An Expanded Host Range for the Muskmelon Pathogen *Monosporascus cannonballus*

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ABSTRACT

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The pathogenicity of *Monosporascus cannonballus* to nine cucurbit and eight noncucurbit species was evaluated in the greenhouse by direct seeding into infested soil. Six of the cucurbit species were also tested under simulated field conditions in artificially infested microplots. In the greenhouse, *M. cannonballus* was isolated from 70–100% of the cucumber, muskmelon, and watermelon plants and from 33–70% of the bean, corn, sorghum, and sugar beet plants 8–9 wk after planting. Perithecia of the fungus were observed on the roots of all cucurbits tested but only rarely on roots of noncucurbits. Discrete brownish lesions, general light discoloration, and necrosis were characteristic symptoms of cucurbit root infection. Consistent reductions in top dry weight were observed in wheat, corn, and all the cucurbits tested. Screening of muskmelon (*Cucumis melo*) cultigens indicated tolerance to *M. cannonballus* in two breeding lines and several cultivars. In the microplots, typical vine decline symptoms were reproduced on muskmelon and watermelon 9 wk after planting. This report is the first to demonstrate pathogenicity of *M. cannonballus* to a wide range of cucurbits on the basis of greenhouse and microplot tests.

Monosporascus cannonballus Pollack & Uecker is a soilborne fungus that causes a severe root rot of muskmelon (*Cucumis melo* L.) in several areas of the world (7,11,18) and also occurs on watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) (12). Early symptoms on muskmelon include discrete brownish lesions and discoloration of the taproot and major secondary roots. Necrotic areas appear distally on severely infected secondary roots and advance toward the taproot. In the late stages of the disease, perithecia of the fungus often form in the cortex of necrotic roots. As a result of the root damage, stunting and vine decline symptoms are manifested above ground. A closely related species, *M. eutypoides* (Petrak) von Arx, causes a root rot leading to "collapse disease" of muskmelon (10) and watermelon (3) in Israel.

In addition to muskmelon and watermelon, *M. cannonballus* has been reported on bottle gourd (*Lagenaria siceraria* (Molina) Standl.) rootstock for watermelon and may be pathogenic to other cucurbits (S. Uematsu, *personal communication*). *Monosporascus* spp. also have been isolated from or observed on the roots of noncucurbit species, including *Achyranthes aspera* L. (2,15), *Medicago sativa* L. (9), *Trifolium pratense* L. (13; F. A. Uecker, *personal communication*), a cultivated *Triticum* sp. (2), and *Sesamum indicum* L. (14). In addition, circumstantial evidence suggests that wheat (*Triticum aestivum* L.) and other small grains may be involved in inoculum increase or carryover of *Monosporascus* spp. between susceptible cucurbit crops (3,16).

The pathogenicity of *M. cannonballus* and *M. eutypoides* to muskmelon in greenhouse tests has been documented in several publications (7,10,17,18). However, reports of *Monosporascus* spp. on other plants are "by association only"; no formal studies have been published that investigate their pathogenicity to other crops. In addition, no information is available on the relative susceptibilities of muskmelon cultivars to either species of *Monosporascus*. In this study, 31 species and cultivars within the family Cucurbitaceae and eight noncucurbit species were evaluated as hosts of *M. cannonballus* in greenhouse tests. A microplot study was undertaken to evaluate the response of several cucurbit species to *M. cannonballus* under simulated field conditions. A portion of this study has been published in abstract form (5,8).

MATERIALS AND METHODS

Production of inoculum. Tx(Cm)90-25, an aggressive isolate of *M. cannonballus* (6), was grown on a sand/oat hull medium and used in all experiments. The medium consisted of 3 L of sand, 275 g of dried oat hulls (ground in a Wiley mill or whole), and 450 ml of distilled water that were mixed thoroughly and dispensed into 30 × 60 cm autoclave bags in 2-L quantities. The bags were sealed around a cylinder of cheesecloth and cotton rolled around a plugged Tygon tube, sterilized by autoclaving on three successive days, and seeded with 10 ml per bag of a suspension of *M. cannonballus*. The suspension was prepared by blending a 5- to 10-day-old culture on PDA with 75 ml of sterile distilled water. After 35–40 days of incubation at 30 C, the sand/oat hull medium was thoroughly colonized by vegetative mycelium interspersed with dark, fertile perithecia. Ascospore numbers and colony-forming units were quantified just prior to use of the inoculum. However, counts of colony-forming units based on mycelial fragments were unreliable, so ascospores were quantified and used as the criterion for inoculum levels.

Greenhouse experiments. Three greenhouse experiments were conducted over a 2-yr period to investigate the host range of *M. cannonballus*. Representative cucurbit and noncucurbit species were tested simultaneously during the spring of 1991 and 1992, and noncucurbits were also tested separately in the fall of 1991. Two additional greenhouse experiments were conducted to evaluate selected muskmelon cultivars and breeding lines. Cantaloupe types were Cruiser, Durango, Explorer, Hale's Best Jumbo, Laguna, Laredo, Magnum 45, Mainpak, Mission, Perlita, Primo, Smith's Perfect, and Topmark; honeydew types were Honey Brew, Honeydew Green Flesh, and Morning Ice; and miscellaneous types were White Crenshaw, MR1, PI 12411, PI 12411 × Perlita, and PI 12411 × Tam Dew Improved (the latter four are breeding lines obtained from the cucurbit seed collection at Texas Agricultural Research and Extension Center, Weslaco). Table 1 presents the conditions and scheduling of these experiments, and Table 2 lists the test species and cultivars.

