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RESEARCH ARTICLE

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Effectiveness of native arbuscular mycorrhiza on the growth of four tree forest species from the Santa Marta Mountain, Veracruz (Mexico)

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Abstract

Aim of the study: The aim of this work was to isolate consortia of arbuscular mycorrhizal fungi (AMF) associated to *Liquidambar styraciflua* in soils of the Santa Marta Mountain in Veracruz, and to select highly effective mycorrhizal consortia on promoting the growth of four tree forest species with economic and ecological importance.

Area of study: Santa Marta Mountain, inside the buffer area of the Los Tuxtlas Biological Reserve in Veracruz (México).

Materials and methods: Ten composite samples of rhizosphere soil were collected from *L. styraciflua* trees of 13-15 cm DBH (diameter at breast height). Roots were fixed in FAA solution to determine the mycorrhizal colonization percentage, the abundance of morphospecies, and its effectiveness in promoting the growth of *L. styraciflua*, *Terminalia amazonia*, *Cordia alliodora*, and *Cojoba arborea*. Soil physical and chemical characteristics were also analysed, and soil type recognition was performed with the Reference Base for Soil FAO-ISRIC World-SICS. Mycorrhizal colonization was determined by the method of clearing and staining roots with trypan blue; total percentage of colonization was estimated by the Linderman-Biermann method. Spores were extracted for counting and identifying morphospecies from each soil sample, those with more effectiveness were selected and inoculated in the four tree species, based upon a completely random design there were evaluated height, number of leaves, total dry weight and foliar area.

Main results: Average mycorrhizal colonization percentage was 45% from natural conditions, samples one and four showed 80% of AMF-colonization. Average number of spores was 617 in 100 g^{-1} of dry soil. Forty-seven AMF-morphospecies were identified. After eight months significant differences were observed in root colonization, height, number of leaves, total dry weight, leaf area and foliar analysis of $N^{5+,}$ P^{5+} and K^{+} on plants inoculated with rhizosphere samples of *L. styraciflua*. *Terminalia amazonia* and *Cojoba arborea* showed greater response to the inoculation of AMF, they showed more height, number of leaves and more total dry weight; whereas *C. alliodora* appears to be low dependent on AMF.

Highlights: *Diversispora aurantia* and *Glomus aggregatum* are reported by the first time from Mexican humid tropics. Native AMF have potential biotechnological application. The mycorrhizal consortium six (*Glomus* and *Acaulospora*) was the more effective in promoting the development of the four tree species used in the experiment.

Keywords: Arbuscular mycorrhiza; liquidambar; cordia; terminalia; cojoba; México.

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Introduction

Arbuscular mycorrhizal fungi (AMF) are obligate symbionts that depend on colonizing plants for obtaining carbon sources for their growth; in reciprocity, fungi favour nutrient uptake such as P, N, Cu, Zn, K, Ca, Fe and Mg in plant hosts (Flores & Cuenca, 2004; Cuenca *et al*., 2007; Hernández & Salas, 2009). Studies on mycorrhizal plant dependency in rainforest have shown that most plant species are colonized by AMF (Zangaro *et al*., 2000; Kiers *et al*., 2000; Allen *et al*., 2003; Hernández & Salas, 2009). Poor nutrient availability in tropical soils constitutes an adequate environment for the development of AMF. Likewise, AMF, promote high tolerance to defoliation caused by herbivores (Saint-Pierre *et al*., 2004), and improve soil structure, preventing erosion (Rillig, 2004). In turn, AMF allow modifications in microbial populations, contributing as regulators of beneficial and pathogenic microbiota and influencing organic carbon dynamics and fertility of soils (Alarcon *et al.,* 2007a). Rodríguez *et al*. (2002) demonstrated that AMF diminishing both leaching and fixation of nutrients, as well as reducing soil erosion since AMF hyphae allow better uptake and mobilization of nutriments to the host, and favour soil aggregation. The symbiotic performance on plant host is equally influenced by hydric status of soil and light availability (Gavito *et al*., 2008; Shukla *et al*., 2008).

