Ecology and Epidemiology

Host Range and Host Colonization, Temperature Effects, and Dispersal of *Fusarium oxysporum* f. sp. *citri*

L. W. Timmer

Associate professor, University of Florida, Institute of Food and Agricultural Sciences, Agricultural Research and Education Center (IFAS, AREC), 700 Experiment Station Road, Lake Alfred 33850.

I thank G. R. Grimm and S. M. Garnsey for helpful discussions and information and Nancy Reinhart, Carl Anderson, and Patricia Atkins for expert technical assistance.

Florida Agricultural Experiment Stations Journal Series Paper 3018.

Accepted for publication 5 October 1981.

ABSTRACT

Timmer, L. W. 1982. Host range and host colonization, temperature effects, and dispersal of *Fusarium oxysporum* f. sp. *citri*. Phytopathology 72: 698-702.

Fusarium oxysporum f. sp. *citri* causes a serious wilt and dieback of Mexican lime (*Citrus aurantifolia*) in Florida greenhouses. Two commonly used rootstock species, Milam (*C. jambhiri* variant) and *C. volkameriana*, as well as *C. amblycarpa* were susceptible to the fungus, but other rootstock and scion species were resistant. All citrus species tested were invaded by *F. oxysporum* f. sp. *citri*, but the fungus was restricted to roots and stem bases in resistant species. Resistant rough lemon (*C. jambhiri*) and sweet orange (*C. sinensis*) showed symptoms when budded on susceptible Mexican lime rootstock. *F. oxysporum* f. sp. *citri* produced no symptoms on 39 species and cultivars of noncitrus plants, but invaded the stem bases of 15 species. Optimal temperature was 27–30 C for growth of the fungus in culture and 21–26 C for disease development. The means by which the fungus may be introduced into greenhouses remain unknown, but apparently it does not enter on seed or budwood. Within greenhouses the fungus was recovered on trap plates indicating possible dissemination by air.

Previously, a serious wilt and dieback of Mexican lime (*Citrus aurantifolia* (Christm.) Swingle) caused by *Fusarium oxysporum* (Schlecht) emend. Snyd. et Hans. f. sp. *citri* was described in Florida (10). In that paper, the etiology, a limited host range, and control measures for the disease were described. The disease is now known to occur with certainty only in Florida greenhouses, where Mexican lime is used as an indicator for citrus tristeza virus. A similar disease was reported in Brazil (9), and is probably caused by the same organism (10).

The present study describes additional hosts, determines the tissues colonized by the fungus in resistant and susceptible species, determines the effect of temperature on the fungus growth and disease development, and investigates the means of spread of the pathogen. An abstract of a portion of this work has been published (11).

MATERIALS AND METHODS

Plant materials and growing conditions. All plants were grown in Pro-Mix® BX potting mixture (Premier Brands, Inc., New York, NY 10017) in greenhouses maintained at 18–35 C.

The following species of citrus and citrus relatives were inoculated with *F. oxysporum* f. sp. *citri*: *C. amblycarpa* (Hassk.) Ochse.; Mexican lime; limequat, *C. aurantifolia* × *Fortunella* sp.; rough lemon, *C. jambhiri* Lush; Milam, a variant of rough lemon resistant to burrowing nematode (*Radopholus similis*); *C. volkameriana* Pasq; sweet orange, *C. sinensis* (L.) Osb. 'Madam Vinous'; grapefruit, *C. paradisi* Macf. 'Duncan'; sour orange, *C. aurantium* L.; lemon, *C. limon* (L.) Burm. 'Eureka'; sweet lime, *C. limettioides* Tan.; calamondin, *C. madurensis* Lour.; citrange, *Poncirus trifoliata* (L.) Raf. × *C. sinensis* 'Rusk'; citrumelo, *P. trifoliata* × *C. paradisi* 'Swingle'; Rangpur × Troyer, *C. limonia* × (*P. trifoliata* × *C. sinensis* 'Troyer'). In addition to the rough lemons mentioned above, a rough lemon resistant to *Alternaria citri* from IFAS, AREC, University of Florida, Lake Alfred, and the following selections obtained from the Budwood Registration Program, Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Winter Haven, FL 33880, were tested for susceptibility to *F. oxysporum* f. sp. *citri*: RL-S-514-29-6XE; RL-S-514-29-12-XE; RL-S-514-29-XE; SPB-51-1-X; Estes rough lemon (F/E21-6), and Red rough lemons (F/50-11 and SF 50-20).

