Effect of Preharvest Pear Fruit Maturity on Decay Resistance

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ABSTRACT

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Quantitative monthly changes in resistance of attached and detached Anjou, Bartlett, and Bosc pear fruits to several decay fungi were determined. During the last month before harvest, susceptibility to decay caused by *Mucor piriformis* increased in Anjou and Bartlett and susceptibility to decay caused by *Botrytis cinerea* and *Penicillium expansum* increased in Anjou. Susceptibility of Bartlett to *B. cinerea* and *P. expansum* appeared to increase gradually during the growing season. Fruits inoculated 3 or 4 mo before harvest with *B. cinerea, M. piriformis,* and *P. expansum* were highly resistant to decay. However, fruits were susceptible to *Pezicula malicorticis* 4 mo before harvest, and susceptibility continued throughout the growing season. This pattern of decay resistance also was evident in detached fruits. Detached fruits inoculated with *P. malicorticis* and *Phialophora malorum* and incubated at 20 C were not infected, but severe decay occurred when fruits were incubated at −1.1 C.

Gray mold (*Botrytis cinerea* Pers. ex Fr.), mucor rot (*Mucor piriformis* Fischer), blue mold (*Penicillium expansum* Lk. ex Thom.), bullseye rot (*Pezicula malicorticis* (Jacks.) Nannf.), and side rot (*Phialophora malorum* (Kidd & Beaum.) McCullock) cause serious postharvest losses to pears (*Pyrus communis* L.) produced in the Pacific Northwest (2,3,10). These losses can be reduced if certain fungicides are applied before harvest, but the optimum timing for application is not known. Information concerning quantitative changes in pear fruit susceptibility at specific times during the growing season is unavailable.

Resistance of young Cox's Orange Pippin apple fruit to *Pezicula malicorticis* infection declines as picking maturity approaches (5,6). Immature Delicious apple fruits are less susceptible than overmature fruit to blue mold decay caused by *Penicillium expansum* (11). Phenolic compounds decrease in apple as the fruit approaches maturity, and this decrease coincides with an increase in susceptibility to gray mold caused by *B. cinerea* (8). Decrease in polygalacturonase inhibitor in Bartlett pear as the fruit matured was correlated with an increase in susceptibility to decay caused by *B. cinerea, P. expansum,* and *Dothiorella gregaria* (1).

The objective of this study was to determine the quantitative monthly changes in resistance of attached and detached Anjou and Bartlett pear fruit to *B. cinerea, M. piriformis, Penicillium expansum,* and *Pezicula malicorticis* and of Bosc pear fruit to *Phialophora malorum* during the growing season.

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MATERIALS AND METHODS

All decay 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 *Pezicula malicorticis* were sprayed to runoff onto attached Anjou and Bartlett fruits at about monthly intervals from 16 wk (Bartlett) or 19 wk (Anjou) to 2 days before harvest. Bosc fruits were inoculated 20 wk before harvest only with *Phialophora malorum*, which causes side rot of Bosc but is not of economic significance on other pear cultivars. The first inoculation of all cultivars was done at the petal fall stage of growth (1 May 1980 and 28 April 1981). Fifty fruits of each cultivar were inoculated monthly with each fungus. Two wounds per fruit were made by needle puncture through drops of inoculum on 25 of the 50 fruits. Each fruit was covered with a plastic bag overlaid with aluminum foil to prevent desiccation and heat buildup. Bags were removed after 2–4 days, and fruit decay was recorded weekly. At harvest, symptomless fruits were placed in polyethylene-lined boxes and stored at −1.1 C for 6 mo (Bartlett and Bosc) or 8 mo (Anjou). Decay was evaluated visually each month throughout the growing season and during storage. At the end of the cold storage period, fruits were ripened 7 days at 20 C and final decay evaluations made. Decay data from all evaluations for each pathogen were combined to give total decay for each fungus at each inoculation date. Distilled water was used on all inoculation dates as the control.

Because apparent changes in resistance could be related to fluctuation of natural environmental factors in the orchard, fruits also were detached and inoculated under controlled conditions. Beginning about 12 wk (Bartlett) or 10 wk (Anjou and Bosc) before harvest, pear fruits were detached about every 4 wk until 2 days before harvest. Fruits were surface-sterilized with 0.525% sodium hypochlorite, rinsed, and inoculated by pipetting drops of inoculum onto the fruit. Twenty wounded and 20 unwounded fruits were inoculated for each fungus-cultivar combination. Half of the fruits were placed in a moist chamber at 20 C and half were stored at −1.1 C in polyethylene-lined boxes. Decay was evaluated visually after 7 days in fruits held at 20 C and monthly in fruits held at −1.1 C. Inoculations of attached fruits were done in 1980 and 1981 and of detached fruits in 1979, 1980, and 1981.

