

# Environmental Factors Affecting Conidial Survival of Five Pear Decay Fungi

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## ABSTRACT

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The survival of conidia of *Botrytis cinerea*, *Mucor piriformis*, *Penicillium expansum*, *Pezizula malicorticis*, and *Phialophora malorum* on pear fruit surfaces in the orchard and under selected temperature-relative humidity combinations was determined. Under controlled conditions, survival half-life ( $T_{50}$ ) of *B. cinerea* and *Penicillium expansum* often exceeded 1 mo, but the  $T_{50}$ s of *M. piriformis* and *Pezizula malicorticis* often were less than 2 wk. Survival of these fungi decreased as temperature increased from  $-1.1$  to  $30$  C. The  $T_{50}$  of *Phialophora malorum* varied from about 2 to 6 wk and was less at 20 than at 10 or 30 C. Conidial survival in the orchard was about 20-40% of that at similar temperature and relative humidity in controlled environments, and the  $T_{50}$ s in the orchard of *B. cinerea*, *Penicillium expansum*, and *M. piriformis* were 14.4, 6.1, and 4.2 days, respectively.

*Botrytis cinerea* Pers. ex Fr., *Mucor piriformis* Fisher, *Penicillium expansum* Lk. ex Thom., and *Phialophora malorum* (Kidd & Beaum.) McCulloch cause decay of stored pears and have been found in soil, surface plant residues, and air (1). *Pezizula malicorticis* (Jacks.) Nannf., the causal agent of bullseye rot, survives on plant surfaces and in cankers (3). Fungal propagules may be deposited on fruit on the tree during harvest or in the packinghouse.

Little is known about factors affecting survival of pear decay fungi. *B. cinerea* conidia survived 2-6 mo at 0 C and 1-3 mo at 20 C and 99% RH (6). *B. cinerea* hyphae on glass slides remained viable for 12 mo when stored in the range between 85 and 100% RH at 0 C (6). The effect of environmental factors on survival of other pear decay fungi has not been studied.

The objective of this study was to determine the survival of conidia of *B. cinerea*, *M. piriformis*, *Penicillium expansum*, *Pezizula malicorticis*, and *Phialophora malorum* on pear fruit surfaces in the orchard and under selected

temperature-relative humidity combinations.

## MATERIALS AND METHODS

### Survival of decay fungi in the orchard.

All fungi were isolated from decayed pear fruits and grown on potato-dextrose agar (Difco, Detroit, MI) acidified with 1.5 ml of 85% lactic acid per liter (APDA). Cultures 1-2 wk old were flooded with sterile water and suspensions adjusted to obtain  $5-6 \times 10^4$  conidia per milliliter. Conidial suspensions of *B. cinerea*, *M. piriformis*, *Penicillium expansum*, and *Pezizula malicorticis* were sprayed to runoff onto Anjou fruits and *Phialophora malorum* onto Bosc fruits at monthly intervals from 4 mo to 2 days before harvest. Side rot, caused by *P. malorum*, is a serious problem on Bosc but is of no importance on other pear cultivars. Control fruits were sprayed with sterile distilled water.

Fruits were removed 1 day, then weekly from 1 to 8 wk, after each monthly inoculation. Two sections of epidermal tissue, each about  $2 \text{ cm}^2$ , were removed from five fruits inoculated with each fungus. Tissue pieces were inverted and placed on APDA. Plates were incubated at 20 C, and fungus survival as evidenced by mycelial growth was evaluated after 1 wk. Linear regression lines developed from  $\log_e$  of percent survival vs. time were analyzed with covariance and comparison of independent estimates of slope.

