

GROWTH OF ARGENTINE MESQUITE INOCULATED WITH VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI

by Chris A. Martin and Jean C. Stutz

Abstract. Argentine mesquite (*Prosopis alba*) seedlings were inoculated with the vesicular-arbuscular mycorrhizal (VAM) fungi, *Glomus intraradices*, container-grown for five months, and transplanted into a simulated landscape in Tempe, Arizona. After transplanting, mesquite trees were either drip irrigated at regular intervals or nonirrigated for one year. Six months after transplanting, VAM fungal colonization was observed only in the roots of inoculated mesquite but by 12 months, roots of both inoculated and noninoculated mesquite were colonized by VAM fungi. Higher levels of VAM fungal colonization occurred in roots of irrigated mesquite. While irrigation promoted mesquite shoot growth, VAM inoculation inhibited shoot growth of nonirrigated trees. Trunk caliper was greater for irrigated trees than for nonirrigated trees and was not affected by VAM infection. VAM fungi promoted the growth of thinner roots for irrigated trees and thicker roots for nonirrigated trees after six months. At the conclusion of the study, root growth was enhanced by drip irrigation and was not affected by previous VAM fungal inoculation.

An estimated two-thirds of all terrestrial plants form vesicular-arbuscular mycorrhizal (VAM) associations (15), and this type of mycorrhizal association is especially predominate in arid climates (1). VAM fungi encourage root uptake of mineral nutrients such as phosphorus in exchange for photosynthetically-reduced carbon, and have been shown to alter plant water relations (3,6,10,12). Several studies have reported an inverse correlation between mycorrhizal colonization and soil phosphorus concentration (14,16). Thus, enhanced root colonization by VAM fungi may be associated with soils of poor fertility such as those found in many disturbed urban planting sites.

Transplant establishment of container-grown trees into urban landscapes is most successful when using landscape systems that promote root growth beyond the container rootball (7,8). Roots of trees grown in nurseries in soilless rooting media, unless specifically inoculated, generally

will be nonmycorrhizal. Mycorrhizal colonization has been associated with changes in root morphology of herbaceous plants by affecting root thickness and branching patterns (4,11). Thus, landscape transplant systems that incorporate inoculation of tree roots with mycorrhizal fungi during the container phase might facilitate transplant establishment by altering root growth and development patterns.

Materials and Methods

We potted 150 seedling liners of Argentine mesquite (*Prosopis alba*) (25 - 35 cm height) into 27-liter containers filled with a 3 pine bark : 1 peat moss : 1 sand medium, pH 6.5. Before potting, 75 of the 150 trees were band inoculated at a depth of 8 to 12 cm below the growth medium surface with approximately 1,000 spores/g of *Glomus intraradices* affixed to attapulgitic clay (Nutrilink, NPI, Salt Lake City, UT). All trees were top-dressed with 15 g Osmocote 18 N - 2.6 P - 9.9 K (Grace-Sierra, Milpitas, CA) and 3 g Micromax (Grace-Sierra, Milpitas, CA) fertilizers and grown for five months in a fiberglass greenhouse under 50% light exclusion. During the container production phase, all trees were watered to container capacity every other day. Prior to transplanting into the landscape, shoot and roots were evaluated for growth. In addition, 20 root segments per tree were sampled, cleared, stained (13) and observed using a light microscope to check for mycorrhizal infection of inoculated trees and noninoculated trees. Percent colonization was calculated as the number of colonized root segments divided by the total number of root segments observed.

After five months, mesquite trees were transplanted into unamended planting holes in a simulated landscape. The soil was a Gilman sandy

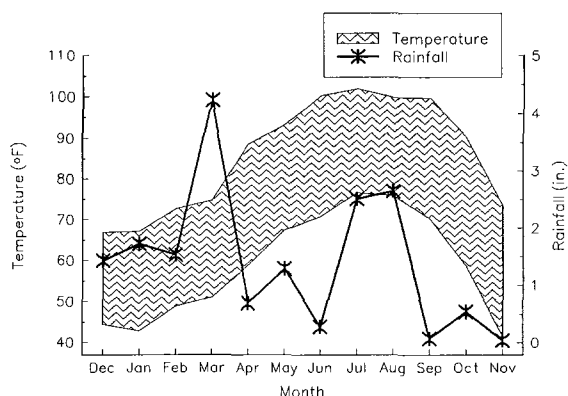


Figure 1. Monthly rainfall and mean daily temperature maxima and minima for Tempe, AZ, from December 1991 to November 1992 (2).

loam, pH 7.3, 11.62 $\mu\text{g P/g}$ soil, 13.2 g organic matter/Kg soil. Each tree was loosely secured to a single 2.6-m tall lodgepole tree stake and pruned to a canopy base height of 1.3 m. Mesquite trees were either drip irrigated every third day with 30 liters per irrigation or nonirrigated. Irrigated trees were watered with two emitters at 7.6 liter/hr per emitter, while nonirrigated trees were flood irrigated once at transplanting. Monthly rainfall and mean daily temperature maxima and minima data are shown in Figure 1 (1).

