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Research article

DISTRIBUTION OF ARBUSCULAR MYCORRHIZAL FUNGI ASSOCIATED WITH LANDSCAPE TREE GROWTH IN INDIAN THAR DESERT

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ABSTRACT: Field and glasshouse pot studies were conducted to determine effects of urban expansion on arbuscular mycorrhizal fungal (AMF) populations and AMF impact on landscape tree growth. Soil and root segments were collected and evaluated for root colonization by AMF of trees at semi arid region sites and nearby, formerly desert, drip-irrigated residential landscape sites in the Jodhpur, Rajasthan, India. Native desert trees had greater colonization by AMF than residential landscape trees, and AMF species composition differed at the two site types. A glasshouse pot experiment using AMF inocula from the desert or residential sites was used to evaluate AMF effects on growth of two landscape trees in pots relative to non-AMF controls. Growth and P nutrition of *Acacia nilotica* and *Acacia senegal* were increased by AMF colonization. We conclude that AMF might significantly increase landscape tree carbon storage potential depending on tree species, AMF population characteristics, soil water availability, and improved P uptake.

Key Words: Urban forest; Mycorrhizae; *Acacia senegal*; *Acacia nilotica, Glomus fasciculatum,* Thar Desert, Landscape trees.

INTRODUCTION

Trees are important components of landscapes whether that is in urban or rural landscapes. Their importance includes their economic, biodiversity, conservation, ecological, aesthetic and spiritual value. Woodlands and forests include stabilization of soil through their root system, absorption of CO2 and the cooling effects of canopies of trees. Arbuscular mycorrhizal fungi (AMF) are obligatory endophytes that form symbiotic associations with approximately 90% of all higher plants. Past research has shown that AMF affect host plant growth, P uptake, water status, and resistance to biotic and abiotic stresses. AMF might extract an estimated 5% to 20% of labile photosynthates from colonized plant roots. AMF have been shown to differentially colonize plant roots, causing a variety of effects on plant growth, biomass allocation, and photosynthesis. Presently, it is unknown to what extent urban expansion might impact AMF population characteristics and AMF effects on landscape tree carbon sink potential. Preliminary evaluation of AMF populations along a time since-development gradient from arid zone’s urban core to the city’s edge showed that recently developed areas (less than 5 years) had less species diversity than landscapes developed 20 to 40 years ago [7].Cities such as jodhpur are places of elevated atmospheric CO_2. Because AMF have been shown to stimulate belowground carbon sink strength under conditions of elevated CO_2 [3], the potential might exist for AMF to increase the carbon sink potential of managed urban landscape trees. One objective of this research was to investigate how land-use change associated with urban expansion affects AMF population and colonization characteristics by comparing patterns of root colonization of native trees at Thar Desert sites to those of landscape trees at nearby, recently developed residential sites. Another objective was to determine if there are differences in the ability of AMF populations from desert or residential sites to affect landscape tree growth.

MATERIAL AND METHOD

Field Study: During the present investigation rhizosphere soil and plant samples of *Acacia* species were collected from Indian Thar desert. Thar Desert of India, also known as Great Indian Desert, is considered to be seventh largest desert of the world having area of about two lakh square kilometers. In India, more than sixty percent of this desert lies in the state of Rajasthan. The life support systems in this region are constrained by bioclimatic and environmental limitations: low precipitation (100-400 mm, mean annual rainfall) high pre-monsoon temperatures (mean maximum of the hottest month: 45-47o C), high wind speed (average annual 8-10 km/h with figures up to 30-40 km/h in summers), high potential evapotranspiration with an annual total of 1500 to 2000 mm. Soils are generally sandy to sandy loam in texture with poor nutrient status and low water holding capacity. Important tree species of the region include *Acacia senegal*, and *A. nilotica.*

Population and colonization characteristics of AMF were evaluated at both desert and residential sites. The residential sites were drip-irrigated, single-family residential yards immediately adjacent to the preserve. Each of the residential yards was landscaped with a mixture of native and exotic vegetation. Overall, the number of plants per unit surface area at the desert sites was about 1.2 times greater than the residential sites; however, overall canopy coverage of landscape plants at the residential sites was about 3.5 times greater than canopy coverage of native vegetation at the desert sites. During August, tree roots and soil at each of the desert and residential sites were evaluated for mycorrhizal colonization and AMF species composition. At each of the three desert sites, a single sample of soil and root segments was collected from the under canopy rhizosphere of two *Acacia* species. All samples were collected at a depth of 20 cm (8 in.) below the soil surface. To isolate AM spores from soil, Wet sieving and decanting technique of Gerdemann & Nicolson (1963) were used which was further proceed by Sucrose centrifugation technique of Jenkins (1964). AM fungal species were identified with the help of manual of Schenek and Parez (1987). Method of Philips & Hayman (1970 was employed for root staining. Percentage of mycorrhizal root infection was estimated, according to Phillips and Hayman (1970).Mycorrhizal colonization was calculated according to gridline intersect method (Giovannetti & Mosse, 1980). Multigeneration trap cultures were established using the method of Stutz and Morton (1996) to evaluate AMF species composition and richness at representative sites and to produce inoculum for greenhouse experiments. Species richness for the desert and residential sites was determined by combining data from the two trees sampled at each of the site replicates.

