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Fungal Inoculation, Fungicide Treatments, and Storage Affect Postharvest Decay and Vase-life of Leatherleaf Fern Fronds

R.H. Stamps and A.R. Chase
Agricultural Research Center, IFAS, University of Florida, 2807 Binion Road, Apopka, FL 32703

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Abstract. **Storage at 4.5°C prevented decay of cut fronds of leatherleaf fern [*Rumohra adiantiformis* (G. Forst) Ching] artificially inoculated with *Cylindrocladium heptaseptatum* Sobers, Alfieri, & Knauss and/or naturally infected with *C. pteridis* Wolf and increased frond vase-life compared to 24° storage. Storage at 4.5° for 10, 21, and 31 days did not affect subsequent frond vase-life. Inoculation of fronds decreased vase-life by 11% in one experiment and had no effect in a second. Prestorage dips in benomyl suspensions at concentrations as low as 38 ppm reduced frond decay by 82% when stored at 24° and increased vase-life of fern stored at both 4.5° and 24°. Benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate] dips at concentrations as high as 300 ppm had no detrimental effect on vase-life. Iprodione [3-(3,5-dichlorophenyl)-*N*-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide] had no effect on vase-life.**

Leatherleaf fern is an important cut foliage crop for florist use. About ¼ of the crop produced domestically is shipped to Europe (2). Occurrence of decay in fern shipments to Europe (6) has stimulated research into methods of controlling decay while anticipation of shipping to more distant markets has stimulated interest in long-term storage.

Cylindrocladium pteridis, *C. heptaseptatum*, and *Rhizoctonia solani* Kuehn have been found to cause decay in harvested fern with *Cylindrocladium* spp. being more common than *Rhizoctonia* (6). These pathogens also cause the most important diseases found in the field (1, 3, 7, 8, 9). Postharvest fungicidal dips, rapid cooling immediately after harvest, and maintaining low temperatures in transit and storage can reduce postharvest fern decay (5). Benomyl is the most widely used fungicide for dipping cut fern, but no research has established a range of effective concentrations or the influence of these dips on the vase-life of the cut fern. In addition, the influence of storage duration, storage temperature, and inoculation with *C. heptaseptatum* on vase-life are unknown.

Experiments were conducted to determine effective benomyl concentrations for decay control using postharvest dips and to study the effects of benomyl and iprodione dips, *C. heptaseptatum* inoculation prior to storage, storage duration, and storage temperature on vase-life of cut leatherleaf fern fronds.

Expt. 1. A 2 × 5 factorial experiment in a randomized complete block design with 4 replications was initiated 3 Mar. 1982 to test the effects of benomyl dip concentrations and *C. heptaseptatum* inoculation on vase-life of cut leatherleaf fern fronds. Ferns were grown in Blanton fine sand ground beds under 73% shade polypropylene fabric. Ferns for this and all subsequent experiments came from the same beds which were naturally infested with *C. pteridis*. Ferns used in this test had not been treated with fungicides for 3 months. Fronds without leaf spots were harvested in the morning using hand clippers. Half of the harvested fronds were sprayed to the point of runoff with a suspension of *C. heptaseptatum* conidia (1×10^4/ml), air dried, and after 1 hr dipped in 0, 38, 75, 150, or 300 ppm benomyl:water suspensions for 10 sec. The *C. heptaseptatum* was isolated from leatherleaf fern fronds collected from a commercial fernery in central Florida in Jan. 1982 and was found to be pathogenic (A.R. Chase, unpublished). Inoculum was grown on potato-dextrose agar medium (infusion from 250 g boiled potatoes and 20 g each agar and dextrose/liter) for 14 days under 2.2 klx cool-white fluorescent light at 24° to 26°C. The noninoculated fronds were sprayed with water, air dried, and dipped in separate benomyl suspensions at the above rates.

