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Arbuscular mycorrhizal association in *Conocarpus erectus* (Combretaceae) in mangroves from Yucatán, Mexico

Asociación micorrízica arbuscular en *Conocarpus erectus* (Combretaceae) en manglares de Yucatán, Mexico

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Abstract
Background: Soil flooding and salinity can be limiting for arbuscular mycorrhizal fungi (AMF), yet they are found in mangrove ecosystems. Arbuscular mycorrhizal association could influence the functioning of mangrove ecosystems, but little is known about its roll and balance in these dynamic systems.
Question: What is the status of the arbuscular mycorrhizal association in *C. erectus* under natural conditions?
Species study: *Conocarpus erectus* is a tree or shrub species that establishes in mangrove ecosystems and is tolerant to elevated levels of salinity and flooding.
Study site and dates: Three zones representing a range of conditions of salinity were selected in the Ría Lagartos Biosphere Reserve in Mexico, as well as two contrasting collecting seasons in 2009 and 2010: northwind season and drought season.
Methods: Roots were sampled from *C. erectus* plants in each zone to evaluate the percentage of arbuscular mycorrhizal colonization and rhizospheric soil samples were taken to evaluate AMF spore density and species richness.
Results: The highest percentage of root colonization was recorded in the site of highest salinity during the northwind season, with this value decreasing in the drought season. The same seasonal pattern was observed in spore density. The highest richness was recorded in the site of lowest salinity in both seasons. A total of 16 AMF species were identified.
Conclusions: The results suggest that seasonality, in its relation with soil salinity and soil water availability, can influence the development and symbiotic association of the AMF in mangrove associated communities dominated by *C. erectus*.
Key words: Arbuscular mycorrhizal fungi, coastal wetland, mangrove, salinity, soil moisture content.

Resumen
Antecedentes: La inundación y la salinidad del suelo pueden ser limitantes para los hongos micorrízógenos arbusculares (HMA), sin embargo se encuentran en los ecosistemas de manglar. La asociación micorrízica arbuscular (MA) podría influenciar el funcionamiento de los manglares pero se conoce poco su papel en estos sistemas dinámicos.
Pregunta: ¿Cuál es el estatus de la asociación MA en *Conocarpus erectus* bajo condiciones naturales?
Especie de estudio: *C. erectus*, especie arbórea o arbustiva, se establece en los manglares y es tolerante a niveles elevados de salinidad e inundación.
Sitio y años de estudio: Se seleccionaron tres zonas representando un intervalo de condiciones de salinidad en la Reserva de la Biósfera Ría Lagartos en México y dos temporadas contrastantes de muestreo: nortes y sequía.
Métodos: Se colectaron raíces de *C. erectus* en cada zona para evaluar el porcentaje de colonización MA y se tomaron muestras de suelo rizosférico para evaluar la densidad de esporas y la riqueza de especies de HMA.
Resultados: El porcentaje de colonización radical más elevado fue registrado en el sitio más salino durante la temporada de nortes, disminuyendo en sequía. Se observó el mismo patrón estacional en la densidad de esporas. La mayor riqueza de especies de HMA fue registrada en el sitio menos salino en ambas temporadas. Se identificaron 16 especies de HMA.
Conclusiones: La estacionalidad, en relación con la salinidad y disponibilidad de agua en el sustrato, puede influenciar el desarrollo e interacción con los HMA en las comunidades asociadas al manglar dominadas por *C. erectus*.
Palabras clave: Contenido de humedad en el suelo, hongos micorrizógenos arbusculares, humedal costero, manglar, salinidad.

Mangrove is a type of wetland found in the intertidal zone of tropical and subtropical coasts (Odum *et al.* 1985, Spalding *et al.* 2010), at the interface between the influence of the saline seawater and discharges of continental freshwater (Moreno-Casasola *et al.* 2006, Rzedowski 2006). In tropical zones, mangrove forests are vital to the maintenance of coastal ecosystems' health (Adeel & Pomeroy 2002). Plant species that develop in mangrove ecosystems are classified into two types: true mangroves and associated species (Tomlinson 1986).

