Incidence of Postharvest Decay of 'd'Anjou' Pear and Control with a Thiabendazole Drench

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ABSTRACT

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Postharvest decay causes losses to commercial pear industries. The incidence of decay in air and controlled-atmosphere (CA)-stored 'd'Anjou' pear fruit was investigated, and the effect of a prestorage thiabendazole drench on decay in CA-stored fruit was determined. In air storage, bull's-eye rot (31.37%) was most prevalent in 1996, whereas incidence of gray and blue mold (1996 and 1997) and bull's-eye rot (1997) were similar. *Mucor*, *Alternaria*, and *Coprinus* rot levels were low. Incidence of stem-end gray mold (2.58%) was significantly higher than calyx-end (0.73%) and puncture gray mold (0.61%). Incidence of gray mold (2.26%) was higher than all other decay in nondrenched CA-storage, and incidence of other decay types were similar. Incidence of puncture gray mold (1.13%) was higher than stem-end gray mold (0.84%), which in turn was higher than calyx-end gray mold (0.36%) in nondrenched CA-storage. Incidence of gray mold (1.04%) in CA-stored fruit was reduced by a prestorage thiabendazole drench. Drenching reduced stem-end (0.34%) and puncture gray mold (0.40%) but had no effect on all other decay or the total decay incidence. These results support the current recommendations of a single postharvest application of thiabendazole to control gray mold in 'd'Anjou' pear fruit.

Additional keywords: *Botrytis cinerea*, *Mucor piriformis*, *Neofabraea* spp., *Penicillium expansum*, *Pezizula* spp., *Phialophora malorum*

The largest volume of winter pear fruit (*Pyrus communis* L.) for fresh consumption in the United States is grown and shipped from packinghouses in Washington and Oregon (19). Of 30 commercial pear fruit packers surveyed in 1993, 22 considered decay as the most serious problem associated with postharvest losses (19). Gray mold (*Botrytis cinerea* Pers.:Fr.), *Mucor* rot (*Mucor piriformis* E. Fisch.), blue mold (*Penicillium expansum* Link), bull's-eye rot (*Neofabraea* spp.; synonym *Pezizula* spp.; 13), and side rot (*Phialophora malorum* (M. N. Kidd & A. Beaumont) McCulloch) cause serious postharvest losses to pear fruit produced in the Pacific Northwest (4,7,40). Although researchers are aware of the specific organisms responsible for postharvest decay in

the pear cv. d'Anjou, there is little documented information available on the relative importance of the decay organisms in relation to each other and levels of specific decay. In a survey of culled pear fruit conducted by the authors in four packinghouses for the period 1994 to 1996, *B. cinerea* caused 55% of the total decay, whereas *Penicillium* spp. and *Mucor* spp. were responsible for 24 and 8%, respectively. The remaining 13% was ascribed to other pathogens, including *Cladosporium* spp., *Alternaria* spp., and *Neofabraea* spp. (21). In long-term storage, secondary spread of decay from infected fruit to adjacent, previously uninfected fruit poses a significant decay risk.

Methods of handling harvested apple and pear fruit changed dramatically between 1955 and 1965 as immersion dumping in the packinghouses replaced picking lug and dry dumping (5). When large volumes of fruit are dumped, there is a rapid accumulation of dirt and debris, as well as spores of decay pathogens, in the immersion dump water (5) and decay becomes a major problem. Chlorine or sodium orthophenylphenate (SOPP) is added to the dump water to control decay (6,19,35). Systemic benzimidazole fungicides, benomyl and thiabendazole, were introduced into pear packinghouses in the 1970s to control postharvest decay caused by *Peni-*

cillium expansum and *B. cinerea* (24,30). Initially, losses were reduced to insignificance; however, by 1975, benomyl-resistant strains of *P. expansum* and *B. cinerea* were found in Oregon and Washington (5). In 1989, all postharvest use of benomyl was removed from the label. Currently, only captan and thiabendazole are registered for postharvest control of decay in pear fruit in the Pacific Northwest. These fungicides are applied as prestorage fruit drenches or line sprays (1). Captan is seldom used because of fungicide residue limits on fruit for the export market.

Current control measures aimed at reducing decay include a preharvest application of ziram and either a postharvest drench or line spray application of thiabendazole. A number of packinghouses have experienced an increase in decay incidence in drenched fruit, particularly decay caused by *Penicillium* spp. and *Mucor* spp. (5,7). For this reason, the majority of packinghouses apply thiabendazole as a line spray (19,20).

