Fusarium Wilt of Chrysanthemum: Cultivar Susceptibility and Chemical Control

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ABSTRACT

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Recent serious outbreaks of Fusarium wilt of pot-grown chrysanthemums in North Carolina were caused by *Fusarium oxysporum* f. sp. *chrysanthemi*, which was isolated frequently from cuttings of susceptible and resistant cultivars received from a commercial propagator. The cultivars Cirbronze, Royal Trophy, and Yellow Delaware were most susceptible to the pathogen, whereas Jamboree, Puritan, and Tuneup were most resistant. Of 10 cultivars screened for resistance to *F. oxysporum* f. sp. *tracheiphilum*, none were highly susceptible, but Escapade and Promenade were moderately susceptible and Cirbronze, Jamboree, Pinktive, Puritan, Royal Trophy, Tuneup, and Yellow Delaware were highly resistant. A single drench of thiophanate-methyl at the rate of 0.21 g a.i./L applied 2, 6, or 10 days after inoculation of rooted cuttings gave excellent control without phytotoxicity. Benomyl also provided control, but 1.2 g a.i./L was required. Thiophanate-methyl (25%) + ethazol (75%) was effective and nonphytotoxic at 0.90 g a.i./L (0.22 g a.i. of thiophanate-methyl per liter). The combination treatment, benomyl + lime + nitrate, gave good control but caused slight stunting and chlorosis.

Fusarium wilt of chrysanthemum (*Chrysanthemum morifolium* Ramat.) may be caused by *Fusarium oxysporum* f. sp. *chrysanthemi* Litt., Armst., & Armst. (FOC) or *F. oxysporum* f. sp. *tracheiphilum* (E. F. Sm.) Snyd. & Hans. race 1 (Armst. & Armst.) (FOT) (1,2). FOC causes wilt on many chrysanthemum cultivars, whereas FOT is reported to be serious only in the cultivars Encore, Escapade, Hostess, Maytime, and Winter Carnival (1,2,4,8). The major plant propagators have controlled the disease for years through culture-indexing. In recent years, however, Fusarium wilt has caused severe losses of pot mums in North Carolina and elsewhere (1–4,6, 9,11). The sudden occurrence of severe outbreaks of Fusarium wilt in several cultivars of culture-indexed pot chrysanthemum cultivars in North Carolina in 1979, 1980, and 1981 led me to suspect that a different race or forma specialis might be involved.

Although Fusarium wilt may be controlled in the greenhouse with culture-indexed plants, resistant cultivars, and good sanitation, chemical control is needed when any of these measures are neglected. Engelhard and Woltz (7) demonstrated excellent control of Fusarium wilt of Yellow Delaware caused by FOC in Florida with an integrated program involving two benomyl drenches before inoculation, highly limed media, and use of $NaNO_3$ as the source of nitrogen. Methyl 1-(methylthioethylcarbamoyl)-2 benzimidazole carbamate (BAS 3201-F) was also very effective. Reports from growers and results of our preliminary work show that the recommended rates of benomyl (0.3–0.6 g a.i./L) failed to adequately control the disease in pots in the greenhouse. Therefore, fungicides were tested for control of the disease.

The objectives of this study were to determine 1) if a new race of *F. oxysporum* had evolved, 2) the source of inoculum, 3) the resistance of 10 cultivars to FOC and FOT, and 4) the efficacy of fungicide drenches for control of the disease.

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MATERIALS AND METHODS

Source of inoculum and spread of pathogen among plants within a pot. To determine if the pathogen was being introduced with rooted cuttings, 50 rooted cuttings of each of 10 cultivars were examined by culture-indexing as they were received from the commercial propagator. After roots were removed, sections of lower stems were surface-sterilized with 0.5% sodium hypochlorite for 6 min, then cut into three 1-cm subsections and placed on sterile absorbent paper. The upper, middle, and lower parts of each section were kept separate, placed on acidified cornmeal agar (ACMA), and incubated at 24 C. Observations were made daily for 7 days. Isolates of the suspected pathogen, taken from two upper and lower sections of each cultivar, were increased and inoculated to four rooted cuttings of Royal Trophy per isolate by the root-dip technique described later for proof of pathogenicity. In addition, macroconidia from each section were examined for conformity to the characteristics of *F. oxysporum*.

