8-HQC + SU solutions. The slow-release Cl, DICA, coupled with sucrose prevented bacterial growth and sustained cut flower life.

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VESICULAR-ARBUSCULAR MYCORRHIZAL INOCULATION AND FERTILIZER LEVEL AFFECT YIELD, MORPHOLOGY, CHLOROPHYLL CONTENT, WATER UPTAKE AND VASE LIFE OF LEATHERLEAF FERN FRONDS[1]

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Abstract. **The vesicular-arbuscular mycorrhizal (VAM) fungus** Glomus intraradices **Schenck & Smith colonized (25% infection) the roots of tissue culture-produced leatherleaf fern**]Rumohra adiantiformis **(G. Forst.) Ching[grown in a sterilized 1:1:1 (sand:peat:perlite) mix in clay pots and fertilized at 3 rates (0, 280, or 560 kg N/ha/yr) with 19-6-12 Osmocote®. Fertilizer level did not affect colonization. Inoculation had no effect on chlorophyll content or plant grade but both increased with increasing fertilization. Frond yield and frond surface areas increased and leaf density thickness decreased with increasing fertilizer level. Inoculation did not affect yield (dry weight basis) but inoculated plants produced fewer and heavier fronds than noninoculated plants. Postharvest longevity of fronds averaged 16.2 days and was not affected by treatments. Average postharvest water uptake was negatively correlated ($r = -0.462$, $P < 0.01$) with vase life. Under the conditions of this experiment, inoculation with** G. intraradices **was of no benefit.**

Leatherleaf fern, besides being a durable cut foliage crop for use in floral arrangements, is a good ground cover for shady locations in central and south Florida (1). Leatherleaf fern, once established as a ground cover, requires little maintenance since its fertilization requirements are relatively low, its pest problems are few (11), and it seldom requires mowing. Potted leatherleaf fern plants are produced commercially for use in the landscape.

Vesicular-arbuscular mycorrhizal (VAM) fungi have been found to associate mutualistically and parasitically with many host plants. Berch and Kendrick (3), Boullard (6), Harley (9), Hepden (12) and Cooper (7) have documented numerous mycorrhizal associations between VA fungi and leptosporangiate ferns. Cooper (7) found 100% of leatherleaf fern samples from 5 locations in New Zealand to be infected, however she did not identify the fungi present. The effects of VAM fungi on leatherleaf fern have not been studied.

The purposes of this experiment were to determine if *G. intraradices* would colonize the roots of leatherleaf fern and if fertilizer level would influence colonization, to see if colonization and/or increasing fertilization levels would improve quality and growth of leatherleaf fern, and to determine the effects of colonization and/or fertilization level on the postharvest longevity of cut leatherleaf fern fronds.

Materials and Methods

A 2 x 3 factorial experiment was initiated May 24, 1983 when individual 10 to 15-cm long terminal leatherleaf fern rhizome pieces were transplanted into 15.2-cm diameter disinfected clay pots. The rhizome source plants had been produced through tissue culture and were found to be free of VAM fungi. The steam-sterilized potting medium contained equal parts of sand, peat and perlite. Half of the plants were inoculated at planting with the mycorrhizal fungus *G. intraradices* by placing a 5-g mixture of chlamydospores, hyphae and infected citrus roots around the rhizomes. The 3 fertilizer levels used were 0, 280 and 560 kg N/ha/yr (0, 0.45 and 0.89 g Osmocote 19-6-12 per pot every 2 months). Treatments were replicated 5 times.

Plants were grown under 73% shade for 1 yr. Production temperatures varied from 4° to 35°C and were not controlled except to maintain the plants above 4°C. Plants were watered as needed. Leaf punches for chlorophyll determinations and root samples for colonization determinations were taken December 21, 1983. Two 0.27-cm² leaf discs were obtained from the most recently matured frond in each pot. Chlorophyll extraction in the dark at −15°C took 48 hr using acidified methanol. Chlorophyll determina-

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tions were made using MacKinney's (14) and Arnon's (2) procedures. Percentage infection was determined using a root-clearing and -staining procedure described by Phillips and Hayman (15).

Plant quality ratings (1 = yellow, not acceptable; 2 = light green, not acceptable; 3 = medium green, commercially acceptable; 4 = dark green, acceptable) were made April 29, 1984. Fronds were harvested May 2, 1984 for postharvest determinations. Postharvest holding conditions were as reported previously (16). Fronds for yield determinations were harvested May 5, 1984.