The research on arbuscular mycorrhizal fungus (AMF) in native tree forest species in Mexico is still incipient. However, several authors agree on the advantages that the AMF inoculation provides on improving root growth, increasing plant survival, reducing the time plants spend in nursery, reducing cost production due to reduction of fertilizer applications, as well as increasing plant quality (Gehring & Connell, 2005; Allen *et al*., 2003; Hernández & Salas, 2009). Other advantages of AMF inoculation are related to the increase of photosynthetic rate during acclimatization and development of micro-propagated plants, the induction of drought resistance, and the protection of roots against pathogen attack (Ferrera-Cerrato & Alarcón, 2004; Gavito *et al*., 2008; Shukla *et al*., 2008).

In particular, some studies reported that seedlings of *Liquidambar* sp. colonized by *Glomus mosseae, G. deserticola* and *G. etunicatum* showed improved P-absorption when compared to non-mycorrhizal plants (Kormanik, 1985). In addition, species of *Terminalia* (*T. arjuna, T. bellirica and T. amazonia*) are very sensitive to source of AMF inoculum ranged from 50 to 60% (Onguene & Kuyper, 2005; Aldrich-Wolfe, 2007). Furthermore, AMF genera such as *Glomus, Acaulospora, Entrophospora, Scutellospora, Gigaspora* and *Archaeospora* were found in *T. amazonia* (Onguene & Kuyper, 2001; Aldrich-Wolfe, 2007). Similarly, Wang & Qiu (2006) reviewed 36 plant species belonging to the Boraginaceae family, and 21 of them showed arbuscular mycorrhizal colonization, eight species showed facultative mycorrhizal dependency, and the remaining seven species did not form this symbiosis. Some *Cordia* species like *C. alliodora* (Allen *et al*., 1998), *C. curassavica* (Camargo-Ricalde *et al*., 2003), *C. ecalyculata* y *C. trichotoma* (Zangaro *et al*., 2003) are mycorrhizal species. There is little specific information about the effects of AMF in *Cojoba arborea* (L.) Britton & Rose. However, most members of the Fabaceae family are nitrogen-fixing trees that establish AMF symbiosis which favor both P-uptake and rhizobial nodulation in roots (Guzman-Plazola & Ferrera-Cerrato, 1990; Ezawa *et al*., 2002). Wang & Qiu (2006) mentioned that 296 out of 315 species for the Fabaceae family, showed mycorrhizal symbiosis, 255 of them had arbuscular mycorrhiza (mainly associated with *Glomus*), and 41 had other types of mycorrhizal association. More importantly, the studies of the mycorrhizal symbiosis in tropical rain forest have increased in the recent years; these studies were focused on understanding the diversity of AMF species, and both the potential application of some of them in tropical forest ecosystems, and the inoculation for restoration of disturbed tropical regions (Gehring & Connell, 2005).

About 95% of the rainforests of Mexico has been lost, and Los Tuxtlas region in Veracruz is one of the most affected. In this area it has been estimated that 75% of the original forest resources have already disappeared; and the remaining 20% is denoted by isolated fragments or as cornfield, shade coffee agroecosystems or grasslands (Castillo-Campos & Laborde, 2006). Soil loss is estimated between 20 to 6,284 ton ha^{-1} yr^{-1} (Ávila-Bello *et al*., 2012), and the later may also affect AMF diversity (Cuenca *et al*., 1998; Gavito *et al*., 2008). The ecological value of Los Tuxtlas Biosphere Reserve lies on being the place where the Huazuntlán River originates. This river supplies drinking water to over 600,000 inhabitants including the cities of Coatzacoalcos, Minatitlán and Acayucan, among others (CONANP, 2006). *Liquidambar styraciflua* L., is a tree species with ecological and economic importance that dominates deciduous forests in Mexico (400 to 1,800 masl), and this species forms arbuscular mycorrhizal symbiosis (Ruiz-Sanchez & Ornelas, 2014; Gual-Díaz & Rendón-Correa, 2014). The aims of this study were 1) to isolate AMF consortia associated to *L. styraciflua* from soils of the Sierra de Santa Marta, Veracruz, and 2) to evaluate an AMF consortium highly effective on promoting the growth of *C. alliodora*, *T. amazonia* and *Cojoba arborea*, when compared to fertilizer application under nursery conditions. The later tree species have high economic, cultural and ecological value in the mentioned tropical region.