RESULTS

Decay susceptibility of attached, unwounded fruit. Susceptibility of unwounded fruits to *B. cinerea, M. piriformis,* and *Penicillium expansum* decay appeared greater at 2 days compared with 3–19 wk before harvest (Tables 1 and 2). Most decay of unwounded fruits was observed at the stem end and occurred after several months at −1.1 C.

Pezicula malicorticis caused substantial decay of unwounded Bartlett and Anjou fruits. Fruits inoculated within 7 wk of harvest appeared more susceptible than less mature fruits (Tables 1 and 2).

Unwounded Bosc fruits were resistant to *Phialophora malorum* at all inoculation dates. Because *P. malorum* caused decay only in wounded Bosc fruits inoculated within 2 wk of harvest, all Bosc data are presented in the text rather than in the tables.

Decay susceptibility of attached, wounded fruit. During the last month before harvest, susceptibility to decay caused by *M. piriformis* increased in

Anjou and Bartlett and susceptibility to decay caused by *B. cinerea* and *Penicillium expansum* increased in Anjou (Tables 1 and 2). Susceptibility of Bartlett to *B. cinerea* and *P. expansum* appeared to increase gradually during the growing season. Fruits wound-inoculated 3 or 4 mo before harvest with *B. cinerea, M. piriformis,* and *P. expansum* were highly resistant to decay (Tables 1 and 2). Anjou and Bartlett fruits were susceptible to *Pezicula malicorticis* throughout the season (Tables 1 and 2).

Twenty-nine percent of wounded Bosc fruits inoculated with *Phialophora malorum* within 2 days of harvest were decayed. No decay resulted from other inoculations of Bosc.

Decay caused by *B. cinerea, M. piriformis,* and *Penicillium expansum* appeared occasionally within 1 wk of inoculation in the orchard but most often after 1 to 2 mo at −1.1 C. Bullseye rot (*Pezicula malicorticis*) was not visible at harvest, however, and only developed during storage at −1.1 C.

Decay susceptibility of detached, unwounded fruit. No decay resulted from any inoculation of detached, unwounded Anjou or Bartlett fruits with *B. cinerea, M. piriformis,* or *Penicillium expansum* and of Bosc fruits with *Phialophora malorum* at −1.1 or 20 C. *Pezicula malicorticis* caused no decay in either pear cultivar incubated at 20 C but caused an average of 49 and 69% decay of Anjou and Bartlett fruits, respectively, held at −1.1 C. There was no difference in susceptibility to *P. malicorticis* between fruits inoculated 2 mo or 2 days before harvest.

Decay susceptibility of detached, wounded fruit. Anjou and Bartlett fruits appeared more susceptible to *B. cinerea, M. piriformis,* and *Penicillium expansum* during the last month before harvest than earlier in the season (Tables 3 and 4). Often these fungi caused no decay in fruits inoculated 2–3 mo before harvest. *Pezicula malicorticis* caused decay in all wounds of both pear cultivars at all inoculation dates when fruits were incubated at −1.1 C, but no decay occurred in fruits held at 20 C (Tables 3 and 4). *Phialophora malorum* caused 87, 63, and 0% decay of Bosc fruits inoculated 0, 3, and 9 wk before harvest, respectively, and incubated at −1.1 C. No *P. malorum* decay occurred in fruits incubated at 20 C.

When distilled water was used as the control on all inoculation dates, decay caused by contamination never exceeded 5% and typically was less than 1%.

DISCUSSION

Anjou pear fruits were shown to increase in susceptibility to *B. cinerea, M. piriformis,* and *Penicillium expansum,* and Bosc, to *Phialophora malorum* during the final month before harvest. Decay usually appeared from within 1 wk of inoculation to after 2 mo of storage at

Table 1. Decay in attached Anjou pear fruits inoculated monthly during the growing season in 1980 and 1981

Time of inoculation before harvest (wk)	Percent decay[a] caused by							
	Botrytis cinerea		*Mucor piriformis*		*Penicillium expansum*		*Pezicula malicorticis*	
	Wounded[b]	Unwounded	Wounded	Unwounded	Wounded	Unwounded	Wounded	Unwounded
0[c]	82	21	18	9	69	11	100	76
6	14	5	0	5	0	3	99	32
9	2	0	0	0	2	4	100	12
15	0	9	0	0	0	0	74	27
19	0	0	0	0	0	0	69	4

[a] Decay is the total from evaluations conducted monthly during the growing season, during storage, and after a 1-wk ripening period. Each value represents the mean of 50 fruits.
[b] Two needle punctures per fruit through drops of inoculum.
[c] Inoculated 2 days before harvest.

Table 2. Decay in attached Bartlett pear fruits inoculated monthly during the growing season in 1980 and 1981

Time of inoculation before harvest (wk)	Percent decay[a] caused by							
	Botrytis cinerea		*Mucor piriformis*		*Penicillium expansum*		*Pezicula malicorticis*	
	Wounded[b]	Unwounded	Wounded	Unwounded	Wounded	Unwounded	Wounded	Unwounded
0[c]	78	2	21	13	47	37	100	83
3	39	14	16	0	43	27	97	52
7	45	4	0	0	32	7	100	87
13	2	4	0	0	11	13	75	44
16	0	5	0	0	1	4	25	19

[a] Decay is the total from evaluations conducted monthly during the growing season, during storage, and after a 1-wk ripening period. Each value represents the mean of 50 fruits.
[b] Two needle punctures per fruit through drops of inoculum.
[c] Inoculated 2 days before harvest.

