The Influence of Mycorrhizal Fungi, Organic and Inorganic Slow Release Fertilizers on Growth and Development of Bush Morning Glory (*Ipomoea carnea*)©

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

This study investigated the utilization of arbuscular mycorrhiza fungi (AMF) to enhance the efficiency of slow-release organic and inorganic fertilizers during container production of bush morning glory (*Ipomoea carnea*). Uniform rooted liners of *I. carnea* were planted into 2-gal (9.6-liter) pots containing a pasteurized soilless medium [pine bark and sand (3 : 1, v/v)]. The mycorrhizal treatments consisted of two commercial AMF inocula: Bioterra Plus and Mycorise Pro, and a noninoculated control [NonAMF]. Fertilizer treatments included an organic slow release fertilizer (SRF) (Nitrell; 5N-3P-4K) and an inorganic SRF (Osmocote; 18N-7P-10K). Nitrell was tested a three levels: 8.4 kg·m^{-3} (14 lb per yd^3), 12 kg·m^{-3} (20 lb per yd^3), and 16.8 kg·m^{-3} (28 lb per yd^3), which were, respectively, 70%, 100%, and 140% of the manufacturer's recommended rate. Osmocote was tested at two levels: 6 lb per yd^3 (3.5 kg·m^{-3}) and 12 lb per yd^3 (7.0 kg·m^{-3}) which were, respectively, 50% and 100% of the recommend rate. With organic and inorganic SRF, both mycorrhizal inocula significantly enhanced the marketability, growth index, root, leaf, shoot and total plant dry mass of bush morning glory. The greatest growth response occurred with the highest level of Osmocote colonized with Bioterra Plus. Organic and inorganic SRF regimes did not inhibit mycorrhizal development, which ranged from 12% to 27% colonization.

INTRODUCTION

The incorporation of new production systems to reduce fertilizer and pesticide usage without reducing plant quality is one of the most important challengers facing the nursery industry. The utilization of best management practices (BMP) such as recycling irrigation water, increased slow-release fertilizer usage, and biological pest control are some of the practices that the nursery industry has implemented. There is much potential in utilizing arbuscular mycorrhiza fungi (AMF) in nursery production systems since AMF enhance plants nutrient and water relations (Davies et al., 1996; Nelsen, 1987; Smith and Read, 1997), and increase plant tolerance to environmental stress (Davies et al., 2000). AMF can also increase disease resistance (Linderman, 1992), increase photosynthesis and plant vigor (Aguilera-Gomez et al., 1999), and reduce transplant stress (Sylvia et al., 1998) — all benefits that enhance crop production value.

The objective of this research was to demonstrate that AMF can enhance the efficiency of organic and inorganic SRF, therefore improving growth and marketability of ornamental plants during production. A long term goal in utilizing AMF is to enhance fertility efficiency, minimize environmental pollution during production, and increase plant marketability.

MATERIALS AND METHODS

This study was conducted under a simulated commercial container production system at the Texas A&M University Nursery and Floriculture Field Complex. Uniform rooted liners of *Ipomoea carnea* were planted into 2-gal (9.6-liter) pots containing pasteurized soiless medium [pine bark and sand (3 : 1, v/v)]. After pasteurization, the medium was amended with 0.9 kg·m^{-3} (1.5 lb per yd^3) of Micromax trace elements (Sierra Chemical Co., Mipitas, Calif), 3.5 kg·m^{-3} (6 lb per yd^3) dolomitic limestone and 1.75 kg·m^{-3} (3 lb per yd^3) gypsum ($CaSO_4$).

Two commercial sources of AMF were used: Bioterra Plus and Mycorise Pro. Bioterra Plus **(**BioTerra Technologies, Inc) is composed of composite mix of seven mycorrhizal isolates including *Gigaspora* and *Glomus* species. The inoculation rate was 60 ml, with a range of 3000 to 3600 propagules per plant calculated by the most probable number (MPN). Mycorise Pro (Premier Tech, Inc.) inoculum was composed of a single isolate, *Glomus intraradices* (Schenck & Smith). The inoculation rate was 40ml, with an estimated range of 90 to 630 propagules per plant, calculated by MPN. The inocula were placed in a dibble hole, upon potting-up/canning of the *I. carnea* rooted liners. One-third of the plants were left as noninoculated controls [NonAMF].