Materials and methods

Study area, sampling collection and processing of soil samples

The study area is located in the Sierra de Santa Marta (SE, Veracruz, Mexico). Rhizosphere sampling was conducted in a deciduous forest with *L. styraciflua* as predominant species (700 masl; 18° 35 ‘N, and 94° 35’ and 95 ° 02 ‘W). Climate is hot and humid with rain all year around, annual average temperature between

22 and 24 ° C, and annual precipitation between 3500-4000 mm. The most important soil types are Acrisols and Versitols (Mariano & García, 2010). Besides *L. styraciflua*, other tree species in such forest are *Clethra mexicana*, *Carpinus* sp., *Quercus affinis*, *Q. skinneri*, and *Virola guatemalensis* (Castillo-Campos & Laborde, 2006).

The sampling was conducted by selecting 10 trees of *L. styraciflua* of 13-15 cm DBH (diameter at breast height) because they were the more abundant individuals in the area. Four samples of rhizosphere soil, call consortium, were taken for each tree (20 cm depth, because at that depth it can be found greater microbial activity), and mixed for obtaining 1 kg of soil (González & Barrios, 1983). Soil samples were stored at 5 °C in properly labelled plastic bags for further chemical properties and AMF-morphospecies analyses. Additionally, root samples were taken and fixed in FAA solution (Sieverding, 1985), to determine the percentage of AMF-colonization.

Soil texture was determined by the method particle size and organic mater of Walkley & Black (1934). In addition, pH with the potenciometric method (APHA, 1998) and the content of N-total with the method of micro-Kjeldahl (APHA, 1998); P-total by Bray I (Bray & Kurtz, 1945) and Ca and Mg with EDTA titration method (Barrows & Simpson, 1962). Soil type recognition was carried out by the baseline for the FAO World Soil-ISRIC-ISSS (1998). Mycorrhizal colonization was made by the method of clearing and staining roots with trypan blue (Phillips & Hayman, 1970), and the total colonization was estimated by the method of Biermann & Linderman (1981).

Extraction, counting and identification of AMF spores from each tree (each soil sample corresponds to one consortium) were based on 100 g of dry soil collected from the field (Gerdeman & Nicolson, 1963; Schenck & Pérez, 1990; INVAM, 2009. Scientific names of AMF morphospecies were corroborated in accordance to the identification keys and scientific papers included in the following web site http://www.amf-phylogeny.com. In addition, culture traps using the soil collected from the field plus sand (1:1 v/v) were set for propagating the native AMF, for six months (Sieverding, 1991). *Brachiaria decumbens* was used as host under greenhouse conditions (average minimum and maximum temperature of 20 °C and 38 °C, respectively), and watered with tap water as needed. After six months, irrigation was suspended for a week to allow the AMF sporulation. Spores were extracted and mounted on slides to carry out their taxonomic identification by following the references previously mentioned.

Assessing and selecting effective AMF consortia

To assess the effectiveness of AMF consortia a completely randomized experimental design was set with three treatments (consortia, Triple 17 fertilizer (N-P-K, 12-24-12) and a control); ten replicates for each treatment (n=10) were distributed. Data were examined by means of an analysis of variance, and the mean comparison test (Tukey, α=0.05) (SAS Institute, 2002).