To gain more information on the source of inoculum and on spread from

Table 1. Frequency of isolation of *Fusarium oxysporum* from the lower 3-cm stem sections of culture-indexed rooted chrysanthemum cuttings from a commercial propagator

Cultivar	Sections yielding *F. oxysporum* (%)[a]			Average for all sections (%)
	Upper	Middle	Lower	
Cirbronze	1.6	0.8	1.6	1.3
Escapade	8.4	4.0	3.5	5.3
Jamboree	2.0	2.0	6.8	3.6
Pinktive	2.4	5.2	10.4	6.0
Promenade	6.0	4.4	6.4	5.6
Puritan	5.2	4.8	6.4	5.5
Royal Trophy	1.6	2.4	5.2	3.7
Torch	10.8	7.6	3.6	7.3
Tuneup	14.4	6.4	7.6	9.5
Yellow Delaware	14.6	5.6	8.8	9.6

[a] Sections were divided into three 1-cm subsections, surface-sterilized, then plated into acidified cornmeal agar and incubated 4 days at 24 C. Upper, middle, and lower subsections were kept separate.

Table 2. Spread of *Fusarium oxysporum* f. sp. *chrysanthemi* and f. sp. *tracheiphilum* in rooted cuttings of pot chrysanthemums in the greenhouse

Cultivar	No. of pots in test (five plants/pot)	No. of diseased plants	
		30 Sept.	20 Nov.
Yellow Delaware			
Inoculated[a]	8	0	2
Uninoculated	12	0	0
Jamboree			
Inoculated	8	1	2
Uninoculated	12	0	1
Royal Trophy			
Inoculated	8	4	30
Uninoculated	12	8	9
Escapade			
Inoculated	8	0	1
Uninoculated	2	0	0
Cirbronze			
Inoculated	8	3	10
Uninoculated	12	3	5
Promenade			
Inoculated	8	0	1
Uninoculated	2	0	0

[a] Roots of one plant per pot were inoculated on 2 September.

plant to plant within a pot, inoculated and uninoculated rooted cuttings were grown in Metro Mix 220 (W. R. Grace and Co., Cambridge, MA), five per pot, in the greenhouse. In half of the pots, one plant was root-inoculated before planting as described later. In other pots, none were inoculated.

Pathogen identification and cultivar susceptibility. The virulence of recently obtained North Carolina isolates of FOC was compared with that of old Florida isolates of FOC and with FOT in 10 popular cultivars. The isolates of FOC from North Carolina were designated NC 510 and NC 513. Isolates of FOC from Florida, obtained through the Pennsylvania State University Fusarium Research Center, were FRC-O-693 and FRC-O-950; two isolates of FOT, also from the Fusarium Research Center, were FRC-O-924 and FRC-O-1084. The fungi were grown at 24 C for 2 wk on potato-dextrose agar (natural PDA) in petri plates. Inoculum was then prepared by blending the contents of the plates in sterile distilled water for 1 min, and it was used immediately.

Rooted cuttings, as received from the propagator, were inoculated by dipping the roots for 5 sec in a suspension containing about 6×10^5 viable propagules per milliliter and transplanting one per 10-cm clay pot into Metro Mix 220. Roots of control plants were dipped in sterile PDA suspension. Each plant received Peters 20-20-20 soluble fertilizer (Robert Peters Co., Inc., Allentown, PA) weekly, beginning 1 wk after transplanting. A 15:1 proportioner was used to apply the fertilizer solution (25 g/L = 350 ppm of N). In addition, 2 wk after transplanting, each plant received 5 cm^3 of 18-9-13 Osmocote (controlled-release fertilizer, Sierra Chemical Co., Milpitas, CA). Plants were grown during long days without pinching (unless noted) and watered as needed

Table 3. Reactions of chrysanthemum cultivars to North Carolina and Florida isolates of *Fusarium oxysporum* f. sp. *chrysanthemi* (FOC) and f. sp. *tracheiphilum* (FOT) compared with uninoculated controls (0)

