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Effect of Commercial Arbuscular Mycorrhizal Fungi on Growth, Survivability, and Subsequent Landscape Performance of Selected Container Grown Nursery Crops[1]

Lucila Amaya Carpio, Fred T. Davies, Jr., and Michael A. Arnold[2]
Department of Horticultural Sciences
Texas A&M University, College Station, TX 77843-2133

Abstract

This research evaluated the effects of commercially available arbuscular mycorrhizal fungi (AMF) on growth of selected ornamental plant species grown under a nursery-container production system. Subsequent plant survivability and growth in the landscape was also evaluated for two seasons. *Acacia greggii, Chilopsis linearis, Diospyros virginiana, Platanus occidentalis, Ipomoea carnea* and *Plumbago auriculata* were inoculated with commercial AMF: EndoNet®, MycorisePro®, or non-inoculated (NonAMF). *Platanus occidentalis* had a fourth mycorrhizal treatment, which included BioterraPLUS®. EndoNet® and MycorisePro® enhanced growth of *C. linearis*, *I. carnea* and *P. auriculata* during nursery-container production. Growth enhancement of *P. occidentalis* was significant with BioterraPLUS®, EndoNet® and MycorisePro® compared to NonAMF. During the container phase, greatest colonization (total arbuscules, vesicles/endospores, and intraradical hyphae) occurred with *I. carnea* and *P. auriculata* inoculated with EndoNet® and MycorisePro®. After the 1st growing season following out planting, AMF inoculated *P. occidentalis* and *C. linearis* had greater growth and AMF inoculated *P. auriculata* had higher survival than NonAMF plants. However, by the end of the 2nd growing season there were no differences in survival or growth among AMF treatments. The similarity in plant growth during the 2nd season was due in part to a high and active indigenous AMF population in the landscape site that colonized the NonAMF plants after transplanting.

Index words: best management practices (BMP), colonization, fertility, inoculum, mycorrhiza.

Species used in this study: *Acacia greggii* Gray [cat claw]; *Plumbago auriculata* Lam. 'Hullabaloo' [blue plumbago]; *Ipomoea carnea* N. von Jacquin subsp. *fistulosa* (K.Von Martinus ex J. Choisy) D.Austin [bush morning glory]; *Chilopsis linearis* (Cav.) Sweet [desert willow]; (*Diospyros virginiana* L. [common persimmon]; *Platanus occidentalis* L. [sycamore].

Significance to the Nursery Industry

Increased environmental regulations and economic pressures to minimize chemical, fertilizer and water inputs have prompted adoption of Best Management Practices (BMP) by the nursery industry (22). Best management practices include reduction of non-point source pollution through capture and recycling of irrigation water and can include use of beneficial, 'environmentally friendly' microorganisms such as arbuscular mycorrhizal fungi (AMF). Incorporation of AMF in a nursery production system may enhance plant growth and development due to an increase in nutrient absorption and may lead to a reduction in fertilizer application. This study demonstrates that commercial AMF inoculum were successful in establishing symbiosis and were able to enhance growth and development of *Chilopsis linearis, Ipomoea carnea, Plumbago auriculata, and Platanus occidentalis* at reduced fertilizer levels (50% of recommended rate) during nursery container production. Colonization with AMF was greatest in *I. carnea* and *P. auriculata* inoculated with EndoNet® and MycorisePro®. Colonization potential of AMF differed among host plant species. Significant container growth responses with AMF colonization levels obtained in this study suggest that incorporation of commercial AMF in a pine bark substrate as part of nursery production practices may allow reduction in fertilizer application and help minimize subsequent nutrient runoff (nonpoint source pollution).

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[2]Graduate Research Assistant, Professor and Associate Professor, respectively.

Introduction

Increased environmental concerns throughout society have resulted in state and governmental regulations which affect water and land use. These regulations are impacting the nursery and greenhouse industries (14). The ornamental industries need to remain competitive, while operating within environmental legislation and regulations. Hence, nursery and greenhouse firms are adopting best management practices (BMP) that minimize nonpoint (diffuse) source pollution by preventing discharge of pesticides and fertilizers into public water (9, 22).