Glasshouse Pot Study

Two regionally common landscape tree species were inoculated with AMF population treatments (Desert, residential, or non-AMF control) to test for any effects of urban expansion on the ability of AMF to affect landscape tree growth. Sand-soil mixture (1:1) was sterilized by autoclaving at 15-lbs/sq inch pressure, 121 0C for 40 minutes. (It was done twice with a day interval in between). The potting mixture was filled in plastic pots (sterilized with alcohol) of 6-inch diameter. The inoculum (containing approximately 2000 chlamydospores of AM fungi) were placed 4-5 cm below the surface of the soil as uniform layer, so that roots pass through the layer. Seedlings of *Acacia nilotica* and *Acacia senegal* are inoculated with different Mycorrhizal spores done by three method – Firstly, by direct inoculation from pot culture inoculum. The inoculum in form of pot soils containing extrametrical chlamydospores and AMF infected roots pieces of Cenchrus ciliaris was placed 4 -5 cm below the soil surface before sowing. Secondly, with Pellet Method by Menge and Timmer, (1982) using a growth media such as peat moss, vermiculite. Thirdly, inoculum was prepared by production of alginate entrapped VAM by Kropacek et al., 1989; Strllu and Plenchette, 1991. Seedlings were used because, in *Acacia,* seed propagation is the method used by regional production nurseries. The present study revealed association of eighteen species of five genera of AM fungi with *Acacia* at different localities. These genera and species were invariably present in the selected localities irrespective of the host plant type present at particular locality. Among the five genera the species belonging to genera *Scutellospora*, *Gigaspora* and *Glomus* was found very common while the species belonging to genera *Acaulospora* and *Sclerocystis* were found comparatively at lower rate in distribution.

Our results support the previous observations about frequent occurrence of *Gigaspora* and *Glomus* in different regions of Indian Thar Desert [5]. Though AM fungal species were not found to be effected by host specificity for its distribution in this region however, some species were found to be more abundant in its occurrence as compare with the others. In the desert inoculum, *Glomus deserticola* comprised approximately 50% of the spores present, and *Acaulospora morrowae* comprised approximately 35%.In the residential inoculum, *G. fasciculatum* comprised approximately 40% of the spores present, and Sclerocystis rubiformis comprised approximately 40%. A volume of inoculum was added to three germinated seedlings per pot for *Acacia*. One week after germination, *Acacia* seedlings were thinned to one per pot. Inoculum was added sub radically during potting into each container. All non-AMF control trees received a 150-ml of mixed inoculum filtrate to establish similar soil micro biota as trees treated with AMF inoculum. All trees were then grown for 5 months in an environmentally controlled glasshouse where average day/night temperature 30/25°C and relative humidity between 55% and 65% during the day. Samples were analyzed microbiologically and chemically for the determination of Total shoot length were measured on 1 and 153 days after potting. Samples of root material from all plants were stained as described above and evaluated for AMF colonization. Shoots and roots were separated and dried in a drying oven at 60°C (140oF) for 72 hr and dry weights recorded. Pulverized leaf tissue samples were analyzed for P concentration by the ascorbic method (Wantabe and Olson 1965). For both field and glasshouse pot studies, all statistical comparisons were made by ANOVA. The level of significance was set at $\alpha = 0.05$ Results.

RESULTS

Field Study: Roots of native trees at the Desert sites were colonized by AMF to a greater extent than were landscape tree roots at the nearby residential sites because of greater root colonization with hyphae (Figure 1). Roots of residential trees were also colonized by septate, nonmycorrhizal fungi, which were not found on roots of desert trees. Eighteen species of five genera of AM fungi were detected in trap cultures from residential and desert sampling sites (Table 1). None of the AMF species occurred at all the sampling sites. AMF species richness at each sampling site ranged from five to seven species at the residential sites and four to five species at the desert sites. Fifteen of the eighteen detected AMF species occurred at both residential and desert sites. Three AMF species, *G. aggregatum*, *Sclerocystis rubiformis* and *Scutellospora nigra* occurred only at residential sites, and two species, *A. morrowae* and *Gigaspora margarita* was only detected at one of the desert sites.

Table 1. Arbuscular mycorrhizal fungal (AMF) species detected in trap cultures from residential and Desert sites in western Rajasthan area.

