Populations of *Mucor piriformis* in Soil of Pear Orchards in the Hood River Valley of Oregon

R. A. SPOTTS, Associate Professor, and L. A. CERVANTES, Experimental Biology Technician, Oregon State University, Mid-Columbia Agricultural Research and Extension Center, Hood River 97031

ABSTRACT

Spotts, R. A., and Cervantes, L. A. 1986. Populations of *Mucor piriformis* in soil of pear orchards in the Hood River Valley of Oregon. Plant Disease 70:935-937.

A method for determining populations of *Mucor piriformis* in soil was evaluated using four textural classes of soil. An average of 85% of the sporangiospores added to the soils were detected. Soil in 97 pear orchards in the Hood River Valley was sampled at depths of 0–5, 5–15, and 15–30 cm. *M. piriformis* was found in 55, 39, and 15% of the orchards with an average of 535, 103, and 9 propagules per gram of dry soil at the respective depths. No significant relationships were found between populations of *M. piriformis* and boron, manganese, zinc, soil moisture, pH, or soluble salts at 0–5 cm. However, a significant relationship was found between populations of *M. piriformis* and boron, manganese, zinc, and soluble salts at 5–15 cm.

Mucor piriformis, causal agent of Mucor rot of pear, occurs in soil and has been isolated from such diverse sources as forest soils, sand dunes, and leaf litter (2,3). Survival of sporangiospores of *M. piriformis* in soil is temperature and moisture dependent and can exceed 1 yr if the temperature remains below 27 C in dry soil (T. J. Michailides and J. M. Ogawa, *unpublished*). Many physical and chemical components of soil, including pH, organic matter, and minerals, have been associated with suppression of pathogens or diseases (5). The effects of many of these components on populations of *M. piriformis* in soil are unknown. Ninety-five to 100% of surviving propagules of *M. piriformis* in soil were sporangiospores, and mycelia buried in orchard soil survived only about 1 wk (6; T. J. Michailides and J. M. Ogawa, *unpublished*). Bertrand and Saulie-Carter (1) surveyed populations of *M. piriformis* in the top 5 cm of soil in apple and pear orchards in the Hood River Valley of Oregon and recovered *M. piriformis* in 21.4% of the orchards. Soils deeper than 5 cm were not studied in this survey. *M. piriformis* is a common contaminant in packinghouse dump-tank water (1,8,9) and is carried into the water in soil on the bottoms of bins (T. J. Michailides and R. A. Spotts, *unpublished*). Fruit floating in contaminated water may become infected, and relationships between populations of *M. piriformis* in water and decay of pear fruit have been established (7).

Oregon Agricultural Experiment Station Technical Paper 7699.

Use of trade names in this article does not imply endorsement by Oregon State University of the products named or criticism of similar products not mentioned.

Accepted for publication 7 May 1986 (submitted for electronic processing).

This research was done to determine natural populations of *M. piriformis* at three soil depths in 97 pear orchards in the Hood River Valley. Relationships between populations of *M. piriformis* and several physical and chemical components of soil, including boron, manganese, zinc, pH, soluble salts, and soil moisture also were evaluated.

MATERIALS AND METHODS

Recovery efficiency in soil textural classes. Soil textural classes and associations were based on definitions and locations described by the Soil Conservation Service for the Hood River Valley (4). Soils in four textural classes most common in Hood River Valley orchards were autoclaved at 121 C for 20 min. A 100-g soil sample was added to a blender containing 12,000 sporangiospores of *M. piriformis* in 200 ml of distilled water. Spores were washed from 1-wk-old cultures of acidified (1.5 ml of 85% lactic acid per liter) potato-dextrose agar (APDA) (Difco), and the concentration was determined with a hemacytometer. Germination of spores on APDA after 24 hr at 15 C was 98%. The soil and sporangiospore suspension was blended for 1 min and allowed to settle for 1 min, then 100-μl samples were plated on APDA. Six replicate plates were made for each sample, and the experiment was repeated once. Plates were incubated at 18 C for 42 hr before the colonies were counted, and identification of *M. piriformis* was confirmed by microscopic examination.

Populations of *M. piriformis* in orchard soils. Soil samples were collected from 97 pear orchards in the Hood River Valley from 27 June to 22 July 1983. These sites represented a wide range of soil textural classes and associations within the 3,650-ha pear-growing area. At each site, loose surface litter was removed and four soil samples were taken from the drip line of each of three Anjou or Bartlett pear trees. Populations of *M. piriformis* in surface litter were very low and averaged about 4% of the population at 0–5 cm deep (T. J. Michailides and R. A. Spotts, *unpublished*). Samples were taken at depths of 0–5, 5–15, and 15–30 cm. Sampling tools were sterilized with 95% ethanol between sampling at each depth. The 12 samples of about 0.5 kg at each depth were combined in plastic bags to represent one orchard site, and bags were placed in an ice chest, returned to the laboratory, and stored 1–2 mo at 0 C until populations were determined. No changes in populations of *M. piriformis* in soil were observed under these storage conditions. Populations of *M. piriformis* were determined in 100 g of soil at each depth from each orchard site as described in the recovery efficiency experiment and expressed as the number of viable propagules per gram of dry soil.