Beneficial microorganisms include arbuscular mycorrhizal fungi (AMF) which are able to colonize and establish symbiotic (mutually beneficial) associations with roots of most nursery crops (6). AMF increase the effective absorptive area of roots by formation of an extensive extraradical hyphae network that enhances efficiency in absorption of nutrients (10). Ornamental plants colonized by AMF have better growth responses, improved water relations, greater tolerance to environmental stresses, and better transplant survivability when compared to similar noncolonized (NonAMF) nursery crops (8, 15, 18, 19, 20).

Bierman and Linderman (5) reported enhancement in shoot dry mass and phosphorus (P) accumulation of *Pelargonium ×hortorum* L.H. Bailey (geranium) colonized by *Glomus fasciulatum* Gerdemann & Trappe when grown at low P levels (11 µg/m1). Growth of *Nandina domestica* Thunb., *Loropetalum chinense* Oliv. and *Salvia gregii* Gary was enhanced when colonized by *G. intraradices* under a commercial nursery production system (9). In the later study, *G.*

intraradices were able to survive, establish colonization, and enhance growth even at high fertility levels common in commercial nursery production systems.

The objectives of this research were to evaluate the effectiveness of different commercial AMF on growth and development of selected container grown ornamental crops at reduced fertilizer levels, and to evaluate the effectiveness of commercial AMF in reducing transplant shock, increasing survivability, and enhancing plant growth in the landscape.

Materials and Methods

The study was conducted in two phases. The first phase was initiated during the summer 1999 under simulated commercial container nursery conditions at the TAMU Field Laboratory at College Station, TX. The second phase was conducted under landscape conditions from summer 1999 to late fall 2000 at the TAMU Teaching Nursery (landscape site), College Station, TX. Containerized NonAMF and AMF plants colonized with commercial isolates from the nursery phase were transplanted into the landscape site and evaluated for plant growth and survivability over two growing seasons.

Container production phase

Six selected ornamental species ranging from herbaceous perennials to trees were used as host plants: seedlings of *Acacia greggii* Gray (cat claw), *Chilopsis linearis* (Cav.) Sweet (desert willow), *Diospyros virginiana* L. (common persimmon), and *Platanus occidentalis* L. (sycamore) were grown until of sufficient size for potting-up/canning (Table 1). Single three-node cuttings of *Ipomoea carnea* N. von Jacquin subsp. *fistulosa* (K.Von Martinus ex J. Choisy) D.Austin (bush morning glory) and *Plumbago auriculata* Lam. 'Hullabaloo' (blue plumbago) were rooted without auxin and grown on perlite substrate under intermittent mist until potting-up/canning.

Uniform rooted cuttings and seedling liners of the selected species were transplanted into 1 gal (3.8 liter) containers with a commercial substrate (pine bark:peat moss:vermiculite:hadite clay, (6:2:1:1 by vol). Container substrate was pasteurized [65C (149F)] during two consecutive days for 4 hours. After steam pasteurization, substrate was amended with 1.5 lbs per cu yd (0.9 kg cu per m) of Micromax® trace element mix, 6 lbs per cu yd (3.5 kg per cu m) of dolomitic limestone, and 3 lb per cu yd (1.75 kg per cu m) of gypsum ($CaSO_4$). Six lbs per cu yd (3.5 kg per cu m) of 18N–$7P_2O_5$–10K Osmocote® inorganic slow release fertilizer (Scotts-Sierra Horticultural Products Co., Marysville, OH), which is 50% of the commercial recommended high fertility rate, was incorporated into the substrate prior to potting-up/canning.