Fertility treatments included the organic SRF, Nitrell [5N-3P-4K] (Fertrell Co; Baimbridge, Pennsylvania) and an inorganic SRF, Osmocote [18N-7P-10K] (Scotts Co., Marysville, Ohio). Nitrell was tested at three levels: [organic-70%] 8.4 kg·m^{-3} (14 lb per yd^3), [organic-100%] 12 kg·m^{-3} (20 lb per yd^3), and [organic-140%] 16.8 kg·m^{-3} (28 lb per yd^3), which were, respectively, 70%, 100%, and 140% of the manufacturer's recommend rate. The organic SRF was top-dressed and covered with a 1-cm layer of pasteurized medium to avoid wind dispersion of the product. Osmocote was tested at two levels [inorganic 50%] 6 lb per yd^3 (3.5 kg·m^{-3}), [inorganic 100%] 12 lb per yd^3 (7.0 kg·m^{-3}) which were, respectively, 50% and 100% of the manufacturer's recommend rate. The inorganic SRF was also top-dressed. The P levels were equilibrated so the organic-70% = inorganic-50% and organic-140% = inorganic-100% SRF.

Plant Growth and AMF Analysis. After 59 days plants were harvested and leaf area, shoot, and root dry mass were determined. Assessment of AMF colonization included arbuscule formation, vesicle, intraradical hyphae, and total colonization. For AMF analysis of roots, 1-cm root segments from five plants per treatment were sampled at harvest and pooled to access colonization percentage, following procedures described by Koske and Gemma (1989).

Chlorophyll Determination. Measurement of total leaf chlorophyll (CHL *a* + *b*) was determined with a nondestructive method (Yadava, 1986) using a portable chlorophyll meter (SPAD-501; Minolta Camera Co., Ltd., Osaka, Japan) at 56 days after the inoculation. Data are presented as % chlorophyll based on SPAD-501 readings.

Leaf Nutrient Analysis. Leaf tissue analysis was conducted on an inductively coupled plasma atomic emission spectrometer (J.R. Peters/Scotts Testing Lab., Allentown, Pennsylvania). Three replicates of a pool of 5 plants per treatment was used in order to determine the mineral status at the end of the experiment.

Marketability Determination. At the end of the experiment a group of three nursery production experts evaluated the marketability of the plants. The selection

Table 1. Effect of mycorrhiza, organic, and inorganic slow-release fertilizers on growth of container grown *Ipomoea carnea*.

Mycorrhiza	Fertility source	Recommended level (%)	Root DM (g)	Leaf DM (g)	Shoot DM (g)	Total plant DM (g)	Growth index[z] (cm^3)	Leaf area (cm^2)	Chlorophyll[y] (%)
NonAMF	Organic	70	3 ± 1	2 ± 0	8 ± 2	11 ± 2	4,398 ± 1187	313 ± 53	31 ± 1
		100	5 ± 1	3 ± 0	8 ± 1	13 ± 2	5,401 ± 1033	389 ± 56	35 ± 1
		140	1 ± 0	1 ± 0	3 ± 1	4 ± 1	1,867 ± 451	121 ± 33	41 ± 1
	Inorganic	50	3 ± 0	2 ± 0	7 ± 1	10 ± 2	4,391 ± 752	248 ± 46	31 ± 1
		100	4 ± 1	3 ± 0	10 ± 1	14 ± 2	7,958 ± 1453	452 ± 68	39 ± 1
Bioterra Plus	Organic	70	8 ± 1	4 ± 0	19 ± 2	27 ± 2	11,011 ± 968	562 ± 48	38 ± 1
		100	5 ± 1	3± 0	12 ± 2	17 ± 3	6,800 ± 1442	410 ± 67	37 ± 1
		140	4 ± 1	2 ± 0	8 ± 2	12 ± 3	3,821 ± 1180	328 ± 59	32 ± 1
	Inorganic	50	11 ± 1	4 ± 0	21 ± 1	31 ± 2	14,505 ± 1554	673 ± 59	39 ± 1
		100	13 ± 1	6 ± 0	26 ± 2	39 ± 3	20,311 ± 2078	968 ± 55	43 ± 3
Mycorise Pro	Organic	70	5 ± 1	3 ± 0	12 ± 2	17 ± 3	7,138 ± 1394	426 ± 59	33 ± 1
		100	5 ± 1	5 ± 0	10 ± 2	15 ± 3	4,920 ± 1519	429 ± 94	33 ± 1
		140	3 ± 1	2 ± 0	6 ± 1	10 ± 2	4,482 ± 929	330 ± 50	36 ± 1
	Inorganic	50	7 ± 1	3 ± 0	14 ± 2	21 ± 2	8,679 ± 1337	522 ± 55	37 ± 1
		100	10 ± 1	5 ± 0	20 ± 2	30 ± 3	16,636 ± 1710	894 ± 48	46 ± 1
Significance (Pr < F)									
Fertility			***	***	***	***	***	***	***
AMF			***	***	***	***	***	***	***
AMF* Fertility			***	**	***	***	***	**	***