Tree shoot and root growth, and soil moisture content were measured 6 and 12 months after transplanting. Root growth was analyzed via the extraction of four soil core profiles in the rhizosphere oriented 60 cm from the tree trunk at the north, east, south, and west compass coordinates using a hand-held auger (4). Each soil core profile

consisted of samples taken at 20 cm intervals from 0 to 140 cm below grade. Roots from the samples were then analyzed for fresh weight and for total length using a Model DIAS Digital Image Analysis System (Decagon Devices, Pullman, Wash.). Approximately one hundred 1-cm root segments per tree were cleared, stained and observed under a dissecting microscope (40X magnification). Percent and length of mycorrhizal colonization was calculated using the grid-line intercept method (9). Mycorrhizal root length density (cm root length colonized/ cm^3 soil) was calculated by dividing the estimated length of root colonized in a soil core by soil core volume. Soil cores were extracted over a similar depth range immediately before an irrigation event. Soil moisture content was determined as a percentage of moisture content by weight. The experiment was a 2 x 2 factorial arranged in a randomized complete block design with 12 blocks.

Results and Discussion

Container Production. After four months in containers, roots of inoculated mesquite trees were colonized (47% of roots sampled) while noninoculated trees remained nonmycorrhizal. The VAM fungal isolate used in this study reduced mesquite total root length and specific root length but did not affect shoot growth or root dry weight (Table 1). These data suggest that the effect of VAM infection on mesquite under near-optimal production conditions in a production container medium was to change mesquite root morphology to shorter, thicker, less-branched roots. This manner of root morphological change suggests

Table 1. Growth of Argentine mesquite in 27-liter containers after 5 months following inoculation (+ or -) with *Glomus intraradices*.

Inoculation treatment	Dry weight (g)		Total shoot length (m)	Total root length (m)	Specific root length (m/g d.w.)
	Shoot	Root			
(+) VAM	117.8a ^z ^y	46.3a	4.74a	7.44b	.161b
(-) VAM	128.3a	48.3a	4.92a	11.85a	.245a

^z Values for shoot and root dry weight, total root length, and specific root length are treatment means, n = 12. Values for total shoot length are treatment means, n = 75.

^y Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using Fisher's LSD test.

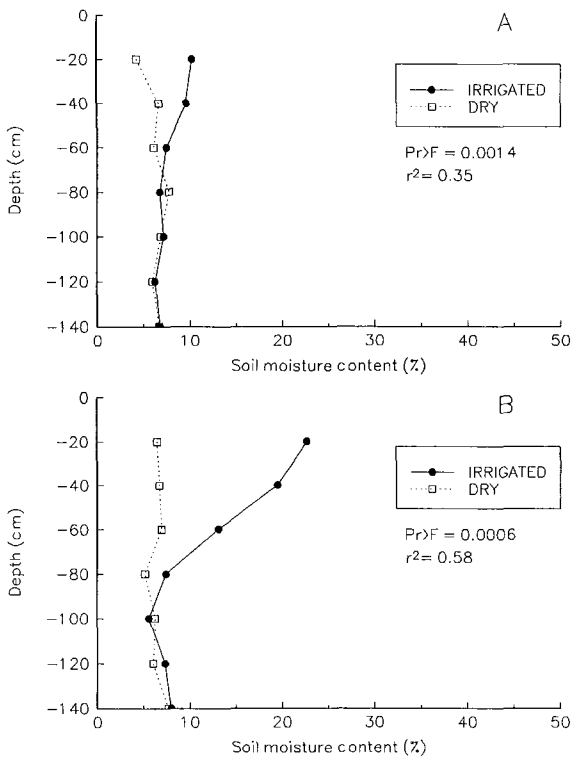


Figure 2. Mean percent soil moisture content of drip irrigated and nonirrigated Argentine mesquite soil cores (0 to 140 cm depth) at A) 6 and B) 12 months (June and December, 1992, respectively) after transplanting ($n = 12$).

that the role of VAM fungi was to substitute for small fine feeder roots and cause the mesquite to allocate more energy resources to enhance root caliper.