Plants were grown outdoors in a graveled container nursery under full sun at the TAMU Field Laboratory. Each species was arranged in a completely randomized design. Irrigation was applied as needed via 2.6 inch spot spitter® with a 160º spray pattern and output of 0.07 gal per minute (Roberts Irrigation Products). Besides the preincorporated fertilizer, all containers were fertigated daily with 50 mg per liter N. Irrigation water was adjusted to pH 6.5 via injection of sulfuric acid.

Arbuscular mycorrhizal fungi treatments. *Platanus occidentalis* plants were either noninoculated (NonAMF) or inoculated with three commercial AMF inoculum (BioterraPLUS®, EndoNet®, MycorisePro®). Whereas, *A. greggii*, *C. linearis*, *D. virginiana*, *I. carnea* and *P. auriculata* plants were either noninoculated (NonAMF) or inoculated with two commercial AMF inoculum (EndoNet® or MycorisePro®). Inoculum was applied in a dibble hole in the container substrate at the time that the liner plants were potted-up/canned. BioterraPLUS® **(**BioTerra Technologies, Inc., Las Vegas, NV) was a composite mix of seven mycorrhizal isolates including *Gigaspora* and *Glomus* species; the inoculation rate was 30 mL with a range of 1,500 to 1,800 spores per plant. Endo Net® (Reforestation Tech International, Salinas, CA) inoculum was composed of a single isolate, *Glomus intraradices* Schenck & Smith. The inoculation rate was 10 mL, with a range of 1000 to 1800 spores per plant. MycorisePro® (Premier Tech, Inc., Riviére-du-Loup, Quebec, Canada) inoculum was also composed of *G. intraradices*. The inoculation rate was 45 mL with an estimated range of 45 to 315 propagules per plant. The fungal propagules were composed of spores, vegetative mycelia and colonized root pieces. Because of the use of single and mixed species isolates and the estimate of most probable numbers (MPN), which included spores and vegetative mycelium, it was not feasible to have an exact equal spore number among AMF inoculum. In all cases the inocula levels used met or exceeded the manufacturer's recommended rate.

Plant growth measurements and arbuscular mycorrhizal fungi colonization. Plants produced from seedling liners during the nursery container production phase (*A. greggii*, *C. linearis*, *D. virginiana* and *P. occidentalis*) were evaluated for growth every 15 days after AMF inoculation until transplanting into the landscape. Evaluations included: height, stem diameter, and number of flowers (where appropriate). Liner plants produced from cuttings (*I. carnea* and *P. auriculata*) were measured every 10 days after AMF inoculation for growth index, number of stems (number of basal branches derived from the main stem), and number of individual flowers. Growth index was calculated using the formula [height × diameter_1 × diameter_2 (measured perpendicular to diameter_1)] (3). Colonization of AMF was reported as the percent of root length colonized with any AMF structure, i.e. arbuscules, vesicles, and internal hyphae (4). Subsamples of nonsuberized roots from five plants per treatment were assayed for AMF colonization at the time containerized plants

Table 1. Taxonomy and habit of selected ornamental nursery crops for the study.

Scientific name	Common name	Family	Habit
Acacia greggii	Catclaw, Texas mimosa, acacia	Fabaceae	Shrub, Small tree
Chilopsis linearis	Desert willow	Bignoniaceae	Small tree
Diospyros virginiana	Common persimmon	Ebenaceae	Medium tree
Ipomoea carnea subsp. fistulosa	Bush morning glory, Shrub morning glory	Convolvulaceae	Tropical Shrub, Herbaceous perennial
Plumbago auriculata	Blue plumbago	Plumbaginaceae	Subshrub, shrub, Herbaceous perennial
Platanus occidentalis	Sycamore	Platanaceae	Large tree

were transplanted into the landscape [summer 1999] (4). Plant roots were cleared and stained (13). Ten 1-cm (0.39 in) stained root segments were placed in each slide and three microscopic observations (top, middle and bottom) at 40X of each 1-cm root piece were evaluated. A total of 250 1-cm root segments per treatment were evaluated (5 slides per plant and 5 plants per treatment; total number of observations = 750; n = 5). The presence of AMF structures was evaluated and the data were statistically analyzed with ANOVA using ± SE (17).