Values are means ± SE, n=15. ^{NS,*,**,***} Nonsignificant or significant at $P \leq 0.05$, 0.01, 0.001 respectively.
[z]Growth Index = (height*$diameter_1$*$diameter_2$ / 3).
[y]Chlorophyll levels were measured with a Spad meter and correlated to chlorophyll levels.

criteria was based on standard commercial size, form, bloom characteristics, and overall plant quality. Plants were rated as either marketable (salable) or nonmarketable (substandard quality or requiring more production time).

Experimental Design. The factorial experiment included 3 AMF treatments (2 commercial inocula + nonAMF control) × 5 SRF treatments (3 organic + 2 inorganic SRF levels) in a completely randomized design with each plant as an experimental unit (n=20). The data were analyzed using analysis of variance procedure (SAS Institute Inc., 1996).

RESULTS AND DISCUSSION

With organic (Nitrell) and inorganic (Osmocote) SRF, both commercial AMF inocula significantly enhanced the growth, nutrient uptake, and marketability of bush morning glory (*I. carnea*). Plants colonized with Bioterra and Mycorise Pro had a greater growth index, root, leaf, shoot, and total plant dry mass, regardless of the SRF source (Table 1). The greatest total dry mass accumulation was obtained at the highest level of inorganic SRF. While P levels were equilibrated between the organic-140% and inorganic-100% SRF, the nitrogen levels of inorganic SRF were higher, which in part led to the greater growth response. The organic-150% depressed plant growth compared to the 70% and 100% recommended levels.

There were higher yields (shoot, root, and leaf dry mass, and leaf area) with the commercial SRF recommended levels (inorganic-100%) followed by inorganic-50% and organic-70% (Table 1). The greatest growth response was obtained with Bioterra Plus commercial inoculum with inorganic-100% at the commercial nursery recommended level of 12 lb per yd^3 (7.0 $kg \cdot m^{-3}$). These results are promising since under commercially recommended fertility levels, the addition of mycorrhiza can improve plant growth.

Plant biomass and growth index increased as the levels of inorganic SRF increased. With organic-70% plants colonized with AMF had a greater total plant mass and growth index than plants at 100% and 140% of the recommended rate. The lowest plant dry weight for AMF treatments was the SRF organic-140%. Growth depression at the higher rate was likely due to ammonium stunting plant growth.

When comparing AMF within a reduced inorganic SRF level (Osmocote-50%), Bioterra Plus increased the total plant dry mass of bush morning glory three-fold [(3×) (32 g)] and Mycorise Pro increased the total dry mass more than two-fold [(2×) (21 g)] compared to NonAMF plants (10g).

Mycorrhiza colonization among inoculated treatments was high, ranging from 12% to 27% (Fig.2). The higher fertility rates for organic and inorganic fertilizer did not depress AMF colonization. These results suggest that the commercial isolates under study are able to survive, colonize and be effective and efficient (they increased dry mass) in a commercial nursery container production system.

The overall improved plant growth of selected AMF and SRF treatments was also reflected in the marketability of plants evaluated after 56 days of container growth (just prior to terminating the experiment). Marketable plants had compact growth, dark green leaf color, good branching, and the presence of blooms or floral buds. Plants that did not meet this criterion were considered nonmarketable (nonsalable). Mycorrhizal plants were more marketable among all SRF treatments (Table 2). In general, AMF plants fertilized with inorganic SRF were more marketable than with organic SRF. Bioterra at 50% and 100% inorganic SRF, and Mycorise Pro at

Table 2. Effect of arbuscular mycorrhiza fungi, organic, and inorganic slow release fertilizers on plant marketability and macroelemental and micro-elemental uptake in leaf tissue of *Ipomoea carnea*.

