Control of Basal Stem and Root Rot of Christmas and Easter Cacti Caused by *Fusarium oxysporum*

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ABSTRACT

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Fusarium oxysporum was isolated from both Christmas and Easter cacti showing symptoms of basal stem and root rot. Fourteen cultivars of Christmas cactus and three of Easter cactus developed basal stem and root rot after inoculation with an isolate of *F. oxysporum* from Christmas cactus. Treatment of Christmas cactus cladode transplants with benomyl protected them from infection. No protection was offered by allowing cladodes to air-dry before transplanting.

Additional key words: Cactaceae, chemical control, *Rhipsalidopsis*, *Zygocactus*

Christmas cactus (*Zygocactus truncatus* Schum.) and Easter cactus (*Rhipsalidopsis gaertneri* (Regel) Moran) are popular ornamental plants sold during the spring and fall holidays. Both plants are members of the family Cactaceae but lack the characteristic spines usually associated with members of this family.

Little information is available on diseases of cacti (3,4), although recently, a review of the more common diseases and pests of cacti was published (1). This paucity of information is traditionally due to the lack of agronomic interest in the Cactaceae. In the past decade, however, the general public has shown increasing interest in the aesthetic value of cacti, which are now grown commercially in increasing numbers. With this increased greenhouse culture, losses to disease are becoming more prevalent.

This work was initiated to determine if cultivars of Christmas or Easter cacti are resistant to basal stem rot caused by *Fusarium oxysporum* Schlecht. (2). Several methods of preventing infection, including air-drying of cladode transplants and treatment with fungicides, were also investigated.

MATERIALS AND METHODS

F. oxysporum was isolated from rotted stem tissue of Christmas cactus cultivar Konigar showing symptoms of wilt and reddened vascular tissue. Cultures were maintained on potato-dextrose agar (PDA) under mineral oil at 4 C. No fungus was isolated from reddened vascular tissue above the third cladode from the soil line.

Inoculum was prepared by flooding

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the surfaces of 7-day-old cultures of *F. oxysporum* grown on PDA with distilled water and suspending spores with an inoculating loop. Spores were counted with a hemacytometer and diluted to 5×10^6 microconidia per milliliter. Christmas cactus cultivars Sabina, Norris, Magic, Red Radiance, Gold Charm, Peach Parfait, Christmas Charm, Marie, Lavender Doll, Rubin, White Christmas, Twilight Tangerine, Kris Kringle, and Konigar and Easter cactus cultivars Pink Rhipsalis, Scarlet O'Hara, and Sutters' Gold were supplied by Westwood Gardens (Fayetteville, AR) in 10.2-cm-square pots in a peat/perlite/vermiculite (2:1:1) mix amended with 6.3 kg of $CaCO_3$ per cubic meter.

Cultivar susceptibility. Cultivar susceptibility was tested two ways. First, six plants of each cultivar were prick-inoculated with a drop of the fungal inoculum, using a hypodermic syringe with a 25-gauge needle. The inoculation was made on the periphery of the stem at the soil line and on the second and third cladodes above the exposed corky stem tissue on each plant. Plants were incubated for 15 hr in a dew-deposition chamber adjusted for constant leaf wetness at 25 C, placed in the greenhouse (23–30 C), and observed daily for 3 wk for disease symptoms. Uninoculated control plants were wounded with a hypodermic syringe containing sterile water. The experiment was conducted twice.

In the second method, cladodes were separated from the parent plants by twisting them off by hand. Six cladodes from each cultivar were immediately planted in 7.5-cm plastic pots containing pasteurized peat/perlite/vermiculite mix (three cladodes per pot). Each pot was previously inoculated with 5 ml of the fungal inoculum, which was thoroughly mixed into the potting material before planting. Plants were grown on greenhouse benches and observed for symptoms of basal rot. Control cladodes were planted in uninoculated potting mixture. The experiment was conducted twice.