Soil moisture content was determined by drying 100 g at 105 C to a constant weight and calculating grams of water per 100 g of dry soil (10). Soil pH was determined by adding 100 ml of distilled water to 100 g of dry soil and mixing for 1 min. After 30 min of settling, pH of the supernatant was measured with a pH meter (Corning Glass Works Model 7, Corning, NY). In a preliminary study, soil (5–15 cm deep) from 18 sites was analyzed at the Oregon State University Soil Testing Laboratory, Corvallis, for 14 factors including phosphorus, potassium, calcium, magnesium, sodium, boron, nitrogen, organic matter, cation exchange capacity, soluble salts, zinc, copper, manganese, and sulfate. Significant (P = 0.05) relationships were determined with regression analysis between numbers of *M. piriformis* propagules and boron, manganese, zinc, pH, and soluble salts, but the other factors, including soil moisture, were not significantly related to numbers of *M. piriformis*. On the basis of this information, boron, manganese, zinc, and soluble salt concentrations were determined in soil from 25 sites at 0–5 cm and 19 sites at 5–15 cm. *M. piriformis* in these soils ranged from 10 to 2,054 propagules per gram of dry soil. The relationships between these soil factors and populations of *M. piriformis* were examined with stepwise multiple regression analysis (NWA Statpak, Northwest Analytical, Portland, OR).

Table 1. Efficiency of recovery of *Mucor piriformis* added to soils of four textural classes

Textural class	Association	Recovery[z] (%)
Silt loam	Parkdale-Dee	79 a
Fine sandy loam	Hood-Van Horne	82 a
Fine sandy loam	Wind River	83 a
Sandy loam	Wyeast	87 a
Stony loam	Oak Grove-Rockford	93 a

[z] Values represent number of colonies on APDA at 18 C in 42 hr as related to calculated number of sporangiospores of *M. piriformis* added to soil. Each value represents the mean of two six-plate replicates. Values followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test.

RESULTS

Recovery efficiency in soil textural classes. Recovery efficiency of sporangiospores of *M. piriformis* varied from 79% with silt loam to 93% with stony loam and averaged 85% for all textural classes of soil (Table 1). Although recovery of *M. piriformis* appeared less efficient from finer textured soils, differences were not signifcant (P = 0.05)

Populations of *M. piriformis* in orchard soils. *M. piriformis* was found in soil from all areas of the Hood River Valley (Table 2). *M. piriformis* was found in 55, 39, and 15% of the orchards, with an average of 535, 103, and 9 propagules per gram of dry soil at depths of 0–5, 5–15, and 15–30 cm, respectively. The highest *M. piriformis* population from a single site was 2,054 propagules per gram of dry soil. Several other *Mucor* species were identified, including *M. hiemalis* Wehmer, *M. genevensis* Lendner, and *M. plumbeus* Bon, but these were not pathogenic to pear fruits. *M. piriformis* constituted 51, 40, and 26% of the total *Mucor* population at 0–5, 5–15, and 15–30 cm, respectively. The average population of *M. piriformis* in soil at 0–5 cm was 591 propagules per gram from around Anjou pear trees and 343 propagules per gram from around Bartlett trees, but the difference was not significant (P = 0.05).

At 0–5 cm, boron, manganese, zinc, pH, and soluble salts varied considerably (Table 3), and the population of *M. piriformis* from 25 sites was not related to any of these factors. At 5–15 cm, a significant (P = 0.01) relationship was established between the population of *M. piriformis* and boron, manganese, zinc, and soluble salts. This relationship was described with the regression equation $Y = 342.8 + 356.5x_1 - 26.2x_2 - 5.5x_3 - 207.2x_4$, where Y = number of propagules of *M. piriformis* per gram of dry soil, x_1 = boron (ppm), x_2 = zinc (ppm), x_3 = manganese (ppm), and x_4 = soluble salts (mmhos/cm). Relationships between populations of *M. piriformis* at 15–30 cm with physical and chemical factors were not examined because of the low propagule concentration at this depth.

Table 2. Populations of *Mucor piriformis* in various orchard soils in the Hood River Valley of Oregon

Area	No. sites[a]	Soil depth (cm)	*M. piriformis*[b] (no. propagules/g)
Dee	7	0–5	800
		5–15	219
		15–30	0
East Side	15	0–5	820
		5–15	111
		15–30	23
Hood River	12	0–5	601
		5–15	139
		15–30	30
Odell	17	0–5	399
		5–15	17
		15–30	0
Parkdale	30	0–5	417
		5–15	117
		15–30	2
Westside	16	0–5	176
		5–15	15
		15–30	2

[a] At each site, soil was sampled from four locations around each of three pear trees, and the 12 samples at each depth were combined.

