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Arbuscular Mycorrhizal Fungi in Tropical Ecosystems: Towards its Management?

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Abstract

Arbuscular mycorrhizal fungi (AMF) are root bound symbiotes that are present in most terrestrial ecosystems. AMF belongs to the Phylum Glomeromycota, with more than 300 species. Mycorrhizal colonization in tropical ecosystems is affected by biotic and abiotic factors. The abundance and diversity of AMF decreases when having degraded soils and contamination produced by agricultural and agrochemical practices. The in vitro propagation of AMF alters the morphology, genetics and functioning given the domestication of the strains. It is important to further examine the effects of domestication on AM fungi and predict how changes could highly affect the environment following inoculation with such strains. Future progress prelude to the development of a future 'ecological engineering of AMF and their associated microorganisms' and its integration into modern plant breeding while taking care of the ecosystem services rendered by these valuable fungi.

Keywords: Arbuscular mycorrizal fungi, Tropical ecosystems, In vitro propagation of AMF biofertilizers

Introduction

Arbuscular Mycorrhizal Fungi (AMF) are root bound symbiotes that are present in most terrestrial ecosystems. AMF belong to the Phylum Glomeromycotan, with more than 300 species, which have suffered classification changes in the last 10 years, currently endorsed as Phylum by Tedersoo [1]. The most recent classification of Glomeromycotan is based on the consensus of ribosomal RNA gene regions: 18S (SSU: Small Unit), ITS1-5.8S-ITS2 (internal transcribed spacers) and 28S (LSU: Large Subunit). Glomeromycotan fungi that produce globoid spores in unorganized sporocarps with a peridium probably have a worldwide distribution and they likely occur not only in undisturbed high-humidity habitats that are rich in organic matter, but also in highly degraded soils Jobim [2]. Taxonomic identification of AMF is traditionally based on spore morphology, a technique that requires a lot of time and considerable experience, and recently on DNA-based methods that are also expensive Crossay [3], however, DNA-based methods analyze the active composition of AMF populations within roots. Both should be considered as complementary. The AMF provides benefits to the host within them, facilitates the absorption of nutrients that are not bioavailable in the soil, mainly phosphorus, nitrogen, calcium, copper, zinc, magnesium, facilitates water intake, increases photosynthesis, and it also provides to the plant: resistance to biotic, abiotic stress and promote growth Kumar [4]. The plant gives it carbon in the form of amino acids, sugars in the form of hexoses, mainly glucose and polyols, which allow the maintenance of the microbiome of the mycorrhizosphere. Symbiotes store carbon from the plant in the form of vesicles (lipids) and use it as an energy source when the plant is not photosynthetically active Bach [5].

Tropical Ecosystems: mycorrhizal colonization in tropical ecosystems is affected by biotic and abiotic factors such as soil pH, water stress, light availability, ability to obtain carbon produced by plants, plant species, level of contamination, degree of soil disturbance, practices of agriculture and agrochemical application. Transfer of resources through shared fungal symbiotes, often called Common Mycorrhizal Networks (CMNs) could alter competitive ability and alter coexistence of plant species. It is possible that shared symbiotes can mediate plant-plant interaction through changes in the density or composition of the symbiotic community Harley & Smith [6]. Mycorrhizal fungi are commonly the key determinant of plant population and community dynamics, with differences between mycorrhizal types Tedersoo [7]. Experimental data has shown that plants are able to select certain fungi that supply most phosphates and reward them with more return carbohydrates Kiers [8]. On the other hand, different species may have different requirements, which could be the reason why different AMF dominate some forest species Haug [9]. An alternative explanation for the stability of mutualism is that both, plants, and fungi are able to detect the variation in resources supplied by their partner, allowing them to adjust to their own resources. As a type of "biological market", there is a shift from the host to more cooperative species or changes in the competitive dynamics between fungi Kiers [8]. However, once colonization is established, plants cannot discriminate between fungal mixtures Kiers [8]. The same mycorrhizal fungal species do not deliver the same proportion of total phosphorus to different plant species Smith [10]. In AMF systems, fungal diversity increases plant diversity and vice versa, by providing species specific benefits and suppressing superior competitors Tedersoo [7]. Among the most abundant AMF are the genera *Glomus* and *Acaulospora*, which could indicate that they have the greatest ability to adapt to different environments, in addition to having tolerance to a wide pH range and producing numerous spores of small diameter. *Glomus* is more associated with grasses than forests, and *Acaulospora* and *Scutellospora* species may be more effective symbiotes for slow-growing plants, such as timber species in resource-limited environments Lovelock [11]. It is important to emphasize that the number of spores does not always correlate with the proportion of root length colonized by most AMF genera Merryweather & Fitter [12], mainly *Acaulospora* and *Glomus* Lovelock [11]. According to Lovelock [11], the causes of the different community structure could be that

1) not all species in the community may be sporulating in the sample at the same time.

2) sporulation may not proportionally represent all species of colonized roots.