Ability of *F. oxysporum* to infect air-dried cladodes. Plants of Christmas cactus cultivar Konigar were used in this experiment. Cladodes were separated from the plant by twisting them off by hand. One-hundred cladodes were piled onto an unfolded newspaper lying on the greenhouse bench. Ten cladodes were immediately planted in 7.5-cm plastic pots containing pasteurized peat/perlite/vermiculite mix (two cladodes per pot). Each pot was previously inoculated with 5 ml of the fungal inoculum, which was thoroughly mixed into the potting material before planting. The remaining cladodes were air-dried on the greenhouse bench. During the next 3 days, 10-cladode samples of the drying cladodes were planted in freshly prepared inoculated potting mixture as previously described. Plants were grown in the greenhouse and observed for symptoms of basal rot. Control cladodes were planted in uninoculated potting mixture. The experiment was conducted twice.

Ability of *F. oxysporum* to infect fungicide-treated cladodes. A total of 120 cladodes were collected from Christmas cactus cultivar Konigar and divided into two groups. Cladodes in group 1 were treated by dipping the lower tip of the cladodes into concentrated fungicide (see footnotes, Table 1) and planting in 5-cm plastic pots containing pasteurized peat/perlite mix (one cladode per pot). Cladodes that were dipped in wettable powder formulations of a fungicide were first wetted with tap water. Five cladodes were used for each fungicide treatment. One-half of the pots in group 1 were each previously infested with 5 ml of the fungal inoculum mixed with the potting material, whereas the remaining one-half were uninfested. After planting, a fungicide drench (40 ml/pot) was also applied to cladode transplants in group 1 (see footnotes, Table 1).

Cladodes in group 2 were treated similarly but received only the fungicide drench. In both groups 1 and 2, four fungicide drenches were applied, one at planting and one each week for the following 3 wk. Plants were watered once between each fungicide drench (40 ml of tap water per pot), and no fertilizers were applied. After 7 wk in the greenhouse, the aboveground portions were removed and oven-dried at 100 C for 24 hr, then dry weights were determined. Control cladode transplants were treated with tap water and planted in inoculated or uninoculated soils. The experiment was conducted twice.

RESULTS

Cultivar susceptibility. All cultivars of both Christmas and Easter cactus were susceptible to an isolate of *F. oxysporum* from Christmas cactus (Table 2). The disease syndrome was similar to that described by Moorman and Klemmer (2)

Table 1. Protection of cladode transplants of Christmas cactus from infection by *Fusarium oxysporum* with fungicide treatments

Treatment	Fungicide[y]	Fungus	Mean dry weight (g)[z]
Drench only	Captan	−	0.0910 ab
		+	0.0070 gh
	Chlorothalonil	−	0.0832 bc
		+	0.0382 ef
	Benomyl	−	0.1058 ab
		+	0.1020 ab
	Duosan	−	0.0661 cd
		+	0.0000 h
	Water	−	0.1127 a
		+	0.0000 h
Dip and drench	Captan	−	0.0570 de
		+	0.0579 de
	Chlorothalonil	−	0.0875 bc
		+	0.0553 de
	Benomyl	−	0.1031 ab
		+	0.0996 ab
	Duosan	−	0.0283 fg
		+	0.0000 h
	Water	−	0.1135 a
		+	0.0048 gh

[y] Final concentrations of active ingredients were: captan 50WP (803 μg/ml), chlorothalonil (Bravo 500, 1,309 μg/ml), benomyl (Benlate 50WP, 803 μg/ml), and Duosan 75WP (241 μg/ml thiophanate-methyl + 963 μg/ml mancozeb).
[z] Values are the means of two experiments, each with five replicates. Means followed by the same letter are not significantly different (LSD = 0.0246, $P = 0.05$).

Table 2. Diameters of lesions produced by *Fusarium oxysporum* on cactus plants 10 days after inoculation

Cactus species and cultivar	Lesion diameter[y] (mm)
Zygocactus truncatus	
Gold Charm	19.5 a[z]
Norris	12.8 b
White Christmas	8.0 c
Rubin	9.0 cd
Christmas Charm	6.8 de
Konigar	6.8 de
Kris Kringle	5.3 e
Lavender Doll	6.3 e
Magic	6.0 e
Marie	6.3 e
Peach Parfait	6.5 e
Red Radiance	5.0 e
Sabina	5.0 e
Twilight Tangerine	5.3 e
Rhipsalidopsis gaertneri	
Pink Rhipsalis	6.8 de
Scarlet O'Hara	6.3 e
Sutters' Gold	6.5 e

[y] Values are the means of two experiments, each consisting of the largest of five lesions per plant.
[z] Means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

but occurred more rapidly. Water-soaked lesions with red margins appeared within 4 days of inoculation. On the basis of lesion diameter, Christmas cactus cultivars Gold Charm and Norris appeared the most susceptible (Table 2). Cladode abscission occurred within 10 days of inoculation for these two cultivars and occurred between 12–20 days with all other cultivars.