Conocarpus erectus L. (Combretaceae) is a tree or shrub mangrove associated species (López-Portillo & Ezcurra 2002) that establishes in a transitional manner in this ecosystem, between the true mangrove species and the plant communities further inland (Odum 1985, Krauss *et al.* 2008). *Conocarpus erectus* represents an important component of the Caribbean mangroves (López-Portillo & Ezcurra 2002), since the transition areas in which it establishes typically present soil with high percentage of sand and conditions of salinity and flooding in which other tree species do not prosper (Tovilla-Hernández & De La Lanza-Espino 1999, Thom 1967, Carter *et al.* 1973, Ellison & Farnsworth 1996, Rzedowski 2006). *C. erectus* possess importance by its medicinal and ornamental uses and as timber species (Tovilla-Hernández & De La Lanza-Espino 1999, Al-Humaid & Moftah 2007, Abdel-Hameed *et al.* 2012, Hussein 2016, Raza *et al.* 2018).

Among the biotic factors that could influence the functioning of mangrove ecosystems we found the arbuscular mycorrhizal association; however, little is known about its importance in these wetlands. Arbuscular mycorrhizal fungi (phylum Glomeromycota; Schüßler *et al.* 2001) are obligate symbionts recognized for providing nutritional benefits to their hosts and conferring tolerance to various stresses, such as elevated salinity in the substrate (Solaiman & Hirata 1996, Sokri & Maadi 2009, Borde *et al.* 2011). For this reason, it is likely that *C. erectus* benefits from association with these symbionts in its natural environment.

Despite the fact that elevated salinity and flooding can be detrimental to arbuscular mycorrhizal fungi (AMF) development (Juniper & Abbott 1993, Juniper & Abbott 2006, Le Tacon *et al.* 1983), mangrove plants present arbuscular mycorrhizal colonization in their roots (Lingan *et al.* 1999, Kumar & Ghose 2008, D'Souza & Rodrigues 2013b, Hu *et al.* 2015, Sengupta & Chaudhuri 2002, Wang *et al.* 2014, Gupta *et al.* 2016) and some assays have shown that the plants that establish in these ecosystems receive nutritional benefits (increased absorption of phosphorus, nitrogen and potassium; Wang *et al.* 2011, Xie *et al.* 2014, Dsouza & Rodrigues 2017) when associated with AMF. This suggest that not only are the AMF present in mangrove ecosystems, but also are effective symbionts for the species that establish there, where they likely perform as important a function as they do in terrestrial ecosystems (Ramírez-Viga *et al.* 2018).

With the aim to achieve an approach of the mycorrhizal status of *C. erectus* under natural conditions, roots and rhizospheric soil were collected from this species in mangroves of the Ría Lagartos Biosphere Reserve in Mexico. To determine temporal and spatial variation of some relevant components of the association in mangrove ecosystems, sampling was conducted in sites with different one-year typical salinity and, due to mangroves being seasonally dynamic environments (Zhang *et al.* 2016), in two contrasting climatic seasons (dry and cold northerly fronts or northwind).

Due to the detrimental effect that salinity and flooding can have on the AMF, we expected that in zones classified as more saline and in the wet season (when flooding may increase due to rain input), the fungal variables of AMF percentage of root colonization, spore density and species richness presented lower values than in zones classified as less saline and in the dry season (when flooding may decrease in de absence of rain input).

Materials and methods

Study area. The study area is found in the Ría Lagartos Biosphere Reserve, in the state of Yucatán, Mexico, between the coordinates: 21° 37' 29.56'' and 21° 23' 00.96'' N, 88° 14' 33.35'' and 87° 30' 50.67'' W. The study area represents a mangrove pertaining to the physionomic kind of "Dwarf mangrove", characterized by being an extreme environment with highly saline and low in nutrient availability soils, strong winds and transient flooding in rain and northwind seasons, where trees heights ranges between 1 and 2 meters (Flores-Guido & Espejel-Carbajal 1994, CONANP 2007)

Three locations, consisting on *Conocarpus erectus* forests, were selected in the study area. These sites were classified into three categories according to salinity data recorded in the zone by the National Commission of Protected Natural Areas (CONANP, by its Spanish acronym) in the year 2009: Higher Salinity (HS), with a mean salinity of 86 ppt (parts per thousand), Medium Salinity (MS) with mean salinity of 70 ppt and Lower Salinity (LS) with mean salinity of 62 ppt.

