduction systems. Once AM fungi colonize the plants, they remainwith the root systems and can be transferred into other soil/substratelocations and plantings on the infested roots[7]. The major roles are generalized in the following sub-titles.

2.1. Nutrient uptake

The roots of almost all plants form mutualistic associations with fungi, known as mycorrhizae, which serve to enhance the uptake of water and mineral nutrients, especially phosphate, by the plants[8]. Studies show that arbuscylarmycorrhizal fungi absorb nutrients like N, P, K, Ca, S, Cu, and Zn from the soil and translocate them to associated plants. However, the most prominent and consistent nutritional effect of AM fungi is in the improved uptake of immobile nutrients, particularly P, Cu, and Zn. The fungi enhance immobile nutrient uptake by increasing the absorptive surfaces of the root[2]. The hyphae of the fungi spread through the soil and infect the roots of plants creating specialized structures for the exchange of nutrients. This relationship generally benefits both organisms by providing carbon to the fungi and increased nutrient uptake (primarily phosphorus) for the plant. Each mycorrhizal plant and fungi is typically involved in multiple simultaneous relationships. It has also been demonstrated that this network of underground connections can facilitate a plant-to-plant exchange of nutrients[9].

2.2. Stress tolerance

Results showed that mycorrhiza can not only improve the growth of high performance crop but also promote their adaptation to different environmental conditions such as deep ground water level [10].Although mycorrhizal fungi are themselves affected by environmental perturbations, they also have the ability

to mediate the responses of plants to different types of environmental stress. The ability of ectomycorrhizal fungi to capture base cations and restrict their loss through leaching, and to release nutrients through weathering of mineral surfaces, may be important in environments influenced by soil acidification[11].

Mycorrhiza fungi play crucial role to benefit the host plant mainly through acquisition of nutrients from soil and also protects from biotic and abiotic stresses[12]. Even though the mechanism needs further research AM fungi plays very important role in minimizing plants drought stress[13].

2.3. Increase surface area for other PGPR interaction

It was reported that in addition to increasing the absorptive surface area of their host plant root systems, the hyphae of symbiotic fungi provide an increased surface area for interactions with other microorganisms, and provide an important pathway for the translocation of energy-rich plant assimilates (products of photosynthesis) to the soil. Bacteria with potential to fix nitrogen have been discovered growing endosymbiotically within arbuscularmycorrhizal hyphae, as well as in association with tuberculate roots of ectomycorrhizal plants. Obviously such tripartite symbioses would be of significance in nitrogen-limited environments.[11].

In addition to the above, mycorrhizal fungi also provide a better transplant performance by offering higher shoot fresh weight, high shoot/root ratio, higher root biomass and higher root growth rate[7].

Mycorrhizae association with plant roots.
Images from; https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.plant-success.com

3. The role of mycorrhiza for pepper production.

Pepper (*Capsicum annuum*) is one of widely cultivated important spices which belong to themember of solanaceae family. It was domesticated 10,000 to 12,000 years ago by the Aztecs, Mayas and the Incas. Columbus in the fifteenth century introduced peppers to Europe and subsequently to Asia and Africa, and later to India, China and Japan through the spice trade. Pepper is an herbaceous annual which matures early under low temperatures. even if it growth form varies from one species to another,pepper has deep taproots with fibrous lateral roots that spreadbetween 50 and 60 cm wide. Its flowers are small with white or purple petals. Pepper flowers develop into fruits which are berries with several white coloured seeds. Fruits from different species of pepper vary in colour, size, formand flavour, from very hot to mild or sweetly pungent. Pepper fruits are commonly green before maturity. But after maturity,fruit colour can either be red, orange, yellow or purple[14].

It is estimated that more than 3 million hectares of peppers are grown annually around the world. Asia is the largest producer, followed by Africa and Europe. Pepper production is found from the humid tropics, to the dry deserts, to the cool temperate climates. The ability of pepper to thrive under this range of climatic conditions has rendered it a common crop worldwide.

Images from; https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.plant-success.com

Endo mycorrhizalArbuscular Fungus was reported to be associated with pepper and even if the degree of association was varied, all studied sampls of pepper plant were found to form association with arbuscularmycorrhiza[15]. As all other plants mycorrhizae association with the root of pepper have different mutualistic benefits and contribute for production of pepper. Inoculation of pepper with arbuscularmycorrhizal fungus had a significant difference on fruit maturity, economic yield and diseases tolerance over the control[16] .The overall effect of arbuscularmycorrhizae on pepper production is the increased soil fertility and plant productivity[17]. But specifically can be discussed as follows

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3.1. Nutrient uptake

A research report shows that native AMF inoculant, *Glomusclaroideum*, in comparison to a commercial inoculant, *Glomusintraradices*, positively affected the production of chili pepper, resulting in more vigorous plants with a higher foliar area and shoot/root ratio, which accelerated fruiting and improved quality, and led to greater quantity of fungal propagules in the soil(Claudia Castillo R et al., 2009). Similarly other studies shows that there were significant differences in plant height, shoot and root fresh and dry weight and root length between inoculated and control of pepper plants[19]. In some problematic soils on which P is not available for the plantmycorrhizal canchange P bound to P available to increase the production of pepper plant[17].