Cultivar	Pathogen	Source	Disease rating[a] (weeks after inoculation) 3	5	8	Height reduction (%)	Incubation period (days)[b]	Susceptibility[c]
Cirbronze	FOC	NC	4.7	4.9	4.8	94	15	VS
	FOC	FL	4.8	4.8	4.8	93	15	VS
	FOT		0.0	0.0	0.5	3	...	VR
	0		0.0	0.0	0.7	...	...	...
Escapade	FOC	NC	0.0	0.0	0.8	27	...	R
	FOC	FL	0.0	0.0	1.5	35	...	R
	FOT	FL	0.0	1.9	2.4	55	40	S
	0		0.0	0.0	0.0	...	...	...
Jamboree	FOC	NC	0.0	0.0	0.2	4.5	...	VR
	FOC	FL	0.0	0.0	0.6	4.4	...	VR
	FOT		0.0	0.0	0.0	0.0	...	VR
	0		0.0	0.0	0.0	...	...	...
Pinktive	FOC	NC	2.1	3.2	3.1	38	20	S/T
	FOC	FL	2.8	3.6	3.8	39	20	S/T
	FOT	FL	0.0	0.0	0.2	0	...	VR
	0		0.0	0.0	0.0	...	...	...
Promenade	FOC	NC	0.0	0.5	1.0	39	...	R
	FOC	FL	0.0	1.1	1.5	41	...	R
	FOT		0.0	2.1	3.5	52	40	S
	0		0.0	0.0	0.0	0	...	...
Puritan	FOC	NC	0.2	0.5	0.7	0.0	...	VR
	FOC	FL	0.0	0.0	0.3	2.1	...	VR
	FOT		0.0	0.0	0.0	0.0	...	VR
	0		0.0	0.0	0.0	...	...	...
Royal Trophy	FOC	NC	3.2	4.9	5.0	100.0	20	VS
	FOC	FL	2.4	4.6	5.0	100.0	20	VS
	FOT		0.0	0.0	2.0	0.5	55	R
	0		0.0	0.0	0.5	...	...	...
Torch	FOC	NC	0.0	1.8	4.1	17	40	S/T
	FOC	FL	0.0	2.1	3.1	10	40	S/T
	FOT		0.0	0.0	0.3	2	...	VR
	0		0.0	0.0	0.2	...	...	...
Tuneup	FOC	NC	0.0	0.0	0.0	0	...	VR
	FOC	FL	0.0	0.0	0.0	4	...	VR
	FOT		0.0	0.0	0.3	1	...	VR
	0		0.0	0.0	0.0	...	...	...
Yellow Delaware	FOC	NC	1.8	3.9	4.7	91	20	VS
	FOC	FL	2.5	4.3	4.9	97	20	VS
	FOT		0.0	0.0	0.0	0	...	VR
	0		0.0	0.0	0.0	...	...	...
LSD ($P = 0.05$)			1.3	1.1	1.1	...	...	...

[a] Disease rating, 8 wk after incoulation, on a scale of 0–5, where 0 = apparently healthy; 1 = slight stunting (15–25% reduction of plant height) and/or slight distortion of foliage or flowers and/or slight chlorosis; 2 = slight wilt (one or two leaves affected) and/or moderate stunting (26–50% reduction of plant height), and/or obvious distortion of foliage or flowers and/or moderate, general chlorosis; 3 = moderate wilt (three leaves to half of plant affected) and/or severe stunting (>50% reduction of plant height) and/or severe chlorosis (entire plant yellowed); 4 = severe wilt (more than half of plant affected); and 5 = dead, whole plant irreversibly wilted, stems necrotic.

[b] Number of days between inoculation and appearance of symptoms.

[c] Susceptibility rating based on the following disease ratings: 0.0–1.0 = very resistant (VR), 1.1–2.0 = resistant (R), 2.1–4.0 = susceptible (S), and 4.1–5.0 = very susceptible (VS). In addition, cultivars rated S or VS but with less than 50% reduction in height were also rated tolerant (T).

with overhead sprinklers. Pots were set on inverted saucers on benches covered with corrugated transite to prevent spread of the pathogen during watering. Plants were misted hourly for 5 sec from 800 to 1700 hours the first 2 days after transplanting to reduce the shock of transplanting. Tests were conducted in summer in the greenhouse during long days when day-night temperatures averaged 36.3 and 21.2 C.