Each rhizosphere soil sample (20 g) collected from field conditions was inoculated in pots containing 1.5 kg of autoclaved substrate (regional soil+sand, 1:2 v/v). After 15-days seedlings of *L. styraciflua* were transplanted and maintained under greenhouse conditions (low shaded to 60% of light and average temperature of 28° C) and irrigated with tap water as needed. After eight months of growing, plant height, leaf number, leaf area, total dry weight (leaves, stem and root) and percentage of mycorrhizal colonization were determined. This experiment allowed to determine which mycorrhizal consortium has the optimum effect on seedlings, which was selected for using in the following experimentation.

Seeds from *Terminalia amazonia*, *Cordia alliodora*, and *Cojoba arborea* were sown and germinated in plastic trays with sterile substrate (local soil+sand, 1:1 v/v). Subsequently, seedlings of 1.5 cm height were transplanted to plastic bags with sterilized substrate with the same composition described above. One third of plants of each tree species was inoculated with 20 g of the mycorrhizal consortium selected from the previous experimental stage (n= 10). Another third of the plants was fertilized with one gram of Triple17; and the remaining third of the seedlings stayed without neither inoculation nor fertilizer application as control treatment. The experiment was conducted under nursery conditions with 60% shade, and average temperature of 28 °C. Plants were daily irrigated to field capacity with tap water. After five months, plants were harvested to measure plant height, leaf number, total dry biomass, all variables used as surrogates of plant growth during the studied period, and percentage of mycorrhizal colonization.

Results

Soils chemical properties and identification of AMF morphotypes

The pH values of soil samples taken in the field ranged from 4.8 to 5.3, and rhizosphere samples showed high organic content (6.7% to 9.9%). In regard to the nutrient content, it was found high content of P (71.6 to 98.5 mg kg^{-1}) in samples 6, 7, 8, 9 and 10; and for all samples the content of N (0.33 to 0.49%), and Ca (436.3 to 1386.5 mg kg^{-1}) was high. The content of Mg was high only for samples 1, 3, and 10 (491.8 to 888.1 mg kg^{-1}). The soil texture was clay (90%) and sandy clay loam (10%) (Table 1). Thirty-three AMF morphotypes were identified from the rhizosphere samples of *L. styraciflua* collected from the field, while in the pots in which AMF were propagated with *B. decumbens*, only 18 morphotypes were identified (Table 2). The most common AMF found in all samples were *Sclerocystis sinuosa, Acaulospora scrobiculata* and *Diversispora aurantia*. In contrast, *S. clavispora* and *Glomus aggregatum* were recorded only for *B. decumbens* pots. Overall, more AMF morphotypes were recorded from *L. styraciflua* at field conditions when compared to the propagation in culture traps. From the 47 AMF morphotypes identified, 41 of them corresponded to *Glomus* (87.2%), five to *Acaulospora* (10%), and one to *Diversispora* (2.8%). From these morphotypes, five were identified to species level: *S. clavispora* (Trappe), *S. sinuosa* (Gerdemann & Bakshi, Almeida & Schenck), *and A. scrobiculata, G. aggregatum* (N.C. Schenck & G.S. Sm. Emend. Koske), and *D. aurantia* (Blaszk., Blanke, Renker & Buscot). The last AMF species was recently reclassified into the family Diversisporaceae (Schüßler & Walker, 2010).

Effectiveness of AMF consortium on growth promotion

The inoculation of *Liquidambar styraciflua* with the rhizosphere samples collected from the field had significant effects on plant growth. The rhizosphere sample number six showed most consistent beneficial effects on height, number of leaves, leaf area, and total dry weight when compared to the remaining samples containing different mycorrhizal consortia and to the control (Figure 1A-D), consortium six shows no statistical differences with the other consortia, except height in sample two. Plants inoculated with consortium six and eight showed high mycorrhizal colonization percentages, 88% and 93%, respectively; no mycorrhizal colonization was observed in control plants. Based on these results, the mycorrhizal consortium number six, that includes *Glomus* and *Acaulospora* species, was selected for the other experimental phase, because it showed more effectiveness in the tree seedlings inoculated, despite no statistical differences between samples.

