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Mycorrhizae, Soil Amendments, Water Relations and Growth of *Rosa multiflora* under Reduced Irrigation Regimes

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ABSTRACT

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Keywords: endomycorrhizae; *Glomus fasciculatum*; *Glomus mosseae*; water stress.

Abbreviations: ψ_s = shoot xylem water potential; VAM = vesicular arbuscular mycorrhizae.

INTRODUCTION

New techniques are needed to increase productivity of Texas field rose bush production. Under present practices less than 65% of cuttings planted are har-

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vested. Since growers traditionally do not irrigate, insufficient rainfall can reduce the success rate of rooting of hardwood cuttings during the winter and the subsequent T-budding operations during the following spring (Davies et al., 1980).

Hydrogels (hydrophilic polymers) have been reported to reduce watering requirements and increase soil water-holding capacity (Gehring and Lewis, 1980; Tu et al., 1985). Mycorrhizal fungi have been shown to increase plant growth and uptake of water and mineral nutrients (Maronek et al., 1982; Strong and Davies, 1982; Sweatt and Davies, 1984; Johnson and Hummel, 1985). *Rosa multiflora* 'Brooks 56', the principal Texas rootstock, is colonized by *Glomus* spp. and *Gigaspora* spp. in commercial production fields (Davies, 1986). Thus, there is potential for incorporation of hydrogels and vesicular–arbuscular mycorrhizal (VAM) fungi in field rose bush production systems. Furthermore, an increasing number of producers are considering containerized production systems of rose bushes which would also lend itself to hydrogel and mycorrhizal incorporation.

The objectives of this research were to determine the effects of mycorrhizae, a soil hydrogel, and wax-impregnated paper mulch on water relations and growth of *Rosa multiflora* under reduced irrigation regimes.

MATERIALS AND METHODS

Inoculum of mycorrhizal fungi *Glomus fasciculatum* (Thaxt. sensu Gerd.) and *G. mosseae* (Nicol. and Gerd.) Gerd. and Trappe were cultured in containers as previously described (Strong and Davies, 1982). Hardwood cuttings of *Rosa multiflora* 'Brooks 56' were rooted under intermittent mist in a glasshouse.

A 3×2 factorial experiment in a completely randomized block design was utilized to determine the influence of a hydrogel substance (Viterra, Union Carbide Corporation, New York) incorporated at the rate of 3 kg m^{-3}, a synthetic mulch surface covering (wax-impregnated cardboard), and a control without a surface covering or polymer incorporation on mycorrhizal and non-colonized 'Brooks 56' understock. The six treatments were replicated 14 times with single plants as experimental units. Rooted cuttings were grown in 15-cm clay pots containing 4 composted bark : 1 sand (v/v) amended with 4.2 kg m^{-3} 18 N–6 P–12 K, 3 kg m^{-3} gypsum, 3 kg m^{-3} dolomitic limestone and fritted trace elements. VAM inoculum was composed of mixed soil and roots containing spores and vegetative propagules following the procedures of Strong and Davies (1982). Approximately 60 g of each VAM inoculum (120 g total) or 120 g of the mycorrhizal-free control inoculum were added to steam-sterilized medium in each container.

Plants were established in a glasshouse with a maximum photosynthetically active radiation of 800μmol s^{-1} m^{-2} at 400–700 nm and grown for 8 months at night temperatures of 23 ± 3 °C and ambient day temperatures of 25 °C mini-

mum. Plants were later evaluated fo
mycorrhizal colonization was asses
Young (1977) and Phillips and Hayn
mycorrhizal roots and non-inoculate
the first 4 months, all plants were wa
back to uniform height before reduc
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for the final 4 months.

Plant water relations . — Water was
the experiment. At this time, xylem
matal resistance were measured wi
(Scholander et al., 1965) and a stead
respectively. Transpiration (mg cm^{-}
from 09.00 to 12.00 h and from 14.
radiation varied from 103 to 340 an
morning and afternoon, respectively
to 1010 in the morning and afternoo
to 1280 and from 211 to 1030 in the
Day 7. Air temperature at the time of
30 °C. Nine measurements per treatm
chamber and the diffusive porometer.
on 10-cm long shoots.

RESULTS

Shoot and root dry weight and roo
was incorporated in the medium, re

TABLE I

Effects of VAM, soil amendments and reduce
'Brooks 56', evaluated 8 months after planting

Mycorrhizal colonized	Soil amendment	Sh (g
No	None	16.
	Hydrogel incorporated	18.
Yes	None	15.
	Hydrogel incorporated	19.