Mycorrhiza	Fertility source	Recommended level (%)	N[Y] ($g \cdot kg^{-1}$)	P ($g \cdot kg^{-1}$)	K ($g \cdot kg^{-1}$)	B ($ug \cdot g^{-1}$)	Fe ($ug \cdot g^{-1}$)
NonAMF	Organic	70	40±10	3±1	36±9	186±37	124±18
		100	60±6	5±0	55±5	244±36	162±18
		140	32±7	2±1	26±5	120±26	77±17
	Inorganic	50	55±4	4±0	47±4	165±13	118±12
		100	90±17	7±2	80±20	326±75	251±77
Bioterra Plus	Organic	70	75±8	6±1	66±4	334±19	211±26
		100	56±12	4±1	51±l2	277±57	135±28
		140	45±9	3±1	44±9	206±34	143±28
	Inorganic	50	105±2	9±0	81±4	386±7	263±19
		100	180±20	13±1	135±16	501±48	441±36
Mycorise Pro	Organic	70	52±10	4±1	46±8	246±43	159±24
		100	50±10	4±1	46±10	231±54	138±22
		140	15±1	3±0	51±3	177±2	130±7
	Inorganic	50	65±1	6±0	35±3	293±20	158±14
		100	178±16	12±0	80±20	533±25	348±26
Significance (Pr < F)							
AMF			***	***	***	***	***
Fertility			***	***	***	***	***
AMF* Fertility			***	*	*	NS	NS

[Y]Values are means ±SE, n=3. NS,*,**,*** Nonsignificant or significant at $P \leq 0.05, 0.01, 0.001$ respectively.

[Z]Marketability: Commercial saleable plants at 56 days after treatments of container bush morning glory; values are percentage, n=20.

inorganic-100% SRF had the greatest number of marketable plants. This is an important result since mycorrhiza inoculation can effectively reduce fertilizer inputs, i.e., high marketability occurred with AMF-treated plants at 50% of the recommended inorganic and 70% of the organic SRF.

CONCLUSIONS

The AMF and inorganic and organic SRF fertilizer regimes increased overall plant growth (plant root, leaf, shoot, and total dry mass) and marketability of container-grown bush morning glory (*I. carnea*). Mineral elemental status of colonized plants was significantly higher than NonAMF plants. Both commercial inocula were able to survive and be effective in improving the growth and development of containerized plants at even the highest level of fertility. AMF also enhanced the growth and marketability of inorganic and organic SRF at lower than recommended fertility levels — hence the potential to lower fertility inputs and still maintain high marketability.

LITERATURE CITED

Aguilera-Gomez, L., F.T. Davies, Jr., V. Olalde-Portugal, S.A. Duray, and **L. Phavaphutanon**. 1999. Influence of phosphorus and endomycorrhiza on gas exchange, plant growth and mycorrhizal development of chile ancho pepper (*Capsicum annuum* L. cv. San Luis). Photosynthesis 36:441-449.

Azcon-Aguilar, C. and **J. M. Barea**. 1997. Applying mycorrhiza biotechnology to horticulture significance and potentials. Sci. Hort. 68(1-4):1-24.

Davies, F.T., Jr., J.A. Sraiva Grossi, L. Carpio, and **A. A. Estrada-Luna.** 2000. Colonization and growth effects of the mycorrhizal fungus *Glomus intraradicies* in a commercial nursery container production system. J. Environ. Hort. 18:247-251.

Davies, F.T., Jr., S.E. Svenson, J.C. Cole, L. Phavaphutanon, S.A. Duray, V. Olalde-Portugal, C.E. Meier, and **S.H. Bo.** 1996. Non-nutritional stress acclimation of mycorrhizal woody plants exposed to drought. Tree Physiol. 16: 985-993.

Koske, R.W. and **J.N. Gemma.** 1989. A motified procedure for staining roots to detect VA mycorrhizas. Mycor. Res. 92:486-505.

Linderman, R. G. 1992. Vesicular arbuscular mycorrhizae and soil microbial interactions. pp 45-70. In: Linderman, R. G. and G. J. Bethlenfalvay (eds.). Mycorrhiza and sustainable agriculture. ASA special publication No. 54. Madison. Wisconsin.

Nelsen, C. E. 1987 The water relations of vesicular arbuscular mycorrhizal system. pp. 71-91. In: Safir G. R. (ed.). Ecophysiology of VA mycorrhizal plants. CRC. Press, Inc., Boca Raton, Florida.

SAS Institute Inc. 1996. SAS/STAT system for windows, release 6.12 edition. Cary, NC. USA: SAS Institute Inc.

Smith D.E., D. M. Read. 1997. Mycorrhizal symbiosis. 2nd Ed. Academic Press Inc., London.

Sylvia, D., A. Alagely, D. Kent, and **R. Mecklenburg.** 1998. Mycorrhiza of landscape trees produced in raised beds and containers. J. Arbor. 24: 308-314.

Yadava, U.L. 1986. A Rapid and Nondestructive method to Determine Chlorophyll in Intact Leaves. HortScience 21:1449-1450.