The following noncitrus plants were tested for susceptibility to *F. oxysporum* f. sp. *citri*: mimosa, *Albizzia julibrissin* Durazz. 'Pudica Pink'; dill, *Anethum graveolens* L.; celery, *Apium graveolens* L.

0031-949X/82/06069805/$03.00/0

var. *dulce* DC 'Golden Self-Branching'; asparagus, *Asparagus officinalis* L. 'Mary Washington'; beet, *Beta vulgaris* L. 'Detroit Dark Red'; Swiss chard, *B. vulgaris* var. *cicla* 'Rhubarb'; mustard, *Brassica juncea* (L.) Coss 'Southern Giant'; cabbage, *B. oleracea* var. *capitata* L. 'Copenhagen Market'; pepper, *Capsicum annuum* L. 'Yolo Wonder'; wallflower, *Cheiranthus cheiri* L.; cantaloupe, *Cucumis melo* L. 'Honey Rock'; cucumber, *C. sativus* L. 'Straight Eight'; blue gum eucalyptus, *Eucalyptus globulus* Labill.; soybean, *Glycine max* (L.) Merr. 'Kanrich'; okra, *Hibiscus esculentus* L. 'Clemson Spineless'; balsam, *Impatiens balsamina* L. 'Double Camellia Flowered'; summer cypress, *Kochia scoparia* (L.) Schrad.; lupine, *Lupinus angustifolia* L. 'Minarette'; tomato, *Lycopersicon esculentum* Mill. 'Homestead', 'Jubilee', and 'Beefsteak'; stocks, *Matthiola incana* (L.) R. Br. 'Gilliflower'; alfalfa, *Medicago sativa* L. 'Ranger'; tree tobacco, *Nicotiana glauca* Graham; wild tobacco, *N. rustica* L.; tobacco, *N. tabacum* L. 'Turkish'; passion vine, *Passiflora edulis* Sims; petunia, *Petunia hybrida* Vilm. 'Grandiflora Ruffled'; bean, *Phaseolus vulgaris* L. 'Bountiful'; pea, *Pisum sativum* L. 'Wando'; radish, *Raphanus sativus* L. 'Long White Icicle'; sesame, *Sesamum indicum* L. 'Criollo'; eggplant, *Solanum melongena* L. 'Black Beauty'; spinach, *Spinacea oleracea* L. 'Nobel'; marigold, *Tagetes erecta* L. 'Rose d'Inde'; Mexican sunflower, *Tithonia rotundifolia* (Mill.) Blake; crimson clover, *Trifolium incarnatum* L.; and cowpea, *Vigna unguiculata* (L.) Walp. 'Lady Finger Round' and 'Black Local.'

Inoculations and reisolations. Stock cultures of *F. oxysporum* f. sp. *citri* were maintained on V-8 juice agar slants (200 ml V-8 juice [Campbell Soup Co., Camden, NJ 08101]; 2.8 g $CaCO_3$; and 15 g agar per liter of deionized water). All cultures were incubated at room temperature (22–25 C) unless otherwise noted. All inoculations were made with isolate ATCC 38032. This isolate was inoculated to Mexican lime periodically and reisolated to assure that pathogenicity had not been lost during repeated subculture. However, the original isolate was still highly pathogenic on Mexican lime after 3 yr in culture.