Experimental design and statistical data analysis. For container growth measurements, each plant species was considered as a separate experiment and arranged in a completely randomized design. There were four AMF levels (3 commercial AMF inocula and a NonAMF control) for *P. occidentalis*, and three AMF levels (2 commercial AMF inocula and a NonAMF control) for all other plants. For growth responses, each containerized plant was considered a single experimental unit, (n = 20). For mycorrhizal colonization, the six species were evaluated as a factorial experiment 6 species × 3 AMF (NonAMF, EndoNet®, and MycorisePro®). All data were analyzed with ANOVA and means were differentiated using Tukey's multiple range test or ± SE (17).

Landscape phase

After completion of the evaluation in the container nursery stage, 15 plants per treatment were transplanted (summer of 1999) into a landscape site at the TAMU Teaching Nursery, College Station, Texas. Plants were evaluated in the landscape for post- transplant survivability and growth for two growing seasons (n = 15). Once plants were transplanted, irrigation was provided by means of a drip irrigation system. The plants were irrigated daily for the first week, on alternate days the second week, twice weekly the following four weeks, and once per week thereafter until mid-November when it was discontinued until resumption in mid-March 2000 at twice weekly intervals. No supplementary fertilizer was applied to the plots. The field soil was a sandy-loam, which was low in nitrate, phosphorus and potassium (Table 2).

Most probable number for indigenous arbuscular mycorrhizal fungi estimation. The most probable number (MPN) assay was conducted to estimate the density of indigenous AMF (1, 21) in the field soil at the end of the two year growth cycle. Field soil samples of the top 15-cm of the soil profile were obtained from 20 random locations in the landscape site. Soil samples were mixed together for a single composite random representative sample used as the original field inoculum for the MPN determination. Field inoculum was serially diluted 10-fold with sterilized sand. Each dilution level was used to fill 11.4 cm (4.5 in) pot container (n = 5) and planted with sorghum (*Sorghum bicolor* L.) as the host plant. Pots were placed in the greenhouse with a maximum photosynthetic photon flux density (PPFD) of 1150 µmol per m per sec at plant level, and a mean day/night temperature of 36/29C (97/84F). All pots were fertilized weekly with a complete Long Ashton nutrient solution (11) to supply 11 µg P per mL. After 8 weeks of growth, roots were removed, washed, stained in 0.05% trypan blue, and evaluated for the presence or absence of mycorrhiza. The MPN of infectious propagules was obtained according to Woomer's MPN (21).

Table 2. Texture and chemical soil analysis from representative soil samples in the landscape site at the TAMU teaching nursery, College Station, Texas; (n = 3).

Sand	71%
Silt	25%
Clay	4%
pH	8.4
Nitrogen	5 µg/g
Phosphorus	15 µg/g
Potassium	27 µg/g
Calcium	760 µg/g
Magnesium	77 µg/g
Sodium	410 µg/g
Sulfur	18 µg/g

Plant growth measurements of landscape transplants, and arbuscular mycorrhizal colonization. Effects of AMF on transplant survival and growth in the landscape site were determined. Seedling transplants (*A. greggii*, *C. linearis*, *D. virginiana* and *P. occidentalis*) were evaluated nondestructively in late October 1999 and 2000. Survival, height, stem diameter (stem width 5 cm above the soil line), leaf number, and number of flowers (where appropriate) were recorded. Nonsuberized roots were sampled from soil cores at the end of the 2nd growing season (October 2000) for assessment of mycorrhizal colonization from four randomly selected plants per treatment. Colonization of AMF was determined following procedures as previously described.