In the greenhouse experiments, 3-L black plastic pots were filled with steam-pasteurized sand and perlite (4:1, v/v) that had been mixed in a cement mixer and infested in bulk at the rate of 25 or 50 cc of inoculum per pot (Table 1). The pots were filled to within 5–6 cm of the top with infested mix and topped off with a 4- to 5-cm layer of noninfested mix. Control pots were prepared similarly, using equivalent quantities of sterile

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ground oat hulls. Seeds of each test cultivar were obtained from commercial sources, washed in 0.5% detergent (Sparkleen) for 5 min to remove seed-treatment fungicides, rinsed in running tap water, and direct-seeded into the pots. After 10–20 days, the plants were thinned to one per pot. Plants in experiments 2–5 were fertilized weekly with 250 ml per pot of a solution containing 2 g/L of Peters 20:20:20, 0.25 g/L of $MgSO_4 \cdot 7H_2O$, and 0.01 g/L of micronutrients (Stem). In experiment 1, no magnesium was applied and Stem was applied once at the rate of 0.3 g/L. To control whiteflies in the greenhouse, acephate (Orthene) and permethrin (Pounce), or abamectin (Avid) and fluvalinate (Mavrik), were applied every 5–7 days.

Experiments 2–5 were concluded 8–9 wk after planting by washing the potting mix from the roots and rating the roots for disease severity on a scale of 0 (healthy) to 4 (extensively lesioned and discolored, or necrotic). Inoculated and control root systems were examined at 10–20× for the presence of perithecia. Isolations were made from selected inoculated and noninoculated plants to confirm the presence or absence of *M. cannonballus*. Three root segments 0.5–1.0 cm long were excised from each plant, surface-disinfected for 45–60 sec in 0.5% sodium hypochlorite, rinsed once in sterile distilled water, and placed on water agar amended with streptomycin sulfate (100 μg/ml). The isolation plates were examined after 3–5 days at 28 C for hyphae and colonies characteristic of *M. cannonballus* and again after 20–25 days for characteristic perithecia. Primary vine lengths and dry weights of roots and tops were recorded for each plant tested. In experiment 1, a number of inoculated cucurbits showed stunting, wilting, and collapse symptoms 4–7 wk after planting. These were harvested along with corresponding controls as the symptoms became severe but before the plants died. Root disease severity, the presence or absence of perithecia, and isolation data were recorded.

Experimental design and analysis. The greenhouse experiments utilized a randomized block design with 10 replications per treatment. Each block consisted of matched pairs of inoculated and noninoculated cultivars, and over the course of the study each cultivar was included in at least two experiments. Vine length, top weight, and root weight of inoculated plants and corresponding controls were compared by paired *t* tests; the percent reduction in these parameters relative to the controls was used to compare individual species and cultivars by analyses of variance (ANOVAs), with and without arcsine square root transformation. Data from similar experiments were combined when nested ANOVA procedures indicated nonsignificant experiment × treatment interactions. Disease severity data were analyzed by two nonparametric methods, the Wilcoxon signed rank test and Friedman's test for randomized blocks. The *t* tests and ANOVAs were processed on SAS (SAS Institute, Cary, NC). Nonparametric tests were run on Biostat I (Sigma Soft, Placentia, CA).

Microplot experiment. A modified version of the host range experiments was conducted in 1992 at College Station, Texas, under simulated field conditions. Nine cultivars representing five species of cucurbits and the wild gourd *Cucurbita texana* A. Gray were planted in 60 microplots. The 0.6 × 1.0 × 0.6 m microplots, their soil types, and procedures involved in their preplant fumigation have been previously described (4). Six microplots (four infested and two noninfested) were dedicated to each cucurbit in a completely randomized experimental design. A microplot was infested by removing the

Table 1. Five greenhouse experiments testing the pathogenicity of *Monosporascus cannonballus* to selected plant species and cultivars

Experiment	Dates	Plants	Temperature (C)	Inoculum[z] Type	Inoculum[z] Ascospores (g/dry wt)	Inoculum[z] Amount (cm^3)
1. Host range 1	Mar.–May 1991	Cucurbits Noncucurbits	24–29	W	2.0×10^4	25
2. *Cucumis melo* 1	July–Sept. 1991	Cultivars	27–37	G	5.2×10^3	25
3. Host range 2	Aug.–Oct. 1991	Noncucurbits	24–32	G	2.6×10^4	25
4. Host range 3	Feb.–Apr. 1992	Cucurbits Noncucurbits	24–30	G	2.3×10^4	50
5. *C. melo* 2	Feb.–Apr. 1992	Cultivars	24–30	G	2.3×10^4	50

[z] A sand/oat hull mixture in which oat hulls were ground (G) or left whole (W).

Table 2. Plants evaluated for susceptibility to *Monosporascus cannonballus* in greenhouse and microplot host range experiments

Family Genus and species	Common name	Cultivar
Cucurbitaceae		
Citrullus lanatus (Thunb.) Matsum. & Nakai	Watermelon	Black Diamond, Royal Sweet
Cucumis melo L. var. *cantalupensis*	Muskmelon, cantaloupe	Magnum 45
C. melo var. *inodorus*	Muskmelon, honeydew	Honeydew Green Flesh
Cucumis sativis L.	Cucumber	Poinsette 76
Cucurbita pepo L.	Pumpkin	Connecticut Field
	Summer squash, yellow	Goldbar Hybrid
	Summer squash, zucchini	Viceroy Hybrid
C. maxima Duchesne	Winter squash	Buttercup
C. moschata (Duchesne) Duchesne ex Poir.	Winter squash	Waltham Butternut
C. texana A. Gray	Texas gourd	...
Lagenaria siceraria (Molina) Standl.	Bottle gourd	...
Luffa aegyptiaca Mill.	Kitchen gourd	...
Chenopodiaceae		
Beta vulgaris L.	Sugar beet	TX-9
Malvaceae		
Gossypium hirsutum L.	Cotton, upland	Paymaster 145
Solanaceae		
Lycopersicon esculentum Mill.	Tomato	Rutgers
Fabaceae		
Medicago stativa L.	Alfalfa	Cimmaron
Phaseolus vulgaris L.	Bean, bush	Improved Commodore
Poaceae		
Sorghum bicolor (L.) Moench	Sorghum	Pioneer 8358
Triticum aestivum L.	Wheat, spring	ERA
Zea mays L.	Corn, field	Asgrow 405W

top 3–5 cm of soil, scattering 300 g of moist sand/oat hull inoculum (= 280 g dry weight) and 240 cc of Osmocote 14:14:14 slow-release fertilizer into the plot, mixing, and returning the topsoil to the plot. The inoculum was prepared as described for the greenhouse experiments and contained approximately 5.2×10^3 ascospores and 3.3×10^3 cfu of vegetative mycelium per gram dry weight of material. Noninfested plots received only Osmocote.