The objectives of this research were to (i) determine the incidence of decay in air-stored d'Anjou pear fruit and (ii) determine the effect of a prestorage thiabendazole drench on incidence of decay in commercial controlled-atmosphere (CA)-stored d'Anjou pear fruit.

MATERIALS AND METHODS

Decay in air storage. Fruit from 14 commercial d'Anjou pear orchards situated in the Mid-Columbia region of Oregon and Washington were picked at commercial harvest in 1996 and 1997. Fruit from each orchard were harvested into 10 wood boxes (18 kg of fruit per box, with each box containing approximately 100 fruit) lined with perforated polyethylene bags and stored in air at -1°C. Based on visual symptoms described in the Compendium of Apple and Pear Diseases (18), fruit were evaluated for incidence of decay after 3, 6, and 8 months. After the 8-month evaluation, fruit were ripened at 20°C for 7 days before a final evaluation of decay. After each evaluation, decayed fruit were removed. The incidence (%) of each decay type was recorded.

Comparison of decay in nondrenched and thiabendazole-drenched fruit. In 1996 and 1997, d'Anjou pear fruit from

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the same 14 orchards were commercially harvested into bins and transported to a packinghouse. At the packinghouse, the bins of fruit either went directly into CA storage at -1.1°C in low O_2 (1% O_2 + 0.05% CO_2), or received a thiabendazole (Mertect 340 F; Syngenta, Greensboro, NC) drench at the registered rate (525 μg a.i./ml) before going into CA storage. Fruit were stored until required for packing and shipping by the packinghouse. The storage period ranged from 4 to 6 months. Fruit then were immersion-dumped and floated onto the packing line. Commercially unacceptable fruit showing signs of physical damage or decay were culled during the packing process. Careful records were made by the packinghouse staff of the incidence of culled fruit and the causes of culling in each lot of fruit from each of the orchards. Culled fruit were evaluated for incidence of decay symptoms (18) caused by postharvest pathogens. Incidences of specific decay types in stored fruit from each of the 14 orchards were calculated as follows: the mean total percent incidence of decay recorded for each orchard, multiplied by the mean percent incidence of specific decay type. Decay incidences (%) in non-drenched and thiabendazole-drenched fruit were recorded.

Data analysis. The Shapiro-Wilk test for normality (29) was performed on all decay incidence (%) data. For both air-stored and CA-stored fruit, incidences of decay data were transformed to logits before being subjected to analysis of variance (SAS/STAT User's Guide; SAS Institute, Inc., Cary, NC). The student's t least significant difference (LSD) was calculated to compare decay means of air-stored fruit, and treatment means of nondrenched and drenched CA-stored fruit.

RESULTS

Decay in air storage. There was a significant interaction between decay types (gray mold, blue mold bull's eye rot, and Alternaria rot) and year in the air-stored fruit. The mean total decay incidence for 1996 was 44.57%, which was significantly higher than that of 1997 (17.7%) ($\text{LSD}_{0.05} = 8.76$). Incidence of gray mold, blue mold, bull's eye rot, Alternaria rot, Mucor rot, and Coprinus rot detected in the 1996 and 1997 crops are presented in Table 1. The incidence of bull's eye rot was significantly higher than that of all other decay types for 1996. Similar incidences of gray and blue mold in both years and bull's eye rot in 1997 were observed. *M. piriformis*, *Alternaria* spp., and *Coprinus* spp. were

responsible for low levels of decay in air-stored fruit.

There was no year-decay type interaction in the data presented in Table 2; consequently, data for these 2 years were combined (Table 2). Incidence of decay caused by stem-end infections by *B. cinerea* was higher than calyx-end or puncture infections (Table 2). The combined incidences of stem-end, calyx, and puncture gray mold represent the incidence of decay caused by primary *B. cinerea* infections (Table 3). Secondary spread of decay from primary *B. cinerea* infections to previously uninfected fruit was recorded as secondary gray mold (Table 3). There was a significant interaction between both primary and secondary gray mold and year; conse-

Table 2. Incidence of stem, calyx, and puncture gray mold in air-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Stem-end gray mold	Calyx-end gray mold	Puncture gray mold
1	4.09	0.31	0.92
2	3.96	1.74	1.19
3	4.84	0.77	0.56
4	4.40	1.15	1.18
5	1.28	0.17	0.47
6	1.66	1.33	0.73
7	1.87	0.70	0.35
8	3.37	1.42	0.77
9	0.88	0.14	0.00
10	2.22	0.40	0.55
11	1.66	0.35	0.15
12	1.48	0.38	0.35
13	2.91	0.32	0.97
14	1.45	1.03	0.25
Mean ^y	2.58 a	0.73 b	0.61 b
$\text{LSD}_{0.05}^z$	0.419	...	...

