Comparative Studies of Two *Mucor* Species Causing Postharvest Decay of Tomato and Their Control

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ABSTRACT

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Growth rates of *Mucor mucedo* (ATCC 48559) and *M. piriformis* (ATCC 38314) were compared on mature green and ripe red tomato fruit and potato-dextrose agar (PDA) at temperatures from 0 to 40 C. *M. mucedo* grew on green and red tomatoes and PDA at temperatures from 5 to 30 C, with optimal growth at 25 C. *M. piriformis* grew on the above substrates at temperatures from 0 to 25 C, with an optimal growth temperature of 20 C. Both fungi grew faster on red than on green fruit; *M. mucedo* was a more aggressive pathogen than *M. piriformis* and was capable of completely decaying tomatoes within 2–3 days of inoculation. Of several fungicides tested, only guazatine showed measurable fungicidal action against the two fungi; it significantly reduced decay on ripe red fruit. This is the first reported incidence of *M. mucedo* as a postharvest pathogen of tomato.

Mucor spp. have been reported to cause decay of numerous fruits and vegetables but usually have been considered of minor importance as storage pathogens (10). These fungi, however, are important postharvest pathogens of strawberries (3,4,9) and sweet potatoes (5). *Mucor* spp. have also been reported to cause postharvest decay of guava (7), pears (1,8), peaches (11), apples (1), and tomatoes (2).

Mucor spp., of which more than 360 are known, belong to the class Zygomycetes and occur typically as saprophytes on soil and dung (6). Two species, *M. mucedo* L: Fr. (ATCC 48559) and *M. piriformis* A. Fisch. (ATCC 38314), are the most prevalent spoilage fungi reported on strawberries (3,9). Smith et al (11) recovered *M. piriformis* from decayed peaches from commercial packing sheds in Maryland. In January 1981, a shipment of fresh-market tomatoes arrived at the Baltimore wholesale market with 60% decay, subsequently determined to be caused by *M. mucedo* (10).

The aim of this study was to compare the rate of growth on potato-dextrose agar (PDA) and lesion development on tomato fruit of *M. mucedo* recovered from decayed tomato fruits with *M. piriformis* initially isolated from peaches (11). The ability of fungicides to inhibit growth of these two fungi was also studied.

MATERIALS AND METHODS

Growth of mass isolates of *M. mucedo* and *M. piriformis* was compared on PDA. This medium was added to 160 (15 × 100 mm) plastic petri dishes, which were divided into two groups of 80 each. Each plate was divided into four numbered quadrants. Forty plates in each of two replicates were inoculated with *M. mucedo* and 40 with *M. piriformis*. Inoculations were made along the edges of the plates so radial growth could be measured. Plates inoculated with these two fungi were divided into eight groups of five plates each. Treatments were placed at the following temperatures: 0, 5, 10, 15, 20, 25, 30, and 35 C. Fungal growth was measured daily. Linear regression analysis was performed on all data.

Two hundred twenty ripe red and 220 mature green Florida-grown tomatoes of uniform size (60–70 mm in diameter) and color, purchased from a local wholesaler, were selected for pathogenicity tests of *M. mucedo* and *M. piriformis*. Fruits were divided into two replicates of 110 ripe red and 110 mature green tomatoes each. Fifty ripe red and 50 mature green surface-sterilized tomatoes were inoculated with *M. mucedo* in each of four quadrants by puncturing them with a spore-laden inoculation needle.

Another 50 ripe red and 50 mature green tomatoes were inoculated with *M. piriformis* as indicated before. Five ripe red and five mature green tomatoes from each of the two replicates, punctured with a sterile inoculating needle, served as uninoculated controls. Treatments of 10 ripe red or mature green inoculated tomatoes each were placed at the following temperatures: 5, 10, 15, 20, and 25 C. Lesion diameter was measured daily. The entire experiment was repeated with another lot of tomato fruit at 2-wk intervals.