Three main climatic seasons occur in the State of Yucatán: (1) the rainy season, which occurs from June to October, and in which the coast of the Yucatán Peninsula receives the majority of its annual mean precipitation (< 700 mm); (2) the season of northwind, which occurs from November to February and is characterized by precipitation (20-60 mm), strong winds (> 80 km/h) and relatively low temperatures associated with polar fronts; and (3) the dry season or drought season, characterized by the

absence of precipitation, which occurs from March to May (Jiménez & Orellana 1999, Vidal-Zepeda 2005). Sampling for this study was conducted in northwind (December 2009) and drought (May 2010) seasons.

Collection and processing of roots and soil. In each of the three collection sites (HS, MS and LS), 20 individuals of *Conocarpus erectus* were selected and georeferenced. Fine roots were taken from each of these individual plants in order to quantify the percentage of arbuscular mycorrhizal colonization. In addition, four rhizospheric soil samples were taken (one from each cardinal point around the plant: 1 kg of soil in total, used as a composite sample per tree) to determine spore density, identify the AMF species from the field samples and for use in of propagation pots. The soil moisture content at each site was evaluated from the rhizospheric soil collected from each individual. For this, a subsample of the soil was oven-dried at 60 °C until reaching constant weight and the difference between the fresh and dry soil weight calculated.

Root staining and evaluation of the percentage of mycorrhizal colonization. Collected roots were washed, stained with trypan blue and mounted on slides, following the procedure of Phillips and Hayman (1970), modified by Hernández-Cuevas *et al.* (2008). The total percentage of mycorrhizal colonization in these roots was quantified following the method of McGonigle *et al.* (1990), modified by Hernández-Cuevas *et al.* (2008).

Spore extraction. The rhizospheric soil was dried at ambient temperature and the spores extracted using the techniques of wet sieving and decantation (Gerdemann & Nicolson 1963) and centrifugation with a saccarose gradient (Daniels & Skipper 1982), modified by Hernández-Cuevas *et al.* (2008). The spores extracted from each sample were placed on slides with polyvinyl alcohol + lactophenol (PVLG) and Melzer reagent for subsequent identification. These spore samples extracted from the rhizosphere were used to quantify the spore density in 50 g of soil and to determine AMF richness. The numbers of potentially viable and non-viable spores were estimated in each sample, categorizing as potentially viable the spores that presented cellular content and apparently undamaged cell walls.

Spore propagation. Arbuscular mycorrhizal fungi spores were propagated in order to obtain samples in better condition than those obtained from field sampling and thus to facilitate the identification of species. Propagation of spore communities was conducted in culture pots, following the method of Hernández-Cuevas & García (2008) and using *Zea mays* as a host species. At the end of this bioassay, the soil was processed with the technique of wet sieving and decantation (Gerdemann &Nicolson 1963) and centrifugation with a sucrose gradient (Daniels & Skipper 1982), modified by Hernández-Cuevas *et al.* (2008). The spores extracted from each sample were placed on slides with PVLG and Melzer reagent.

Identification of AMF species. Determination of the AMF species present in the rhizosphere of *C. erectus* was conducted using the AMF spores extracted from the rhizosphere of the mangroves and from the propagation pots. From these propagules, the arrangement, consistency, shape, size, color, wall texture, number of layers that comprise the wall, ornamentation, type of hyphae, auxiliary structures and scars were recorded. This was conducted using an optical microscope with a ruler reticle and objectives of 10X, 40X, 60X and 100X. The spore descriptions were compared with those of Schenck & Pérez (1988), those of West Virginia University (2019) International Culture Collection of (vesicular) Arbuscular Mycorrhizal Fungi (INVAM, by its Spanish acronym) (invam.wvu.edu/), those of the website of Janusz Blaszkowski (2003) (www.zor.zut.edu.pl/Glomeromycota/) and those of Arthur Schüßler (2020) (www.amf-phylogeny.com/).

Statistical analyses. Soil moisture content, arbuscular mycorrhizal colonization and AMF spore density were analyzed using two-way analysis of variance, with season and collection site as factors. This analysis was conducted with the software SigmaStat 3.2. Correlation analysis was performed to know the strength and direction of the relation between soil water content and total percentage of colonization.

Results

Soil moisture content. Soil moisture content (Figure 1) differed significantly among sites and between seasons of sample collection ($F_{2, 114}$= 7.888; $p < 0.001$). The highest values of moisture content in the sites HS and MS were recorded during northwind season.