Experimental design and statistical data analysis. Each species was considered a separate experiment; hence, there were six different field experiments for growth responses. There were four blocks per species. In a given block there were three AMF levels, with the exception of *Platanus occidentalis* which had four AMF levels. There were five repetitions per treatment in each of the blocks arranged in a randomized complete block design. For AMF colonization, the plant species were evaluated as a factorial experiment with 6 species × 3 AMF (NonAMF, EndoNet® and MycorisePro®). All data were analyzed with ANOVA and means were differentiated using Tukey's multiple range test or ± SE (17).

Results and Discussion

Nursery container production phase

Plant growth measurements, and arbusucular mycorrhizal colonization. The mean effect of AMF inoculation on plant seedling growth response at the reduced fertilizer level varied according to species and AMF. AMF inocula (EndoNet® and MycorisePro®) induced significant ($P \leq 0.001$) increases in height and stem diameter for *C. linearis* and *P. occidentalis* when compared with the NonAMF control plants during the nursery container production phase (Table 3). MycorisePro® increased stem diameter of *A. greggii*, while EndoNet® did not. Growth of *D. virginiana* was not affected by AMF. The height and stem diameter of all species increased over time (days), except the stem diameter of *D. virginiana* (Table 3).

The source of commercial inoculum (EndoNet® and MycorisePro®) also influenced plant response. With *P. occidentalis*, EndoNet® produced greater height (27.8 cm) than MycorisePro® (24.8 cm), while with *C. linearis* and *P. auriculata* no growth differences occurred between MycorisePro® and EndoNet® (Tables 3 and 4). The total colonization levels in inoculated containerized plants of *C. linearis* and *P. occidentalis* were 3.2% and 3%, respectively (Fig. 1);

Table 3. Effect and interaction of arbuscular mycorrhizal fungi (AMF) and time (Days) on height and stem diameter of selected ornamental species grown with reduced fertility during container nursery production.

Species AMF	Height (cm)	Stem diameter (cm)
Acacia greggii		
NonAMF	31.4a[z]	2.7b
EndoNet®	34.2a	2.6b
MycorisePro®	35.0a	2.9a
Significance ($P \geq F$)[y]		
Days	***	***
AMF	NS	**
Days × AMF	NS	NS
Chilopsis linearis		
NonAMF	32.6b	2.5b
EndoNet®	38.5a	2.9a
MycorisePro®	40.5a	3.0a
Significance ($P \geq F$)		
Days	***	***
AMF	***	***
Days × AMF	NS	NS
Diospyros virginiana		
NonAMF	29.6a	4.0a
EndoNet®	30.3a	3.8a
MycorisePro®	32.3a	3.7a
Significance ($P \geq F$)		
Days	NS	***
AMF	NS	NS
Days × AMF	NS	NS
Platanus occidentalis		
NonAMF	20.2c	2.7b
Bioterra Plus®	25.2b	3.3a
EndoNet®	27.8a	3.4a
MycorisePro®	24.8b	3.2a
Significance ($P \geq F$)		
Days	***	***
AMF	***	***
Days × AMF	NS	NS

[z]Means in each column followed by different letter significantly different (P ≤ 0.05) according to Tukey's multiple range test; n = 20.

[y]NS,*,**,*** Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001 respectively.

AMF plants had greater growth responses than NonAMF treatments. However, colonization levels are not good predictors of growth enhancement or nutrient uptake in response to AMF inoculation (12). Niemira et al. (16) reported beneficial growth responses at very low levels (0.4%) of *G. intraradices* colonization in a greenhouse study with minituber potato (*Solanum tuberosum* L.).

Ipomoea carnea and *Plumbago auriculata* had an increased growth index [height × diamter$_1$ × diameter$_2$] with AMF inoculation of MycorisePro® compared to NonAMF plants (Table 4). With EndoNet® there was a nonsignificant trend in increasing growth index (3078 cm^2) compared to the control (1568 cm^2). However among AMF, there were no differences in the growth index between MycorisePro® and EndoNet® (Table 4). Both isolates enhanced the number of flowers of *P. auriculata* (Table 4).