The addition of mycorrhiza (consortium composed by *Glomus* and *Acaulospora*) showed differential effects on the growth of the other three tree species (Figure 2). *Cordia alliodora* showed significantly greater growth (height and total dry weight) due to fertilization than control or inoculated plants (Figure 2A and C). *Terminalia amazonia* presented greater height, leaf number, and total dry weight due to the inoculation of the AMF consortium than control or fertilized plants (Figure 2A, B, and C). In contrast, *C. arborea* showed growth variations due to treatment effects; plant height was not significantly stimulated by either fertilization or AMF inoculation (Figure 2A); in contrast, the number of leaves decreased significantly due to fertilization (Figure 2B), while the total dry

Table 1. Physical and chemical characteristics*, mycorrhizal colonization and spore number in 100 g of dry soil of arbuscular mycorrhizal fungus (AMF) from ten samples collected at a *Liquidambar styraciflua* plantation in La Sierra de Santa Martha, Veracruz.

Rhizosphere sample	Texture	pH	Organic mater (%)	Nutritional content				Mycorrhizal colonization (%)	Number of spores (100 g dry soil)
				Total N (%)	Total P (%)	Mg (mg kg^{-1})	Ca (mg kg^{-1})		
1	Clay	5.3	8.2	0.41	24.6	491.8	843.9	80	810
2	Clay	5.3	6.6	0.33	29.1	390.6	701.8	58	450
3	Clay	5.3	7.9	0.39	24.6	632.3	922.9	49	650
4	Clay	5.2	7.4	0.37	29.1	355.5	436.2	78	720
5	Clay	5.2	6.6	0.33	52.2	362.7	719.4	49	610
6	Clay	4.8	7.5	0.37	71.5	270.9	838.8	50	730
7	Silty-Clay-Loam	5.1	8.7	0.43	90.1	349.1	1192.3	68	675
8	Clay	5.2	9.9	0.49	98.5	279.6	1386.5	10	425
9	Clay	5.1	8.1	0.41	90.1	276.7	1011.3	60	680
10	Clay	4.9	8.1	0.41	96.8	888.1	999.2	60	620

*Data for soil properties are given on the basis of values provided by a specialized laboratory, and do not include replicates for estimating either standard deviations or standard errors for each soil parameter.

Table 2. AMF morphotypes associated with *Liquidambar styraciflua* (A) under field conditions, and trap crops of *Brachiaria decumbens* (B), after eight months of propagation.

	(A)	(B)
Glomerales/ Glomeraceae	*Sclerocystis sinuosa* Gerd. & Bakshi*	*Sclerocystis clavispora* Trappe*
	Glomus sp. 1, *Glomus* sp. 2	*Glomus aggregatum* Schenck & Sm.*
	Glomus sp. 3, *Glomus* sp. 4	*Sclerocystis sinuosa* Gerd. & Bakshi*
	Glomus sp. 5, *Glomus* sp. 6	*Glomus* sp. 28
	Glomus sp. 7, *Glomus* sp. 8	*Glomus* sp. 29
	Glomus sp. 9, *Glomus* sp. 10	*Glomus* sp. 30
	Glomus sp. 11, *Glomus* sp. 12	*Glomus* sp. 31
	Glomus sp. 13, *Glomus* sp. 14	*Glomus* sp. 32
	Glomus sp. 15, *Glomus* sp. 16	*Glomus* sp. 33
	Glomus sp. 17, *Glomus* sp. 18	*Glomus* sp. 34
	Glomus sp. 19, *Glomus* sp. 20	*Glomus* sp. 35
	Glomus sp. 21, *Glomus* sp. 22	*Glomus* sp. 36
	Glomus sp. 23, *Glomus* sp. 24	*Glomus* sp. 37
	Glomus sp. 25, *Glomus* sp. 26	*Glomus* sp. 38
	Glomus sp. 27. Esporocarpo	*Glomus* sp. 39. Esporocarpo
Diversisporales/ Acaulosporaceae	*A. scrobiculata* Trappe*, *Acaulospora* sp.1 *Acaulospora* sp. 2, *Acaulospora* sp. 3	*A. scrobiculata* Trappe* *Acaulospora* sp. 4
Diversisporales/Diversisporaceae	*Diversispora aurantia* (Błaszk., Blanke, Renker & Buscot) Walker & Schuessler*	*Diversispora aurantia* (Błaszk., Blanke, Renker & Buscot) Walker & Schuessler*