Results and Discussion

The VAM fungus *G. intraradices* colonized roots of leatherleaf fern with an average infection level of 25.3% for inoculated plants. Noninoculated plants were not infected. Fertilizer level did not affect colonization ($P < 0.36$).

Inoculation had no effect on chlorophyll content or plant grade but there was an effect from fertilizer level (Table 1). Chlorophyll content and plant grade increased with increasing fertilizer level. Plants receiving Osmocote at either rate were generally commercially acceptable, however the higher level was necessary to produce dark green foliage. Frond yield on a dry weight basis and frond number increased with increasing fertilizer level but frond number was reduced in pots inoculated with *G. intraradices*. Inoculated plants therefore produced fewer but heavier fronds.

Water uptake (ml/cm²) by harvested fronds declined logarithmically over time [uptake = 0.0693 − 0.0429 ln (day), r = 0.955, $P < 0.05$]. Treatments had no effect on water uptake for the first 5 days postharvest. Average water uptake (ml/cm²/day) over the postharvest life of cut fronds was reduced by increasing fertilizer level (Table 2). Postharvest weights of fronds also declined logarithmically over time [% of initial weight = 106.75 − 1.445 ln (day), r = 0.944, $P < 0.05$] and was not influenced by treatments.

Vase life of cut fronds averaged 16.2 days and was not influenced by treatments (Table 2). Fresh weights, dry weights, specific leaf weights and frond water contents at time of harvest were not different due to treatments. Leaf density thickness (g fresh weight/cm²) decreased with increasing fertilizer level and frond surface area increased with increasing fertilizer level. Fronds from the high fertilizer level treatment had 68% larger surface area than the unfertilized controls.

Vase life was positively correlated with both yield statistics, frond numbers (r = 0.427 $P < 0.02$) and dry weight (r = 0.418, $P < 0.02$). Average water uptake (ml/cm²/day) of fronds was negatively correlated (r = −0.462, $P < 0.01$) with vase life. Previous research (16) has suggested that high rates of frond water uptake may be a symptom of a lack of effective control of water loss by harvested fronds. In this experiment, 50% of the cut fronds were terminated due to frond curl (desiccation).

The lack of growth stimulation by *G. intraradices* may have been due to the low light levels used in this experiment. Studies have found decreased infection and lack of growth stimulation under low light conditions (8, 9). Koch and Johnson (13) showed that at least 3 to 5% of citrus seedling photosynthates were allocated to mycorrhizae-related events and others (4, 5) have suggested that carbohydrate demand on the host by the endophyte (VAM fungus) may even reduce growth when the shoot-to-root ratio and photosynthetic source capacity of the host are low. Under the low light, restricted root area conditions of this experiment, VAM fungal inoculation was of no benefit.

Table 1. Influence of inoculation with *Glomus intraradices* and fertilizer level on chlorophyll content, quality, and yield of leatherleaf fern grown in pots.

Treatments					
G. intraradices inoculation	Osmocote 19-6-12 (g/pot/ 2 months)	Chlorophyll content (μg/cm²)	Plant grade[z]	Frond yield (number per pot)	Frond yield (g dry wt per pot)
No	0	39.3	1.6	30.2	22.3
	0.45	47.4	2.9	55.2	46.8
	0.89	53.9	3.9	55.2	59.3
Yes	0	36.5	1.9	23.8	22.8
	0.45	50.9	3.4	36.0	42.7
	0.89	54.3	3.6	51.0	52.2
		Significance based on F values			
Main effects					
Inoculation (I)		0.9748	0.7575	0.0407	0.3531
Fertilizer (F)		0.0009	0.0001	0.0003	0.0001
Interaction (I x F)		0.7236	0.3200	0.3698	0.7137

[z]1 = yellow, not acceptable; 2 = light green, not acceptable; 3 = green, commercially acceptable; 4 = dark green, acceptable.

Table 2. Influence of inoculation with *Glomus intraradices* and fertilizer level on average water uptake, vase life, and other characteristics of leatherleaf fern fronds.