Ripe red tomatoes of uniform color and size were selected and surface-sterilized with 70% ethanol to test the ability of fungicide treatments to inhibit lesion expansion. Each fruit was punctured with a 1-mm-diameter nail head to a depth of 2 mm in four numbered quadrants. Fruits were submerged in nutrient broth containing 1×10^5 spores of *M. mucedo* or *M. piriformis*, respectively. Fruits were air-dried for 1 hr, then dipped for 2 min in one of the following fungicides: benomyl (0.5 g/L), captan (0.5, 1.0, and 1.5 g/L), benomyl plus captan (5:5 g/L), thiophanate-methyl (0.75 g/L), guazatine (0.7 g/L), imazalil (1 g/L), or vinclozolin

Table 1. Comparison of growth rates of *Mucor mucedo* and *M. piriformis* on potato-dextrose agar at various temperatures[a]

Temperature (C)	*M. mucedo* growth rate (mm^2/hr)	R^2	*M. piriformis* growth rate (mm^2/hr)	R^2
0	–[b]	...	3.68	0.99
5	8.48	0.98[c]	19.63	0.99
10	22.00	0.99	34.86	0.99
15	54.98	0.99	54.98	0.99
20	73.31	0.99	69.78	0.99
25	89.31	0.99	–	0.99
30	33.91	0.99	–	...

[a] Growth expressed as increase in colony area.
[b] No growth observed.
[c] Coefficient of variability.

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(0.5 g/L). All fungicide concentrations refer to active ingredients (a.i.). Each treatment was applied to two replicates, each with 10 ripe red fruits. Ten fruits were used as inoculated and 10 as untreated checks.

Dipped fruits were air-dried and placed on fiber trays covered with perforated plastic bags to maintain a high relative humidity (RH). All treatments were stored at 20 C and lesion diameter was measured at 3 and 6 days.

Two lots of 10 mature green and 10 ripe red fruits, puncture-inoculated with *M. mucedo*, were placed in covered plastic trays containing wet paper towels to maintain an atmosphere of nearly 100% RH. Similar lots of 10 mature green and 10 ripe red fruits were placed in open trays in the chamber at 70% RH. Fruit were stored at 20 C.

RESULTS AND DISCUSSION

Temperatures for optimal growth of *M. mucedo* and *M. piriformis* were 25 and 20 C, respectively (Table 1). Growth of *M. mucedo* occurred at 0 and 35 C but was not sufficient to allow measurement. *M. piriformis* grew at temperatures from 0 to 20 C, with an optimal growth temperature of 20 C (Table 1); growth was also observed at 25 C but was insufficient to allow measurement.

Rates of lesion expansion of both fungi were greater on ripe red than on mature green fruits (Table 2). The most rapid rate of lesion expansion of *M. mucedo* on red and green fruit was observed at 25 C. *M. piriformis* grew fastest on red and green fruits at 20 C.

Of the fungicides tested, only guazatine showed measurable fungicidal action against both fungi by significantly reducing decay on tomato fruits (Tables 3 and 4).

Comparison of lesion development on ripe red and mature green fruits revealed that fruit maturity has a significant effect on decay development. It was difficult to distinguish the two species without microscopic examination because their growth was quite similar. The decay caused by *M. mucedo* and *M. piriformis* on ripe tomatoes was similar. However, *M. mucedo* was more aggressive than *M. piriformis* and caused rapid decay within 48–72 hr of inoculation.

The optimal growth temperature for *M. mucedo* was 25 C on tomatoes and PDA. *M. piriformis* grew on the above substrates at temperatures from 0 to 25 C, with optimal growth at 20 C. Therefore, it was possible to separate the two species on the basis of optimal growth temperatures.