Arbuscular mycorrhizal colonization and AMF spore density. In the roots of *C. erectus*, arbuscular mycorrhizal colonization (Figure 2) of types *Arum* and *Paris* were recorded. The most and least frequent structures were hyphae and arbuscules, respectively. These structures were recorded in the roots from all collection sites and in both seasons. Analysis of variance revealed significant differences for the percentage of total colonization between collection seasons ($F_{1, 114}$ = 5.687; p = 0.019) and the interaction of these with the collection sites ($F_{2, 114}$ = 6.185; p = 0.003). The percentage of total colonization (Table 1) varied significantly between seasons only in site HS, decreasing during the drought season. Of the three sites, HS

presented the highest values of colonization in the northwind season. During the drought season, no significant differences were found among sites. Correlation analysis showed a significant relationship between soil water content and total percentage of AMF colonization ($p < 0.05000$) with a correlation coefficient of -0.2994.

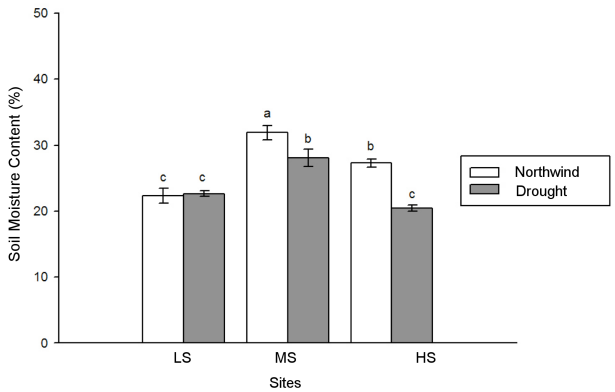

Figure 1. Soil moisture content in the sampling sites in the two periods sampled: northwind and drought seasons. LS = lower salinity, MS = medium salinity, HS = higher salinity

A total of 94 % of the field spores presented signs of parasitation, had no content or were damaged, for which reason they were considered non-viable. Spore density (Table 1) did not vary significantly among sites but did between seasons in the site HS ($F_{1, 107} = 4.826$; $p = 0.030$), with the highest values of density presented during the northwind season.

Richness of AMF species. A total of 16 AMF species associated with the rhizosphere of *C. erectus* (Table 2) were identified. These belonged to eight genera and five families. The species found in all of the sites were *Acaulospora scrobiculata*, *Funneliformis geosporum, Claroideoglomus etunicatum*, *Glomus rubiforme* and *Scutellospora erythropus*. In addition to these 16 species, a morphotype of the genus *Gigaspora* was recorded that could not be identified to species level.

The site that presented the greatest richness in both seasons sampled was LS (16 species for both seasons), followed by HS (10 species for both seasons) and finally MS (9 species for both seasons) (Table 2). No different species were recorded in the propagation pots. *Gigaspora* sp. and *Sclerocystis microcarpus* were registered only in the drought season and *Acaulospora foveata*, *A. myriocarpa*, *A. appendicula*, *Funneliformis coronatum*, *Glomus lacteum* and *G. microaggregatum* were only registered in the northwind season. Also we found some unique species by study site: *A. myriocarpa* was only found in the MS site and the species *A. foveata*, *A. appendicula*, *Gigaspora* sp., *F. coronatum*, *G. lacteum* and *S. microcarpus* were only registered in LS site. We did not find unique species in the HS site (Table 2).