Post Transplant. Irrigated soils were generally wetter than nonirrigated soils prior to an irrigation event, particularly in the top 80 cm of soil (Fig. 2). This difference was more pronounced in November than June, most likely due to cooler weather and lower soil evaporation rates.

Six months after transplanting, VAM colonization was observed only in the roots of inoculated mesquite. By 12 months roots of both inoculated and non-inoculated mesquite were colonized by VAM fungi; however, the level of colonization and mycorrhizal root length density were higher for irrigated than for non-irrigated trees (Table 2). Consequently, a strong relationship is suspected

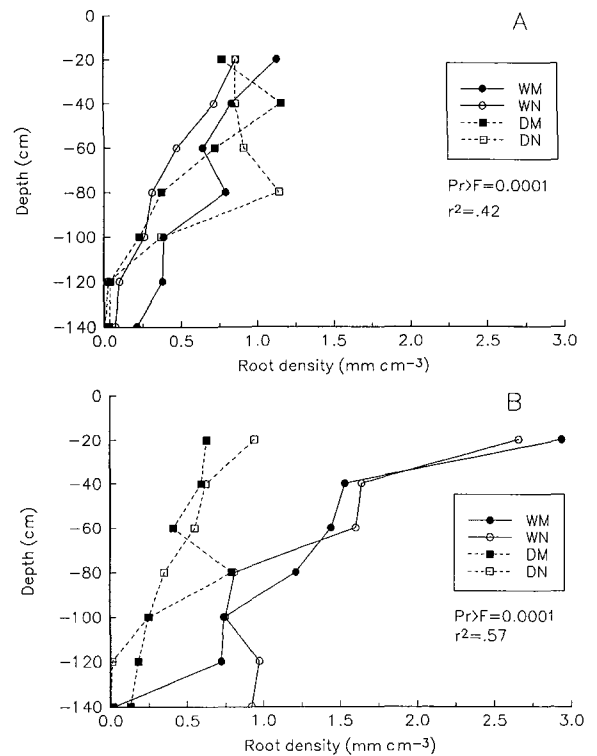


Figure 3. The effect of irrigation on rooting density ($\text{mm root length}/\text{cm}^3$ soil volume) of VAM inoculated (M) or noninoculated (N) Argentine mesquite, 60 cm from the trunk at depths of 0 to 140 cm below ground surface, A) 6 and B) 12 months (June and December, 1992, respectively) after transplanting into a simulated landscape ($n = 12$). Statistical probabilities shown above are for the interaction of irrigation and mycorrhizal treatments. W = drip irrigated regularly; D = dry.

between mycorrhizal colonization of roots and maintenance of ample soil moisture.

Drip irrigation promoted mesquite shoot extension, whereas VAM infection inhibited shoot extension of nonirrigated trees (Table 2). Trunk caliper was greater for irrigated trees than for non-irrigated trees (Table 2). Trunk caliper was not affected by VAM infection. Inhibition of shoot extension by VAM fungi under dry conditions suggests 1) a competition with shoots for photosynthetic assimilates or 2) a change in the root to shoot hormonal signaling patterns resulting in slowed shoot growth (2). The later is more likely because mycorrhizal colonization rates were low

Table 2. The effect of irrigation on shoot extension (SE), trunk caliper (TC), percent VAM fungal infection (% VAM), and mycorrhizal root length density (MRLD) of Argentine mesquite, inoculated or noninoculated (+ or -) with *Glomus intraradices* 6 and 12 months after transplanting.

	SE (cm)	TC (mm)	% VAM	MRLD
Irrigated				
<i>6 months</i>				
(+) VAM	151.2±25.0 ^z	16.5±3.3	4.4±2.5	4.0±1.9
(-) VAM	177.8±30.15	16.7±1.9	0.0	0.0
<i>12 months</i>				
(+) VAM	567.3±135.4	45.7±14.7	28.9±8.6	42.9±14.5
(-) VAM	669.6±105.7	47.9±7.9	18.7±7.9	24.5±7.3
Nonirrigated				
<i>6 months</i>				
(+) VAM	89.7±9.5	13.7±2.4	3.2±2.3	1.8±1.8
(-) VAM	122.0±27.7	14.7±1.4	0.0	0.0
<i>12 months</i>				
(+) VAM	117.7±9.0	29.8±11.8	4.2±2.2	2.3±1.2
(-) VAM	146.0±19.6	31.7±8.4	7.1±3.1	3.5±1.0

^z Mean values±SE, n = 12 and 3 for growth and mycorrhizal data, respectively.

under dry conditions making it unlikely that VAM fungi were engaged in photoassimilate competition with shoots.