[b] Populations based on number of colonies on APDA at 18 C in 42 hr and represent number of propagules per gram of dry soil.

Table 3. Boron, manganese, zinc, pH, and soluble salt concentrations in orchard soils in the Hood River Valley of Oregon

Soil depth[a] (cm)	Range	Boron (ppm)	Manganese (ppm)	Zinc (ppm)	Soluble salts (mmhos/cm)	pH
0–5	Minimum	0.65	7.66	1.28	1.0	4.8
	Maximum	3.52	131.40	35.60	3.4	6.3
5–15	Minimum	0.48	1.60	0.54	0.3	5.3
	Maximum	2.88	65.00	13.80	1.0	6.3

[a] Values based on soil from 25 and 19 sites at depths of 0–5 and 5–15 cm, respectively.

DISCUSSION

M. piriformis is widely distributed in pear orchards of the Hood River Valley. Orchards were grouped into six geographic areas up to 23 km apart. The orchards varied in average annual temperature and precipitation from 10.2 C and 78 cm, respectively, in Hood River to 7.9 C and 116 cm, respectively, in Parkdale at the base of Mt. Hood. Within each geographic area, considerable variation in soil populations of *M. piriformis* occurred among orchard sites.

Although the population of *M. piriformis* was related to boron, manganese, zinc, and soluble salts at 5–15 cm, no relationship was established at 0–5 cm, the zone in which populations of *M. piriformis* are highest. Effects of individual factors, such as pH, moisture, organic matter, and various heavy metal ions, on populations of *M. piriformis* are difficult to quantify under orchard conditions because of the complex interaction of many soil factors, especially near the surface, and are best studied under controlled conditions. During the 4 wk that orchard soils were sampled, total rainfall was 1.7 cm and soil moisture in Hood River orchards depended primarily on irrigation frequency and duration. Thus, samples taken immediately after irrigation would have a high moisture content, but changes in population of *M. piriformis* may lag behind the rapid changes in moisture, making relationships difficult to determine. Also, seasonal and annual variability of populations of *M. piriformis* have not been studied and may account for the fewer orchards with *M. piriformis* in 1974 (1) than in this study. The difference in levels of occurrence of *M. piriformis* sporangiospores with soil depth is of practical importance relative to fruit decay. During harvest, soil adheres to the bottoms of bins used to collect harvested fruit (T. J. Michailides and R. A. Spotts, *unpublished*). Bins are immersed in water in packinghouses to remove fruit by flotation, and contamination of dump and flume water with *M. piriformis* results (1,8,9). Fruit decay is quantitatively related to levels of *M. piriformis* in the water (7). Populations of *M. piriformis* are highest in the upper 5 cm of soil, and care must be taken to minimize contamination of bins. In the Hood River Valley, bin loading areas often are covered with wood chips, and bins are not moved when soil is wet after rain.

ACKNOWLEDGMENTS

This project is supported in part by cooperative agreement 58-0401-5-00036 between the USDA and Oregon State University for pome fruit disease research and by the Winter Pear Control Committee.

LITERATURE CITED

1. Bertrand, P., and Saulie-Carter, J. 1980. Mucor rot of pears and apples. Ore. State Univ. Exp. Stn. Spec. Rep. 568. 21 pp.
2. Christenberry, G. A. 1940. A taxonomic study of the Mucorales in the Southeastern United States. J. Elisha Mitchell Sci. Soc. 56:333-366.
3. Domsch, K. H., Gams, W., and Anderson, T. H. 1980 Compendium of Soil Fungi. Vol. 1. Academic Press, New York. 859 pp.
4. Green, G. L. 1981. Soil Survey of Hood River Area, Oregon. U.S. Dep. Agric. Soil Conserv. Serv. 116 pp.
5. Hornby, D. 1983. Suppressive soils. Annu. Rev. Phytopathol. 21:65-85.
6. Michailides, T. J., and Ogawa, J. M. 1983. Survival of *Mucor piriformis* in soil. (Abstr.) Phytopathology 73:803.
7. Spotts, R. A. 1986. Relationships between inoculum concentrations of three decay fungi and pear fruit decay. Plant Dis. 70:386-389.
8. Spotts, R. A., and Cervantes, L. A. 1985. Effects of heat treatments on populations of four fruit decay fungi in sodium ortho phenylphenate solutions. Plant Dis. 69:574-576.
9. Spotts, R. A., and Cervantes, L. A. 1986. Populations, pathogenicity, and benomyl resistance of *Botrytis* spp., *Penicillium* spp., and *Mucor piriformis* in packinghouses. Plant Dis. 70:106-108.
10. U.S. Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Dep. Agric. Handbk. 60. 160 pp.