The significant growth responses observed in *I. carnea* and *P. auriculata* were correlated with intermediate AMF

Table 4. Effect of arbuscular mycorrhizal fungi (AMF) and time (Days) on the growth index and flowers number of *Ipomoea carnea* and *Plumbago auriculata* grown with reduced fertility during container nursery production.

Species AMF	Growth[z] Index (cm^3)	Flowers (No.)
Ipomoea carnea		
NonAMF	7535b[y]	—
EndoNet®	9555a	—
MycorisePro®	8902a	—
Significance ($P \geq F$)[y]		
Days	*	—
AMF	**	—
Days × AMF	NS	—
Plumbago auriculata		
NonAMF	1568b[y]	7.3b[y]
EndoNet®	3078ab	13.1a
MycorisePro®	4084a	15.5a
Significance ($P \geq F$)[x]		
Days	*	***
AMF	***	***
Days × AMF	NS	NS

[z]Growth index = height × diameter$_1$ × diameter$_2$ [measured perpendicular to diameter$_1$].

[y]Means in each column followed by different letter significantly different (P ≤ 0.05) according to Tukey's multiple range test; n = 20.

[x]NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001 respectively.

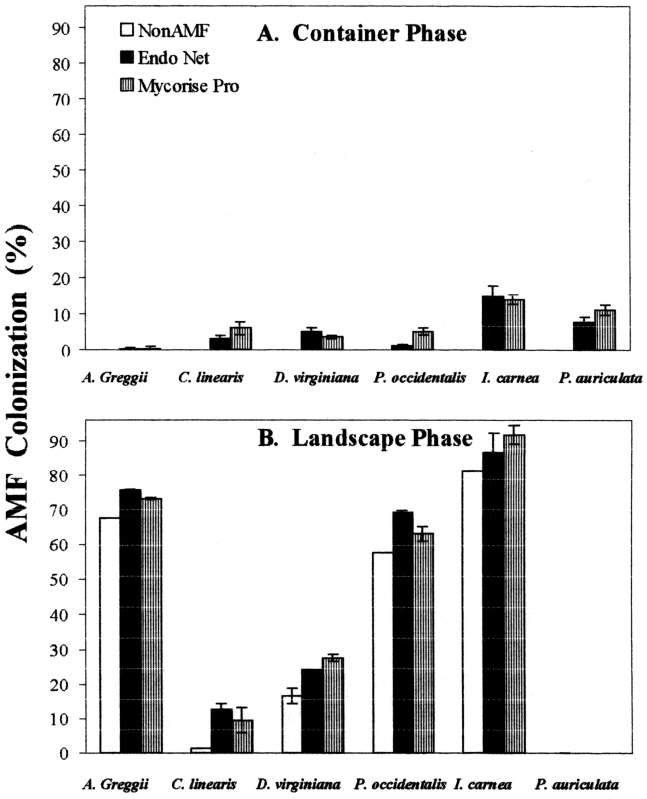

Fig. 1. Effects of inoculation with arbuscular mycorrhizal fungi (AMF) on total mycorrhizal colonization of selected nursery species. (A) at the end of the container production phase, and (B) after the 2nd growing season in the landscape site. *Plumbago auriculata* did not survive the 2nd season; number of observations = 750; n = 5; ± SE.

colonization levels in the EndoNet® and MycorisePro® treatments, with mean colonization of 14.9% and 9.4%, respectively (Fig. 1). Davies et al. (9) reported similar growth enhancement in AMF inoculated *Nandina domestica*, which only had 10% total colonization with the mycorrhiza *Glomus intraradices*. That study was done in a commercial nursery site with fertility levels of 4.2 kg cu m (7 lbs cu yd) of Osmocote 24N–4P_2O_5–8K_2O. Significant differences ($P \leq 0.05$) in the growth index due to time (days) after AMF inoculation occurred with *I. carnea* and *P. auriculata* (Table 4).