The microplots were direct-seeded in May 1992 with five to 10 seeds per plot of each test species and thinned to three seedlings per plot 10–20 days after planting. Irrigation was supplied by surface drip lines. Fungicides and insecticides were applied as needed. Nine weeks after planting, cultivars were rated for vine decline according to the categories none, slight, moderate, and severe, with the latter indicating extensive deterioration or total collapse of the leaf canopy.

The experiment was concluded in several stages 10–14 wk after planting, corresponding to each cultivar's maturity date. At that time, the tops of the plants were removed and the root systems were excavated, washed, and examined for perithecia. Those root systems lacking visible perithecia were buried in moist, pasteurized loamy-sand, incubated in the greenhouse for 2 wk, and reexamined. Isolations were made as previously described except that the isolation medium (water agar) was amended with 1 μg a.i./ml of benomyl (Benlate 50WP) in addition to 100 μg/ml of streptomycin sulfate.

RESULTS

Greenhouse experiments. *Noncucurbits. M. cannonballus* colonized and reproduced on the roots of several noncucurbit crops. The pathogen was isolated from the roots of inoculated plants at frequencies ranging from 13% for wheat to 70% for bush bean and sugar beet (Table 3). In addition, fertile perithecia were observed on a few intact roots of wheat (Fig. 1F), bean, corn, and sorghum. A statistical analysis of root disease severities indicated significant differences between infested and noninfested treatments for corn, tomato, and wheat. Root and top dry weights, when expressed as percent reduction relative to controls, showed considerable variability both within treatments and from experiment to experiment. However, corn and wheat showed positive top weight reductions (i.e., inoculated plants had lighter tops, on average, than controls) in all three experiments (Table 3, Fig. 1D). In addition, when data from the three experiments were pooled, root weight reductions were statistically significant for tomato and wheat (Table 3, Fig. 1E) and positive for all other crops except cotton.

Cucurbits. All 12 cucurbits, representing five genera and nine species, were susceptible to *M. cannonballus* (Table 4). The pathogen was isolated readily from diseased roots of watermelon and muskmelon but was recovered with more difficulty from *Cucurbita* spp. (pumpkin, squash, and *C. texana*). However, perithecia were observed on the roots of *Cucurbita* spp. (Fig. 1C) and all other cucurbits tested during the first host range test. Corresponding reductions in root mass and top growth also occurred in this test (Fig. 1A and B). In contrast, perithecia were observed at relatively low frequencies on only five cucurbits during the replicate test (the third host range test). Root disease severities were also generally lower in the replicate test, but even in this test, average root disease indices for inoculated cucurbits were significantly higher than those of the controls. In addition, *M. cannonballus* caused significant reductions in top dry weight for most of the cucurbits tested and significantly reduced root mass of the two watermelon cultivars and Buttercup squash. Watermelons were severely affected, with top weight reductions exceeding 50%, while *Cucurbita* spp., with the exception of Buttercup squash, were relatively less stunted.

Cucumis melo *cultigen tests.* All muskmelon lines and cultivars included in the greenhouse tests were susceptible to *M. cannonballus* (Table 5). Root disease severities ranged from a low of 1.6 for the breeding line PI 12411 × Tam Dew Improved to 2.6 for Magnum 45. Reductions in root weight and top weight were substantial, averaging 20.2 and 25.5%, respectively. Vine length was recorded in both experiments to test its utility as a convenient, nondestructive disease criterion for infection by *M. cannonballus*. Correlation analysis showed highly significant, moderately strong positive relationships between vine length reduction and top weight reduction ($r = 0.49$ for the first experiment and 0.61 for the second).

Because relatively few muskmelon cultivars have been tested for reaction to *M. cannonballus* (7,11,17), an important objective of this study was to determine if resistance or tolerance is present in the species. In this paper, tolerance is interpreted in a broad sense to include differences in biomass reduction between cultivars, since actual yield data could not be obtained under the greenhouse conditions employed in these experiments. Mean separation in the four categories used to measure disease severity was generally poor because of variation within cultivars and between experiments and because a single variate (percent reduction) derived from two other variates (dry weights of inoculated and control plants) was used to make comparisons. This resulted in few significant differences between cultivars (Table 5). However, some cultivars scored relatively well (resistant or tolerant) in most categories, while others were consistently poor (susceptible). The cultivars were ranked in each category (Table 5), with the most tolerant or resistant cultivar ranked number 1 and increasing numbers indicating increasing susceptibility. Table 5 lists cultivars and breeding lines in order of increasing susceptibility based on a sum of their four individual rankings. By this classification, the cultivars Explorer, Mainpak, Mission, and Magnum 45 and a single breeding line (PI 12411 × Perlita) were more susceptible to *M. cannonballus* than cvs. Cruiser, Durango, Laredo, Hale's Best Jumbo, and Honeydew Green Flesh and two other breeding lines (PI 12411 and PI 12411 × Tam Dew Improved).

