Effect of a Surfactant on Control of Decay of Anjou Pear with Several Fungicides

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ABSTRACT

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Wounded pear fruits (cultivar Anjou) were immersed for 5 min in 0.35% sodium ortho phenylphenate tetrahydrate (SOPP), 0.35% SOPP plus 0.5% Ortho X-77, or water at 2, 10, and 20 C. Each solution contained 1, 2, or 10×10^3 conidia per milliliter of *Penicillium expansum, Botrytis cinerea,* or *Mucor piriformis,* respectively. SOPP reduced decay caused by *B. cinerea* but not that caused by *M. piriformis* or *P. expansum*. Addition of Ortho X-77 to SOPP increased decay caused by all fungi. Solution temperature did not affect decay. Addition of Ortho X-77 to captan or iprodione increased decay caused by *P. expansum*, and addition of Ortho X-77 to captan or etaconazole increased decay caused by *B. cinerea*. Addition of Ortho X-77 to captan also increased decay caused by *M. piriformis*. In two packinghouses, treatment of wound-inoculated pear fruit with a commercial detergent containing SOPP before inoculation resulted in increased incidence of decay. Addition of Ortho X-77 at 0.1, 0.3, and 0.5% a.i. to 1,500 ppm a.i. of captan increased the incidence of decay and decreased captan residue on the fruit as measured with bioassay. Addition of Ortho X-77 to benomyl also reduced fungicide residue on the fruit. SOPP treatments did not reduce fungal spore germination and appeared to stimulate germ tube growth of *M. piriformis*.

Control of postharvest decay in pears is of prime importance to packinghouses in the Pacific Northwest. Generally, decay becomes more severe as time in storage increases, and normal control procedures may not be sufficient for long-term storage. Pears (*Pyrus communis* L. 'Anjou') are commonly held at −1.1 C in controlled-atmosphere storage for more than 7 mo (3), and storage life has been extended even longer with low-oxygen atmospheres (1).

Fungicides registered for postharvest decay control of pears are few and include only benomyl, thiabendazole, captan, sodium ortho phenylphenate tetrahydrate (SOPP), and chlorine (4). In a previous study (7), addition of surfactants to chlorine significantly improved penetration of chlorine into wounds of pears and reduced decay. The effects of surfactants on other registered and experimental fungicides for postharvest decay control of pears have not been studied.

The objectives of this study were to evaluate the effects of addition of the surfactant Ortho X-77 on fungicidal control of pear decay, evaluate a commercial detergent containing SOPP under packinghouse conditions, and determine the effects of Ortho X-77 on fungicide residues on fruit surfaces. An abstract of this work has been published (5).

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MATERIALS AND METHODS

Effects of Ortho X-77 on decay control with several fungicides. *Botrytis cinerea* Pers. ex. Fr., *Mucor piriformis* Fischer, and *Penicillium expansum* Lk. ex. Thom were grown on acidified potato-dextrose agar (APDA) (Difco) as described previously (6). Conidia were harvested after about 2 wk and the suspensions adjusted to 1, 2, and 10×10^3 conidia per milliliter of the fungicide solution described for *P. expansum, B. cinerea,* and *M. piriformis,* respectively.

Pear fruits (cultivar Anjou) were surface-sterilized in 0.525% NaOCl, rinsed, and puncture-wounded (3 mm diameter, 4 mm deep) with the head of a finishing nail at five locations per fruit. Wounded fruits were immersed for 5 min at 2, 10, or 20 ± 2 C in 0.35 ± 0.03% SOPP, 0.35% SOPP plus 0.5% a.i. of Ortho X-77, or water. The SOPP concentrations were determined by sodium thiosulfate titration. Ten fruits were treated with each fungus-fungicide-temperature combination, and the experiment was done twice. Fruits were held in polyethylene-lined boxes at 20 C and evaluated after 4–6 days for decay incidence of each wound.

