Contact the author for availability of cutting material and sources of plants. Although they have not been tested over a wide geographical range, it is quite likely that some will be adaptable to the more southern areas.

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MYCORRHIZAE IN CONTAINER PLANT PRODUCTION

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Mycorrhizae refers to a symbiotic association between a nonpathogenic or weakly pathogenic fungus and living cells of plant roots. Most all plants of the world are mycorrhizal, although wetland rice, cypress, and many plants in the Chenopodiaceae and Cruciferae are not mycorrhizal (1,2,6).

Mycorrhizae are categorized into three major groupings: ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae. Ectomycorrhizae are predominantly found in association with coniferous trees, and the fungi that form them have aboveground mushroom fruiting bodies. These disseminate small air-borne spores. They form a thick covering on roots called a mantle, which is essentially an accumulation of mycelium. The most common form of endomycorrhizae are vesicular-arbuscular (VA) mycorrhizae, which form on a majority of the angiosperms of the world. In comparison to the ectos, the spores of VA mycorrhizal fungi are large (size of a pin head) and are disseminated by water or mechanical means. Both types of mycorrhizal fungi penetrate into outer regions of roots (cortical cells), but only the endomycorrhizal fungi enters the cells. Neither penetrates the endodermis of roots and, therefore, neither enters the vascular system of plants. Ectendomycorrhizae possess characteristics of both types are are commonly found on the Ericaceae (3).

Cultural practices in container production of ornamentals eliminate or significantly reduce populations of these beneficial organisms. Media components such as pine bark, vermiculite, perlite, builder's sand, and most peatmosses are usually devoid of mycorrhizal fungi. Many nurserymen steam, pasteurize, or chemically treat media to eradicate harmful pathogens. These procedures also eliminate beneficial organisms such as mycorrhizal fungi. Nurserymen compensate for absence of mycorrhizae by applying luxury amounts of fertilizer and water in order to achieve desired growth. High levels of nutrition and irrigation will not always be feasible because of petroleum shortages used in manufacture of inorganic fertilizers and rigid restrictions on water utilization. In addition runoff water is being carefully monitored by environmental regulatory groups for the presence of nutrients and pesticides.

Inoculation of container-grown plants with mycorrhizal fungi provides a possible means of reducing the need for current high levels of irrigation, fertilizers, and pesticides. A research program was established at University of Florida to determine potential benefits of mycorrhizae in container production and landscape establishment.

MATERIALS AND METHODS

Experiment I. VA mycorrhizae benefit growth of numerous agricultural plant species (1,6), but research on container-grown woody ornamentals is limited.

Rooted stem cuttings of *Viburnum suspensum*, *Podocarpus macrophyllus*, and *Pittosporum tobira* were transplanted into 3 liter pots containing a methyl bromide-treated 1 peatmoss: 1 sand (by volume) mixture. The growing medium was amended with 4.2 kg (9.2 lb) dolomite lime, 1.0 kg (2.2 lb) superphosphate, and 0.9 kg Perk (2.0 lb) per m^3 (1.3 yd^3).

Rooted cuttings were inoculated with a 10 g mixture of *Glomus fasciculatum* or *G. mosseae* spores (200 spores/gm), hyphae and infected roots of bahia grass at time of transplanting. We have found that a living root must be present for establishment to occur. An inoculum filtrate was applied to roots of nonmycorrhizal plants. Plants were grown under 25% shade and fertilized every other week with 224 kg N,K/ha.yr^{-1} (200 lb/acre yr^{-1}). Mycorrhizae require good aeration, so it is important to avoid overwatering. Measurements of plant height, stem caliper, and dry weight of shoots and roots were recorded after 6 months. Root segments from all plants were cleared, stained, and percent infection determined according to procedures of Phillips and Haymen (8) at the experiment termination.

Experiment II. High levels of P have been shown to reduce mycorrhizae ,and subsequent plant growth benefit (5,7). However, effects of N and K on mycorrhizal benefit to woody plants have received less attention. This experiment was established to determine if N and K at various levels would negate benefits of mycorrhizal inoculation.