Microplot experiment. Most of the

Table 3. Pathogenicity of *Monosporascus cannonballus* to eight noncucurbit crops in three replicated greenhouse experiments

Crop	Root disease severity[w]	Root weight reduction (%)	Top weight reduction (%)	Perithecia		Isolations	
				No. of plants[x]	%	No. of plants[y]	%
Alfalfa cv. Cimmaron	0.2 ns	14.3 ns[z]	−1.0 ns[z]	0/20	0	2/10	20
Bean cv. Improved Commodore	0.2 ns	7.0 na	−0.1 na	10/20	50	7/10	70
Cotton cv. Paymaster 145	−0.1 ns	−5.3 ns	−8.8 ns	0/20	0	0/10	0
Corn cv. Asgrow 405W	0.7**	1.5 na	8.0**	2/30	7	5/15	33
Sorghum cv. Pioneer 8358	0.3 ns	3.0 ns	2.0 na	3/30	10	6/15	40
Sugar beet cv. TX-9	0.1 ns	3.2 ns	2.2 na	0/20	0	7/10	70
Tomato cv. Rutgers	0.5*	10.3*	9.0 na	0/20	0	0/10	0
Wheat cv. Era	0.8**	19.0**	22.3 na	3/30	10	2/15	13

[w] Evaluated on a scale of 0 (healthy) to 4 (extensively lesioned and discolored, or necrotic). Values represent disease severities of inoculated plants corrected for symptoms, if any, in controls. Wilcoxon signed rank comparison of root disease indices for inoculated and noninoculated plants of each cultivar: ns = no significant difference; * and ** = significant at $P = 0.05$ and 0.01, respectively.

[x] Number of plants with perithecia on roots/total plants.

[y] Number of plants from which *M. cannonballus* was isolated from roots/total plants.

[z] Calculations based on weight differences between inoculated and control plants for each crop (*data not shown*) that were pooled from all three experiments and analyzed by paired *t*-tests: ns = not significant; * and ** = significant at $P = 0.05$ and 0.01, respectively; na = analysis not performed because of significant differences between experiments for the indicated category and crop. Percentage reductions are shown for ease of comparison between crops.

results obtained in the greenhouse cucurbit tests were corroborated in the microplots (Figs. 2 and 3). Perithecia developed on the roots of all the cucurbits tested (Table 6, Figs. 2D and 3D). In the case of Viceroy Hybrid summer squash, however, perithecia were not detected at the time of harvest but formed later in low numbers on roots incubated in pasteurized soil. *M. cannonballus* was isolated from the roots of 50–67% of the pumpkin and squash plants and of 100% of the other cucurbits. Both watermelon cultivars (Fig. 3) and Magnum 45 muskmelon (Fig. 2) showed severe vine decline symptoms 67 days after planting. These symptoms corresponded with extensive root damage and the presence of abundant perithecia on necrotic roots (Table 6). Foliar and root disease symptoms were less severe for the muskmelon cultivars Hale's Best Jumbo and Durango than for Magnum 45. Conspicuous vine decline symptoms were not evident on the other species 67 days after planting. Later in the season, whitefly populations and symptoms associated with systemic virus infection (mosaic, mottling, leaf distortion, etc.) were so severe on pumpkin, squash, and cucumber that the plants could not be rated for vine decline.

DISCUSSION

One of the major objectives of this study was to determine if the host range of *M. cannonballus* extends to other members of the cucurbit family in addition to muskmelon and watermelon. In the greenhouse, *M. cannonballus* colonized and reproduced on the root systems of all cucurbits tested, a pathogenic interaction that generally caused significant levels of root disease and dramatic decreases in top weight (Table 4, Fig. 1). Many of the same species and cultivars also were susceptible to *M. cannonballus* under simulated field conditions in microplots (Table 6, Figs. 2 and 3). Therefore, the greenhouse results were not artifacts of high inoculum density or an artificial growing environment.

Both in the greenhouse and in the microplots, populations of competing, parasitic, or antagonistic microorganisms were eliminated initially by steam pasteurization or chemical fumigation. Therefore, the symptoms reported here may be more severe than those that might develop in the field. This is one possible explanation for the virtual absence of reports associating *M. cannonballus* with root rots or vine declines of other cucurbit crops. On the other hand, *M. cannonballus* was associated with diseased watermelon plants in Spain in 1991 (12). In addition, we recently isolated *M. cannonballus* from watermelons growing in the Lower Rio Grande Valley of Texas (*data not shown*). Other researchers have linked *M. eutypoides* to the collapse of watermelon plants in Israel (3). In analyzing these reports, it should be noted that the genus *Monosporascus* was erected only 19 yr ago (9) and that the two recognized species, *M. cannonballus* and *M. eutypoides*, are similar in many respects and may be conspecific (14).

The second objective of this study was to determine if noncucurbits could serve as alternative hosts to *M. cannonballus*. The first report of *Monosporascus* in the United States noted that the disease was more severe on muskmelon planted in rotation with small grains (16). Similar circumstantial evidence for wheat as a host to *M. eutypoides* was provided by Krikun (3) in Israel. In addition, Hawksworth and Ciccarone (2) isolated *M. eutypoides* from the darkened base of an unnamed *Triticum* sp. in Libya. None of these reports, however, conclusively proved pathogenicity to wheat via Koch's postulates.