[1]Means followed by the same letter within col
cording to Duncan's multiple range test; $n = 14$

mum. Plants were later evaluated for shoot and root dry weight. Percentage of mycorrhizal colonization was assessed using the techniques of Ambler and Young (1977) and Phillips and Hayman (1970). Colonized plants had 60–85% mycorrhizal roots and non-inoculated plants had 0–6% mycorrhizal roots. For the first 4 months, all plants were watered as needed and all shoots were pruned back to uniform height before reduced irrigation regimes of 3 irrigations per week were initiated. Plants were grown under the reduced irrigation regimes for the final 4 months.

Plant water relations. — Water was withheld for 1 week before terminating the experiment. At this time, xylem water potential, transpiration and stomatal resistance were measured with a Scholander-type pressure chamber (Scholander et al., 1965) and a steady-state diffusive porometer (Licor 1600), respectively. Transpiration (mg cm^{-2} s^{-1}) and resistance (s cm^{-1}) were taken from 09.00 to 12.00 h and from 14.00 to 16.30 h. Photosynthetically active radiation varied from 103 to 340 and from 45 to 770 (μmol m^{-2} s^{-1}) in the morning and afternoon, respectively, of Day 1, from 175 to 700 and from 310 to 1010 in the morning and afternoon, respectively, of Day 4, and from to 134 to 1280 and from 211 to 1030 in the morning and afternoon, respectively, of Day 7. Air temperature at the time of measurement fluctuated between 25 and 30°C. Nine measurements per treatment were recorded with both the pressure chamber and the diffusive porometer. Leaf xylem water potential was recorded on 10-cm long shoots.

RESULTS

Shoot and root dry weight and root:shoot ratio were higher when hydrogel was incorporated in the medium, regardless of rose colonization treatment

TABLE I

Effects of VAM, soil amendments and reduced irrigation regimes on growth of *Rosa multiflora* 'Brooks 56', evaluated 8 months after planting

Mycorrhizal colonized	Soil amendment	Shoot dry wt. (g)	Root dry wt. (g)	Root:Shoot ratio (dry wt.)
No	None	16.6 b[1]	16.0 b	1.0 b
	Hydrogel incorporated	18.1 a	22.4 a	1.2 a
Yes	None	15.1 b	15.3 b	1.0 b
	Hydrogel incorporated	19.0 a	23.3 a	1.2 a

[1]Means followed by the same letter within columns are not significantly different ($P<0.05$) according to Duncan's multiple range test; $n=14$.

TABLE II

Effects of VAM, soil amendments and reduced irrigation regimes on transpiration ($\mu g\ cm^{-2}\ s^{-1}$) and diffusive resistance ($s\ cm^{-1}$) of *Rosa multiflora* 'Brooks 56' 1, 4 and 7 days after withholding water

Mycorrhizal colonized	Soil amendment	Day 1				Day 4				Day 7			
		Transpiration		Diffusive resistance		Transpiration		Diffusive resistance		Transpiration		Diffusive resistance	
		a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
No	None	2.46 cd[1]	2.23 a	4.67 b	5.54 b	3.28 b	3.06 a	4.70 b	5.62 b	2.73 a	2.53 a	8.16 bc	8.67 b
	Hydrogel in-corporated	6.33 a	2.05 b	1.81 c	5.71 b	5.56 a	3.14 a	2.63 c	4.50 b	2.57 a	2.25 ab	7.70 c	8.63 b
Yes	None	1.71 d	1.40 c	7.04 a	7.18 a	2.53 b	1.82 b	6.76 a	7.97 a	2.28 ab	2.16 ab	8.56 bc	9.33 b
	Hydrogel in-corporated	4.15 b	2.23 a	2.72 c	5.08 b	2.59 b	1.85 b	6.09 a	8.26 a	1.83 b	1.61 b	12.06 a	11.97 a

[1]Means followed by the same letter within columns are not significantly different ($P<0.05$) according to Duncan's multiple range test; $n=9$.

TABLE III

Effects of VAM and soil amendments o
56' 2 and 6 days after withholding water

Mycorrhizal colonized	Soil amendment
No	None
	Hydrogel incorporated
Yes	None
	Hydrogel incorporated

[1]Means followed by the same letter wit
cording to Duncan's multiple range test.
[2]Means followed by the same letter withi
to Duncan's multiple range test. S = cha

(Table I). Use of the wax-impre
had no effect on plant growth or
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resistance either with or without
II). Roses in hydrogel-incorpora
the highest transpirational rates.
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greatest changes in ψ_s occurred
III).