3) Tree species differ in growth rate and phenology.

these species can differentially alter fertility and other physical and chemical characteristics of the soil. AMF have different colonization strategies, for example *Glomus* and *Acaulospora* colonize from all types of inocula. While *Gigaspora* and *Scutellospora* colonize mainly by spores and very limited by root fragments Klironomos [13]. *Scutellospora* does not produce vesicles because the infection can be by intra-radical or extra-radical hyphae associated with root fragments and *Gigaspora* lacks runner hyphae. The vesicles can be infective segments of living or dead roots that can be an inoculum resource for the development of new roots Klironomos [13]; however, spores are the preferred method of propagation. Spore abundance may be the result of seasonal changes in inoculum potential or changes in the AMF community for which seeds are exposed to germinate which could impact recruitment. Variation in relative abundance of the few dominant species may be able to differentially alter seedling recruitment and growth Lovelock [11]. The niches of AMF species have been proposed to be a function of nutrient supply and plant growth rate, which is affected by environmental factors including light Lovelock [14]. HMAs secretes substances that influence the immediate environment (amino acids and complete proteins) that can have a direct selective effect on the microbial community of the rhizosphere. Furthermore, they can induce changes in the plant physiology, such as root exudation and carbohydrate metabolism of the plant that can indirectly affect the microbial community Aggagant [15].

The abundance and diversity of AMF decreases when having degraded soils and contamination produced by agricultural and agrochemical practices. Pesticide application and tillage are practices that impose strong ecological and evolutionary selection on AMF in ecosystems, decreasing diversity and affecting community composition Roy [16]. Previous studies have demonstrated the deleterious effects of conventional agriculture on the diversity of AMF and the selection of specific taxa of AMF Roy [16]. Progressively, there is a loss of AMF taxa throughout the years of conventional agriculture until less wealth is obtained in old agricultural crops. Available P: N stoichiometry is the most important predictor of AMF richness and community composition. The establishment of the native soil community is a limiting factor in restoring native plant diversity and composition. However, inoculation with native soil microbes has shown to increase the rate of establishment of native plants Bever [17]. AMF were previously considered to have asexual reproduction only. But the mycelium of AMF contains from hundreds to thousands of nuclei within a continuous cytoplasm, which is reported to have inter-nuclear recombination in the dikaryotic life-stage, which varies in frequency between strains, despite the recombination of all nuclear genomes that have an average similarity of at least 99.8% Chen [18]. Therefore, AMF have a high plasticity to colonize a wide range of hosts and environments, by rapidly producing variable progeny, increasing their probability of producing offsping with different fitness than their parents Angelard [19]. Given the forced biotism of AMF, it makes the production of inoculants difficult, so the fungus requires metabolically active roots to complete its life cycle Souto [20]. Transformed root cultures are used to mass-produce *in vitro* propagules of AMF. Mosse and Hepper [21] were the first to use the dual culture system for the growth of *Glomus moseae* in root crops in clover; monoaxenic crops are used in research, agriculture, and ecological restoration Kokkoris and Hart [22]. To develop an *in vitro* culture system for newly isolated AM fungi, a great deal of optimization needs to be performed, such as the selection of appropriate culture systems and symbiotic host root partners, as well as the determination of appropriate culture conditions Akbar and Widianto [23]. Because the plant (host shift) directs the genetics of the fungus since it has high nuclear activity. Nuclei migrate favoring one type nucleus or another (changes in the frequencies of type nuclei). Therefore, it is not convenient to only make monosporic cultures, since it claims to have a tax on, but information is lost (types of nuclei). It is important to have a shelter in the greenhouse with different monocot and dicot hosts to avoid selection (Fracchia personal communication).

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The native consortium is a more feasible alternative to use as growth promoters in some species and may be a good option as biofertilizers under greenhouse conditions Quiñones-Aguilar [24]. AMF-based biofertilizers that can reduce production losses at both the nursery, and transplant and established plantation levels, since they increase the root surface and improve plant nutrition, which is reflected survival increments at the nursery level and transplantation, biomass production capacity and the quality of the final product, which, for the forest producer, it becomes more competitive and sustainable, with reductions in production costs and improved income. The mycorrhizal industry is very promising, challenges though remain and there are numerous bottlenecks to solve Vosatka [25]. Fundamental and applied research, farmers and industry must be conducted to provide consisting evidence for benefits of mycorrhiza in the real conditions of plant production Vosatka [25]. The *in vitro* propagation of AMF alters the morphology, genetics and functioning given the domestication of the strains. It is important to further examine the effects of domestication on AM fungi and predict how changes could highly affect the environment following inoculation with such strains Kokkoris and Hart [22]. Future research should determine whether region specific genomic recombination is linked to an isolated phenotype (eg, increased spore production, hyphal density, or mycorrhization rate) or to the suitability of economically important plants and crops Chen et al. [18]. Future progress prelude to the development of a future 'ecological engineering of AMF and their associated microorganisms' and its integration into modern plant breeding while taking care of the ecosystem services rendered by these valuable fungi Wifp [26].

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