This study provides new evidence that wheat and other noncucurbits may be hosts to *M. cannonballus*. Inoculated wheat seedlings showed the largest reductions in root weight and top weight of all noncucurbits tested (Table 3, Fig. 1D and E). *M. cannonballus* was isolated from 33 and 40% of inoculated corn and sorghum plants, respectively. It may be significant that all three monocots included in this study showed some degree of susceptibility. Alfalfa, bush bean, and sugar beet roots were also colonized. For alfalfa, the relatively large reduction in root weight was not statistically significant ($P = 0.05$) and may have been caused by inadequate fertilization in the

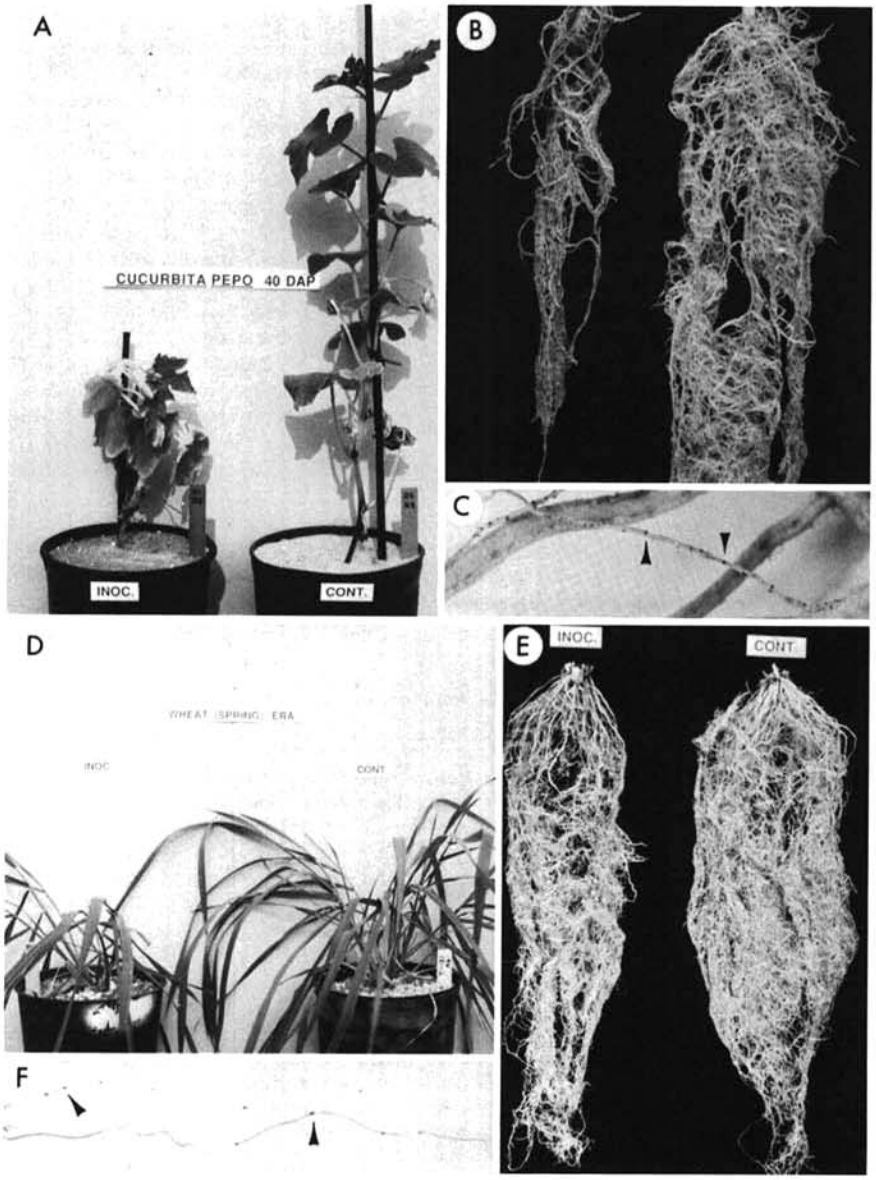

Fig. 1. Symptoms caused by *Monosporascus cannonballus* on pumpkin cultivar Connecticut Field and spring wheat cultivar ERA in greenhouse tests: **(A)** Stunting of inoculated pumpkin (left) compared with control (right); **(B)** reduction and discoloration of roots of inoculated pumpkin (left) compared with control (right); **(C)** pumpkin roots with embedded perithecia (arrows); **(D and E)** stunting or reduction of tops and roots of inoculated wheat (left) compared with controls (right); and **(F)** wheat roots with embedded perithecia (arrows).

absence of nodulation or by irregular germination and establishment.

M. cannonballus was not isolated from cotton and tomato and failed to produce perithecia on the roots of these two species. On the basis of these data, a lack of symptom expression, and no reduction in root dry weight (Table 3), cotton apparently is a nonhost. Tomato showed significant levels of disease and a large reduction in root weight in the first experiment, which accounted for much of the overall 10.3% decrease (Table 3). However, these trends were not confirmed in two subsequent experiments when magnesium was included in the fertilizer regime. Given these results, the host status of tomato merits further study.

Temperature variation between experiments also had an effect on the results. Significant reductions in top weight and root weight were common in the second host range experiment, which was conducted in the summer at a higher average temperature than the first and third host range experiments, which were conducted in the spring (Table 1). *M. cannonballus* is a pseudothermophile with an optimum temperature range of

Table 4. Pathogenicity of *Monosporascus cannonballus* to 12 cucurbit species and cultivars in host range experiment 1 (HR1) and host range experiment 3 (HR3)