Table 3. Decay in detached, wound-inoculated Anjou pear fruits during the growing season

Time of inoculation before harvest (wk)	Percent decay[a] caused by							
	Botrytis cinerea (incubation temp. [C])		*Mucor piriformis* (incubation temp. [C])		*Penicillium expansum* (incubation temp. [C])		*Pezicula malicorticis* (incubation temp. [C])	
	−1.1	20	−1.1	20	−1.1	20	−1.1	20
0[b]	55	77	20	20	4	91	100	0
2	79	26	0	45	1	70	100	0
5	57	0	0	0	0	7	100	0
6	30	0	0	0	0	33	100	0
10	51	0	0	0	0	0	100	0

[a] Each value represents the average of 1979, 1980, and 1981, 10 fruits per year. Decay is the total from evaluations conducted monthly during the growing season, during storage, and after a 1-wk ripening period.
[b] Inoculated 2 days before harvest.

Table 4. Decay in detached, wounded Bartlett pear fruits during the growing season

Time of inoculation before harvest (wk)	Percent decay[a] caused by							
	Botrytis cinerea (incubation temp. [C])		*Mucor piriformis* (incubation temp. [C])		*Penicillium expansum* (incubation temp. [C])		*Pezicula malicorticis* (incubation temp. [C])	
	−1.1	20	−1.1	20	−1.1	20	−1.1	20
0[b]	90	60	40	33	61	47	100	0
4	54	0	21	0	34	36	100	0
8	5	0	0	0	70	0	100	0
12	...	0	...	0	0	0	100	0

[a] Each value represents the average of 1979, 1980, 1981, 10 fruits per year. Decay is the total from evaluations conducted monthly during the growing season, during storage, and after a 1-wk ripening period.
[b] Inoculated 2 days before harvest.

−1.1 C. Changes in the susceptibility of Bartlett appear similar to those in Anjou, but Bartlett may increase in susceptibility to *B. cinerea* and *Penicillium expansum* up to 2 mo before harvest. However, resistance of both Anjou and Bartlett fruit to *Pezicula malicorticis*, the causal agent of bullseye rot, is low even at the petal fall stage (4 mo before harvest), although decay was not evident until after several months at −1.1 C. This pattern of increased decay susceptibility during the last month before harvest also was evident in detached fruits that were inoculated and incubated under constant, controlled conditions, thus eliminating changes in natural environmental factors as the primary cause for observed differences in decay susceptibility during the growing season.

Whereas *B. cinerea, M. piriformis, Penicillium expansum,* and *Phialophora malorum* required a wound for infection, *Pezicula malicorticis* readily infected unwounded fruits. Infection by *B. cinerea, M. piriformis,* and *Penicillium expansum* in orchard-inoculated, unwounded fruits stored at −1.1 C occurred primarily through the stem end. Unwounded, detached fruits that were inoculated with carefully placed inoculum drops rather than with spray (as were attached fruits) were only infected by *Pezicula malicorticis*. The *B. cinerea, M. piriformis,* and *Penicillium expansum* stem end decay of attached fruits inoculated 2 days before harvest probably reflects a high level of survival of these fungi and contamination of the open stem end with inoculum during harvest. Detaching pear fruits before inoculation did not appear to affect decay resistance.

Penicillium expansum caused slight decay of wounded Anjou fruits incubated at −1.1 C but caused severe decay at 20 C. This agrees with a previous report that *P. expansum* germinated at 0 C but did not cause decay if fruit remained at 0 C (4). Reasons for *P. expansum* decay of detached Bartlett fruits at −1.1 C are not known but may be related to severe skin cracking and senescence late in the storage period and during ripening, thus increasing the number of entry points for the fungus.

Detached fruits inoculated with *Pezicula malicorticis* and *Phialophora malorum* and incubated at 20 C were not infected, but severe decay occurred when fruits were incubated at −1.1 C. Pierson (9) reported that incubation time was reduced significantly when apples infected with *Pezicula malicorticis* were held at 18 and 27 C rather than 0.6 C. However, the apple fruits were infected before harvest and were exposed to a variety of temperatures after infection. It appears likely that physiological resistance factors affecting bullseye and side rot decay in fruit may be operative at 20 but not −1.1 C.

The increase in the susceptibility of pear fruit to decay during the month before harvest provides evidence to support application of protective fungicides during this time. Both mancozeb (zinc ion and manganese ethylenebisdithiocarbamate) and ziram (zinc dimethyldithiocarbamate) currently are recommended in the Mid-Columbia area of Oregon (7).

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