Inoculum was prepared by growing the fungus for 5–7 days on Difco cornmeal agar (CMA) plates (Difco, Inc., Detroit, MI 48201). Agar bearing mycelium and microconidia was comminuted in deionized water for about 30 sec in a blender. Microconidia were counted using a hemacytometer, and the concentration was adjusted to 5×10^5 spores per milliliter. Plants were usually inoculated by soaking the root systems in the spore suspension for about 1 hr, then repotting and adding about 50 ml of inoculum around each seedling. In other tests, three holes were made in the potting mix around each seedling, and 50 ml of inoculum was added per plant. In tests with Mexican lime, there was no significant difference between the two methods of inoculation in symptom severity or in time of symptom appearance. Control seedlings were treated with a suspension prepared from uninoculated CMA plates.

Citrus species were inoculated when they were about 6 mo old and 15–40 cm tall, except the large Milam seedlings that were about 1 yr old and 60–80 cm tall. Budded plants were about 1.5 yr old and 5–8 mm in diameter above the bud union when inoculated. Noncitrus plants were inoculated when they were 15–20 cm tall and past the tender seedling stage. Generally, 8–10 plants of each species were inoculated and four to five uninoculated controls were used.

Symptoms were rated on the following scale: 0 = healthy; 1 = mild epinasty and reticulate chlorosis; 2 = moderate chlorosis and wilt; 3 = leaf drop, twig dieback, and wilt; and 4 = dead.

Reisolations from inoculated plants and examination for vascular discoloration were made 12–18 wk after inoculation. Reisolations were made from taproots, stem bases, midstems, twigs, and leaf midribs of inoculated citrus seedlings; from the rootstock base, scion base, and upper plant parts of budded plants; and from the stem bases only of noncitrus plants. Each of the above tissues was cut from at least three, and usually six to 10, plants of each species. Plant tissues were surface disinfested first in 0.5% NaOCl for 1.0 min, then in 70% ethanol for 1.0 min, and rinsed in sterile deionized water. Three pieces from each tissue on each plant were plated on Komada's selective medium (5) and incubated for 7 days. Data were expressed as the percentage of the pieces from which *F. oxysporum* f. sp. *citri* was isolated. Similar isolations were attempted from the stem bases of four control plants of each citrus species and three control plants of each noncitrus species.

Dilutions of potting mix from inoculated and control plants were plated on Komada's medium to determine the number of propagules per gram of *F. oxysporum* f. sp. *citri* at the end of each experiment. Data were expressed as propagules per gram dry weight of potting mix.

Identification and pathogenicity tests. Various isolates of *Fusarium* recovered from inoculated plants were identified and tested for pathogenicity on Mexican lime. Cultures were transferred from Komada's medium to autoclaved bermudagrass (*Cynodon dactylon* Pers.) stems incorporated in 1.5% water agar. These cultures were maintained under continuous fluorescent light for 2 wk for production of typical spore structures. Cultures identified as *F. oxysporum* were then single-spored and tested for pathogenicity on three Mexican lime seedlings.

Temperature studies. Mycelial plugs of isolate ATCC 38032 grown on CMA were transferred to CMA plates and incubated at 9, 21, 24, 27, 30, 32, 33, and 36 ± 1.0 C. Three plates were used for each temperature, and colony diameter was measured daily. The experiment was repeated with an isolate of *F. oxysporum* f. sp. *citri* from a naturally infected Milam seedling.