	Root disease severity[u]		Root dry weight reduction[v]		Top dry weight reduction[v]		Plants with perithecia[w] (%)		Frequency of isolation[x] (%)	
Crop	HR1	HR3	g	%	g	%	HR1	HR3	HR1	HR3
Watermelon cv. Black Diamond	3.6	2.2**[y]	0.44**[y]	37.1 ab[z]	7.7**[y]	58.0 b[z]	90	0	80	100
Watermelon cv. Royal Sweet	3.1	3.2**	0.48**	57.0 a	8.2**	75.8 a	70	0	...	70
Muskmelon cv. Magnum 45	3.0	1.3**	0.12 ns	7.0 c	2.6**	14.8 c	60	10	100	100
Muskmelon cv. Honeydew Green Flesh	3.2	1.1**	0.09 ns	3.9 c	3.9*	22.7 c	75	0	...	80
Cucumber cv. Poinsette 76	3.3	1.4**	−0.03 ns	−4.3 c	2.0*	10.5 c	80	0	...	100
Pumpkin cv. Connecticut Field	2.5	1.1**	−0.06 ns	−9.1 c	1.2 ns	6.4 c	90	30	60	20
Squash cv. Goldbar Hybrid	3.4	0.9**	−0.21*	−41.3 d	1.5*	10.9 c	100	0	60	60
Squash cv. Buttercup	1.9	0.9**	0.20*	17.0 bc	3.9**	25.8 c	90	0	80	80
Squash cv. Waltham Butternut	1.0	0.5**	−0.08 ns	−11.9 c	1.9**	13.0 c	90	0	30	20
Cucurbita texana	...	0.7**	0.01 ns	1.1 c	1.6 ns	13.3 c	...	10	...	40
Lagenaria siceraria	3.4	2.0**	−0.01 ns	−3.3 c	3.7**	21.8 c	100	20	80	100
Luffa aegyptiaca	2.2	0.9**	0.00 ns	−1.7 c	3.0**	17.0 c	70	10	60	100

[u] Evaluated on a scale of 0 (healthy) to 4 (extensively lesioned and discolored, or necrotic). Values represent disease severities of inoculated plants corrected for symptoms, if any, in controls.
[v] Average weight reduction of inoculated plants relative to controls. Data are from HR3 only, as different harvest intervals were used in HR1.
[w] Percentage of inoculated plants with *M. cannonballus* perithecia on intact roots.
[x] Percentage of inoculated plants from which *M. cannonballus* was isolated from roots.
[y] Statistical comparison of inoculated and noninoculated treatments for each cultivar made by Wilcoxon signed rank test (disease severity data) and paired *t* tests (weight data): ns = no significant difference; * and ** = significantly different at $P = 0.05$ and 0.01, respectively.
[z] Means in a column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Table 5. Pathogenicity of *Monosporascus cannonballus* to 21 muskmelon cultivars and breeding lines in two replicated greenhouse tests

	Root disease severity[w]		Root weight reduction		Top weight reduction		Vine length reduction		Sum of ranks
Cultivars and lines[v]	Rating	Rank[x]	%	Rank[x]	%	Rank[x]	%	Rank[x]	
PI 12411 × Tam Dew Improved	1.6 a[y]	1.5	16.2 ab[z]	6	20.1 ab[z]	5	8.7 a[z]	1	13.5
Cruiser	1.9 a	7.5	3.7 a	1	19.6 abc	4	16.0 abcd	9	21.5
Durango	1.8 a	5.5	23.4 bc	15	15.7 a	1	9.9 ab	3	24.5
PI 12411	1.7 a	3.5	11.6 ab	2	27.9 bcd	16	12.0 abc	4	25.5
Laredo	1.9 a	7.5	17.3 bc	7	18.5 ab	2	16.5 abcd	11	27.5
Hale's Best Jumbo	1.6 a	1.5	25.1 bc	16	24.0 abcd	7.5	14.4 abcd	5	30.0
Honeydew Green Flesh	2.1 a	14.5	17.4 abc	8	19.4 ab	3	14.8 abcd	7	32.5
Laguna	1.8 a	5.5	18.6 abc	10	25.0 bcd	9	18.0 abcd	14	38.5
Honey Brew	2.0 a	11	15.8 ab	4	25.4 bcd	11	17.0 abcd	12.5	38.5
Morning Ice	2.0 a	11	19.4 bc	12	25.9 bcd	13.5	15.9 abcd	8	44.5
Topmark	2.0 a	11	13.8 ab	3	25.9 bcd	13.5	21.5 bcd	17	44.5
MR1	1.7 a	3.5	16.1 ab	5	34.9 d	21	18.5 bcd	16	45.5
Perlita	2.1 a	14.5	29.3 bc	20	25.1 bcd	10	8.8 ab	2	46.5
Primo	2.0 a	11	19.8 bc	13	24.0 bcd	7.5	18.1 abcd	15	46.5
Smith's Perfect	2.2 a	16.5	18.5 bc	9	25.6 bcd	12	16.3 abcd	10	47.5
White Crenshaw	2.4 a	19	27.7 bc	17	22.6 abcd	6	14.5 abcd	6	48.0
Explorer	2.3 a	18	19.3 abc	11	27.7 bcd	15	23.3 cd	19	63.0
Mainpak	2.0 a	11	20.1 bc	14	30.0 bcd	17	24.3 d	21	63.0
Mission	2.2 a	16.5	28.5 bc	19	32.2 cd	18	23.2 d	18	71.5
PI 12411 × Perlita	2.6 a	20.5	34.1 c	21	33.3 bcd	19	17.0 abcd	12.5	73.0
Magnum 45	2.6 a	20.5	28.0 bc	18	33.5 cd	20	23.4 d	20	78.5
Average	2.0		20.2		25.5		16.8		

[v] Listed in order of increasing susceptibility to *M. cannonballus* based on an arithmetic sum of individual ranks in each of the four disease assessment categories.
[w] Evaluated on a scale of 0 (healthy) to 4 (extensively lesioned and discolored, or necrotic). Values represent disease severities of inoculated plants corrected for symptoms, if any, in controls.
[x] Order of increasing susceptibility to *M. cannonballus* in each of the four disease assessment categories; ties in any category were assigned an average of ranks, resulting in identical fractional ranks for some cultivars.
[y] Rating distributions (represented by average root disease severities) followed by the same letter are not significantly different at $P = 0.05$ according to a nonparametric sum of squares simultaneous procedure following Friedman's test for randomized blocks.
[z] Numbers in a column followed by the same letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

30–35 C for in vitro growth (6,18). The possible effects of nutrition and temperature on disease progress and severity are unknown.