* For these AMF species the keys for its description were based on the information provided at the web site: http://www.arbuscular-mycorrhiza.net/amphylo_species.html (retrieved on July 2016).

weight significantly increased due to AMF inoculation (Figure 2C). Mycorrhizal colonization in the three tree species ranged from 2 to 99 %. The AMF consortium was very infective in *C. alliodora* and *T. amazonia* (71.5 and 99.1%, respectively), but mycorrhizal colonization in *C. arborea* only reached 20.8%.

Discussion

The ten rhizosphere soil samples collected from *L. styraciflua* trees at field conditions had high fertility and strongly acid pH, that probably cause several problems of toxicity by aluminium and magnesium. The later coincides with the studies of Castillo (2004), Álvarez-Sánchez *et al*. (2007) and Mariano & García (2010), conducted in the same region, in which they reported Acrisol soils with clay texture, acid pH (4-5), and 6% of organic matter content.

Sample nine had the lowest content of organic matter, P and N, but had more spores and high mycorrhizal colonization. In this sense, Egerton-Warburton *et al*. (2007) mentioned that when soil fertility is high, the abundance of spores is low; the later highlight that soil fertility is an important factor for these fungal propagules (Johnson *et al*., 1992). The average number of spores recorded (640 in 100 g of dry soil) in *L. styraciflua* rhizosphere is greater than that (141 in 100 g of dry soil) reported by Rodríguez-Morelos (2011) at the same study area. Similarly, root colonization percentages from field samples do not always correlates with the number of spores. Cuervo & Rivas (2007) indicated that the number of spores and the colonization percentage are indicators of AMF establishment in roots, but they do not indicate the mycorrhizal effectiveness on host. Shi *et al*. (2006) referred that when the AMF species richness is greater, the root colonization percentage is higher too, regardless the spore number in the soil. For *L. styraciflua* the number of spores found in the AMF rhizosphere at field conditions might indicate that the native mycorrhizal inoculum has high infectivity in roots as it was observed in the sample nine (> 50% colonization). According to the field samples results, it can be concluded that soil fertility and pH are not affecting the performance of native AMF; this statement is strongly supported by the number of spores found (640 in 100 g of dry soil), the number of AMF morphospecies (47), and the mycorrhizal colonization percentages (73.9% to 93%).

The total number of AMF associated with the rhizosphere of *L. styraciflua* recorded in this study was 47 morphoespecies, and 97.8% of those corresponded to *Acaulospora* and *Glomus* morphospecies. The inoculum characterization from field samples and culture traps showed dominance of *Glomus* (87.2%) whose morphotypes were not identified. The spores of *Glomus* and *Acaulospora* genera have strong association with *L. styraciflua*. *G. aggregatum* and *S. clavispora* are reported by the first time in the Mexican tropic.