DISCUSSION

Hydrogel had the greatest effe
irrigation regime. This would s
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and Lewis, 1980; Tu et al., 1985)
ing hydrogel not only had amor
(most negative) ψ_s and highest
with a larger shoot mass there
accounted for the low ψ_s. This p
to controls) grown in a contain
undergoing greater water stress h
1983; Sweatt and Davies, 1984).
treatments vs. control. In fact, i
were of equal size, there was a
creased by incorporation of a h
1980).

TABLE III

Effects of VAM and soil amendments on shoot water potential (ψ_s) of *Rosa multiflora* 'Brooks 56' 2 and 6 days after withholding water

Mycorrhizal colonized	Soil amendment	Day 2[1] (MPa)	Day 6 (MPa)	Total change[2] (MPa)
No	None	−0.15 b	−0.58 b	−0.43 bS
	Hydrogel incorporated	−0.18 a	−0.80 a	−0.62 aS
Yes	None	−0.16 b	−0.65 ab	−0.49 bS
	Hydrogel incorporated	−0.18 a	−0.82 a	−0.64 aS

[1]Means followed by the same letter within columns are not significantly different ($P<0.05$) according to Duncan's multiple range test.
[2]Means followed by the same letter within rows are not significantly different ($P<0.05$) according to Duncan's multiple range test. S = change in ψ_s significant, 5% level; $n=9$.

(Table I). Use of the wax-impregnated cardboard to cover the medium surface had no effect on plant growth or water relations (data not presented). In general, mycorrhizal plants had lower transpirational rates and a higher diffusive resistance either with or without hydrogel incorporation in the medium (Table II). Roses in hydrogel-incorporated medium without mycorrhizae had among the highest transpirational rates. Xylem water potential in shoots (ψ_s) of roses with hydrogel-incorporated medium was lowest (more negative) and also the greatest changes in ψ_s occurred, regardless of mycorrhizal treatment (Table III).

DISCUSSION

Hydrogel had the greatest effect on enhancing rose biomass under a reduced irrigation regime. This would support reports that hydrophilic polymers increase soil water-holding capacity and reduce watering requirements (Gehring and Lewis, 1980; Tu et al., 1985). Non-mycorrhizal roses with media containing hydrogel not only had among the largest biomass, but one of the lowest (most negative) ψ_s and highest transpirational rates; this would indicate that with a larger shoot mass there were greater transpirational demands, which accounted for the low ψ_s. This phenomenon of a larger plant size (compared to controls) grown in a container of restricted soil volume and subsequently undergoing greater water stress has been reported in other species (Levy et al., 1983; Sweatt and Davies, 1984). We did not observe greater wilting in hydrogel treatments vs. control. In fact, in an earlier report, with other species which were of equal size, there was a delay in wilting and moisture stress was decreased by incorporation of a hydrogel in the medium (Gehring and Lewis, 1980).

Mycorrhizae had minimal effect on water-stressed *Rosa multiflora*, even though VAM treatments generally had lower transpirational rates and a higher diffusive resistance. Mycorrhizal *Rosa hybrida* was reported to have similar ψ_s and higher leaf conductance (g) than controls (Augé et al., 1986). Mycorrhizal fungi have been shown to improve plant water relations (Hardie and Leyton, 1981). However, reports in the literature vary from increased to decreased root hydraulic conductivity and leaf water potential (Safir et al., 1972; Levy et al., 1983; Allen, 1983; Sweatt and Davies, 1984). Possible mechanisms for a mycorrhizal effect on plant water status include enhanced plant water uptake by exploiting larger soil volumes, drought avoidance by better maintenance of a soil–root continuum, nutrition and/or stomatal regulation (Reid, 1979). Generalizations across species concerning mechanisms of regulation are not yet possible (Augé et al., 1986).

Rosa multiflora naturally forms VAM associations under commercial field conditions (Davies, 1986). However in a container (as opposed to the field) there is a limited volume of soil and moisture to be exploited by the mycorrhizal association. Mycorrhizal *Rosa multiflora* response to water stress in a container may be different from that in field conditions. Unlike earlier mycorrhizal studies where controls have characteristically been nutritionally deficient, this experiment was done under non-rate-limiting fertility and P conditions. Under our experimental conditions, VAM were of minimal benefit to rose water relations.

The synthetic mulch surface covering (wax-impregnated cardboard) which was placed on the container medium surface enhances survivability and decreases moisture loss of selected containerized species under reduced outdoor irrigation regimes (Davies and Marsh, 1986). However, under greenhouse conditions it had no effect on plant growth or water status of *Rosa multiflora*.

Under non-rate-limiting fertility regimes, incorporation of a hydrogel into growth medium has the greatest benefit in improving growth and water status of *Rosa multiflora* containerized plants under reduced water regimes. Incorporation of the hydrogel could be of benefit both in the containerized production of roses and for their post-harvest handling in retail nurseries.

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