Six months after transplanting, mesquite rooting density (RD) decreased with increased depth and was not affected by drip irrigation or mycorrhizal treatments (Fig. 3a). Twelve months after transplanting, mesquite RD decreased with in-

creased depth, but was much higher for irrigated trees 0 to 80 cm below the ground surface than for nonirrigated trees (Fig 3b). VAM inoculation did not affect RD. Drip irrigation and mycorrhizal treatments interacted at 6 months to affect specific root length density (SRLD) (Fig. 4a). Under drip irrigated conditions, roots of inoculated trees were generally thinner than roots of noninoculated trees;

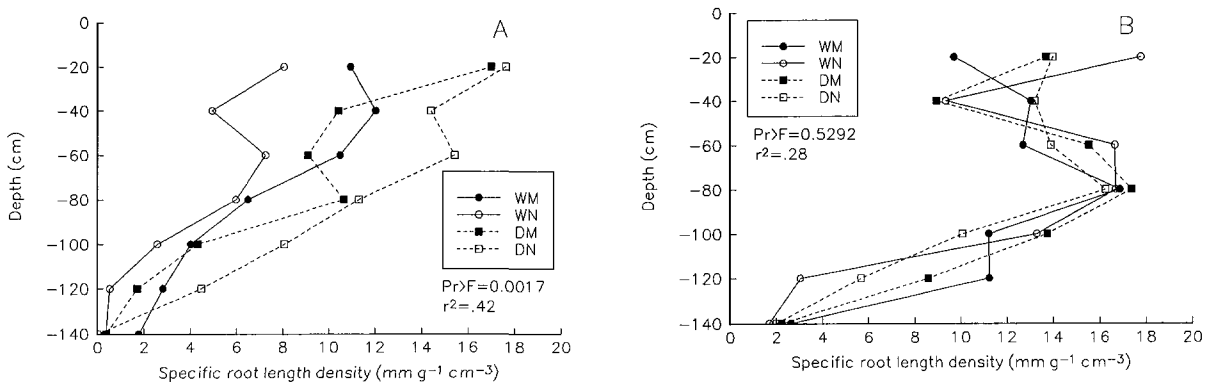


Figure 4. The effect of irrigation on specific root length density (mm root length/g fresh root weight/cm³ soil volume) of VAM inoculated (M) or noninoculated (N) Argentine mesquite, 60 cm from the trunk at depths of 0 to 140 cm below ground surface, A) 6 and B) 12 months (June and December, 1992, respectively) after transplanting into a simulated landscape (n = 12). Statistical probabilities shown above are for the interaction of irrigation and mycorrhizal treatments. W = drip irrigated regularly; D = dry.

whereas, under nonirrigated conditions roots of inoculated trees were thicker than roots of noninoculated trees. At 12 months, SRLD was not affected by irrigation or mycorrhizal treatments (Fig. 4b). SRLD varied with depth and was highest in the top 80 cm indicating a higher concentration of thinner roots at this depth. At lower depths, roots were fewer in number and thicker (Fig 3b and 4b).

Conclusions

Pre-transplant inoculation of Argentine mesquite roots enhanced mycorrhizal root colonization, especially under irrigated conditions for up to one year after transplanting. Low soil moisture drastically reduced growth of Argentine mesquite and mycorrhizal colonization of tree roots. If mycorrhizal symbiotic efficiency is measured in terms of a stimulation of host plant growth, then the isolate of *G. intraradices* used to inoculate mesquite was not a very efficient symbiont under low soil moisture content because it suppressed growth after transplanting. However, this growth suppression might be caused by mycorrhizal-induced changes in the root to shoot hormonal signalling patterns and therefore may act as a survival mechanism resulting in the sequestration of photoassimilates particularly in the roots as evidenced by root thickening or decreased SRLD. Other geographic isolates of VAM fungi, especially those indigenous to more arid regions, might promote an alternate tree response.