Mexican lime seedlings were inoculated as described above and the pots were immersed in water-filled temperature tanks maintained at 15, 21, 26, and 32 C. Pots were sealed at the base except for a tube connected to a manifold, which permitted drainage of excess irrigation water to the outside of the tanks. Tops were exposed to ambient greenhouse temperatures. Six replicate pots with two

TABLE 1. Effect of inoculation of citrus species with *Fusarium oxysporum* f. sp. *citri* on symptom development and soil populations of the fungus

Citrus species or scion/rootstock	Symptom severity[y]		Propagules per gram potting mix $(\times 10^3)$
	Early	Late	
Experiment I			
Mexican lime	2.6 a[z]	2.4 a	12.1 a
Milam (small seedlings)	1.6 b	1.4 b	6.3 ab
Milam (large seedlings)	0.8 c	0.7 c	8.1 ab
Citrus volkameriana	2.0 b	0.0 d	9.8 ab
C. amblycarpa	1.0 c	0.7 c	8.6 ab
Limequat	0.0 d	0.0 d	12.7 a
Eureka lemon	0.0 d	0.2 d	3.2 b
Sweet lime	0.0 d	0.0 d	2.6 b
Rusk citrange	0.0 d	0.0 d	2.0 b
Swingle citrumelo	0.0 d	0.0 d	2.7 b
Rangpur × Troyer	0.0 d	0.0 d	1.1 b
Calamondin	0.0 d	0.0 d	2.4 b
Experiment II			
Mexican lime	2.6 a	3.3 a	46.1 a
Sour orange	0.0 b	0.0 b	14.7 b
Duncan grapefruit	0.0 b	0.0 b	27.7 b
Sweet orange	0.0 b	0.0 b	19.8 b
Rough lemon	0.0 b	0.0 b	18.2 b
Experiment III			
Mexican lime	2.6 a	2.9 a	···
Rough lemon	0.0 c	0.0 c	···
Sweet orange	0.0 c	0.0 c	···
Rough lemon/ Mexican lime	0.7 b	1.1 b	···
Mexican lime/ rough lemon	0.0 c	0.0 c	···
Sweet orange/ Mexican lime	1.6 b	2.0 ab	···
Mexican lime/ sweet orange	0.0 c	0.0 c	···

[y] Symptoms rated on a scale of 0 = healthy to 4 = dead. Symptoms rated at 7 (early) and 12 wk (late) in Exp. I and II and at 10 (early) and 18 wk (late) in Exp. III.

[z] Means within columns and within experiments followed by the same letter are not significantly different according to Duncan's multiple range test, at $P = 0.05$.

inoculated plants each and six uninoculated control pots with one plant each were randomized in each tank. Symptoms were rated weekly and the fresh weights of the tops determined after 10 wk.

Dispersal. Trap plates were exposed on greenhouse benches to determine whether airborne spread of the fungus occurred. Greenhouses in Lake Alfred, FL, were monitored in October, November, and December 1979, and April and June 1980. A greenhouse in Orlando, FL, was checked in June 1980. All greenhouses were cooled with evaporative coolers with large fans for circulation. Plates were placed on open benches in greenhouses with many infected plants, but not within 1 m of any plant. On each date, 20 plates of Komada's medium were exposed for 2 hr in midafternoon, covered, and incubated for 7 days. Fusarium colonies developing on the selective medium were identified, and *F. oxysporum* isolates were tested for pathogenicity.

Isolations were made from Mexican lime seed and from the twigs of a seed source tree to try to determine the original source of introduction of the fungus into the greenhouses. About 250 seeds were halved aseptically and plated on Komada's medium. Pieces of 13 twigs suffering from dieback were surface disinfested as above and plated on Komada's medium. Plates were incubated for 7 days, selected isolates were identified, and eight isolates of *F. oxysporum* from seed and three from twigs tested for pathogenicity.

RESULTS

Host range and colonization. Three species of citrus, Milam, *C. amblycarpa* and *C. volkameriana*, were new susceptible hosts of *F. oxysporum* f. sp. *citri* (Table 1). Symptoms on these hosts were less severe than on Mexican lime. In addition, two Eureka lemon plants had symptoms of mild epinasty and wilt symptoms on occasion. Although Milam, a variant of rough lemon, was susceptible to the disease, none of the other seven rough lemon selections had symptoms. Data presented for rough lemon (Tables 1 and 2, Exp. II) are averages of seven rough lemon selections tested; there were no significant differences among them. Although rough lemon and sweet oranges were resistant as seedlings, they had mild-to-moderate symptoms when budded on Mexican lime rootstock (Table 1).

