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Arbuscular mycorrhizal fungi AND THEIR SYMBIOSIS WITH VEGETABLE CROPS

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Abstract: *Arbuscularmycorrhiza fungus is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant. Mycorrhiza plays a significant role in sustainable vegetable crop production and has mutualistic symbiotic association with vegetable crop roots. There are several species of mycorrhiza and among the species studied Glomusmosseae is well known to colonize several vegetables crops. Symbioses and beneficial effects of arbuscularmycorrhiza fungi (AMF) with tomato (Solanumlycopersicum), brinjal (S. melongena), potato (S. tuberosum), lady's finger (Abelmoschusesculentus), cucumber (Cucumissativus), bean (Phaseolus vulgaris), pepper (Capsicum annuum), has been reported by many authors. Application of AMF increased nutrient uptake, water relations and perform as bio-protectants against pathogens and toxic stresses. In order to further improve their benefits, it is necessary to ensure the management practices comprising low tillage, abridged use of chemical fertilizers, especially the phosphatic fertilizers.*
Keywords: *Arbuscularmycorrhiza (AM), Colonization, Spore population, Vegetable crop.*

Introduction: Living together is one of the most prevalent phenomena in the biological world, especially in the plant kingdom and in the underground environment. Underground world also harbors one of the most common symbiotic associations between plant root and fungus called "Mycorrhiza" [1]. More than 6,000 fungal species are capable of establishing mycorrhiza with about 240,000 plant species, but relatively few anatomical types of plant-fungus interaction results from such impressive bio-diversity.

Taxonomy and Systematics: Arbuscularmycorrhizae (AM) fungi are restricted to the order Glomales with three families having six genera, namely Glomus, Acaulospora, Gigaspora, Sclerocystis, Scutellospora and Entrophospora [2], which biotropically colonize the root cortex where large proportion of the mycelium occupies an endocellular position, differentiating into a highly branched haustoria, the arbuscules, which are the site of nutrient exchange. The recent work provides convincing evidence for a positive interaction of symbiotic fungus with several members of Crucifereae [3].

Habitat: Mycorrhizal association is found in a broad range of habitats. These include ecosystem ranging from aquatic to desert [4], from lowland tropical rain forest [5] to high altitudes and in the canopy epiphytes [6]. AM fungi are found in nearly all soil where plants grow, including environments that are considered stressful to plant growth. In fact, mycorrhizas to have their greatest impact where plant grows, including environmental stress.

The Fungal Partner: The fungi involved in AM symbiosis are obligate biotrophs.. They reproduce asexually, forming multinucleate spores. Unusual polymorphism of ribosomal RNA in individual spores has led to the concept of inter nuclear variation in single spores, defining AM fungi as heterokaryotic organisms [7]. Heterokaryosis has been assumed to be of decisive importance to ecology and application of AM fungi. This concept, however, has recently been challenged by experiments suggesting that single spores contain a uniform population of nuclei characterized by intranuclear polymorphism [8].

Establishment of Symbiosis and Cytological Features of AM Plant Roots: Fungal development starts with the germination of hyphae from resting spores. In the absence of a host plant, AM fungi show only limited hyphal growth whereas in the presence of root exudates growth and branching of hyphae is strongly increased [9]. The development of AM fungi prior to root colonization, known as presymbiosis, consists of three stages: spore germination, hyphal growth, host recognition and appressorium formation and characterized by the activation of specific genes followed by subsequent physiological and morphological changes. In return, germinating spores produce diffusible factors which are perceived by plant roots leading to the expression of specific genes even in the absence of direct physical contact [10]. Spores of the AM fungi are thick-walled multi-nucleate resting structures [11]. The germination of the spore does not depend on the plant. However rate of germination can be increased by host root exudates [12]. The growth of AM hyphae through the soil is controlled by host root exudates known as strigolactones, and the soil phosphorus concentration [13]. Low-phosphorus concentrations in the soil increase hyphal growth and branching as well as induce plant exudation of compounds that control hyphal branching intensity [14]. During colonization, the fungal arbuscule occupies a major portion of the plant cortex cell, but is separated from the cell protoplast by a part of the host plasma membrane, the periarbuscular membrane. This membrane completely surrounds the arbuscule, leading to up to a fourfold increase of the surface of the plasma membrane. Hyphae of fungi grown in the exudates from roots starved of phosphorus grew more and produced tertiary branches compared to those grown in exudates from plants given adequate phosphorus. This chemotaxic fungal response to the host plants exudates is thought to increase the efficacy of host root colonization in low-phosphorus soils [12]. It is an adaptation for fungi to efficiently explore the soil in search of a suitable plant host. Further evidence that arbuscularmycorrhizal fungi exhibit host-specific chemotaxis, that enablehyphal growth toward the roots of a potential host plant.