Plants were rated weekly for 8 wk for symptoms of Fusarium wilt according to the following severity index: 0 = apparently healthy; 1 = slight stunting (15–25%) and/or distortion of foliage or flowers (detectable) and/or slight chlorosis; 2 = slight wilt (one or two leaves affected) and/or moderate stunting (26–50%) and/or distortion of foliage or flowers (very obvious) and/or moderate, general chlorosis; 3 = moderate wilt (three leaves to half of plant affected) and/or severe stunting (>50%) and/or severe chlorosis (entire plant yellowed); 4 = severe wilt (more than half of plant affected); and 5 = dead, whole plant irreversibly wilted, stems necrotic.

The heights of diseased plants were measured and compared with those of uninoculated plants as an index of stunting. Cultivars were replicated 10 times in a completely randomized block design. The test was repeated once.

Chemical control. Fungicides were evaluated for efficacy, time of application, frequency of application, concentration, and phytotoxicity. It was assumed that commercial growers use culture-indexed plants grown in sterile media, so the emphasis was on arresting rather than preventing the disease.

Roots of plants were inoculated as described 2 days before the initial fungicide drench, except the inoculum consisted of equal numbers of propagules of the six isolates listed before.

Fungicides tested (g a.i./L) included benomyl (Benlate 50W) at 0.3, 0.6, 1.2, 2.4, and 4.8; ethazol + thiophanate-methyl (Banrot 15W + 25W) at 0.36 and 0.72; bitertanol (Baycor 25W) at 0.3 and 0.6; thiabendazole (Mertect 340F, 42.28F) at 0.24 and 0.47; vinclozolin (Ronilan 50W) at 0.6, 1.2, and 2.4; iprodione (Rovral 50W) at 0.6, 1.2, and 2.4; quintozene + ferbam (Terraclor 75W + Ferbam 76W) at 0.90 + 0.91 and 1.80 + 1.82; quintozene + ethazol (Terraclor Super X, 23.2E + 5.8E) at 0.21 + 0.05 and 0.42 + 0.10; thiophanate-methyl (Topsin M 70W) at 0.21, 0.42, 0.84 and 1.68; and carboxin (Vitavax 3F, 400 g a.i./gal) at 0.31 and 0.62.

An additional treatment was benomyl, 1.2 g a.i./L + 4 g $CaOH_2$/0.028 m^3 of media + $NaNO_3$ at 3.2 g/L, to simulate the control recommendations of Engelhard and Woltz (6). Benomyl was applied 1 day before inoculation and again 8 days after inoculation as a drench of 118 ml/pot. The $NaNO_3$ was applied at the rate of 200 ppm of nitrogen 9 days after inoculation, then at 400 ppm of nitrogen weekly. All other treatments received the same amount and the same schedule of nitrogen but with Peters 20-20-20 instead of $NaNO_3$. In addition, all pots except those treated with benomyl + lime + nitrate received 5 cm^3 of Osmocote 18-9-13, 2 wk after transplanting. The $CaOH_2$ added to the benomyl + lime + nitrate treatment raised the pH of that medium from 6.0 to 6.8 as measured 18 hr after application. Fungicides were applied as soil drenches (118 ml/pot) 2, 6, or 10 days after inoculation, and half of the pots (five) received a second application 10 days later. Excess fungicide leached through the pots and ran off the bench. Control pots received an equal amount of water. There were five replicates per treatment in a completely randomized block design. Plants received water as needed, beginning the day after the fungicide drench; however, they were misted as described before to reduce the shock of transplanting. Plants were observed at least every other day and rated for disease symptoms and phytotoxicity about twice a week for the first 3 wk, then weekly for the following 5 wk. Heights of plants, from the soil line, were measured 4 and 8 wk after inoculation.