Although guazatine effectively controlled the two fungi, other fungicides had different levels of inhibition of decay on ripe red tomatoes (Tables 3 and 4). Both fungi were inhibited by thiophanate-methyl by 3 and 6 days after inoculation. *M. mucedo* lesion development was

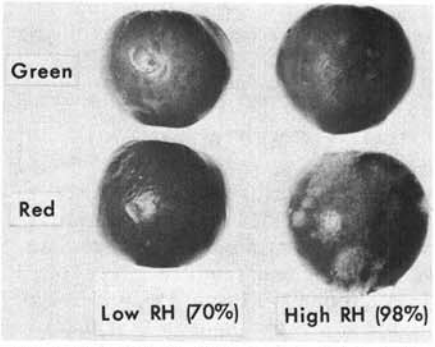

Fig. 1. Comparison of *Mucor mucedo* growth at 20 C on mature green and ripe red tomatoes after 3 days at 70 and 98% relative humidity (RH). Note the absence of hyphae and sporangiophores at 70% RH.

Table 2. Comparison of lesion expansion rates of *Mucor mucedo* and *M. piriformis* on red and green tomatoes at various temperatures[a]

Fruit maturity	Temperature (C)	*M. mucedo* Growth rate (mm^2/day)	*M. mucedo* R^2	*M. piriformis* Growth rate (mm^2/day)	*M. piriformis* R^2
Red	5	–[b]	...	1.74	0.99
	10	4.34	0.99[c]	3.36	0.99
	15	8.81	0.99	7.57	0.97
	20	17.51	0.99	7.62	0.99
	25	14.92	0.99	–	...
Mature green	5	–	...	0.74	0.98
	10	2.08	0.99	2.28	0.99
	15	3.82	0.99	2.74	0.99
	20	6.47	0.99	4.06	0.99
	25	5.74	0.99	–	...

[a] Growth expressed as increase in lesion area.
[b] No growth observed.
[c] Coefficient of variability.

Table 3. Effects of selected fungicides on decay of tomatoes caused by *Mucor mucedo*[a]

Treatment and rate[b]	Decay 3 days after inoculation: Mean lesion diameter (mm)	Decay 3 days after inoculation: Percent inhibition[c]	Decay 6 days after inoculation: Mean lesion diameter (mm)	Decay 6 days after inoculation: Percent inhibition[c]
Control	36.2	0.0 a	56.1	0.0 a
Benomyl (0.5 g/L)	33.5	7.4 a	55.4	1.2 a
Captan (0.5 g/L)	30.1	16.9 ab	45.2	19.4 ab
Captan (1.0 g/L)	32.0	11.6 ab	44.9	20.0 ab
Captan (1.5 g/L)	32.2	11.1 ab	45.1	19.6 ab
Benomyl/captan (0.5:0.5 g/L)	31.6	12.7 ab	50.0	10.8 ab
Thiophanate methyl (0.75 g/L)	20.0	44.8 c	40.8	27.5 b
Guazatine (0.7 g/L)	0.0	100.0 d	22.3	60.2 c
Guazatine (1.4 g/L)	0.0	100.0 d	6.9	93.1 d
Imazalil (1.0 g/L)	27.2	24.9 b	50.6	9.8 a
Vinclozolin (0.5 g/L)	26.4	26.8 b	52.6	6.2 a

[a] Each treatment was applied to 10 ripe red fruit as a 2-min dip.
[b] All fungicide concentrations represent active ingredients.
[c] Mean separation within column by Duncan's multiple range test ($P = 0.05$).

Table 4. Effects of selected fungicides on decay of tomatoes caused by *Mucor piriformis*[a]

Treatment and rate[b]	Decay 3 days after inoculation: Mean lesion diameter (mm)	Decay 3 days after inoculation: Percent inhibition[c]	Decay 6 days after inoculation: Mean lesion diameter (mm)	Decay 6 days after inoculation: Percent inhibition[c]
Control	11.6	0.0 a	37.5	0.0 a
Benomyl (0.5 g/L)	10.5	9.5 a	36.2	3.5 a
Captan (0.5 g/L)	7.9	31.9 b	25.4	32.3 b
Captan (1.0 g/L)	7.6	34.5 b	24.8	33.9 b
Captan (1.5 g/L)	6.7	42.2 b	23.4	37.6 b
Benomyl/captan (0.5:0.5 g/L)	6.8	41.4 b	29.1	22.4 b
Thiophanate methyl (0.75 g/L)	4.4	62.1 c	25.2	32.8 b
Guazatine (0.7 g/L)	0.0	100.0 d	8.4	77.6 c
Guazatine (1.4 g/L)	0.0	100.0 d	7.1	82.1 c
Imazalil (1.0 g/L)	9.4	18.9 ab	36.6	0.0 a
Vinclozolin (0.5 g/L)	2.4	79.3 c	18.6	50.4 bc