Rooted cuttings of *Pittosporum tobira* and *Podocarpus macrophyllus* were transplanted into 3 liter pots containing a methyl bromide-treated 1 peat: 1 sand (by volume) medium. The growing medium was amended with 4.2 kg (9.2 lb) dolomite lime, 1.0 kg (2.2 lb) superphosphate and 0.9 kg (2.0 lb) Perk per m^3 (1.3 yd^3). Half the plants were inoculated with *Glomus spp.* (*G. mosseae* and *G. fasciculatum*) according to procedures described in Experiment I. Factorial combinations of fertilizer solutions were applied monthly to provide 250, 750 and 1500 kg/ha.yr^{-1} (223, 670, 1340 lb/ac.yr^{-1}) N and K from NH_4NO_3 and KNO_3.

Plants were grown in an unshaded fiberglass greenhouse for 9 months. Shoot and root weights were determined at experiment termination and root segments from all plants were cleared, stained and percent root infection determined according to procedures described in Experiment 1.

RESULTS AND DISCUSSION

Experiment I. *Glomus fasciculatum* and *G. mosseae* infection resulted in a 2- to 3-fold increase in growth of the 3 woody plant species (Table 1). The percent root infection was high for the 3 plant species and was similar for both mycorrhizal fungi. This research indicated that production of high quality woody ornamentals is possible with mycorrhizal inoculation and low fertilizer levels.

Experiment II. Percent infection was reduced with increased N rates for inoculated plants (Table 2). Potassium, on the other hand had little influence on the amount of infection. Other researchers (5,7) have found similar reduction of infection in response to high P, but influence of N and K on infection has received less attention.

Table 1. Growth of 3 woody ornamentals grown for 6 months with or without VA mycorrhizae.

Species	Inoculum Source	Plant ht[x] (cm)	Stem Caliper[y] (cm)	Shoot fresh wt (g)	Root fresh wt (g)	Root infection (%)
V. suspensum	Control	18.2a[z]	4.3 a	33.9 a	17.7 a	0
	G. fasciculatum	39.9b	5.2 b	62.1 b	37.3 b	69
	G. mosseae	39.6b	5.2 b	63.0 b	38.2 b	77
P. macrophyllus	Control	14.1a	3.4 a	19.2 a	9.4 a	0
	G. fasciculatum	36.3b	4.3 b	52.1 b	33.7 b	73
	G. mosseae	34.3b	4.3 b	53.3 b	32.3 b	71
P. tobira	Control	12.3a	3.3 a	17.9 a	8.4 a	0
	G. fasciculatum	29.2b	4.7 b	30.1 b	16.1 b	67
	G. mosseae	31.2b	5.0 b	34.7 c	18.1 b	79

[x] Measured from pot rim to terminal of tallest stem.
[y] Measured 1 cm above media surface.
[z] Mean separation, within column, for each plant species by Duncan's multiple range test, 1% level.

Table 2. Effect of N and K on root infection of two woody ornamentals inoculated with VA mycorrhizae (*Glomus fasciculatum* and *G. mosseae*).

Inoculation treatment	Fertilizer rate ($kg/ha.yr^{-1}$)	Roots infected (percent)	
		P. macrophyllus	*P. tobira*
Noninoculated control		0[y]	0
Inoculated			
Glomus spp.	N-250[z]	58	54
	750	50	46
	1250	44	45
Linear		*	*
Glomus	K-250[z]	51	49
	750	50	48
	1250	50	48
Linear		NS	NS

[y] Mean of 6 plants.
[z] 223, 670, 1340 lb. N or $K/ac.yr^{-1}$.
* N significant at 5% (*) or not significant (NS).