^x Incidence of decay detected in 10 boxes of d'Anjou pear fruit after 8 months in regular air storage at -1°C , followed by a ripening period of 1 week at 20°C . Data shown as percentage of total fruit evaluated.

^y For mean gray mold incidence, values followed by the same letter are not significantly different at $P = 0.05$.

^z LSD = least significant difference.

Table 1. Incidence of postharvest decay in air-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Gray mold		Blue mold		Bull's eye rot		Alternaria rot		Mucor rot		Coprinus rot
	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997	1997
1	14.57	8.56	0.31	0.5	39.85	11.11	0.19	0	0	0	0
2	25.46	5.77	0.12	2.35	21.59	16.27	0.62	0	0	0.1	0
3	12.84	15.38	0.19	3.35	36.2	6.75	0.13	0	0	0	0.1
4	16.95	12.16	0	1.6	17.37	14.28	0	0	0	0	0.2
5	5.7	0.98	5.37	4.96	18.58	3.82	0.42	0.26	0.25	0	0
6	11.04	3.77	5.74	4.53	13.05	0.72	0.39	0	0	0	0
7	5.65	2.54	0.94	11.28	80.06	2.67	0	0.27	0.07	0	0
8	15.03	3.84	2.58	5.02	37.84	15.56	0.31	0.11	0	0	0.13
9	1.59	1.45	1.96	3.36	29.36	1.53	0.91	0	0	0	0
10	6.53	3.22	1.41	2.84	38.71	7.76	1.13	0.14	0	0	0
11	6.25	1.22	3.76	3.99	18.06	1.86	0.11	0.16	0	0	0
12	4.17	2.56	1.41	7	35.98	3.27	1.15	0	0	0	0
13	9.74	7.43	2.1	3.21	32.29	7.23	0.56	0.15	0	0	0
14	6.92	3.99	8.22	16.51	20.26	9.53	0.94	0.28	0	0	0
Mean ^y	10.17 b	5.21 bcd	2.44 cd	5.04 bcd	31.37 a	7.31 bc	0.49 d	0.1 d	0.02	0.01	0.03
$\text{LSD}_{0.05}^z$	5.29	...	...	...	...	...	...	...	...	...	...

^x Incidence of decay detected in 10 boxes of d'Anjou pear fruit after 8 months in regular air storage at -1°C , followed by a ripening period of 1 week at 20°C . Data shown as percentage of total fruit evaluated.

^y For mean gray mold, blue mold, bull's eye rot, and Alternaria rot incidence, values followed by the same letter are not significantly different at $P = 0.05$. For Mucor and Coprinus rot, there were insufficient data points for statistical analysis of the data.

^z LSD = least significant difference.

quently, the data for the 2 years were analyzed separately. Incidence of primary *B. cinerea* was significantly higher in 1996 than 1997. Primary and secondary gray mold incidence were similar in both years (Table 3). Secondary *B. cinerea* infections caused high levels of decay in both years.

Decay incidence in nondrenched and thiabendazole-drenched fruit. There was no year-decay type interaction in the data collected from this experiment; consequently, data for the 2 years were combined. In nondrenched CA-stored fruit, the incidence of gray mold was significantly higher than all other postharvest decay types (Table 4). There was no significant difference in incidence of blue mold, *Mucor* rot, bull's-eye rot, or decay caused by other minor pathogens in nondrenched CA-stored fruit. Analysis of the incidence of stem, calyx, and puncture gray mold in

nondrenched and drenched fruit revealed a significant treatment (nondrench and drench) effect at the 10% level; consequently, the *t* test was adapted to test for significant differences at $P = 0.1$ for these data (Table 5). In nondrenched fruit, puncture gray mold incidence was significantly higher than stem-end gray mold, and calyx-end gray mold incidence was significantly lower than stem-end gray mold (Table 5). Incidence of primary gray mold was significantly higher than secondary gray mold in nondrenched fruit (Table 6).