The growth of leaves, height and foliar area of *L. styraciflua* was significantly enhanced due to the inoculation of the ten consortia, however there is no

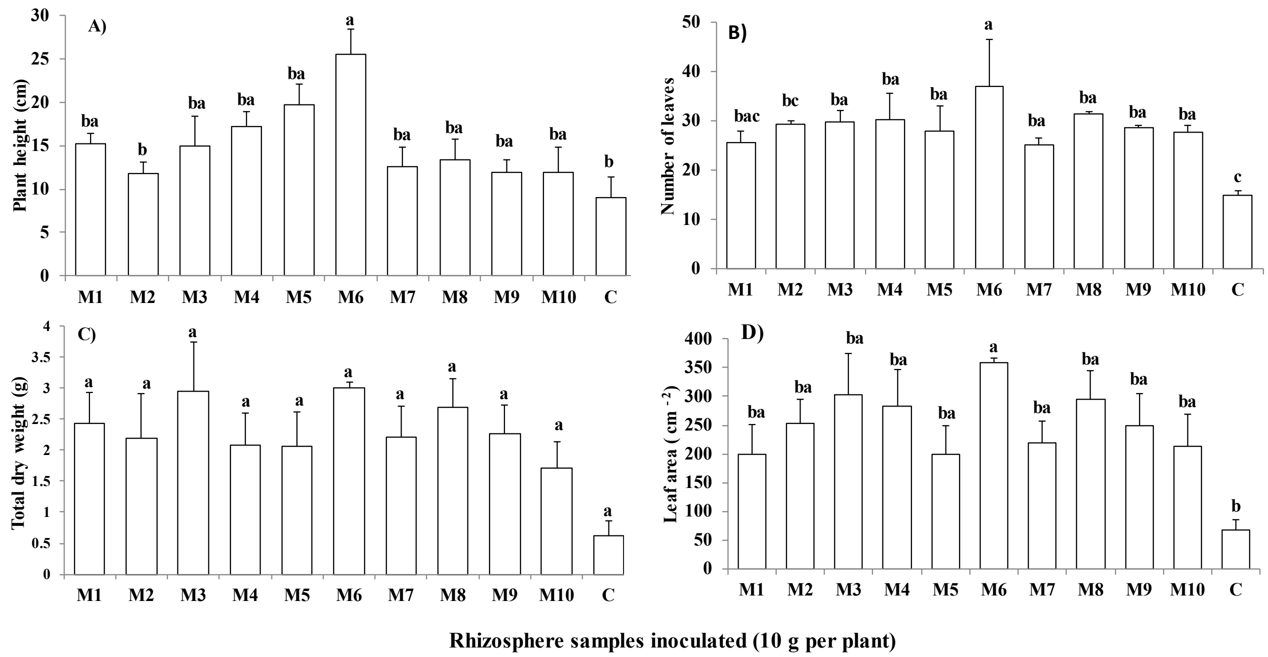

Figure 1. Height (A), number of leaves (B), leaf area (C), and total dry weight (D) of *Liquidambar styraciflua* plants due to the inoculation of ten arbuscular mycorrhizal consortia (M1 to M10) collected from a liquidambar forest at Sierra de Santa Marta, Veracruz, after eight months of inoculation. C = Control plants. Means ± Standard error (n= 5). Different letters between treatments indicate significant differences.

statistical significance between the different consortia, only consortia six shows statistical significance when compared to the control. *L. styraciflua* shows some dependency on species of *Glomus* and *Acaulospora*, genera found in the AMF consortium from sample number six.

Terminalia amazonia and *Liquidambar styraciflua* were the species with the highest response to AMF inoculation, while *C. alliodora* presented no significant growth response to inoculation. Furthermore, *C. alliodora* is a plant species naturally associated with *Glomus*, *Entrophospora* and *Gigaspora* fungi species (Caballero & Cortés, 1991; Cuervo & Rivas, 2007); however, under our experimental conditions, *C. alliodora* had only response to inorganic fertilization. In contrast, *Cojoba arborea* had greater growth response due to AMF inoculation than fertilizer application, but lower when compared to control plants. Unfortunately, there are scarce studies about the effect of AMF inoculation on this tree species. Abd-Alla *et al*. (2000) demonstrated that the dual inoculation of both *Rhizobium* and AMF in legumes increase the growth rate in *C. arborea,* similar to our present results. The limited response to fertilization by *C. arborea* might be due to salinization effects caused by the fertilizer application, or because this plant species requires higher fertilization at different growth stages as indicated by Cordero *et al*. (2003). In contrast, AMF inoculation resulted in positive effects on growth, which has not been extensively documented.