Shoot growth of noninoculated *P. macrophyllus* was increased with high rates of N, but *P. tobira* response with increased N was small and inconsistent (Figure 1). Increased levels of K showed only small growth increase of shoots for both plant species. Root development of *P. macrophyllus* was improved with high K, but other treatments showed no consistent response. Highest shoot fresh weight of inoculated *P. macrophyllus* and *P. tobira* was at the middle rates of N and K. Inoculation at all N fertilization rates improved root fresh weight, but only the K treatments for *P. macrophyllus* showed mycorrhizal response.

Container production of woody ornamental plants lends itself to use of VA mycorrhizal fungi even at high rates of N

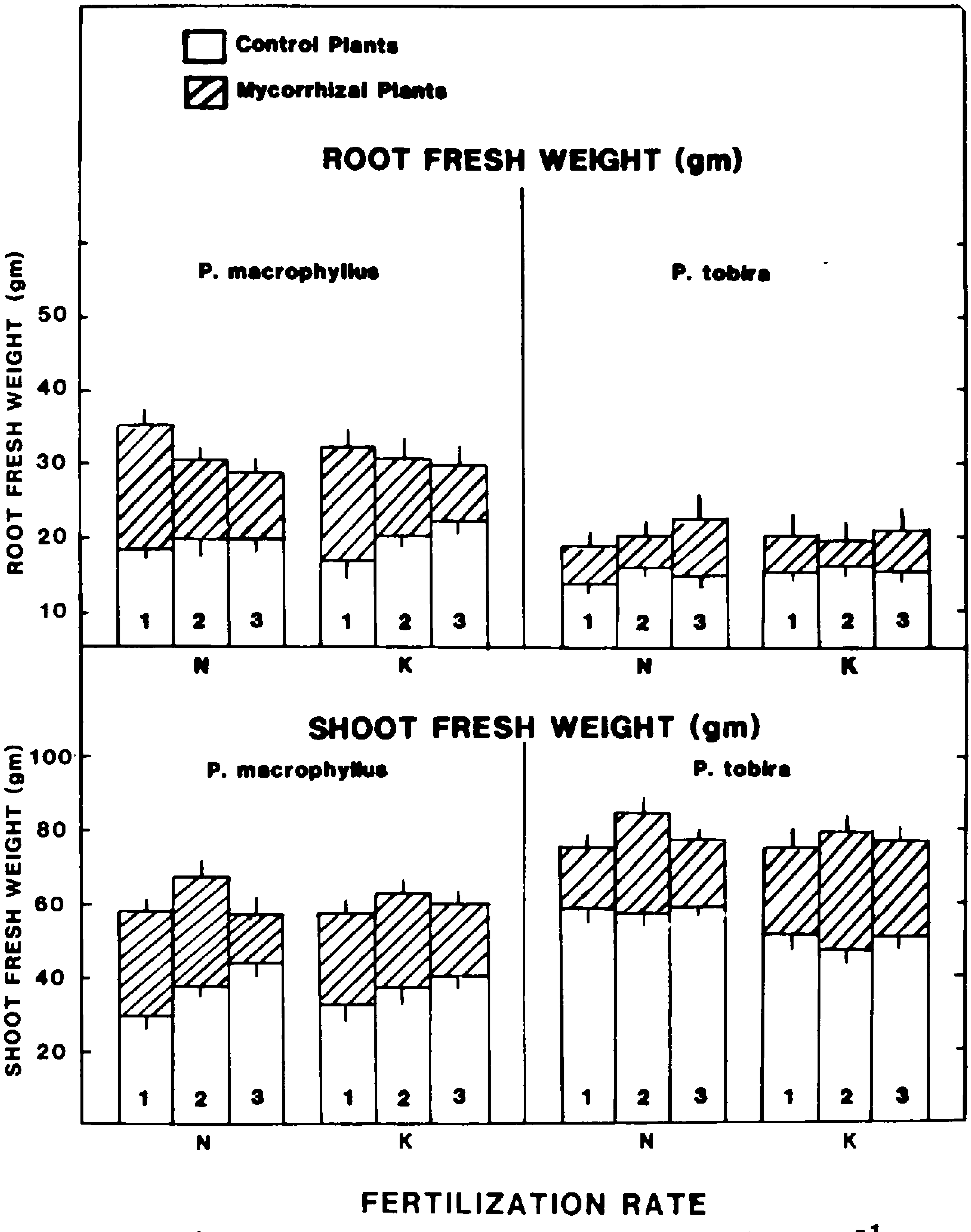

Figure 1. Fresh weight of shoots and roots of two woody ornamentals after 9 months, as influenced by mycorrhizae. Vertical lines represent standard deviation of means.