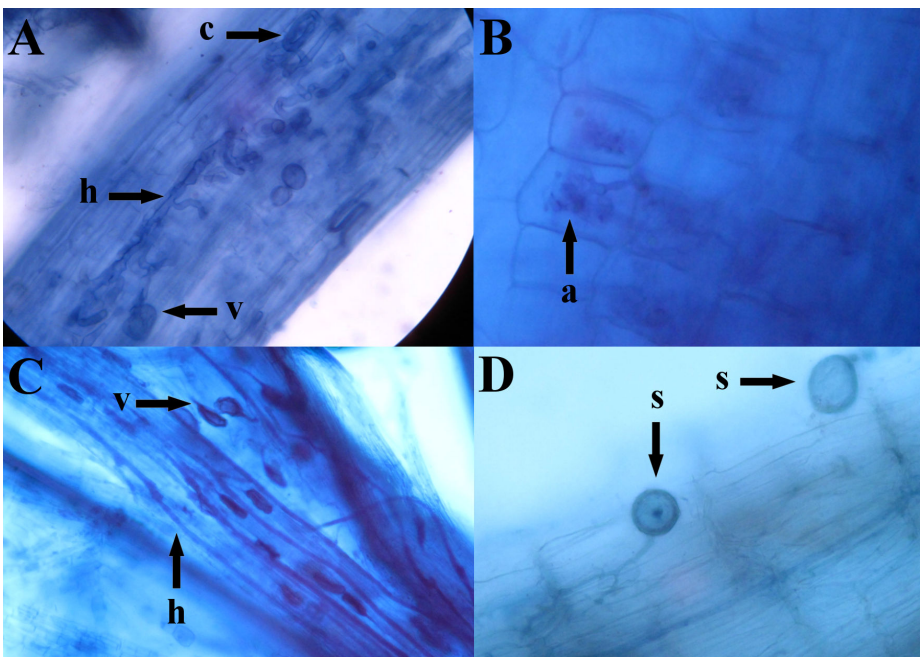

Figure 2. A-D. Arbuscular mycorrhizal fungi structures colonizing roots of *C. erectus*. h = hyphae, v = vesicles, s = spores, c = coil and a = arbuscule are pointed out with arrows in the different images. Photographs taken in optic microscope: A 10X, B 60X, C 10X, D 40X

Table 1. Total percentage of mycorrhizal colonization in the roots of *Conocarpus erectus* and AMF spore density in its rhizosphere (number of spores/50 g of soil) mean ± S.E., in each study site (HS = higher salinity, MS = medium salinity, LS = lower salinity) and sampling season (northwind, drought). Lower case superscript letters denote differences among sites in each season and upper-case superscript letters denote differences in each site between seasons, for each of the variables. Different letters indicate significant differences ($p< 0.05$). n = 20

Variable	Season	Site		
		HS	MS	LS
Percentage of colonization	Northwind	71.09 ± 5.12 ^{aA}	48.87 ± 5.45 ^{bA}	54.21 ± 3.95 ^{abA}
	Drought	40.70 ± 5.24 ^{bB}	45.49 ± 5.35 ^{aA}	58.02 ± 5.50 ^{aA}
Spore density	Northwind	13.26 ± 1.45 ^{aA}	15.22 ± 4.74 ^{aA}	9.62 ± 1.01 ^{aA}
	Drought	9.67 ± 1.26 ^{aB}	7.60 ± 2.02 ^{aA}	8.29 ± 0.98 ^{aA}

Table 2. List of arbuscular mycorrhizal fungi identified in the rhizosphere of *Conocarpus erectus* in each sampling site (HS = higher salinity, MS = medium salinity, LS = lower salinity) and season (N: northwind D: drought).

Species	Site - Season					
	HS-N	HS-D	MS-N	MS-D	LS-N	LS-D
Acaulospora foveata Trappe & Janos					*	
Acaulospora myriocarpa Spain, Sieverd. & N.C. Schenck			*			
Acaulospora rehmii Sieverd. & S. Toro	*	*				*
Acaulospora scrobiculata Trappe	*	*	*	*	*	*
Ambispora appendicula (Spain, Sieverd. & N.C. Schenck) C. Walker					*	
Claroideoglomus etunicatum (W.N. Becker & Gerd.) C. Walker & A. Schüßler comb. nov.	*	*	*	*	*	*
Gigaspora decipiens I.R. Hall & L.K. Abbott	*	*	*		*	*
Gigaspora sp.						*
Scutellospora erythropus (Koske & C. Walker) C. Walker & F.E. Sanders [as 'erythropa']	*	*	*	*	*	*
Funneliformis coronatum (Giovann.) C. Walker & A. Schüßler comb. nov.					*	
Funneliformis geosporum (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler comb. nov.	*	*	*	*	*	*
Glomus deserticola Trappe, Bloss & J.A. Menge	*	*	*	*	*	*
Glomus lacteum S.L. Rose & Trappe [as 'lacteus']					*	
Glomus microaggregatum Koske, Gemma & P.D. Olexia	*				*	
Glomus microcarpum Tul. & C. Tul. [as 'microcarpus']	*	*	*	*		*
Glomus rubiforme (Gerd. & Trappe) R.T. Almeida & N.C. Schenck	*	*	*	*	*	*
Sclerocystis microcarpus S.H. Iqbal & Perveen						*
Total AMF species richness:	10	9	9	7	12	11

Discussion

According to Carmona *et al.* (2013) recordings, arbuscular mycorrhizal fungi was found colonizing the roots of *Conocarpus erectus*. AMF colonization were registered in both seasons and in all sampling sites, and a high AMF species richness were found in its rhizosphere.