[a] Each treatment was applied to 10 ripe red fruit as a 2-min dip.
[b] All fungicide concentrations represent active ingredients.
[c] Mean separation within column by Duncan's multiple range test ($P = 0.05$).

inhibited by imazalil and vinclozolin treatments 3 days after inoculation, but neither treatment significantly reduced decay after 6 days. *M. piriformis* lesion development was inhibited by all captan treatments, benomyl plus captan, and vinclozolin 3 days after inoculation and decay was also reduced by these treatments after 6 days. Of the fungicides tested, however, only guazatine shows promise for the control of decay caused by *Mucor* spp. on tomatoes. This is significant because there are no other reports of fungicides capable of controlling decay caused by *Mucor* spp.

Fruit inoculated with *M. mucedo* and incubated at high RH developed abundant surface mycelium, whereas those incubated at lower RH did not (Fig. 1). There was no significant difference in the progess of lesion development at the two humidities; fruit were completely decayed after 3 days.

Although *M. mucedo* has not been reported previously as a major postharvest pathogen of tomato fruit, our recovery of this fungus from decayed tomatoes in a wholesale market underscores the importance of continued market surveys. Decay caused by *M. mucedo* could also be mistaken for Rhizopus rot by untrained personnel. The rapidity with which *M. mucedo* can decay tomatoes at normal transit and storage temperatures (13–20 C) further necessitates that care be taken to make sure fruit do not become contaminated during harvest and packing. Because most tomatoes receive no fungicide treatment after harvest, contamination could cause significant losses. The shipment that contained fruit infected by *M. mucedo* sustained a loss in excess of 60% within 1 wk of harvest. *M. piriformis* is also a potential pathogen of fresh-market tomato; however, to our knowledge, it has not yet been recovered from decayed fruit.

LITERATURE CITED

1. Bertrand, P., and Sauli-Carter, J. 1980. Mucor rot of pears and apples. Ore. Agric. Exp. Stn. Spec. Rep. 568. 21 pp.
2. Butler, E. E. 1959. Fungi and rot in California canning tomatoes. Plant Dis. Rep. 43:187-192.
3. Dennis, C., and Davis, R. P. 1977. Susceptibility of strawberry varieties to post-harvest fungi spoilage. J. Appl. Bacteriol. 42:197-206.
4. Edney, K. L. 1964. Post-harvest rotting of strawberries. Plant Pathol. 13:87-89.
5. Harter, L. L., and Weimer, J. H. 1929. A monographic study of sweet potato diseases and their control. U.S. Dep. Agric. Tech. Bull. 99. 117 pp.
6. Hesseltine, C. W., and Ellis, J. J. 1973. Mucorales. Pages 187-217 in: The Fungi. Vol. 4B. G. C. Ainsworth, F. K. Sparrow, and A. S. Sussman, eds. Academic Press, New York.
7. Kunimoto, R. K., Ito, P. J., and Ko, W. H. 1977. Mucor rot of guava fruit caused by *Mucor hiemalis*. Trop. Agric. (Trinidad) 54:185-187.
8. Lopateck, L. E., and Peters, W. 1972. A rot of pears in cold storage caused by *Mucor piriformis*. Can. J. Plant Sci. 52:875-879.
9. Lowings, P. H. 1956. The fungal contamination of Kentish strawberry fruits in 1955. Appl. Microbiol. 4:84-88.
10. Moline, H. E. 1981. Identification of *Mucor mucedo* as a postharvest pathogen of fresh market tomato. (Abstr.) Phytopathology 71:769.
11. Smith, W. L., Moline, H. E., and Johnson, K. S. 1979. Studies with *Mucor* species causing postharvest decay of fresh produce. Phytopathology 69:865-869.