and K fertilization. The greatest plant growth and potentially economic benefit from using mycorrhizae would be realized at low to medium fertilization rates. However, this research indicates that VA mycorrhizal fungi could be used over a wide range of nursery fertilizer regimes.

Potential Economic Benefits: Because VA mycorrhizal fungi occur on a wide variety of woody plant species and also because they improve growth, the potential of these fungi as commercial "biotic fertilizers" is great.

Fertilization currently constitutes 3 to 4% of current nursery production expenses (9), but will become a much greater portion of the nursery budget in the future. Data from our research on woody plants indicates P fertilizers could be reduced by approximately 70%. Current levels of N, K and micronutrient fertilizers could be reduced by 30 to 40%. This potentially could reduce fertilizer expenditures by 25% for a savings of approximately $12.13 per 1000 gallon containers annually for woody plants grown under a typical fertilization program (Table 3).

Table 3. Estimated fertilizer costs[x] for woody landscape plants grown in gallon containers with and without VA mycorrhizae.

Fertilizer		Annual fertilization cost for 1,000 gallon containers		
Material	Rate[y,z]	Without VA mycorrhizae	With VA mycorrhizae	Potential Savings
Micronutrients	31.2 g/ft 3 (1.1 oz/ft^3)	8.97	5.38	3.59
Superphosphate	2.2 kg/yd^3 (5 lb/yd^3)	3.72	1.11	2.61
25-0-25	Avg. 130 ppm N	35.90	21.54	14.36
VA mycorrhizal inoculum	2 gm/container		8.43	-8.43
		$48.59	$36.46	$12.13

[x] Based on December, 1982, price estimates.
[y] Fertilization rates based on commercial woody nursery operations using overhead fertigation system.
[z] Phosphorus levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA mycorrhizal fungi.

Preliminary research has indicated that an additional benefit is in improved establishment and survival of mycorrhizal plants in landscape soils (4). Improved plant survival and reduced costs for water and fertilizer should create consumer demand for mycorrhizal plants in the landscape.

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IMPROVED PRODUCTION OF NURSERY CROPS WITH MYCORRHIZAL FUNGI

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Mycorrhizae are the symbiotic (beneficial) association of helpful fungi with the fine roots of plants. All horticultural crops form associations with mycorrhizal fungi. What we need to do is learn how to manipulate mycorrhizal associations to reduce nursery production costs and increase profits (2).

Some of the problems confronting the nursery industry are increased production costs and greater governmental regulations, which may curtail water usage of water runoff containing undesirable levels of salt fertilizers, fungicides, pesticides, etc. We also need to produce and market more stress-efficient native ornamental plants that utilize lower levels of water and fertilization. The California industry is currently facing strict water runoff regulations and water salinity problems. The Texas nursery industry stands to benefit from more efficient production systems utilizing mycorrhizal fungi that enable production of nursery crops under reduced watering and fertility regimes. Nurseries throughout the Southeast can benefit from knowledge of mycorrhizal associations for the same and other reasons.

The association with mycorrhizal fungi makes plants more efficient in absorbing nutrients and water from the soil. Other benefits are increased pathogen resistance, adventitious root formation, enhanced seedling growth and plant establishment in the landscape. It has been documented that mycorrhizal nursery crops, which are more efficient and stress resistant, may consequently command a premium price on the market place.

Clearly there is a need for more research to be done with nursery crops looking at mycorrhizal benefits and potential