Table 4. Efficacy of fungicide drenches for control of Fusarium wilt of Royal Trophy chrysanthemum grown in pots in the greenhouse

Fungicide[a]	Rate (g a.i./L)	Disease rating[b]	Height (cm)	Phytotoxicity rating[c]
Benomyl	1.2	1.0	46.5	0.0
	2.4	0.4	45.0	0.5
	4.8			
Ethazol + thiophanate-methyl	0.5 + 0.9	0.4	48.5	0.0
	1.1 + 1.8	0.6	47.8	1.5[d]
Bitertanol	0.3	5.0	10.5	4.0
Triadimefon	0.08	3.0	18.0	6.0
Thiabendazole	0.24	3.2	4.1	9.0
Vinclozolin	1.2	4.8	10.3	0.0
	2.4	2.2	39.2	1.5
Iprodione	0.6	4.5	19.7	0.0
	1.2	3.7	4.2	6.0
Quintozene + ferbam	0.90 + 0.91	5.0	2.0	6.0
Quintozene + ethazol	0.42 + 0.10	3.0	22.4	0.5
Thiophanate-methyl	0.21	1.0	49.5	0.0
	0.42	0.6	49.8	0.0
Carboxin	0.31	5.0	0.0	10.0
Benomyl + lime + nitrate[e]		1.2	42.8	2.0
None				
Uninoculated		0.2	49.5	...
Inoculated		4.9	4.0	...
LSD ($P = 0.05$)		0.76	...	...

[a] Fungicides were applied once as a drench 2 days after inoculation, except the benomyl + lime + nitrate treatment, where benomyl was applied twice, once before and once after inoculation. Five replicates per treatment were arranged in a completely randomized block design.

[b] Disease rating, 8 wk after inoculation, on a scale of 0–5, where 0 = apparently healthy; 1 = slight stunting (15–25% reduction of plant height) and/or slight distortion of foliage or flowers and/or slight chlorosis; 2 = slight wilt (one or two leaves affected) and/or moderate stunting (26–50% reduction of plant height), and/or obvious distortion of foliage or flowers and/or moderate, general chlorosis; 3 = moderate wilt (three leaves to half of plant affected) and/or severe stunting (>50% reduction of plant height) and/or severe chlorosis (entire plant yellowed); 4 = severe wilt (more than half of plant affected); and 5 = dead, whole plant irreversibly wilted, stems necrotic.

[c] Phytotoxicity rating, 8 wk after inoculation, on a scale of 1–10, where 0 = none and 10 = dead plants.

[d] Ethazol + thiophanate-methyl caused temporary stunting and chlorosis 2–4 wk after application, but plants recovered.

[e] See footnote a above and text for an explanation of the benomyl + lime + nitrate treatment.

RESULTS AND DISCUSSION

Source of inoculum and spread of pathogen among plants within a pot. *F. oxysporum* grew from some upper, lower, and middle sections from all cultivars examined (Table 1). When rooted cuttings of Royal Trophy were inoculated with isolates from these sections, symptoms of Fusarium wilt resulted from cultures from each cultivar regardless of its susceptibility. The fungus was cultured less frequently from the most susceptible cultivars, Royal Trophy and Cirbronze, than from some of the more resistant cultivars (Table 1). On the average, only 1.0 and 3.7% of sections of Cirbronze and Royal Trophy, respectively, yielded *F. oxysporum*, whereas an average of 9.5% of the sections of the highly resistant cultivar Tuneup were positive. Overall, the frequency of occurrence of the pathogen in the upper portion of rooted cuttings was about the same as that in the lower portion (6.7 vs. 6.0%, respectively). These results are significant not only because the pathogen was found in many rooted cuttings from a commercial propagator but also because it may reside within rooted cuttings of highly resistant cultivars that may never show symptoms of Fusarium wilt. These

symptomless carriers may serve as a source of inoculum for susceptible cultivars. These results also indicate that the culture-indexing system used in conjunction with propagation of rooted chrysanthemum cuttings should be closely scrutinized and improved.

Eight of 60 uninoculated rooted cuttings of Royal Trophy were diseased 28 days after planting in sterile medium, strongly indicating that plants were infected when received (Table 2). Spread of the pathogen from plant to plant within a pot was demonstrated since 30 Royal Trophy plants became diseased within 48 days of planting, when only eight were inoculated (Table 2). Similar rapid increases in incidence of Fusarium wilt were observed in the greenhouse potmum industry in North Carolina during 1979–1982.