In general, propagule counts of *F. oxysporum* f. sp. *citri* from inoculated plants at the end of the experiment were greater in the potting mix in which susceptible species had grown than in that in which resistant species had grown (Table 1, Exp. I and II). Potting mix in control plants became infested with low levels of *F. oxysporum* f. sp. *citri*, possibly by splashing of potting mix from inoculated plants during watering or by airborne spread. Propagule counts in controls in Exp. I ranged from 0.2×10^3/g for Rusk citrange to 2.2×10^3/g for the large Milam seedlings and in Exp. II ranged from 0.2×10^3/g for sour orange to 0.9×10^3/g for Mexican lime.

F. oxysporum f. sp. *citri* was recovered from a high percentage of the taproots of citrus species regardless of their susceptibility to the disease (Table 2). The fungus was reisolated from 100% of the stem bases of susceptible citrus species, but was usually recovered from less than 50% of the stem bases of resistant species. The more severe the disease symptoms on a citrus species, the farther up the stem the fungus progressed (Tables 1 and 2). Although *F. oxysporum* f. sp. *citri* was unable to invade beyond the stem base of rough lemon and sweet orange when they were inoculated as seedlings, the fungus readily invaded much of the plant when these two species were budded on highly susceptible Mexican lime rootstock (Table 2, Exp. III). Sweet orange appeared to be more readily invaded by *F. oxysporum* f. sp. *citri* than was rough lemon. In isolations attempted from four control plants of each citrus species in Tables 1 and 2, *F. oxysporum* f. sp. *citri* was recovered from one large Milam seedling.

Vascular discoloration was observed frequently in susceptible species and also occurred in stem bases of some resistant species. The fungus was isolated from discolored xylem in almost all cases, and was recovered occasionally from symptomless xylem.

TABLE 2. Colonization of various tissues of citrus species following root inoculation with *Fusarium oxysporum* f. sp. *citri*

	Positive isolations (%)[w]				
Citrus species	Tap root or rootstock[x]	Seedling or scion base[y]	Midstem	Twig	Midrib
Experiment I					
Mexican lime	100	100 a[z]	100 a	78 a	0
Milam (small seedlings)	100	95 a	100 a	0 b	0
Milam (large seedlings)	100	90 a	0 c	0 b	0
Citrus volkameriana	100	100 a	78 ab	11 b	0
C. amblycarpa	100	95 a	56 b	0 b	0
Limequat	···	52 b	···	···	···
Eureka lemon	67	43 b	0 c	0 b	0
Sweet lime	···	27 b	···	···	···
Rusk citrange	···	22 b	···	···	···
Swingle citrumelo	···	33 b	···	···	···
Rangpur × Troyer	···	19 b	···	···	···
Calamondin	67	14 b	0 c	0 b	0
	N.S.				N.S.
Experiment II					
Mexican lime	100	100 a	89 a	100 a	20 a
Sour orange	100	17 c	0 b	0 b	0 b
Duncan grapefruit	100	22 c	0 b	0 b	0 b
Sweet orange	100	67 b	0 b	0 b	0 b
Rough lemon	97	26 c	0 b	0 b	0 b
	N.S.				
Experiment III					
Rough lemon	···	0 c	0 c	0 b	0 b
Sweet orange	···	33 b	0 c	0 b	0 b
Rough lemon/Mexican lime	100 a	68 a	48 b	7 b	5 b
Mexican lime/rough lemon	6 b	0 c	0 c	0 b	0 b
Sweet orange/Mexican lime	100 a	100 a	76 a	25 a	28 a
Mexican lime/sweet orange	10 b	4 c	2 c	0 b	0 b

[w] Percent of the tissue pieces from which *F. oxysporum* f. sp. *citri* was isolated on Komada's medium.