A thiabendazole drench prior to storage significantly reduced the incidence of gray mold but had no effect on the incidence of blue mold, *Mucor* rot, bull's eye rot, or other minor decay types caused by *Alternaria* spp. and *Cladosporium* spp. (Table 4). The thiabendazole drench significantly ($P = 0.1$) reduced the incidence of primary

gray mold infections of stem ends and punctures, but had no effect on incidence of calyx-end gray mold (Table 5) or secondary gray mold (Table 6). The mean total decay incidence in nondrenched (3.20%) and drenched (1.77%) fruit was not significantly different ($LSD_{0.05} = 1.47$).

DISCUSSION

We have shown that decay can cause significant postharvest losses in air-stored d'Anjou pear fruit. Postharvest decay may be caused by infection in the orchard (17,23,31), and infections as early as 4 months before harvest cause significant decay in stored d'Anjou pear fruit (31). Postharvest pathogens do not need a wound to infect; however, incidence of decay is higher in wounded pear fruit (31).

In air-stored fruit, gray mold, caused by *B. cinerea*, and blue mold, caused by *P. expansum*, were observed at similar levels of incidence. Incidence of stem-end gray mold was higher than calyx-end and puncture gray mold. The short fleshy stems of d'Anjou pear fruit are particularly susceptible to infection by *B. cinerea*. The abscission zone of d'Anjou pear stems functions as a wound in this cultivar and provides an ideal infection site for both *B. cinerea* and *P. expansum* (31). Secondary infection of fruit from primary *B. cinerea* infections of stems, calyxes, or puncture wounds resulted in nests of decaying fruit. These secondary infections resulted in high levels of decay in air-stored fruit. Recently, *Phacidiopycnis piri* has been isolated from about 15% of pear fruit with symptoms similar to gray mold, and additional research is necessary to determine the incidence of this fungus in the Mid-Columbia region of Oregon and Washington (C. Xiao, unpublished data).

The incidence of decay in CA-stored nondrenched d'Anjou pear fruit was low. Nondrenched fruit had significant levels of *B. cinerea* infections at punctures. Thus, wounds resulting from handling of the fruit

Table 3. Incidence of primary and secondary gray mold in air-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Primary		Secondary	
	1996	1997	1996	1997
1	7.17	3.49	7.41	5.06
2	10.72	3.06	14.73	2.7
3	6.78	6.56	6.06	8.82
4	7.98	5.5	8.97	6.66
5	3.02	0.84	2.68	0.13
6	6.01	1.42	5.03	2.34
7	4.25	1.6	1.4	0.93
8	7.86	3.26	7.17	0.57
9	1.15	0.88	0.44	0.56
10	3.87	2.47	2.66	0.75
11	3.59	0.74	2.66	0.48
12	3.16	1.28	1	1.27
13	4.11	4.59	5.64	2.84
14	3.64	1.83	3.28	2.15
Mean ^y	5.24 a	2.68 b	4.91 a	2.52 b
$LSD_{0.05}^z$	1.357	...	...	...

^x Incidence of decay detected in 10 boxes of d'Anjou pear fruit after 8 months in regular air storage at -1°C , followed by a ripening period of 1 week at 20°C . Data shown as percentage of total fruit evaluated.

^y For mean gray mold incidence, values followed by the same letter are not significantly different at $P = 0.05$.

^z LSD = least significant difference.

Table 4. Incidence of postharvest decay in nondrenched and thiabendazole-drenched controlled-atmosphere (CA)-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Gray mold		Blue mold		Mucor rot		Bull's eye rot		Other decay	
	Nondrenched	Drenched	Nondrenched	Drenched	Nondrenched	Drenched	Nondrenched	Drenched	Nondrenched	Drenched
1	6.21	2.41	0.05	0.29	0.014	0.03	0.29	0.35	0.08	0.13
3	0.00	1.47	...	0.46	...	0.05	...	0.12	...	0.05
5	2.55	0.59	0.09	0.58	0.03	0.04	1.07	0.11	0.01	0.09
6	2.45	1.18	0.18	0.58	0.18	0.05	0.03	0.02	...	0.03
7	1.37	1.16	0.11	1.21	0.02	0.05	0.37	0.46	0.05	0.06
8	5.49	0.69	0.16	0.52	0.31	0.01	1.96	0.1	0.05	0.02
9	1.17	0.32	0.17	0.15	0.02	0.001	0.55	0.06	0.04	0.03
11	1.65	1.69	0.1	0.36	0.012	0.02	0.17	0.11	0.05	0.03
12	2.05	0.46	0.22	0.42	0.03	...	...	0.13	0.25	0.21
13	1.68	1.14	0.1	0.22	0.03	0.005	0.41	0.13	0.05	0.04
14	1.05	0.28	0.13	0.7	0.07	0	0.04	0.05	0.18	0.05
15	1.41	...	0.13	...	0.03	...	0.22	...	0.04	...
Mean ^y	2.26 a	1.04 b	0.13 c	0.50 bc	0.07 c	0.03 c	0.51 bc	0.15 c	0.08 c	0.07 c
$LSD_{0.05}^z$	0.5672	...	...	...	...	...	...	...	...	...