Pathogenicity tests with *C. melo* cultivars and breeding lines in the greenhouse indicated a range of responses to *M. cannonballus* from tolerant to susceptible. On the basis of the sum of rank calculations, PI 12411 × Tam Dew Improved, Cruiser, Durango, PI 12411, Laredo, Hale's Best Jumbo, and Honeydew Green Flesh are tolerant and Explorer, Mainpak, Mission, PI 12411 × Perlita, and Magnum 45 are susceptible (Table 5). Although tolerance cannot be related to an actual yield effect in the greenhouse tests, some cultivars looked healthier and had more vine growth. The plausible effect of this response would be higher yield, and, in fact, results from field variety trials and anecdotal information from commercial producers in the Lower Rio Grande Valley support this conclusion. In 1987, 12 muskmelon cultivars were tested in replicated field trials at four locations in the Lower Rio Grande Valley (1). At three of these locations, Magnum 45 and Mission were severely affected by vine decline based on a foliar rating system (*unpublished*). Recently, more hectarage has been planted to Cruiser cantaloupe and honeydew melons on farms known to be infested by *M. cannonballus*. Moreover, we have had less success isolating the fungus from Honeydew Green Flesh than from other muskmelon cultivars, even when it is grown in fields having a history of Monosporascus root rot/vine decline (*data not shown*). Like the greenhouse tests, these observations suggest that tolerance or differences in susceptibility to *M. cannonballus* may exist in *C. melo*.

This study is the first to prove pathogenicity of *M. cannonballus* to important cucurbit species outside the *C. melo*

Table 6. Response of nine cucurbit cultivars and the wild gourd *Cucurbita texana* to *Monosporascus cannonballus* under simulated field conditions (microplots)[v]

Crop	Days to harvest[w]	Perithecia (no. plots)[x]	Isolation frequency[y] (%)	Vine decline severity[z]
Watermelon cv. Black Diamond	84	4	100	+++
Watermelon cv. Royal Sweet	84	4	100	+++
Muskmelon cv. Magnum 45	80	4	100	+++
Muskmelon cv. Hale's Best Jumbo	80	4	100	++
Muskmelon cv, Durango	80	3	100	+
Cucumber cv. Poinsette 76	74	2	100	nr
Pumpkin cv. Connecticut Field	98	2	60	nr
Squash cv. Viceroy Hybrid	70	0	50	nr
Squash cv. Waltham Butternut	98	2	67	nr
Cucurbita texana	98	3	100	nr

[v] Four infested and two noninfested microplots were used for each cultivar or species.
[w] Number of days after planting at which plants were excavated and evaluated.
[x] Number of infested plots in which one or more plants were found with perithecia on the roots (four plots = 100%). Perithecia were not detected on Viceroy Hybrid roots at harvest but formed later in low numbers on buried roots incubated in pasteurized soil.
[y] Percentage of plants growing in infested plots from which *M. cannonballus* was isolated.
[z] Rated 67 days after planting: +++ = extensive deterioration of leaf canopy, ++ = moderate deterioration of foliage, + = slight deterioration of older crown leaves, nr = not rated.