[x] Isolations from the taproot in Exp. I and II and from rootstock bases in Exp. III.

[y] Isolations from stem bases of seedlings or scion bases of budded trees.

[z] Means within columns and within experiments followed by the same letter are not significantly different according to Duncan's multiple range test, at $P = 0.05$.

None of the inoculated noncitrus species and cultivars had disease symptoms. However, *F. oxysporum* f. sp. *citri* was reisolated frequently from the stem bases of inoculated, noncitrus species, but was not recovered from others (Table 3). The fungus was not recovered from the stem bases of noncitrus species listed in the Materials and Methods that are not included in Table 3. *F. oxysporum* f. sp. *citri* was not reisolated from the stem bases of any of the control plants of noncitrus species. Soil propagule counts of *F. oxysporum* f. sp. *citri*, determined at the end of the experiment were generally high, but were not related to the ability of the fungus to invade the stem bases of a given plant species (Table 3). *F. oxysporum* f. sp. *citri* was not recovered on soil dilution plates of controls of 17 of 28 noncitrus species, but population densities as high as 370, 450, and 1,100 colony-forming units per gram were recovered from soil in which Beefsteak tomato, pea, and pepper, respectively, were growing.

F. oxysporum f. sp. *citri* produced readily identifiable colonies on Komada's medium. Small colonies generally formed after 2–3 days and a characteristic reddish-purple pigment was produced after 5–6 days. Growth on water agar plus bermudagrass stems, on CMA, and on V-8 agar was appressed with little or no aerial mycelium. Reisolates from the various plant species were identified as *F. oxysporum* and were typical of *F. oxysporum* f. sp. *citri*. At least one, and usually two, isolates from each of the citrus and noncitrus species from which the fungus was recovered were tested and all were found to be pathogenic to Mexican lime.

Temperature effects. Colony diameters at 9, 21, 24, 27, 30, 32, 33, and 36 C were 10, 40, 54, 56, 58, 28, 18, and 0 mm, respectively, after 96 hr. A nearly identical pattern was observed with an isolate from a naturally infected Milam seedling.

Disease severity was greatest at 21–26 C and only slightly less at 32 C (Table 4). Disease severity was significantly less at 15 C than at 21 or 26 C, but growth of healthy limes was poor at that temperature. There was no significant difference in the fresh weight of the tops of inoculated lime plants at any of the temperatures studied.

Dispersal. Only 19 total isolates of *Fusarium* spp. were recovered from plates exposed on benches in all greenhouses monitored. The number of isolates did not vary appreciably with time of year or location. Of the 19 isolates recovered, 11 were identified as *F. oxysporum* and six of those were pathogenic to Mexican lime and were identified as *F. oxysporum* f. sp. *citri*.

F. oxysporum f. sp. *citri* sporulated frequently on dead and dying Mexican lime seedlings in the greenhouse. Abundant microconidia and occasional macroconidia were observed by light microscopy especially at the nodes where petioles had abscissed.

Many Fusarium isolates were obtained from seed and from dying branches of a seed source tree. All these isolates produced appressed, compact, light pink colonies on Komada's medium. Many were *F. oxysporum*, but other *Fusarium* spp. were also recovered. Eight *F. oxysporum* isolates from seed and three from twigs were tested on Mexican lime, but none was pathogenic.