Similar results were observed when cladodes were planted in inoculated soil. The cultivars Gold Charm and Norris showed symptoms of basal stem rot within 6 days of planting. The remaining cultivars showed symptoms of rot within 9 days of planting. All cladodes planted in *F. oxysporum*-infested potting mix eventually died.

Protection of cladode transplants. Air-drying cladode transplants did not prevent infection by *F. oxysporum*. Cladodes dried for 72 hr and planted in inoculated soil were just as susceptible as those planted in inoculated soil immediately after separation from the mother plants. All cladodes transplanted into *F. oxysporum*-infested potting mix eventually died.

Duosan significantly decreased growth of cladodes transplanted into uninoculated soil (Table 1). Captan and Duosan drenches were less phytotoxic to Christmas cactus than the dip and drench treatments. Cladodes drenched with benomyl in inoculated soil grew as well as cladodes in controls. Cladodes treated with Duosan, captan, or water drenches in inoculated soil were destroyed from basal stem rot. Chlorothalonil-drenched transplants had green tops but had poorly developed root systems plus basal stem rot.

Dip and drench of cladodes with either captan or Duosan resulted in a significant decrease in plant dry weight compared with uninoculated controls (Table 1). In inoculated treatments, benomyl-treated transplants grew as well as uninoculated controls. These transplants developed disease-free, well-developed root systems. Cladodes treated with chlorothalonil produced less biomass when grown in inoculated soil than when grown in uninoculated soil; however, the roots were disease-free. Captan-treated cladodes grown in inoculated soil had green tops and comparable biomass to chlorothalonil-treated cladodes but had poorly developed root systems and basal rot. Cladodes treated with water or Duosan and planted in inoculated soil were destroyed by basal stem rot.

DISCUSSION

Basal stem and root rot is a devastating disease of Christmas and Easter cacti in nursery operations. Mature plants 3–5 yr old can be diseased but lack symptoms. When mature plants are ready to sell, they are induced into dormancy and symptoms suddenly appear because of physiological stress associated with flower induction. The grower would already have a large investment in maintaining plants this long. The density of plants also facilitates spread of the fungus from one pot to the next if bench tops are not corrugated.

Because all cultivars of Christmas and Easter cacti tested were susceptible to basal stem and root rot, control measures should be instigated to deter this pathogen. Christmas cactus cultivars Norris and Gold Charm were especially susceptible and might serve as an early-warning indicator that the disease management program currently used by the grower is not sufficient.

A common practice of commercial growers is to air-dry cladodes during propagation. This is believed to allow the wound to heal over and protect the transplant from infection. Although this may offer some protection against a bacterial infection, air-drying did not prevent infection by *F. oxysporum*. Cladodes air-dried up to 72 hr were just as susceptible to infection as cladodes placed immediately in inoculated soil.

Two nonsystemic (captan and chlorothalonil) and two systemic (Duosan and benomyl) fungicides were evaluated for phytotoxicity and efficacy to control basal stem and root rot. Benomyl provided complete control of this fungus when applied either as a drench or as a dip and drench treatment and showed no deleterious effect on plant growth. Chlorothalonil provided good disease control when applied as a dip and drench, although root proliferation was diminished. In general, contact fungicides worked more efficiently when applied as a dip and drench vs. drench treatment in controlling basal rot. Duosan was phytotoxic to transplants at the rates used and should be reevaluated at rates below those that caused phytotoxicity.

As the demand for Christmas and Easter cacti increases, so will commercial production. It is also probable that disorders of cacti will increase under current production methods. Data collected in these experiments indicate that current control strategies should be reevaluated for each specific disease (e.g., air-drying cladodes to prevent pathogen invasion). Fungicides used to control similar pathogens on other crops should be tested for efficacy as well as phytotoxicity on cacti. Work in progress is oriented toward providing this information to growers.

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