Symbiosis: Modification in Fungus and Host Cell Architecture: Once inside the parenchyma, the fungus forms highly branched structures for nutrient exchange with the plant called "arbuscules" [15]. These are the distinguishing structures of arbuscularmycorrhizal fungus. Arbuscules are the sites of exchange for phosphorus, carbon, water, and other nutrients [11]. The host plant exerts a control over the intercellular hyphal proliferation and arbuscule formation. There is a decondensation of the plant's chromatin, which indicates increased transcription of the plant's DNA in arbuscule-containing cells. Major modifications are required in the plant host cell to accommodate the arbuscules. The vacuoles shrink and other cellular organelles proliferate. The plant cell cytoskeleton is reorganized around the arbuscules. Once colonization has occurred, short-lived runner hyphae grow from the plant root into the soil. These are the hyphae that take up phosphorus and micronutrients, which are conferred to the plant. AM fungal hyphae have a high surface-to-volume ratio, making their absorptive ability greater than that of plant roots [16].

Nutrient Uptake and Exchange between AMF and Plants: AM fungi are obligate symbionts. They have limited saprobic ability and depend on the plant for their carbon nutrition [17]. AM fungi take up the products of the plant host's photosynthesis as hexoses. Carbon transfer from plant to fungi may occur through the arbuscules or intraradical hyphae [18]. Secondary synthesis from the hexoses by AM occurs in the intraradical mycelium. Inside the mycelium, hexose is converted to trehalose and glycogen. Trehalose and glycogen are carbon storage forms that can be rapidly synthesized and degraded and may buffer the intracellular sugar concentrations [18]. The intraradical hexose enters the oxidative pentose phosphate pathway, which produces pentose for nucleic acids. Lipid biosynthesis also occurs in the intraradical mycelium. Lipids are then stored or exported to extraradical hyphae where they may be stored or metabolized. The breakdown of lipids into hexoses, known as gluconeogenesis, occurs in the extraradical mycelium [18].

Increasing the plant's carbon supply to the AM fungi increases uptake and transfer of phosphorus from fungi to plant [19]. Likewise, phosphorus uptake and transfer is lowered when the photosynthate supplied to the fungi is decreased. Species of AMF differ in their abilities to supply the plant with phosphorus [20]. The main benefit of mycorrhizas to plants has been attributed to increased uptake of nutrients, especially phosphorus. Phosphorus travels to the root or via diffusion and hyphae reduce the distance required for diffusion, thus increasing uptake. The rate of phosphorus flowing into mycorrhizae can be up to six times that of the root hairs [21].

Response to Plant Communities: Due to the complexity of interactions between the fungi within a root and within the system, it is difficult to analyze the host specificity, host range, and degree of colonization of mycorrhizal fungi. The ability of the same AM fungi to colonize many species of plants has ecological implications. Plants of different species can be linked underground to a common mycelial network [22]. One plant may provide the photosynthate carbon for the establishment of the mycelial network that another plant of a different species can utilize for mineral uptake. This implies that arbuscularmycorrhizae are able to balance below-ground intra–and interspecific plant interactions. Since Glomeromycota fungi live inside plant roots, they can be influenced substantially by their plant host and in return affect plant communities as well. Plants can allocate up to 30% of their photosynthate carbon to AM fungi [23] and in return AM fungi can acquire up to 80% of plant phosphorus and nitrogen. The diversity of AM fungal communities has been positively linked to plant diversity, plant productivity and herbivory [24]. Investigated for VAM fungal association among vegetables crops and found that presence of 23 VAM fungi [25] associated with different vegetable crops (Table 1).Table 2 indicates data on qualitative composition and specific association with host plants and represented by Glomus10 species, Acaulospora by six species, Scutellospora by three species, Gigaspora by three species and Entrophosporawas represented by one species [25].

Table 1: Vesicular Arbuscular Mycorrhizal fungus status in the roots of vegetable crops.