DISCUSSION

At present, Fusarium wilt of citrus is not recognized as a problem in Florida citrus groves, but *F. oxysporum* has been isolated from field Mexican lime trees on Rangpur lime (*C. limonia* Osb.) rootstock in Brazil (9). In limited tests, we did not isolate *F. oxysporum* f. sp. *citri* from nurseries or from declining grove trees in Florida (10, and Timmer et al, *unpublished*). Previously, only one rootstock species, Rangpur lime, which is used to only a limited extent in Florida, was found by artificial inoculation to be susceptible to *F. oxysporum* f. sp. *citri* (10). Three more *Citrus* spp. were susceptible to the fungus when inoculated in the greenhouse. *C. volkameriana* is being used more frequently because rough lemon rootstock is highly susceptible to citrus blight. Milam is important to the Florida citrus industry, because it is the only acceptable rootstock with a high degree of resistance to the burrowing nematode. Although Milam was quite susceptible to *F. oxysporum* f. sp. *citri*, all other rough lemon selections tested were resistant to the fungus. Taken together, rootstocks susceptible to *F. oxysporum* f. sp. *citri* constitute a significant portion of the Florida citrus acreage. Fusarium wilt could become a field problem if the fungus spread to groves with susceptible rootstock species. Resistant scion cultivars might be affected if grown on a susceptible rootstock. It is uncertain at present whether *F. oxysporum* f. sp. *citri* constitutes a problem only when it colonizes sterilized soil, or whether it could be a problem in natural Florida citrus soils.

Although the host range of *F. oxysporum* f. sp. *citri* is limited, the fungus is able to invade and colonize a wide range of citrus species and relatives. As with Fusarium wilt in other plant species (2,6,7), only the roots and stem bases of resistant citrus species and cultivars were colonized by the fungus. Symptoms did not occur and growth did not appear to be affected in citrus species in which the fungus was localized in roots and stem bases.

F. oxysporum f. sp. *citri* infected the roots and invaded the stem bases of some noncitrus plants, but produced no symptoms. Noncitrus plants could serve as reservoirs of the fungus and allow multiplication of the pathogen in the absence of the primary host as occurs with other forma speciales of *F. oxysporum* (1,3,4).

The optimum temperature range for the fungus and the disease

TABLE 3. Recovery of *Fusarium oxysporum* f. sp. *citri* from stem bases and potting mixture following inoculation of noncitrus plants with the fungus

Plant species	Positive isolations[y] (%)	Propagules per gram potting mix ($\times 10^3$)
Swiss chard	79 a[z]	7.1 de
Mustard	67 ab	2.3 e
Pea	42 bc	10.5 cde
Spinach	39 bcd	14.9 abcde
Cabbage	38 bcd	2.5 e
Stocks	33 cde	4.2 e
Wallflower	22 cde	18.5 abcd
Jubilee tomato	19 cde	5.4 e
Radish	13 cde	2.7 e
Cantaloupe	13 cde	25.2 ab
Cucumber	8 de	3.5 e
Petunia	8 de	24.8 ab
Mexican sunflower	8 de	17.5 abcd
Tobacco	4 e	13.1 abcde
Passion vine	3 e	26.3 a
Asparagus	0 e	11.0 cde
Beet	0 e	21.6 abc
Clover	0 e	7.0 de
Celery	0 e	15.2 abcde
Beefsteak tomato	0 e	4.3 e
Homestead tomato	0 e	6.3 e
Alfalfa	0 e	4.4 e
Eucalyptus	0 e	10.4 cde
Mimosa	0 e	12.2 bcde
Soybeans	0 e	14.2 abcde
Pepper	0 e	10.3 cde

[y] Percent of the stem bases from which *F. oxysporum* f. sp. *citri* was recovered.

[z] Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test, at $P = 0.05$.

TABLE 4. Effect of temperature on disease severity and on the growth of healthy Mexican limes and limes inoculated with *Fusarium oxysporum* f. sp. *citri*

Temperature (C)	Disease severity[x] 6 wk	9 wk	Fresh weight (g)[y] Healthy	Inoculated	Reduction in growth (%)
15	0.4 b[z]	1.9 c	8.2 b	5.5 a	33 b
21	1.8 a	3.4 a	16.5 a	4.2 a	79 a
26	1.9 a	2.8 ab	13.8 a	4.4 a	68 a
32	1.5 a	2.6 bc	17.3 a	7.4 a	57 a

[x] Rated on a scale of 0 = healthy to 4 = dead.