Pathogen identification and cultivar susceptibility. Isolates of FOC from North Carolina and Florida caused similar reactions in test cultivars (Table 3), dispelling the suspicion that a new pathogen was involved.

The two cultivars subject to outbreaks of Fusarium wilt in recent years, Cirbronze and Royal Trophy, were rated very susceptible to Fusarium wilt caused by FOC, which apparently is the prevailing pathogen associated with this disease in North Carolina (Table 3). Yellow Delaware also was very susceptible to FOC. Pinktive and Torch were moderately susceptible to this pathogen; Escapade and Promenade were resistant; and Jamboree, Puritan, and Tuneup were highly resistant. None of the 10 cultivars tested were highly susceptible to FOT but Escapade and Promenade were moderately susceptible. All others were highly resistant except Yellow Delaware, in which slight symptoms were observed late in the season; therefore, this cultivar was rated resistant.

The incubation period (Table 3) varied from 15 days for Cirbronze inoculated with FOC to 55 days for Royal Trophy inoculated with FOT. This is an important observation relative to the assignment of a value for resistance. For example, if disease was rated 3 instead of 8 wk after inoculation, the susceptible cultivar Torch would have been rated highly resistant as previously reported (8). Also, Escapade and Promenade, susceptible to FOT but with 40-day incubation periods, were symptomless and thus would have been rated highly resistant after 3 wk. Some wilting occurred after 3–5 wk in Pinktive inoculated with FOC, after which some recovery was noted, and symptoms did not increase. Height reduction after 8 wk was only 38–39%; therefore, the cultivar was considered tolerant. Another cultivar rated tolerant to FOC was Torch; however, this tolerance rating was based on symptoms that developed after 6–8 wk and reduced plant height only 10–17%.

Table 5. Efficacy of benomyl versus thiophanate-methyl drenches for control of Fusarium wilt of Royal Trophy chrysanthemum grown in pots in the greenhouse

Fungicide	Rate (g a.i./L)	Application (days after inoculation)	Disease rating[a]	Height (cm)	Phytotoxicity rating[b]
Benomyl	0.6	2	3.9	22.4	0.0
		2 + 12	3.4		
		6	4.5		
		6 + 16	4.1		
	1.2	2	1.0	46.5	0.0
		2 + 12	1.2		
		6	1.6		
		6 + 16	0.8		
	2.4	2	0.4	45.0	0.5
		2 + 12	0.0		
		6	0.8		
		6 + 16	0.6		
Thiophanate-methyl	0.21	2	1.0	49.5	0.0
		2 + 12	0.4		
		6	0.8		
		6 + 16	0.8		
		10	0.6		
		10 + 20	0.2		
	0.42	2	0.6	49.8	0.0
		2 + 12	0.6		
		6	0.8		
		6 + 16	0.8		
		10	0.6		
		10 + 20	0.2		
Control					
Uninoculated			0.1	49.5	...
Inoculated			4.9	4.0	...
LSD ($P = 0.05$)			0.76	...	...

[a] Disease rating, 8 wk after inoculation, on a scale of 0–5, where 0 = apparently healthy; 1 = slight stunting (15–25% reduction of plant height) and/or slight distortion of foliage or flowers and/or slight chlorosis; 2 = slight wilt (one or two leaves affected) and/or moderate stunting (26–50% reduction of plant height), and/or obvious distortion of foliage or flowers and/or moderate, general chlorosis; 3 = moderate wilt (three leaves to half of plant affected) and/or severe stunting (>50% reduction of plant height) and/or severe chlorosis (entire plant yellowed); 4 = severe wilt (more than half of plant affected); and 5 = dead, whole plant irreversibly wilted, stems necrotic.
[b] Phytotoxicity rating, 8 wk after inoculation, on a scale of 1–10, where 0 = none and 10 = dead plants.

Several workers have reported on chrysanthemum cultivar susceptibility to FOC and FOT (2,4,5,8–11). Ratings have been reported for 59 cultivars, of which 55 and 88% were resistant to FOC and FOT, respectively, and 41 and 12%, respectively, were susceptible to these pathogens.