The dual inoculation and multi inoculation of bell pepper plants with *Glomusmosseae*, *Acaulosporalaevis* and *P. fluorescens* increased growth, photosynthetic rate, fruit number, fruit weight, total nitrogen content and phosphorus content at P levele, below the recommended supplied P was over unfertilized as well as heavy fertilized plants by enhanced bioavailability and mobility of plant nutrients [19].

Other studiesalso shows that use of AMF from a native inoculum in agriculture contributes to improving the nutritional status of the plant, which is reflected in the increased leaf area, root and fruit fresh weight of the chili plants evaluated[20].

3.2. Disease tolerance

Researches reports also show that Arbuscularmycorrihzal fungi are very important to control foot rot disease on pepper production. The use of ArbuscularMycorrhizal fungi could control the disease intensity of the pepper foot rot on the pepper seedlings planted in the infected soil. The single treatment of mycorrhizae was more effective in suppressing the rate of disease progress. Sterilization of the infected soil with hot water vapor for 3 hours still could not control the pathogens[21].

3.3. Salt stress tolerance

It is reported that pre–inoculation of green pepper transplants with AM fungi have positive enhancement effects in reducing the effects of salt stress through enhancing plant growth, fruit yield and nutrient uptake under relatively medium salinity levels[22].Arbuscularmycorrhizal fungi alleviate detrimental effects of salinity on growth, improve nutrition (higher K and P and lower Na concentrations in leaf tissue) and alleviate salinity impacts on cell membrane stability, at high P concentration and high saline conditions. Thus, use of AMF provides a sustainable and environmentally safe treatment to improve salinity tolerance[23].

Mycorrhizal inoculation is capable of alleviating the damage caused by salt stress conditions on pepper plants, to maintaining the membranes stability and plant growth, and this could be related to P nutrition. Another study also shows that plants inoculated with *G. intraradices*had less lipid peroxidation, and therefore itcan be said that these plants have an advantage under salt stress and *G. intraradices* would be more effective as a defense strategy during long termsalt stress conditions in the pepper plant.[24].

3.4. Heavy metal stress tolerance

Arbuscularmycorrhizal associations play an important role in protecting plants in heavy metal contaminated sites. Plants with mycorrhizal association, growing in heavy metal contaminated areas, are more tolerant as compared to the plants of clean areas. Fungal hyphae can approach the soil which is beyond the approach of plant roots; hence absorption of water and mineral nutrients is enhanced by increasing the exposed absorptive area[25]. It is also reported that Mycorrhizationincreases pepper plant tolerance to high heavy metals like Cr concentrations in the soil and modifying proline metabolism to make the response more efficient [26].

4. Applications of Arbuscolar Mycorrhizal fungi

Even though mycorrhizal fungi are very important for plant growth, it was reported that inoculation with mycorrhiza in biologically active soil is not necessary. However they may be useful in sterile substrate, newly created artificial landscapes, and soils in soils that has been managed using non selective sterilization methods, such as fumigation[20].

Large-scale application of AM fungi in crops of economic importance, such as pepper and sweet pepper, is still a challenge due to the obligatory nature of the symbiosis, which requires the presence of a host for production[27].

The occurrence of mycorrhizal fungi is not dependent on the common type of soil; rather it is mostly likely dependent on the type of agronomic practice and inputs used. Therefore it is recommended to apply the appropriate mycorrhizal fungi at the nursery level [27].Other findings also indicate that inoculating at nursery was more effective than inoculating after transplanting[22]. Therefore for horticultural plants inoculating mycorrhizal fungi at seedling level in the nursery will be more effective.

5. Conclusion

Arbuscularmycorrhizae and plant association is best important biological association which improve the growth and productivity of plants. In pepper production it plays a great role in increasing economic yield, diseases tolerance and improving maturity. The mechanisms which Arbuscularmycorrhizal fungus contributes to the growth and productivity of pepper are, improving nutrient availability and uptake and reducing different stresses. But naturally it is abandon in most biologically active soils. Generally the use of mycorrhizal fungi in pepper production can play a significant role in agricultural sustainability and ecological functioning. Because they can significantly increase productivity and reduce the use of different agrochemicals used in pepper production. Applying AM at nursery is better than applying after transplanting.

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