The efficacy of postinoculation fungicide treatments in controlling pear decay was tested using captan (Orthocide 50WP), etaconazole (Vangard 10WP), and iprodione (Rovral 50WP). Wounded fruits, 10 per treatment, were immersed for 5 min in a water suspension of conidia of *P. expansum, B. cinerea,* or *M. piriformis* prepared at the concentrations shown previously. After air-drying (about 50 min), inoculated fruits were immersed for 5 min at 10 C in one of three fungicide mixtures prepared with or without 0.5% a.i. of the surfactant Ortho X-77. Captan, etaconazole, and iprodione were prepared as suspensions at concentrations of 1,500, 90, and 300 ppm a.i., respectively, according to manufacturers' recommendations. Fruits were evaluated for decay incidence after 6 days at 20 C.

Evaluation of a SOPP detergent in packinghouses. A commercial fruit detergent containing SOPP (formulation unavailable, Shield-Brite Corp., Kirkland, WA), in use at two packinghouses, was evaluted for control of decay caused by *M. piriformis* and *P. expansum*. Wounded pear fruits (cultivar Bosc) were inoculated by immersion in 2×10^3 or 1.5×10^4 conidia per milliliter of *P. expansum* or *M. piriformis*, respectively, for 5 min at 8 C. Inoculated fruits were divided into three groups. The first group was given no additional treatment. The second group was placed on the packinghouse line and subjected to the SOPP detergent spray followed by a fresh water spray-rinse. The third group received only the fresh water rinse. A fourth group of uninoculated fruits was treated on the line with SOPP detergent and rinsed, then inoculated. Twenty fruits were included in each group, and the experiment was done twice in one packinghouse and once in another. The SOPP concentration in the detergent solution was 0.09 ± 0.02%, and fruits were exposed for 10–20 sec. After treatment, fruits were held at 20 C in polyethylene-lined boxes and evaluated for decay incidence after 5–7 days.

Effects of several Ortho X-77 concentrations in captan on decay control. Pear fruits (cultivar Anjou) were surface-sterilized, rinsed, and wounded as described previously. Fruits were immersed for 3 min in solutions of 1,500 ppm a.i. of captan with 0, 0.1, 0.3, and 0.5% a.i. of Ortho X-77. Fruits were air-dried, then inoculated with 1-wk-old cultures of *P. expansum, B. cinerea,* or *M. piriformis* by pipetting 1, 2, and 10×10^3 conidia per milliliter, respectively, into the wounds, using 0.028 ml per wound. Decay of inoculated fruit was evaluated after 6 days as described previously. Ten fruits were treated with each Ortho X-77 concentration, and the

experiment was repeated twice.

Bioassay of fungicides. Five days after captan plus Ortho X-77 treatments were applied, 6-mm-diameter disks (four per fruit) were removed from the peels of six fruits per treatment and placed surface-down on 10-cm-diameter petri plates containing 15 ml of PDA. After 24 hr, a suspension of conidia (5×10^4/ml) of *P. expansum* was atomized on the agar surface. After 3 days at 20 C, inhibition zones around each disk were measured. Bioassays also were done with this method on fruit immersed for 5 min in solutions at 15 C of benomyl (Benlate 50WP), captan, and etaconazole at 300, 1,500, and 90 ppm a.i., respectively, alone or containing 0.5% a.i. of Ortho X-77. The pH of each fungicide solution was measured.

Effects of SOPP on conidial germination. Conidia of *B. cinerea, M. piriformis,* and *P. expansum* were added to solutions of 0.35% SOPP, 0.35% SOPP plus 0.5% a.i. of Ortho X-77, and water to achieve a final concentration of 5×10^4 conidia per milliliter. After 5 min, conidia were removed by filtration through a Millipore filter, rinsed, and placed on APDA as described previously (6). The percentage of germination of 100 conidia per treatment was determined after 18 hr at 20 C.

RESULTS

SOPP significantly ($P = 0.05$) reduced the incidence of pear decay caused by *B. cinerea* but not that caused by *M. piriformis* or *P. expansum* (Table 1). Addition of Ortho X-77 to SOPP significantly ($P = 0.05$) increased the incidence of decay caused by *B. cinerea* and *P. expansum* and increased the pH from 10.6 to 11.0. Temperatures of the solutions did not affect decay control, and temperature treatments were combined for statistical analysis of decay incidence.