Chemical control. The most effective fungicide in these studies was thiophanate-methyl (Table 4). Thiophanate-methyl provided excellent disease control at a rate of 0.21 g a.i./L, and rates as high as 1.68 g a.i./L were not phytotoxic (Table 3). The material was effective even when applied once, 10 days after inoculation. Ethazol + thiophanate-methyl (which is 25% thiophanate-methyl) was equally effective and nonphytotoxic when used at 12 oz formulated/100 gal (0.22 g a.i. of thiophanate-methyl per liter). Benomyl was effective but not at the rates usually recommended. Benomyl gave excellent control at 1.2 g a.i./L, comparable to that provided by thiophanate-methyl at 0.21 g a.i./L, but at twice or four times that rate, benomyl was slightly to moderately phytotoxic (marginal leaf chlorosis and stunting). Other fungicides tested were either ineffective or phytotoxic.

The combination treatment, benomyl + $CaOH_2$ + nitrate gave good control, but slight stunting and chlorosis were noted. Complete control of symptoms as reported in Florida (7) was not attained in these studies, possibly because different media were used in the two studies and because fungicides were applied before inoculation in Florida but after inoculation in our studies. Thiophanate-methyl and benomyl were as effective when applied 6 or 10 days after inoculation as they were when applied 2 days after inoculation and one application was as efficacious as two, 10 days apart (Table 5). Benomyl and thiophanate-methyl are systemic and apparently arrested the pathogen after infection.

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LITERATURE CITED

1. Armstrong, G. M., and Armstrong, J. K. 1965. Wilt of chrysanthemum caused by race 1 of the cowpea Fusarium. Plant Dis. Rep. 49:673-676.
2. Armstrong, G. M., Armstrong, J. K., and Littrell, R. H. 1970. Wilt of chrysanthemum caused by *Fusarium oxysporum* f. sp. *chrysanthemi*, forma specialis nov. Phytopathology 60:496-498.
3. Emberger, G., and Nelson, P. E. 1981. Histopathology of a susceptible chrysanthemum cultivar infected with *Fusarium oxysporum* f. sp.

chrysanthemi. Phytopathology 71:1043-1050.
4. Engelhard, A. W., and Woltz, S. S. 1971. Fusarium wilt of chrysanthemum: Symptomatology and cultivar reactions. Proc. Fla. State Hortic. Soc. 84:351-354.
5. Engelhard, A. W., and Woltz, S. S. 1972. Fusarium wilt of chrysanthemum. Univ. Fla. Bradenton Agric. Res. Educ. Cent. (AREC) Mimeo. Rep. GC-1972-1. 4 pp.
6. Engelhard, A. W., and Woltz, S. S. 1972. The Fusarium wilt disease. Fla. Flower Grower 9(7):1-6.
7. Engelhard, A. W., and Woltz, S. S. 1973. Fusarium wilt of chrysanthemum: Complete control of symptoms with an integrated fungicide-lime-nitrate regime. Phytopathology 63:1256-1259.
8. Fisher, N. L., and Toussoun, T. A. 1983. Symptom response and colonization and measures of resistance in chrysanthemum cultivars inoculated with *Fusarium oxysporum* f. sp. *chrysanthemi*. Plant Dis. 67:376-378.
9. Garibaldi, A., and Gullino, G. 1975. Malattie della piante da fiore ed ornamentali nuove o poco note in Italia. IV. Sulla presenza in Italia di due formae speciales di *Fusarium oxysporum* patogene del Crisantemo. Inf. Fitopatol. 25:9-12.
10. Strider, D. L., and Jones, R. K. 1981. Fusarium wilt of chrysanthemums–It's usually worse the second time around. North Carolina Flower Growers Bull. 25:710.
11. Von Gerlach, W., Schickedanz, F., and Dalchow, J. 1980. Erstes Auftreten einer Fusarium-Welke der Chrysantheme in Deutschland. Nachrichtenbl. Dtsch. Pflanzenschutzdienstes (Braunschweig) 32:1-4.