Experimental units consisted of 10, mature fronds which were individually sealed in nonvented polyethylene bags immediately after dipping. Bags were placed in waxed, corrugated, fiberboard cartons and stored for 12 days at 4.5°C. Additional bags of inoculated and noninoculated water-dipped fronds were stored at 24° to check pathogenicity since research has shown that inoculated fern may not become infected when held at 4.5° (6). Fronds were rated as decayed if disease symptoms rendered them unmarketable. After fronds were removed from storage and rated for decay, stipes of marketable fronds were recut with clippers 2 cm from base and placed in 1-liter glass jars filled with deionized water. Fronds were held in rooms lighted 12 hr per day by cool-white fluorescent lamps at 18 μmol s^{-1} m^{-2} intensity. Rooms were maintained at 24° ± 3° and 30% ± 20% relative humidity. Fronds were rated for vase-life at 3-day intervals and were discarded when they started to wilt or become chlorotic.

All inoculated fronds and 85% of the noninoculated fronds stored at 24°C decayed, indicating high virulence and the presence of naturally occurring pathogens. Fronds held at 4.5° were not decayed. Benomyl treatments had no effect on vase-life of fronds. Vase-life means were 13.6, 14.1, 13.6, 14.4, and 12.9 days for benomyl treatments at 0, 38, 75, 150, and 300 ppm, respectively. Noninoculated fronds lasted 11% longer ($P < 2.5\%$) than inoculated fronds (14.4 and 13.0 days, respectively). There was no interaction between benomyl concentration and inoculation.

Expt. 2. A 2 × 2 × 3 factorial in a randomized complete block design with 4 replications was initiated 26 Mar. 1982. Tested were the effects of *C. heptaseptatum* inoculation; high (24°C) and low (4.5°) storage temperatures; and 0, 38, and 150 ppm benomyl dip concentrations on decay and vase-life of cut leatherleaf fern fronds. Fern stock beds had not been sprayed with fungicides for 15 weeks prior to the test. Fronds were harvested and handled as in expt. 1. Storage was for 13 days. Percentage data were transformed to the arc sine of the square root of the percentage before statistical analysis.

Interaction between storage temperature and benomyl dip concentration showed no difference among dip rates and no decay at 4.5°C storage; decreased decay occurred with increased dip concentration at 24° (Table 1). Benomyl at concentrations about ½ and ⅑ previously tested (5) reduced decay at the high storage temperature. I × C, I × T, and C × T interactions for vase-life were significant at the 5%, 1%, and 0.1% significance levels, respectively (Table 1). Inoculation had no effect at 0 and 150 ppm benomyl concentrations, but noninoculated fronds at 38 ppm lasted longer ($P < 1\%$) than inoculated fronds. Inoculated fronds showed increased vase-life with increasing dip concentration ($P < 0.1\%$). Noninoculated fronds showed increased vase-life with increased concentration from 0 to 38 ppm, but not from 38 to 150 ppm ($P < 0.1\%$). Inoculation had no effect at 4.5° storage and noninoculated fronds lasted longer ($P < 5\%$) than inoculated fronds at 24°. Both inoculated and noninoculated fronds stored at 4.5°

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Table 1. Effects of inoculation with *Cylindrocladium heptaseptatum* (I), benomyl dip concentration (C), and storage temperature (T) on decay and vase-life of cut leatherleaf fern fronds.

C. heptaseptatum inoculation	Benomyl concn (ppm)	Storage temp (°C)	Decay (% of fronds)	Vase-life (days)
No	0	4.5	0	12.8
		24.0	100	---[z]
	38	4.5	0	14.6
		24.0	20	11.1
	150	4.5	0	14.3
		24.0	15	10.9
Yes	0	4.5	0	14.0
		24.0	100	---
	38	4.5	0	14.6
		24.0	15	7.8
	150	4.5	0	14.9
		24.0	2.5	11.1
		Significance based on F values		
Main effects				
I			NS	NS
C			0.1%	0.1%
T			0.1%	0.1%
Interactions				
I × T			NS	5%
I × C			NS	1%
C × T			0.1%	0.1%
I × C × T			NS	NS

[z]All fronds decayed during storage.

had longer ($P < 0.1\%$) vase-life than fronds stored at 24°. Fronds dipped at each 3 benomyl concentration had increased ($P < 0.1\%$) vase-life at 4.5° compared to 24° storage. Fronds dipped at 38 and 150 ppm benomyl had increased vase-life ($P < 5\%$) compared to water-dipped fronds at 4.5° storage. At 24° storage, increasing dip concentrations resulted in increased vase-life ($P < 0.1\%$).