S.N.	Host Plants	Fungal Structure	Colonization rate (%)	Spore density (number per 20gm)
1.	*Benincasahispida*(Thunb.) Cogn. (Ash gourd)	ap, ar,v,h	27.0	26
2.	*Citrulluslanatus*(Thunb.) Manf. (Water melon)	v, h	13.1	6
3.	*Cocciniaindica* W. I. A. (lvy gourd)	v, h	10.1	8
4.	*Cucumismelo* L. (Musk melon)	ar, r, h	21.5	66
5.	*Cucumissativus*L. (Cucumber)	ar, r, h	31.6	28
6.	*Cucurbita maxima* Duch. (Pumpkin)	v, h	41.2	60
7.	*Lagenaria vulgaris* Ser. (Bottle gourd)	ar, r, h	43.2	38
8.	*Luffaacutangula*(L.) Roxb. (Ridged gourd)	ap, ar, r, h	40.5	44
9.	*Momordicacharantia* L. (Bitter gourd)	v, h	12	10
10.	*Trichosanthesanguina* L. (Snake gourd)	ar, r, h	31.7	50

Table 2: VesicularArbuscularMycorrhizal fungus status in the roots of vegetable crops.

Host Plants	VAM fungal species (No.)
Benincasahispida (Thunb.) Cogn. (Ash gourd)	*Acaulosporafoveata, A. laevia, Gigaspora candida, Glomusfasciculatum, Gl. multisubtensum and Scutellosporaheterogama*(6)
Citrulluslanatus (Thunb.) Manf. (Water melon)	*Acaulosporabireticulata, A. gerdemannii, A. nicolsonii, Gigaspora margarita, Glomusfasciculatum, Gl. glomeratum, Gl. multicaule and Gl. rubiformis*(8)
Cocciniaindica W. I. A. (lvy gourd)	*Acaulosporabireticulata, A. mellea, A. nicolsonii, Gigaspora candida, G. margarita, Glomusconstrictum, Gl. fasciculatum, Gl. heterosporum, Gl. macrocarpum, Gl. minuta, Scutellospora calospora and S. scutata*(12)
Cucumismelo L.(Musk melon)	*Acaulosporabireticulata, A. gerdemannii, Entrophospora columbiana, Glomusfasciculatum, Gl. glomeratum, Gl. Multicaule and Gl. multisubtensum*(7)
Cucsativus L. (Cucumber)	*Acaulosporalaevis, A. nicolsonii, Gigasporagigantea, Glomus fasciculatum, Gl. fistulosum, Gl. macrocarpum, Gl. multicaule and Gl. sinuosa*(8)
Cucurbita maxima Duch. (Pumpkin)	*Acaulosporamellea, Gigaspora margarita, Glomus citricola, Gl. macrocarpum and Gl. minuta*(5)
Lagenaria vulgaris Ser.(Bottle gourd)	*Acaulosporadilatata, A. laevis, A. nicolsonii,Gl. fasciculatum, and Scutellosporaheterogama*(5)
Luffaacutangula (L.) Roxb.(Ridged gourd)	*Acaulosporabireticulata, Entrophosporacolumbiana,Gigaspora candida, Glomusfasciculatum,Gl. macrocarpum, Gl. minuta and Gl. sinuosa*(6)

*Momordica charantia*L. (Bitter gourd)	*Acaulosporabireticulata, A. mellea, A. nicolsonii, A. spinosa, Glomuscitricola, Gl. fasciculatum, Gl. fistulosum, Gl. glomeratum, Gl. heterosporum, Gl. macrocarpum, Gl. rubiformis, Gl. sinuosa and Scutellosporascutata*(13)
*Trichosanthes anguina*L. (Snake gourd)	*Acaulosporaelegans, A. foveata, Gigasporagigantea, Glomusfasciculatum, Gl. glomeratum, Gl. macrocarpum,Gl. multisubtensum, Scutellosporacalospora and S. scutata*(9)

Conclusions: Isolation and identification of plant symbiotic signals open up new ways for studying the molecular basis of plant–AM-fungus interactions. Mycorrhizal technology would be least expensive, simple, and nature farming technology. Increased crop production and decreased toxicity of vegetable crop has particularly importance for human health and suggests that mycorrhizal inoculation may contribute to minimize crop production cost and enhance of quality of vegetable produce.As a wide range of host, fungal and environmental factors are known to influence AM formation andsubsequent spore production; these two phenomena may notnecessarily be related.

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