^x Incidence of decay detected in pear fruit after CA storage in a commercial packinghouse. Data shown as percentage of total fruit evaluated.

^y For mean decay incidence, values followed by the same letter are not significantly different at $P = 0.05$.

^z LSD = least significant difference.

at harvest and during storage are important sites of infection by *B. cinerea*, particularly in nondrenched fruit. Spotts et al. (36) found that 3% of d'Anjou pear fruit were wounded during harvest. Although wounds undergo a healing process in storage, they remain susceptible to infection by *M. piriformis*, *Penicillium expansum*, and *B. cinerea* at -1°C for 2, 4 and 8 weeks, respectively (36). Primary infection of fruit wounds (puncture gray mold) and stem ends (stem-end gray mold) by *B. cinerea* caused the highest incidences of decay in nondrenched CA-stored fruit. Incidence of stem-end decay caused by *B. cinerea* was low in CA-stored fruit, supporting the results of Chen et al. (11), who found less stem end decay caused by fungi in d'Anjou pear fruit stored at -1.1°C in low O₂ (1% O₂ + 0.05% CO₂) than in fruit stored in air. We observed a low incidence of calyx-end gray mold in CA-stored fruit. The increase in blue mold of cv. Bosc pear fruit in stepwise oxygen storage (12) was not seen in d'Anjou pear fruit here. Incidence of bull's-eye rot caused by *Neofabraea* spp. was low in CA-stored nondrenched fruit. CA storage, including ultralow-oxygen conditions, has been shown to reduce decay caused by *Neofabraea* spp. (11,15,17).

The application of a prestorage thiabendazole drench significantly reduced the incidence of gray mold; however, it had no effect on the incidence of all other decay types. The mean total decay incidence in nondrenched and drenched fruit was not significantly different. The effect on gray mold was brought about by the significant reduction in stem-end and puncture gray mold. The drench had no effect on calyx-end gray mold or secondary gray mold. These findings support those of previous studies showing that good control of *B. cinerea* can be achieved through a single postharvest application of a benzimidazole to pear fruit in the packinghouse (2,3,9,16). Benzimidazoles are effective

protectants (2,27) and eradicants (2) of postharvest decay in pome fruit. In a recent study (22), we found a low level of thiabendazole resistance (0.59%) in *B. cinerea* isolates from orchard air samples and from d'Anjou pear fruit not exposed to thiabendazole, indicating that *B. cinerea* populations from pear orchards in the Mid-Columbia region of Oregon and Washington are sensitive to thiabendazole.

A thiabendazole drench had no effect on the incidence of decay caused by *P. expansum* in CA-stored d'Anjou pear fruit. Sanderson and Spotts (28) recovered a number of *Penicillium* spp. from drench solutions from pear packinghouses. During drenching, inoculum of *P. expansum* is washed into fruit wounds sustained during harvest and transport to the packinghouse. Consequently, more wounds are exposed to pathogenic *P. expansum* inoculum in drenched than undrenched fruit. Spotts and Cervantes (32) found that 15 to 31% of

pathogenic *Penicillium* spp. isolates from packinghouse air and dump-tank water were resistant to benomyl. As a result of cross-resistance among the benzimidazole fungicides (14), it is likely that a significant proportion of the drench suspension population of pathogenic *P. expansum* is resistant to thiabendazole. Thus, a combination of increased exposure of wounds to pathogenic *Penicillium* spp. and survival of resistant pathogenic *Penicillium* spp. isolates would explain why thiabendazole-drenched d'Anjou fruit had a similar incidence of decay caused by *P. expansum* than nondrenched fruit.