Expt. 3. A 2 × 2 × 2 factorial in a randomized complete block design with 4 replications was initiated on 14 Apr. 1982. Tested were the effects of 2 fungicides (benomyl and iprodione) at 2 concentrations (38 and 300 ppm) and at 2 storage temperatures (4.5° and 24°C) on the vase-life of cut leatherleaf fern fronds artificially inoculated with *C. heptaseptatum*. Fronds were harvested and handled as in expt. 1. Storage was for 9 days. Ferns had been sprayed in the field 2 weeks prior to harvest with benomyl and mancozeb at 0.28 and 1.34 kg/ha, respectively.

Table 2. Effect of fungicides (F), fungicide dip concentration (C), and storage temperature (T) on vase-life of cut leatherleaf fern fronds.

Fungicide	Concn (ppm)	Storage temp (°C)	Vase-life (days)
Benomyl	38	4.5	12.6[z]
	300	4.5	13.6
	38	24	8.5
	300	24	12.3
Iprodione	38	4.5	13.0
	300	4.5	14.3
	38	24	9.0
	300	24	8.4

[z]Main effects of C and T were significant at 1% level and F × C, F × T, and F × C × T interactions were significant at the 5% level by F test.

The lack of severe disease development, 5% and 12.5% decay, respectively, in the inoculated and noninoculated water-dipped checks held at 24°C may have been due to the preharvest fungicide application. Unsprayed fronds subsequently inoculated with conidia from the same isolation developed severe disease symptoms. Dips at 300 ppm increased vase-life 13% compared to 38 ppm dips (Table 2). F × C interaction occurred at 24° storage due to benomyl increasing vase-life ($P < 0.1\%$) at the higher concentration, while there was no difference resulting from increased concentration of iprodione. Storage at 4.5° increased vase-life 40% over 24° storage. Recommended storage temperatures for leatherleaf fern are 1° to 4.5° (3, 4). F × T interaction occurred at both dip concentrations. There were no differences between the fungicides at either storage temperature at 38 ppm; storage at 4.5°, as compared to 24°, increased vase-life ($P < 0.1\%$) of fronds dipped in each fungicide. At 300 ppm, fronds dipped in benomyl and stored at 24° lasted as long as benomyl-dipped fronds stored at 4.5°. At 4.5° storage, fungicide dips made no difference.

Expt. 4. A 3 × 3 factorial in a randomized complete block design with 4 replications was initiated on 12 Apr. 1982 to test the effects of storage duration (10, 21, 31 days) and benomyl dip concentration (0, 38, 300 ppm) on vase-life of cut leatherleaf fern frond. Fronds were harvested and handled as in expt. 1, inoculated with *C. heptaseptatum* and stored at 4.5°C.

Benomyl dips had no effect on vase-life (Table 3). Storage had no effect on vase-life with averages of 13.1, 12.8, and 10.7 for 10-, 21-, and 31-day storage, respectively.

Table 3. Effect of storage duration (D) and benomyl dip concentrations (C) on vase-life of cut leatherleaf fern fronds.

Storage at 4.5°C (days)	Benomyl dip concn (ppm)	Vase-life (days)
10	0	13.8[z]
	38	12.0
	300	13.4
21	0	14.4
	38	11.3
	300	12.8
31	0	12.1
	38	9.4
	300	10.8

[z]Main effects of D and C, and interaction of D × C were not significant at the 5% level by F test.

Conclusions. These studies show that storage at 4.5°C controls decay and maintains vase-life of leatherleaf fern fronds stored for up to 1 month. The establishment and maintenance of this storage temperature is often unrealized in commercial situations and therefore the effectiveness of benomyl dips in reducing decay and increasing vase-life at higher temperatures, as demonstrated in these experiments, is of commercial significance. The question raised in expt. 3 of whether preharvest fungicide sprays can control postharvest decay is also of commercial interest.

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