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Résumé. Des semis de mesquite blanc (*Prosopis alba*) furent ou non inoculés avec le champignon de mycorrhize vésiculaire-arbusculaire *Glomus intraradices* et furent laissés en croissance dans des contenants de 27 litres pour une période cinq mois au terme de laquelle ils furent transplantés dans un aménagement artificiel à Tempe en Arizona. Après la transplantation, les mesquites étaient soit irrigués au goutte-à-goutte à intervalles réguliers ou non irrigués (irrigation abondante en une seule fois lors de la transplantation) pour une durée d'un an. Six mois après la transplantation, une colonisation par des mycorrhizes vésiculaires-arbusculaires fut observée seulement sur les racines de mesquites inoculés, mais 12 mois après, toutes les racines inoculées ou non au début furent colonisées par des mycorrhizes. Le taux de colonisation des racines par les mycorrhizes fut plus élevé pour les mesquites irrigués en comparaison de ceux non irrigués. L'irrigation favorisa la croissance des pousses de mesquite et l'inoculation de mycorrhizes inhiba la croissance des pousses chez les arbres non irrigués. Le diamètre du tronc fut plus élevé pour les arbres irrigués que ceux ne l'étant pas et il ne fut pas influencé par le taux de colonisation en mycorrhizes.

Zusammenfassung. Argentinische Mesquite (*Prosopis alba*) Sämlinge wurden mit dem 'vesicular-arbuscular mycorrhizal' (VAM) Pilz *Glomus intraradices* entweder geimpft oder nicht geimpft, für fünf Monate in 27 l-Kontainern gezogen und anschließend in eine vorgegebene Landschaft in Tempe, AZ, verpflanzt. Nach der Verpflanzung wurden die Mesquite-Bäume entweder in regelmäßigen Abständen tröpfchenbewässert oder nicht bewässert (Flut-bewässerung nur einmal in der Verpflanzungszeit). Sechs Monate nach der Verpflanzung wurde eine Kolonisation von VAM-Pilzen nur an den Wurzeln von geimpften Mesquite-Pflanzen beobachtet, aber nach zwölf Monaten konnte eine Kolonisation durch VAM-Pilze an den Wurzeln von geimpften und nicht geimpften Pflanzen beobachtet werden. Auf den Wurzeln von bewässerten Pflanzen verglichen mit nicht bewässerten war die Kolonisationsrate durch VAM-Pilze höher. Die Bewässerung förderte das Wachstum der Mesquite-triebe und die VAM-Impfung nahm das Wachstum der Triebe von nichtbewässerten Pflanzen. Der Stammdurchmesser bei bewässerten Pflanzen gegenüber unbewässerten war größer, und wurde durch die VAM-Infektion nicht beeinflusst.

New Books

Tree Anatomy by Alex L. Shigo, 1994, hard-cover, 104 pages, 94 color photos. Published by Shigo and Trees, Associates, P.O. Box 769, Durham, New Hampshire 03824, U.S.A. Price US\$79.00 plus US\$4.00 shipping.

Over past decades we've all enjoyed both the great enthusiasm of his talking and the unusual beauty of his slides as we attended numerous lectures by Alex Shigo at professional tree conferences of all types. But as any teacher realizes, one drawback of lecturing from slides is that your students/audience cannot carry away your pictures for later thoughtful study. Now our problem is solved. In this 9x12-inch book, of "coffee-table" quality, Dr. Shigo gives us here what he considers to be his 94 best photos chosen by him among the 3,000 which he considered eligible for this publication. He has taken care to include trees from many regions and climates, and to show the original size of the field photographed for each of these photo-micrographs. Moreover, each photo is accompanied by a paragraph of appropriate commentary, written in his inimitable style. There are micro-photos of flowers, fruit, leaves, needles, buds, pith, young stems, bark, wood, tropical wood, trunk vs. root wood, roots, compartmentalization, palms, wood in other tropical trees, mycorrhizae, and slime molds. To all this he has added: a 50-item summary, a bibliography of 59 books (some of which I'd never known before), a subject index, and indices of species shown and species mentioned. This book will give you all the pleasure you got from hearing Dr. Shigo speak at any of his seminars, but this time it will happen at your own convenience and in your own home. I'm very pleased to be able to add it to my library. (Dr. Francis W. Holmes)

Native Plants for Southwestern Landscapes by Judy Meilke. University of Texas Press. P.O. Box 7819, Austin, Texas 78713, phone (512) 471-4032. \$39.95 cloth, \$22.95 paper. 5.75 x 8.25 inches, 384 pp, 350 color photos.

Native plants have gained in popularity over the past decade, but the amount of information available about growing them hasn't kept pace. This book will help close the gap. It is written in a style easily understood by beginning gardeners, yet it contains enough information to satisfy the needs of landscape professionals. The heart of the book lies in the complete descriptions and beautiful color photographs of plants native to the Mojave, Sonoran, and Chihuahuan desert regions of the southwestern United States and northern Mexico. Judy Mielke characterizes each plant's foliage, flowers, fruits, and mature sizes. She gives detailed information on its natural habitat, its water, soil, light, temperature, and pruning requirements, and its possible uses in landscape design.