All species were able to establish symbiosis when inoculated with commercial AMF and none of the NonAMF plants were initially mycorrhizal in the container study (Fig. 1). There were significant differences ($P \leq 0.001$) in total AMF colonization among plant species and commercial AMF isolates (Fig. 1). Greatest total colonization (arbuscules, vesicles/endospores, and intraradical hyphae) was observed in *I. carnea* and *P. auriculata* when inoculated with EndoNet® and MycorisePro® (Fig. 1). *Acacia greggii* inoculated with EndoNet® and MycorisePro® had the lowest levels of colonization (0.4%) and no arbuscules were observed (Fig. 1). Results from this experiment support the premise that AMF colonization potential differs among host plant species and commercial AMF isolate.

Landscape phase

Most probable number assay (MPN). The most probable number (MPN) assay was conducted to estimate the density of indigenous AMF propagules in the landscape site. There was a positive colonization in all samples through the 4th dilution level [10^{-3} dilution]. The MPN obtained from the probability table in Woomer (21) was 13,826 by dividing this value by the inoculation soil volume (1,974 ml) used for each dilution level, there was a total MPN of 70 infective propagules of native AMF population per ml of soil at the landscape site. A MPN of 70 indicates very high propagule levels which contributed to the high colonization levels of the initially noninoculated NonAMF plants when roots were sampled at the end of the 2nd growing season (Fig. 1).

Plant growth measurements of landscape transplants, and arbuscular mycorrhizal colonization. Except for the greater survival of AMF treated *P. auriculata* (100% vs. 80% compared to NonAMF [($P \leq 0.05$)]) during the 1st growth season, there were no differences in survival among the remaining five species during the two seasons in the landscape. *Plumbago auriculata* failed to survive the 1999–2000 Texas winter so it was not included in the 2nd growing season data. Transplant survivability was high among the remaining five species (95 to 100% survivability). High survivability may be attributed in part to greater transplant potential of the remaining five ornamental species and regular irrigation with a drip irrigation system. Hence, plants never experienced drought stress, which frequently occurs in Texas landscapes. At the end of the 1st growing season, AMF had no growth effect on *A. greggi*, *D. viginiana*, *I carnea* or *P. auriculata*. However, MycorisePro® enhanced the height of *C. linearis* (58.6 ± 2.0 cm vs. the control 47.5 ± 1.2 cm) [$P \leq 0.05$] and stem diameter (4.0 to 4.2 cm vs. the control 3.3 cm) [$P \leq 0.05$] of *P. occidentalis*. By the end of the 2nd growing season there were no differences in growth parameters between AMF and NonAMF plants. In part this may be due to the natural colonization of initially noninoculated NonAMF plants by the high levels of indigenous AMF at the landscape site (Fig. 1, Table 5).

Absence of a mulch application to the rows, a common winter practice to protect plants in the landscape, may account for some low survivability observed in *P. auriculata*. *Plumbago auriculata* also requires high fertility (2). Low fertility levels detected in the soil analysis [5 µg N/g, 15 µg P/g and 27 µg K/g] (Table 2) could have also contributed to the losses of *P.auriculata*.

There was a significant interaction of plant species and AMF treatments on percentage mycorrhiza colonization and percentage hyphae observed of the five ornamental species at the end of the 2nd growing season (Table 5). However, while NonAMF (noninoculated) plants had become colonized with indigenous mycorrhiza, AMF colonization among the different plants species was always highest for plants which were inoculated during the container production phase. The presence of a relatively high and active indigenous AMF population (MPN = 70 propagules per ml soil) may explain the lack of significant difference in growth during the 2nd growing season between AMF plants and NonAMF controls during the landscape phase of the study. No supplemental fertilizer was added to the landscape which could have limited plant growth among all treatments and enhanced the AMF colonization potential of the nutritionally stressed NonAMF plants. Low fertilization is known to enhance AMF coloni-

Table 5. 2nd Growing Season: Effect of commercial arbuscular mycorrhizal fungi (AMF) inoculation on mycorrhizal colonization of five selected container nursery crops grown in the landscape site at TAMU (late October 2000).