Both *Arum* and *Paris* kind of AMF colonization were found in *C. erectus* roots, this being a common finding in other plant species that has been studied in mangrove ecosystems (D'Souza 2016). Sengupta & Chaudhuri (2002) report 58.6 - 81 % of AMF colonization in trees pertaining to different successional states of a mangrove ecosystem in India. The studies that register AMF radical colonization in mangrove systems point out that these percentages depend both on the soil characteristics and on the form of life, identity and phenology of the phytobiont (Kumar & Ghose 2008, Muthukumar & Udaiyan 2000, Sengupta & Chaudhuri 2002, Sosa-Rodríguez *et al.* 2009). In his thesis

dissertation, Echeverría (2006) reports less than 20 % of AMF colonization in *C. erectus* growing in a Petén near Yucatan's coast, lower percentage than the one registered in this study. This difference could emphasize the soil properties influence on the AM association, as the Petenes are a kind of wetland with distinct characteristics in relation to those typically found in dwarf mangroves, as the presence of vegetation islands conformed by medium forest and mangrove in the center, with exterior influence of sea water and interior influence of freshwater and with high organic matter content in its soil (Moreno-Casasola *et al.* 2006).

Conocarpus erectus is typically found in substrates with salinities of 0-90 ppt but can tolerate salinities of up to 120 ppt (Agraz-Hernández *et al.* 2006). The substrate conditions in the three sites analyzed in the present study are considered hypersaline (FAO 1994) and can cause damage through the toxicity of the ions themselves or by osmotic stress to both the plants and the AMF (Juniper & Abbott 2006, Munns & Tester 2008, Evelin *et al.* 2009). However, it has been reported that the AMF are capable of providing benefits to their hosts in conditions of elevated salinity (Kumar *et al.* 2015). In this study, arbuscules were recorded within the roots of *C. erectus* in all three sites, indicating that the association is functional (Espinosa-Victoria 2000) under the entire range of salinities analyzed. This suggests that this fungal mycelium is morphologically and physiologically adapted to extreme environments, as it has been pointed out by Klironomos *et al.* (2001) and Sosa-Rodríguez *et al.* (2009).

Salinity and flooding affect the mycorrhizal association depending on the level at which they are present and the interaction between these two factors (Carvalho 2003, Sosa-Rodríguez *et al.* 2009, Wang *et al.* 2011). Correlation coefficient showed a negative correlation between soil water content and total percentage of colonization, this means that as soil water content increases, total percentage of colonization tends to decrease. In addition, although we did not measure the salinity in each collection point, our data suggest that the variation in the fungal variables studied could be also related to the season (in relation to the change in soil water content) effect on the salinity soil concentration. The highest percentage of colonization was recorded in the site of highest salinity (HS) in the northwind season (when highest soil water content was registered). This site apparently represents the most contrasting environment of the three sampling sites between seasons and presented a statistically significant decrease in the percentage of colonization, as well as in the spore density and species richness in the drought season, compared to the northwind season. During this latter season, precipitation in the coastal zones can flush the excess salts from the soil and thus favor development of the soil biota (Moreno-Casasola *et al.* 2006), including AMF. In the drought season, on the other hand, salt commonly concentrates in the substrate due to the intense evaporation (Kozlowski 1997), thus raising the salinity and inhibiting the development and association of AMF.

AMF species richness reported in this study results lower than that reported by Kumar & Ghose (2008) and Muthukumar & Udaiyan (2000), who found 44 and 35 species respectively in India mangroves. For their part, Sengupta & Chaudhuri (2002), Kothamasi *et al.* (2006) (both mangroves in India) and Wang *et al.* (2010) (mangrove in China), report seven, five and six species respectively, being these quantities lower than our finding. This variation could be related with the extension of the collection or with edaphic or hosts diversity characteristics of the sites. The AMF species richness in our study was greater in the least saline site (LS) in both seasons. This site would be less stressful in terms of salinity, compared to the other sites, giving more sensitive AMF species the opportunity to develop and produce spores (6 unique species were recorded in this site. See table 2). The conditions of site LS would be even less stressful in the northwind season, when the highest species richness value of all of the sites and both seasons was recorded.