**Survival of decay fungi in controlled environments.** Mature Anjou pear fruits were harvested and surface-sterilized with 0.525% sodium hypochlorite, rinsed, and air-dried. Conidia of the five fungi used in orchard inoculations were harvested from 3-wk-old APDA cultures, adjusted to  $5 \times 10^4$  conidia per milliliter, and sprayed onto the fruits to runoff. Fruits were allowed to air-dry, then placed at  $-1.1 \pm 1.5$ ,  $10 \pm 1.5$ ,  $20 \pm 1$ , and  $30 \pm 1$  C. Relative humidities in the

experiment included  $95 \pm 5\%$  at  $-1.1$  C;  $90 \pm 10\%$  at 0, 20, and 30 C; and  $40 \pm 10\%$  at 20 and 30 C. Relative humidity at  $-1.1$  C was measured with electronic sensors (American Instrument Co., Silver Spring, MD), and at other temperatures, with calibrated hygrothermographs (Belfort Instrument Company, Baltimore, MD). Fruits at 10, 20, and 30 C were exposed to continuous light energy of  $550 \mu\text{W}/\text{cm}^2$  at  $400 \mu\text{m}$ . Fruits at  $-1.1$  C were placed in a commercial, polyethylene-lined fruit storage box in the dark. Epidermal tissue pieces  $0.5 \times 1 \text{ cm}$  were removed weekly (biweekly from fruits held at  $-1.1$  C) from four positions on each of four fruits inoculated with each fungus and placed with the cuticle down on APDA. Fungus survival was evaluated after 1 wk. Data were analyzed with linear regression, and survival half-life ( $T_{50}$  [the time after which the inoculated fungus produced colonies from half of the plated epidermal pieces]) was calculated from regression equations.

## RESULTS

**Survival of decay fungi conidia in the orchard.** *B. cinerea* conidial survival on the surface of attached Anjou pear fruits declined at a significantly ( $P = 0.01$ ) slower rate than *Penicillium expansum* or *M. piriformis* (Fig. 1). The  $T_{50}$ s of *B. cinerea*, *P. expansum*, and *M. piriformis* were 14.4, 6.1, and 4.2 days, respectively, and were all significantly different ( $P = 0.01$ ). Survival of *Pezizula malicorticis* and *Phialophora malorum* conidia could

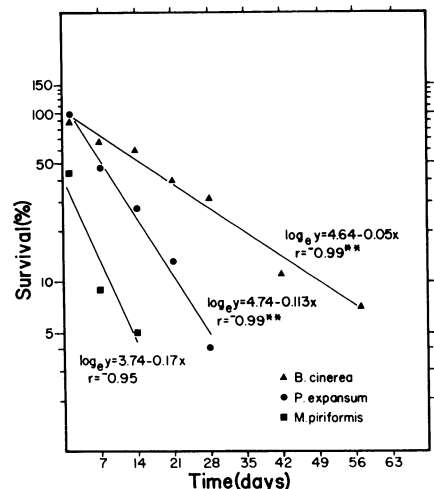


Fig. 1. Survival of decay fungi conidia in the orchard on the surfaces of attached Anjou pear fruits. Each point represents the mean of three to 20 fruits, two tissue sections per fruit. \*\* = Correlations significant at  $P = 0.01$ .

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**Table 1.** Conidial survival half-lives ( $T_{50}$ ), in days, of five decay fungi on the surface of Anjou pear at selected temperature-relative humidity combinations

| Fungus                       | $T_{50}$ <sup>a</sup> at each temperature (C)/relative humidity (%) |       |                    |       |       |
|------------------------------|---|-------|--------------------|-------|-------|
|                              | 10/90   | 20/40 | 20/90              | 30/40 | 30/90 |
| <i>Botrytis cinerea</i>      | 35.8  | 46.2  | 20.5               | 30.8  | 12.4  |
| <i>Mucor piriformis</i>      | 14.9  | 12.0  | 15.7               | 8.8   | 5.8   |
| <i>Penicillium expansum</i>  | 133.3   | 36.5  | >27.0 <sup>b</sup> | 26.1  | 16.2  |
| <i>Pezicula malicorticis</i> | 7.8   | 12.2  | 11.1               | 8.8   | 6.8   |
| <i>Phialophora malorum</i>   | 40.6  | 13.5  | 11.8               | 18.4  | 25.4  |

<sup>a</sup> $T_{50}$  values in days were calculated from linear regression equations of fungal survival at weekly intervals. Survival was determined by presence of fungal growth from Anjou epidermal tissue on APDA. Correlation coefficients of survival with time of all fungi are significant ( $P = 0.05$ ) except *M. piriformis* at 30 C/90% RH and *P. malorum* at 10 C/90% RH.