Species AMF	Arbuscule (%)	Ves/End[z] (%)	Hyphae (%)	Total Colonization (%)
Acacia greggii				
NonAMF	35.3 ± 6.4[y]	0.3 ± 0.3	67.5 ± 0.0	67.5 ± 0.0
EndoNet®	31.7 ± 4.9	3.6 ± 2.0	75.5 ± 0.3	75.5 ± 0.3
MycorisePro®	35.8 ± 5.5	9.4 ± 2.1	73.1 ± 0.3	73.1 ± 0.3
Chilopsis linearis				
NonAMF	0.0 ± 0.0	0.3 ± 0.3	1.4 ± 0.0	1.4 ± 0.0
EndoNet®	2.5 ± 0.8	0.0 ± 0.0	12.5 ± 1.8	12.5 ± 1.8
MycorisePro®	1.7 ± 1.1	0.3 ± 0.3	9.4 ± 3.6	9.4 ± 3.6
Diospyros virginiana				
NonAMF	3.9 ± 1.1	1.7 ± 0.9	16.7 ± 2.2	16.7 ± 2.2
EndoNet®	4.7 ± 1.3	1.1 ± 0.4	24.2 ± 0.0	24.2 ± 0.0
MycorisePro®	3.3 ± 0.6	1.1 ± 0.6	27.5 ± 0.9	27.5 ± 0.9
Platanus occidentalis				
NonAMF	22.5 ± 3.2	1.1 ± 0.6	57.5 ± 0.0	57.5 ± 0.0
Endo Net®	31.9 ± 5.7	5.0 ± 1.6	69.3 ± 0.3	69.3 ± 0.3
MycorisePro®	35.6 ± 6.3	7.5 ± 1.6	63.0 ± 2.1	63.0 ± 2.1
Ipomoea carnea				
NonAMF	62.5 ± 5.0	29.4 ± 2.1	81.1 ± 0.0	81.1 ± 0.0
EndoNet®	71.7 ± 6.1	22.8 ± 3.4	86.7 ± 5.5	86.7 ± 5.5
MycorisePro®	66.4 ± 9.1	37.2 ± 9.4	91.7 ± 2.6	91.7 ± 2.6
Significance ($P \leq F$)[x]				
Plant species	***	***	***	***
AMF	NS	**	**	*
Plant species × AMF	NS	NS	**	**

[z]Ves/End = vesicules and/or endospores.

[y]Values are means ± SE, total observations = 750; n = 5.

[x]NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001 respectively.

zation (15, 18). In disturbed landscape sites where construction and digging leads to changes in soil profile and soil structure, the quantity of indigenous AMF would have potentially been lower (i.e. lower MPN) than the landscape site utilized in this study. The landscape site also had previously been planted with a grass cover crop, which was conducive to build-up of AMF inoculum.

In summary, commercial AMF were able to survive container production and initially enhance plant growth of the containerized plants at reduced fertility levels (50% of commercially recommended rate). While AMF enhanced survival of *P auriculata* during the 1st growing season, it could not overcome its poor winter survival compounded by low soil fertility. AMF enhanced growth of *C. linearis* and *P. occidentalis* during the 1st growing season, but by the 2nd growing season no growth differences occurred. This was likely due to high indigenous AMF populations and low soil fertility. A goal in utilizing AMF systems is to initially increase transplanting survival and establishment in more stressful sites compared to NonAMF plants. In this study, none of the plants in the landscape experienced drought stress and over time, high native inocula levels colonized all noninoculated plants. Disturbed landscape sites are frequently low in AMF (7), which was not the case in this study. The initial benefit of AMF inoculation should come in transplant establishment and growth. In time native AMF present in the soil of the landscape site, if in sufficient quantity, would also start to colonize the root system of the transplant (9, 15, 19).

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