A major problem associated with drenching of fruit prior to storage is the washing of *M. piriformis* spores from dirt and debris onto clean fruit (7). *M. piriformis* commonly is isolated from pear orchard soil (25,32,33) and from packinghouse dump-tank water (25). *M. piriformis* is insensitive to both captan and thiabenda-

Table 6. Incidence of primary and secondary gray mold in nondrenched and thiabendazole-drenched controlled-atmosphere (CA)-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Primary		Secondary	
	Nondrenched	Drenched	Nondrenched	Drenched
1	5.58	1.81	0.63	0.6
3	...	1.35	...	0.12
5	2.48	0.56	0.07	0.03
6	2.24	1.08	0.21	0.1
7	1.24	1.08	0.13	0.08
8	5.33	0.66	0.16	0.03
9	1.11	0.31	0.06	0.008
11	1.63	1.59	0.02	0.1
12	2.05	0.46	...	...
13	1.54	1.12	0.14	0.02
14	1.03	0.28	0.02	...
15	1.41	...	...	...
Mean ^y	2.33 a	0.94 b	0.16 c	0.12 c
LSD _{0.05} ^z	0.75	...	...	...

^x Incidence of decay detected in pear fruit after CA storage in a commercial packinghouse. Data shown as percentage of total fruit evaluated.

^y for mean gray mold incidence, values followed by the same letter are not significantly different at *P* = 0.05.

^z LSD = least significant difference.

Table 5. Incidence of stem, calyx, and puncture gray mold in nondrenched and thiabendazole-drenched controlled-atmosphere (CA)-stored 'd'Anjou' pear fruit from orchards in the Mid-Columbia region of Oregon and Washington for the 1996 and 1997 crops^x

Orchard	Stem-end gray mold		Calyx-end gray mold		Puncture gray mold	
	Nondrenched	Drenched	Nondrenched	Drenched	Nondrenched	Drenched
1	2.45	0.63	0.91	0.55	2.21	0.64
3	...	0.51	...	0.23	...	0.31
5	1.04	0.14	0.26	0.06	1.18	0.35
6	0.94	0.39	0.32	0.14	0.97	0.55
7	0.34	0.23	0.14	0.11	0.75	0.73
8	1.37	0.19	1.03	0.21	2.92	0.24
9	0.49	0.05	0.15	0.08	0.48	0.17
11	0.91	0.86	0.14	0.13	0.57	0.6
12	0.19	0.08	0.03	0.08	1.82	0.29
13	0.82	0.62	0.31	0.12	0.41	0.38
14	0.19	0.08	0.32	0.11	0.52	0.09
15	0.46	...	0.32	...	0.64	...
Mean ^y	0.84 b	0.34 c	0.36 c	0.17 c	1.13 a	0.40 c
LSD _{0.05} ^z	0.283	...	...	...	...	...

^x Incidence of decay detected in pear fruit after CA storage in a commercial packinghouse. Data shown as percentage of total fruit evaluated.

^y For mean gray mold incidence, values followed by the same letter are not significantly different at *P* = 0.1.

^z LSD = least significant difference.

zole (1,8,9,26) and no fungicidal control for *M. piriformis* has been found (34). For this reason, the majority of packers apply thiabendazole as a line spray (19,20). Very low levels of decay caused by *M. piriformis* were detected in both air-stored and CA-stored fruit. A thiabendazole drench did not significantly reduce the incidence of Mucor rot in CA-stored fruit, reflecting the insensitivity of *M. piriformis* to this fungicide (9,26). The incidence of Mucor rot detected in culled fruit from CA storage, for both undrenched and drenched fruit, may be artificially low because this rot can cause severe disintegration of the fruit. A significant proportion of fruit with Mucor rot is removed and discarded as the fruit floats out of the storage bins (presort) after immersion dumping and does not appear on the cull line where the culled fruit inspected.

These results support the current recommendations of a single postharvest application of thiabendazole to control postharvest gray mold in d'Anjou pear fruit. These recommendations are in compliance with the recognized method for reducing the selection pressure on an at-risk fungicide by restricting its use to one or two critical periods (41). However, packers need to be aware of the potential risk of increased decay caused by *Penicillium* spp. in drenched pear fruit. This risk would be considerably reduced by the application of fungicide in a line spray.

Recent research has indicated the need for a more integrated approach to the control of postharvest decay in pear fruit (37), including use of preharvest strategies (23,38). Combination of yeast biological control agents with low dosages of thiabendazole has been shown to effectively control decay caused by *B. cinerea*, *P. expansum*, *M. piriformis*, and *Neofabraea* spp. in d'Anjou pear (9,10,39). Inclusion of biological control in this integrated approach to decay control would reduce the selection pressure from thiabendazole and, possibly, provide better control of blue mold in areas where incidence of resistance in the *P. expansum* population is high.

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