S.No.	AMF Species	Desert Sites	Residential Sites
1	*Acaulospora morrowae*	_	+
2	*A. laevis*	+	+
3	*A. mellea*	+	+
4	*A .sporocarpia*	+	+
5	*Gigaspora margarita*	_	+
6	*Glomus deserticola*	+	+
7	*G. fasciculatum*	+	+
8	*G. mosseae*	+	+
9	*G. geosporum*	+	+
10	*G. macrocarpum*	+	+
11	*G. aggregatum*	+	_
12	*Sclerocystis rubiformis*	+	_
13	*S. corieomoides*	+	+
14	*S. microcarpus*	+	+
15	*Scutellospora callospora*	+	+
16	*S. nigra*	+	_
17	*S. heterogama*	+	+
18	*S. aurigloba*	+	+

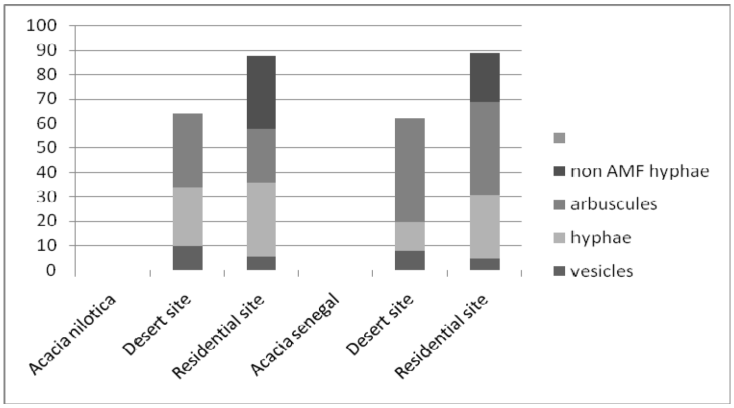

Figure 1. Percentage of root colonization of *Acacia* in response to arbuscular mycorrhizal fungal (AMF) inoculum derived from under canopy rhizosphere of trees at Desert or nearby residential sites in western Rajasthan area.

Glasshouse Pot Study: Roots of all trees inoculated with the non-AMF control drench remained nonmycorrhizal. Both Desert and residential AMF populations colonized roots of trees differently (Figure 1). Roots of *Acacia* inoculated with either the desert or residential AMF population treatments were strongly mycorrhizal. The residential AMF treatment elicited a 60% increase in P uptake by *Acacia* compared with the non mycorrhizal control treatment (Table2). In general, AMF differentially affected growth of the two landscape trees i.e., *A.nilotica* and *A.senegal* (Table 2). For *Acacia*, AMF from the desert sites increased tree total shoot length (SL), total dry weight (TDW), shoot dry weight (SDW), root dry weight (RDW), and shoot to root ratio (SR) compared with AMF species Residential Desert.

AMF from the residential sites increased *Acacia* growth variables except for TDW, SDW, and RDW, which were similar to those of the non-AMF controls. Desert and residential AMF populations increased carbon assimilation (A) by *Acacia* leaves by about 80% compared with the non-AMF control treatment.

DISCUSSION

Previous research has shown that soil disturbance substantially lowers AMF diversity (Giovannetti and Gianinazzi-Pearson 1994). The process of urbanization and in particular the change from a relatively natural, undisturbed desert habitat into suburban communities of medium-density single family homes with intensively managed landscapes typically begins with disturbance of the rhizosphere profile. Therefore, we may assume that the initial disturbances associated with the transition of our residential sites from their original undisturbed desert habitat into a residential land use had an adverse effect on the residing native AMF population structure (Roldan et al. 1997). Our data showed that after disturbance and landscape installation, the association of AMF species found in soil at the residential sites was different from that of nearby remnant desert habitats and this difference was accompanied by less root colonization with hyphae. Re-establishment of AMF populations at the residential sites after initial disturbance and landscape installation may be dependent on three factors: the mode of AMF dispersal, the time elapsed since disturbance (Jasper et al. 1991), and the biophysical environment at these intensively managed residential landscapes. At present, we know of no studies examining modes of AMF dispersal into urban areas, though we speculate that such modes might include wind dispersal, the local and regional transport of mycorrhizal nursery stock to landscape transplant sites, and/ or movement of AMF spores and assemblages by humans. Also, cultural practices such as watering and fertilization, the root characteristics of the host plant and host–fungus compatibility, and edaphic conditions such as pH, nutrient levels, moisture, salinity, and temperature can have a substantial effect on AMF population characteristics (Brundrett 1991).

Although AMF are generally thought to have little host specificity, there may be a certain degree of plant/endophyte compatibility, and some plants may even resist AMF colonization (Brundrett 1991). In the present study, we found that growth, carbon assimilation, and P nutrition of two regionally common landscape trees in response to AMF population from residential or desert sites were different. AMF colonization elicited increased growth and P uptake for both *Acacia* species. . For Acacia, shoot and root growth enhancement which gives clear evidence of an increase in photosynthate production coincident of the AMF association. These effects were more pronounced for *Acacia* trees inoculated with AMF from the desert site than the residential site.

CONCLUSION

Our data suggest that urbanization can alter the composition of AMF populations and that modification of the soil environment, particularly the practice of landscape irrigation, might reduce AMF colonization of some tree roots. Our data also suggest that AMF can increase tree carbon storage potential in the urban areas, although this capacity in managed residential landscapes might be somewhat less than in nearby undisturbed soils because of a higher carbon cost to benefit ratio. Ultimately, the ability of AMF to increase landscape tree growth is likely a function of tree species and factors such as water availability and enhanced P uptake.

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