The spore density recorded in the *C. erectus* rhizosphere coincides with that found by Kumar & Ghose (2008), who reported between 5 and 60 spores per gram of soil in the rhizosphere of mangrove species. The distribution of the mangrove on the Ría Lagartos lough is discrete and fragmented and is associated with other ecosystems such as tular, grassland, tropical low flooding deciduous forest, coastal dune vegetation and peten (Andrade 1997). The higher AMF spore density recorded in the northwind season coincides with that reported by Ramos-Zapata *et al.* (2011) for coastal dune areas. Those authors propose that the spores are transported by water in the rainy season from adjacent terrestrial ecosystems, in addition to the fact that this season is characterized by strong winds that can carry spores from other sites (Warner *et al.* 1987, Egan *et al.* 2014). The fact that no differences were recorded among sites in terms of the number of spores as differences were recorded between seasons (with higher numbers in the northwind season), suggests that the pattern observed may be due to transport of spores by the rainwater (this spores not necessarily retaining viability, as we observed) rather than changes in AMF sporulation in the different sites. This coincides with that suggested by Xu *et al.* (2016), who state that many of the AMF propagules in the wetlands are transported by water and can remain in the soil after the flooding has subsided. A total of 17 AMF species were found in the rhizosphere of *C. erectus,* which coincides with the values of richness often found in mangrove vegetation,

ranging from 5 to 45 species (Kothamasi *et al.* 2006, Gupta *et al.* 2016), depending on the sampling area.

Acaulospora scrobiculata, *Funneliformis geosporum, Claroideoglomus etunicatum* and *Glomus rubiforme* were present in the rhizosphere of *C. erectus* of all the three sites (lower, medium and higher salinity) and have been reported in other mangrove (Kumar & Ghose 2008, Wang *et al.* 2010, D'Souza & Rodrigues 2013a, b, Xie *et al.* 2014, Gupta *et al.* 2016) and "semi-mangrove" (Wang *et al.* 2015) ecosystems. According to Chagnon *et al.* (2013), these species could present ruderal (Glomeraceae) and stress resistance (Acaulosporaceae) strategies. Gupta *et al.* (2016) state that the presence of *F. geosporum* in zones of high salinity could indicate that it is adapted to such conditions. Arbuscular mycorrhizal communities within a host can change significantly over various seasons, being the primary driver of local adaptation of AM fungal species the edaphic factors (D'Souza 2016). The unique species found in the lower salinity (LS) site, particularly in the northwind season (*Acaulospora foveata*, *A. appendicula*, *Funneliformis coronatum* and *Glomus lacteum*), could be the most salinity vulnerable species, but also be especially adapted to flooding conditions. *A. foveata, Gigaspora decipiens, F. coronatum* and *G. lacteum,* have also been reported by other authors in mangrove ecosystems (Kumar & Ghose 2008, Wang *et al.* 2010, D'Souza & Rodrigues 2013a). It has been proposed that the AMF species that are found in certain ecosystems can be particularly adapted to the environmental conditions that domain in those systems, so given that previously named species have been recorded in various mangroves, it is hypothesized that they are adapted to survive and prosper in the flooded and/or the saline conditions that (in differing degree) prevail in these ecosystems (Krishna 2005, Saint-Etienne *et al.* 2006, Egerton-Warburton *et al.* 2007, Wang *et al.* 2010). Field data, as reported by Miller & Bever (1999) suggests that the AMF are not physiologically equivalent in their tolerance to wetland conditions, and for that reason we can find significant differences in species composition related to relative water depth, and although a reduction of AMF radical colonization along with salinity rising levels has been reported in wetlands (Saint-Etienne *et al.* 2006), it is recognized that some AMF species are more tolerant than others to elevated salinity (Borde *et al.* 2011).

The presence of AMF arbuscules in the roots of *C. erectus* indicates that there is an exchange of nutrients between these symbionts. On the other hand, the differences in the percentages of mycorrhizal colonization, spore density and AMF species richness found among the sites and seasons of collection suggest that variation in the edaphic environment could affect the dynamics of the association and both fluctuate according to seasonal variation. These dynamics require further study, in particular in relation to the substrate moisture content and the interstitial salinity and the interaction of both. Due to its potential adaptation to flooding and/or saline soil conditions, the AMF species reported in this study and in other mangrove ecosystems does have a potential use in the restauration of damaged wetlands.

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