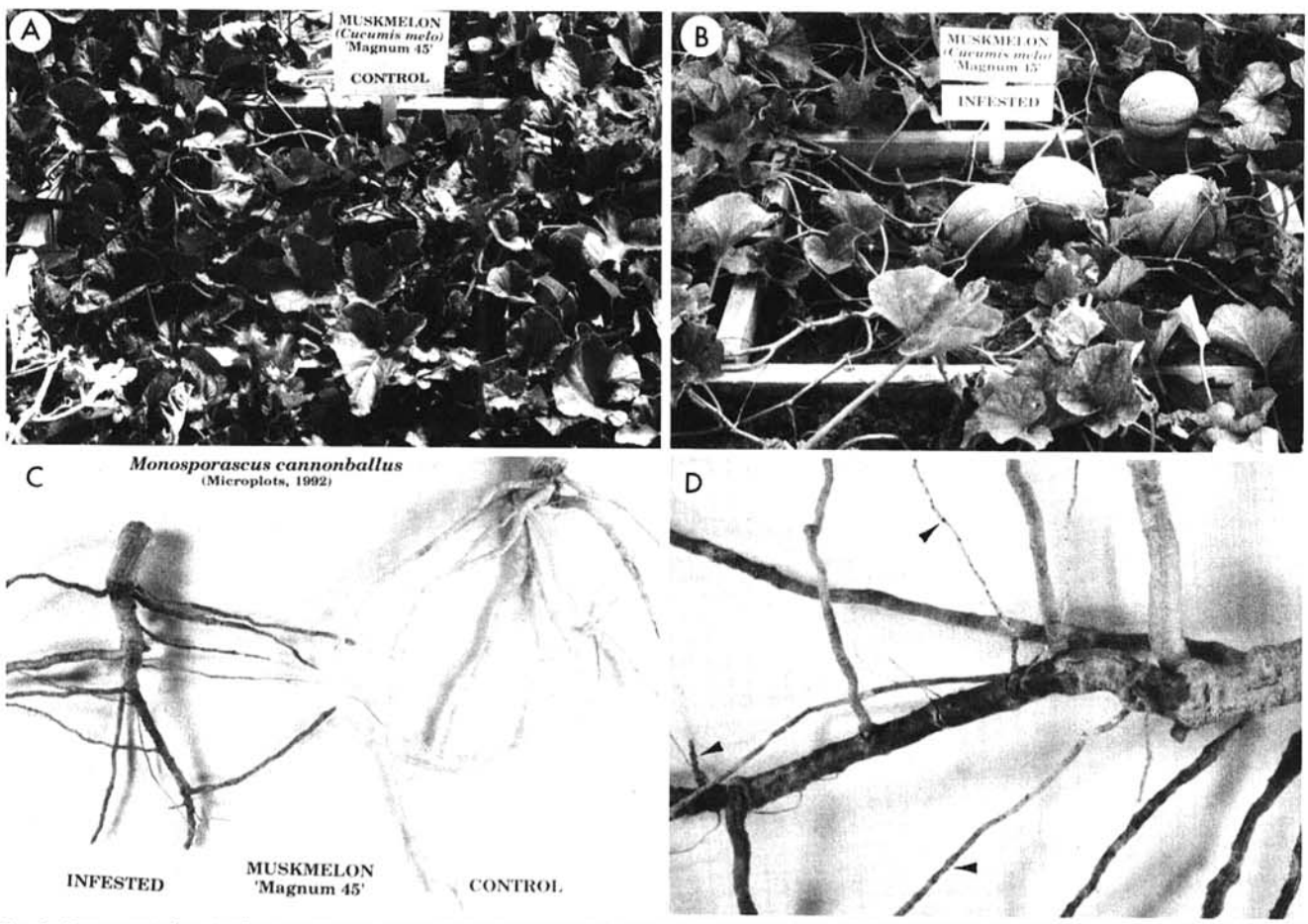

Fig. 2. Root rot/vine decline symptoms on muskmelon cultivar Magnum 45 caused by *Monosporascus cannonballus* under simulated field conditions in microplots: **(A)** Control plot; **(B)** infested plot showing collapse of leaf canopy and exposed fruit; **(C)** root systems of plants in control plot (right) and infested plot showing discoloration and necrosis (left); and **(D)** roots with embedded perithecia (arrows).

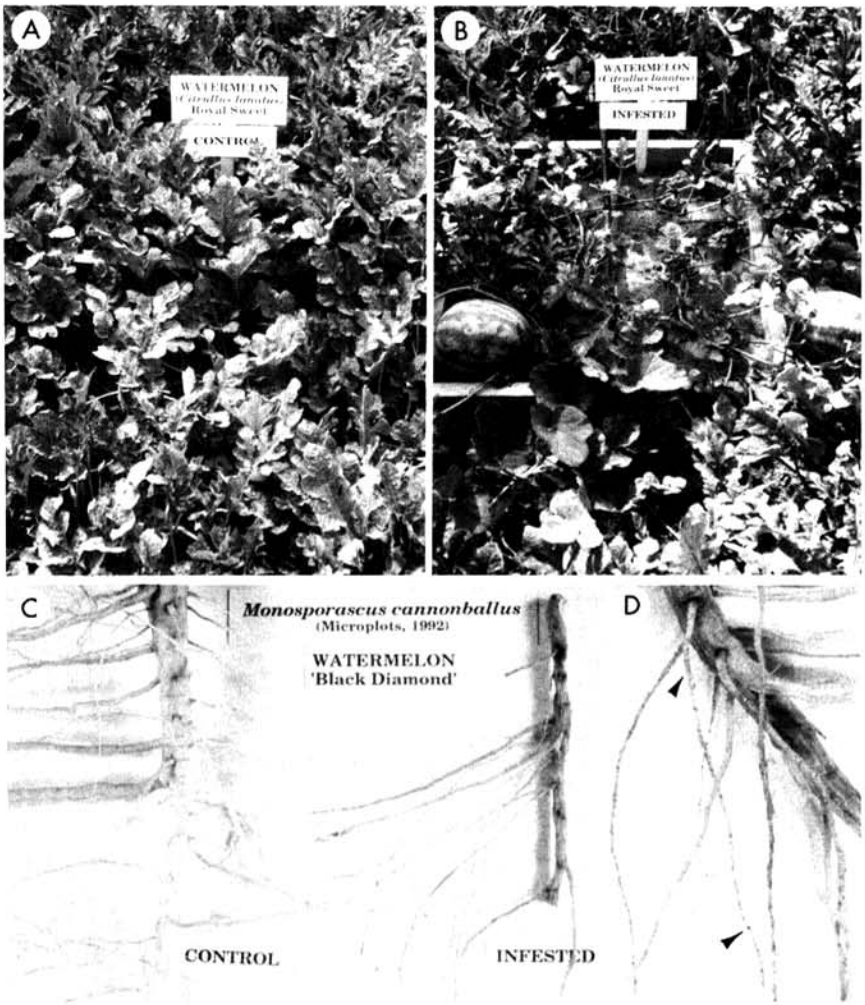

Fig. 3. Root rot/vine decline symptoms on watermelon cultivars Royal Sweet and Black Diamond caused by *Monosporascus cannonballus* in microplots: **(A)** Control plot of cv. Royal Sweet and **(B)** infested plot showing foliar deterioration; **(C)** root systems of cv. Black Diamond plants in control plot (left) and infested plot showing necrosis and reduced numbers of secondary roots (right); and **(D)** roots of cv. Black Diamond plants with embedded perithecia (arrows).

group. It also shows that wheat and other noncucurbits can be colonized and occasionally damaged by *M. cannonballus* under greenhouse conditions. These conditions may have been stressful to some of the species tested. Stress conditions (e.g., high temperature) may be the common denominator in reports associating *Monosporascus* spp. with wheat and small grains in Libya, Israel, and the desert valleys of Arizona (2,3,16). Given the present evidence, *M. cannonballus* can be characterized as a primary and potentially severe pathogen of cucurbits and as an opportunistic parasite and stress pathogen of certain noncucurbits. The Lower Rio Grande Valley constitutes a hot, semiarid environment where watermelons, cucumbers, squash, corn, and sorghum are extensively grown, often in rotation with each other. These conditions may serve to increase or perpetuate the fungus and could explain the widespread occurrence of *M. cannonballus* in these soils.

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