Treatments		Average postharvest water uptake (liter/cm²/ day)	Vase life (days)	Frond fresh wt (g)	Frond dry wt (g)	Specific leaf weight (mg dry wt/cm²)	Frond water content (%)	Leaf density thickness (mg fresh wt/cm²)	Frond surface area (cm²)
G. intraradices inoculation	Osmocote 19-6-12 (g/pot/2 months)								
No	0	18.7	11.4	5.84	1.77	14	69.5	47	121.8
	0.45	9.0	19.4	5.74	1.66	11	70.6	38	151.5
	0.89	10.3	17.8	8.68	2.47	11	71.0	37	229.4
Yes	0	14.9	15.6	7.19	1.96	15	72.5	57	134.8
	0.45	13.4	13.0	9.32	2.82	13	70.8	43	215.6
	0.89	9.3	20.0	8.11	2.45	12	69.9	40	202.3
				Significance based on F values					
Main effects									
Inoculation (I)		0.9949	1.0000	0.1248	0.1290	0.2087	0.5865	0.1854	0.2944
Fertilizer (F)		0.0098	0.0713	0.2626	0.2321	0.0569	0.9282	0.0399	0.0004
Interaction (I x F)		0.1901	0.0580	0.2012	0.2056	0.9868	0.3965	0.7926	0.0743

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VASE LIFE OF LEATHERLEAF FERN HARVESTED AT VARIOUS TIMES OF THE YEAR AND AT VARIOUS FROND AGES[1]

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Abstract. **Newly emerging fronds (fiddleheads) of leatherleaf fern** [Rumohra adiantiformis **(G. Forst.) Ching**] **were tagged every 4 weeks for 1 yr. Ten fronds were then harvested 6 weeks after tagging and again at 4-week intervals until fern had been harvested 6 times. Fiddleheads emerging in June, July and August had the shortest vase life, 2-8 days, those emerging September through November lasted 3-16 days, while those emerging December through March lasted 7-28 days. Although inconsistent, fern harvested 6 weeks after emergence usually had longer vase life than older fern. The correlation coefficient of frond age to vase life was −0.98, height at 7 weeks to vase life was −0.82, and the b factor of the quadratic equation of growth to vase life was −0.96.**

The short vase life of leatherleaf fern has been a serious postharvest problem for at least 10 yr, occurring primarily in summer or early fall (4, 6). Soil moisture was implicated as a causal factor of fern wilt and the suggestion was made that leatherleaf fern is often overwatered (1, 7). A 3-yr test (5) showed very slight differences in vase life when watered at 1.25 inches/week or 2.5 inches/week, but all fern in the experiment lasted 17 days or longer except 1 group harvested in September which showed a vase life of 8 days. Henny (2) suggested blockage of the vascular tissue in the basal 0.5 inch of the stripe as a cause of fern wilt. Nell, et al. (6) suggested reduced water uptake was due to blockage of the stem. Prange and Ormrod (8) reported that the osmotic potential of the ostrich fern [*Matteuccia struthiopteris* (L.) Tod.], was higher in immature fronds than in mature fronds, water stress in immature fronds decreased total water and pressure potentials, but stress of mature fronds increased total water and pressure potentials. Marousky (3) reported mature leatherleaf fronds had a shorter vase life than immature fronds. Research in 1979-1980 (4) indicated that high fertilization with urea should be avoided due to adverse effects on yield. Fronds harvested from 63 or 73% shade showed no difference in fern wilt at 1 location and reduced wilt under 73% shade at a second location (9). This report (9) was the first publication to distinguish between fern wilt, actually a leaf curl phenomenon, and yellowing, a loss of chlorophyll in the center portion of the frond, both presenting an unattractive frond. The objective of this experiment was to determine vase life of different aged fronds cut during different seasons.

Materials and Methods

A 7-yr-old fern bed on Blanton fine sand at AREC-Apopka under 73% shade receiving about 1 inch water weekly was utilized for the test. Beginning April 19, 1982, 65 fiddleheads were tagged and thereafter 65 additional fronds were tagged every 4 weeks for 1 yr. Ten fronds were harvested 6, 10, 14, 18, 22 and 26 weeks after each tagging for vase life determinations. Fertilization rate was 750 lb. N/acre-year applied as 0.57 lb./32 ft² monthly from an 8-4-7 (N-P-K) ratio fertilizer. Fronds were harvested between 8 and 10 AM, placed in deionized water filled beakers with the pinna exposed to light in rooms with light intensities of 150 ft-c supplied by Cool White fluorescent lamps 12 hr daily. Temperatures in the rooms were maintained at 70-78°F and relative humidities were 50 ± 15%. Wilt and yellowing of the harvested fronds were recorded for 28 days or until vase life was terminated. Wilting of fern was characterized by partial or complete folding of green pinna along the mid vein and/or loss of overall frond rigidity. A frond was considered as yellow when the yellowing covered 5% of the frond surface.

Results and Discussion

Data from this test clearly show the influence of season

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