The mycorrhizal inoculation demonstrates that the species present in the AMF consortium number six (*Glomus* and *Acaulospora*) are highly effective on stimulating the growth of three tree species (*L. styraciflua*, *T. amazonia*, and *C. arborea*) studied in this research. Low percentages of mycorrhizal colonization could limit the symbiosis benefits to plants due to reduced arbuscular interface, which is responsible for the nutrient exchange in both symbionts (Bago *et al*., 2000). However, mycorrhizal colonization does not necessarily correlate with the beneficial effects on plants (Alarcón *et al*., 2007a; Alarcón *et al*., 2007b), since *C. arborea* was the tree species with the lowest mycorrhizal colonization percentage, but produced greater dry biomass when compared to the control. In contrast, *C. alliodora* did not showed significant growth promotion than control plants in spite of the AMF colonization was about 70%.

Our results suggest that native AMF have potential biotechnological applications in greenhouses where tropical tree species are propagated, but the expected results will depend on the tree species.

Conclusions

Liquidambar styraciflua harbours abundant AMF morphospecies that exert positive effects on this species growth at nursery conditions. The amount of AMF morphospecies found at field conditions was

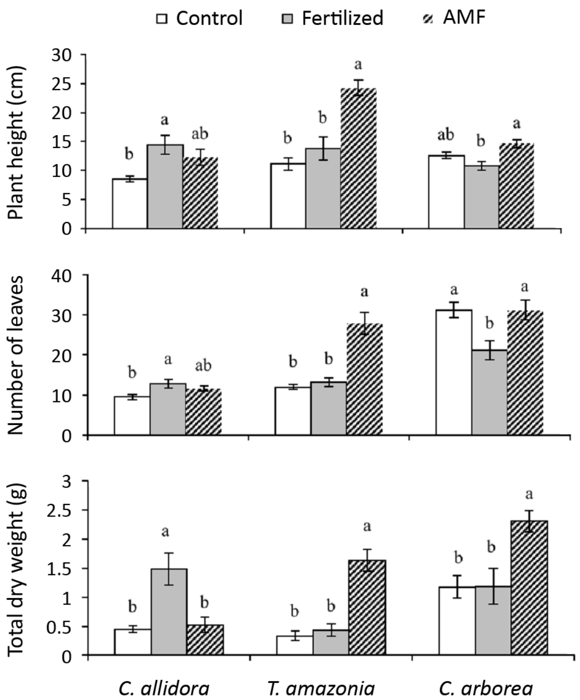

Figure 2. Height (A), number of leaves (B), and total dry weight (C) of *Cordia alliodora*, *Terminalia amazonia,* and *Cojoba arborea* plants growing with three treatments: inoculated with an arbuscular mycorrhizal consortium (AMF) isolated from a liquidambar forest; fertilized with triple 17 (1 g pot^{-1}), and control conditions. Measurements were carried out (ANOVA and Tukey test) after five months of treatments application under greenhouse conditions. Means ± Standard error (n= 5). Different letters between treatments indicate significant differences.

higher than that identified at culture trap. The effect of inoculation with those AMF, particularly a consortium of *Glomus* and *Acaulospora*, on other three species depended on the species when compared to control or fertilized plants. *Terminalia amazonia* showed the highest response to the applied AMF consortium, whereas *C. alliodora* seems to be a plant species with low AMF dependence to promote seedling growth. The positive response of three of the four studied species suggests the possibility of carrying out technological developments based on native mycorrhizae, to be used in reforestation programs for rural areas.

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