[y] Fresh weights of the tops determined after 10 wk.

[z] Means within columns followed by the same letter are not significantly different according to Duncan's multiple range test, at $P = 0.05$.

appears to correspond to the usual range of temperatures at which Mexican lime grows well. Since *F. oxysporum* f. sp. *citri* did not grow at 36 C, it may be possible to grow Mexican limes at high temperature to control the disease.

The original source of *F. oxysporum* f. sp. *citri* and the means by which it is introduced into greenhouses remain unknown. Seed or budwood from source trees appear to be unlikely means of introduction because the pathogen could not be isolated from them. Spread within the greenhouses obviously could occur by splashing of soil and water. However, separate benches of Mexican lime seedlings in steamed potting mix have become infested without obvious exposure to infested soil. These preliminary results indicated that freshly steamed soil for seed flats and pots could possibly become contaminated by airborne propagules carried as spores from dead or dying plants, or on dust from other parts of the greenhouse. Compared to the numbers of Fusarium isolates recovered from trap plates in tomato greenhouses in Ohio (8), numbers in citrus greenhouses in Florida are relatively low. However, a much higher percentage of the airborne *Fusarium* spp. was composed of pathogenic isolates in citrus than in tomato greenhouses.

Information still is needed on sources of inoculum, the ability of the fungus to survive in natural soils, and the effect of soil and other environmental factors on infection to assess potential damage from the disease and to develop appropriate control measures.

LITERATURE CITED

1. Armstrong, G. M., and Armstrong, J. K. 1975. Reflections on the wilt fusaria. Annu. Rev. Phytopathol. 13:95-103.
2. Beckman, C. H., Elgersma, D. M., and MacHardy, W. E. 1972. The localization of fusarial infections in vascular tissue of single-dominant-gene resistant tomatoes. Phytopathology 62:1256-1260.
3. Hendrix, F. F., Jr., and Nielson, L. W. 1958. Invasion and infection of crops other than the forma suscept by *Fusarium oxysporum* f. sp. *batatas* and other formae. Phytopathology 48:224-228.
4. Katan, J. 1971. Symptomless carriers of the tomato Fusarium wilt pathogen. Phytopathology 61:1213-1217.
5. Komada, H. 1975. Development of a selective medium for quantitative isolation of *Fusarium oxysporum* from natural soil. Rev. Plant Protection Res. 8:114-125.
6. Mace, M. E., and Veech, J. A. 1971. Fusarium wilt of susceptible and resistant tomato isolines: Host colonization. Phytopathology 61:834-840.
7. Ribeiro, R. de L. D., and Hagedorn, D. J. 1979. Inheritance and nature of resistance in bean to *Fusarium oxysporum* f. sp. *phaseoli.* Phytopathology 69:859-861.
8. Rowe, R. C., Farley, J. D., and Coplin, D. L. 1977. Airborne spore dispersal and recolonization of steamed soil by *Fusarium oxysporum* in tomato greenhouses. Phytopathology 67:1513-1517.
9. Takatsu, A., and Dianese, J. C. 1974. Xylem infection of Rangpur lime by *Fusarium oxysporum* in Brazil. Cienc. Cult. (São Paulo) 26:153-155.
10. Timmer, L. W., Garnsey, S. M., Grimm, G. R., El-Gholl, N. E., and Schoulties, C. L. 1979. Wilt and dieback of Mexican lime caused by *Fusarium oxysporum.* Phytopathology 69:730-734.
11. Timmer, L. W., Grimm, G. R., and Garnsey, S. M. 1980. Host range and distribution of *Fusarium oxysporum* f. sp. *citri* within citrus plants. (Abstr.) Phytopathology 70:261.