<sup>b</sup>Exact calculation of  $T_{50}$  not possible because of incomplete data.

not be determined because these slow-growing fungi, if viable, were masked with other microorganisms present on fruit surfaces in the orchard. *B. cinerea* and *Penicillium expansum* were isolated from less than 4% of the tissue sections from fruits sprayed with distilled water. No other decay fungi were isolated from control fruits.

**Survival of decay fungi in controlled environments.** The  $T_{50}$  of each fungus at each selected temperature-relative humidity combination is presented in Table 1. The  $T_{50}$ s of *M. piriformis* and *Pezicula malicorticis* were similar and generally ranged from about 1 wk at 30 C to 2 wk at 10 and 20 C. The  $T_{50}$ s of *B. cinerea*, *Penicillium expansum*, and *Phialophora malorum* were much longer than those of *M. piriformis* and *Pezicula malicorticis* and ranged from 2 to 4 wk at 20 and 30 C and more than 4 wk at 10 C. The  $T_{50}$  of *Penicillium expansum* at 10 C exceeded 4 mo.

With few exceptions, the  $T_{50}$ s of *B. cinerea*, *M. piriformis*, *Penicillium expansum*, and *Pezicula malicorticis* declined as temperature increased. The  $T_{50}$  of *Phialophora malorum*, however, was greater at 30 than at 20 C. With the exception of *M. piriformis* at 20 C and *P.*

*malorum* at 30 C, the  $T_{50}$ s of all fungi were less at 90 than at 40% RH within each temperature.

At -1.1 C, survival of *M. piriformis* and *P. malorum* remained at 100% at the end of the 30-wk experiment. *B. cinerea* and *Penicillium expansum* survival decreased only slightly after 30 wk, and the  $T_{50}$  was calculated as 19 mo. The  $T_{50}$  of *Pezicula malicorticis* at -1.1 C was 7.3 mo.

## DISCUSSION

Survival of conidia of decay fungi varied greatly among species, temperature, and relative humidity. The  $T_{50}$ s of *B. cinerea* and *Penicillium expansum* exceeded 1 mo under most conditions, but those of *M. piriformis* and *Pezicula malicorticis* were often less than 2 wk. *B. cinerea* conidia were reported to survive less than 1 mo at 20 C and 90% RH, but length of survival varied with strain (6). Currently, a fungicide application is recommended within 2 wk of harvest for pear decay control. This timing appears to coincide with the need 1) for protection of fruit as susceptibility to decay increases (5) and 2) to reduce decay spore populations that could survive from 2 wk to harvest and infect fruit during harvest

and postharvest handling procedures.

The  $T_{50}$  of conidia in the orchard was about 20–40% of that at similar temperature and relative humidity in controlled environments. Several factors that likely reduced orchard survival include fluctuations and extremes in temperature and relative humidity and ultraviolet (UV) light. However, orchard inoculations were repeated several times during the growing season, and decreases in  $T_{50}$  did not appear consistently related to temperature or relative humidity. *B. cinerea* is extremely sensitive to UV light, and exposures longer than 2 hr decreased viability (4). Spores of a *Botrytis* sp. from apple were killed on an agar surface by a 1-min exposure to a UV light placed 15 cm from the culture (2).

Survival of conidia of all decay fungi exceeded 7 mo at -1.1 C in this study and may have important practical significance. In the Pacific Northwest, Anjou and Bosc pears commonly are stored at -1.1 C as long as 8 mo. Fungi that survive through the storage period could cause additional fruit decay during packaging, transport, and ripening at terminal markets.

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