Addition of Ortho X-77 to captan or iprodione significantly ($P = 0.05$) increased decay caused by *P. expansum*, and addition of Ortho X-77 to captan or etaconazole increased decay caused by *B. cinerea*. Addition of Ortho X-77 to captan also increased decay caused by *M. piriformis* (Table 2).

In two packinghouses, decay caused by *P. expansum* was reduced when inoculated fruits were treated with SOPP detergent followed by a water rinse (Table 3). However, using SOPP detergent preceding the rinse did not significantly ($P = 0.05$) reduce decay compared with rinsing only. Preinoculation treatment of wounded fruits with SOPP detergent resulted in increased decay caused by *P. expansum* compared with postinoculation treatment. SOPP detergent applied either before or after inoculation did not provide significant ($P = 0.05$) control of *M. piriformis* (Table 3).

When several concentrations of Ortho X-77 in 1,500 ppm a.i. of captan were evaluated, no significant differences ($P = 0.05$) in decay caused by *B. cinerea* or *P. expansum* were observed with 0.1, 0.3, and 0.5% a.i. of Ortho X-77 (Table 4), but addition of any of these Ortho X-77 concentrations to captan resulted in increased decay and decreased captan residue on the fruit surface as measured with bioassay (Table 4). In a second bioassay experiment, addition of 0.5% a.i. of Ortho X-77 to captan or benomyl reduced fungicide residue on the fruit (Table 5). Etaconazole residue could not be determined with this bioassay procedure. Addition of Ortho X-77 appeared to lower the pH of both fungicides slightly (Table 5).

Germination of conidia of *B. cinerea, M. piriformis,* and *P. expansum* exposed to SOPP or SOPP plus Ortho X-77 for 5 min ranged from 90 to 100% and was not different from water alone. Germ tube growth of conidia of *M. piriformis* treated with SOPP plus Ortho X-77 appeared greater than with other treatments.

DISCUSSION

Although addition of several surfactants, including Ortho X-77, to chlorine have reduced decay of pear cultivar Anjou (7), addition of Ortho X-77 to SOPP, captan, iprodione, and etaconazole resulted in increased decay. This effect was consistent using several fungi and various inoculation techniques.

The commercial SOPP detergent evaluated in this report is used in packinghouses either at the end of the packing line or before fruit reenters water, where it may be reexposed to fungal spores. In this study, use of SOPP detergent before inoculation resulted in

Table 1. Effects of Ortho X-77 on decay control of Anjou pear with SOPP

Treatment[x]	Percent decay[y] caused by		
	Botrytis cinerea	*Mucor piriformis*	*Penicillium expansum*
SOPP	5 a[z]	49 a	21 a
SOPP + Ortho X-77	55 b	65 a	50 b
Water	50 b	38 a	27 a

[x] Fruits immersed for 5 min in solutions containing 1, 2, or 10×10^3 conidia per milliliter of *P. expansum, B. cinerea*, and *M. piriformis*, respectively (SOPP at 0.35% and Ortho X-77 at 0.5% a.i.).
[y] Each value represents the average of 60 fruits, each wounded five times. Decay was evaluated after 4–6 days at 20 C.
[z] Numbers followed by the same letter within columns are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

Table 2. Effects of Ortho X-77 on decay control of Anjou pear with several fungicides

Treatment[x]	Percent decay[y] caused by		
	Botrytis cinerea	*Mucor piriformis*	*Penicillium expansum*
Iprodione	0 a[z]	68 a	2 a
Iprodione + Ortho X-77	10 a	94 a	62 b
Etaconazole	6 a	92 a	0 a
Etaconazole + Ortho X-77	100 b	100 a	0 a
Captan	28 a	54 a	24 a
Captan + Ortho X-77	50 b	96 b	52 b

[x] Fruits immersed for 5 min in solutions containing 1, 2, or 10×10^3 conidia per milliliter of *P. expansum, B. cinerea,* and *M. piriformis*, respectively, and dried, then immersed for 5 min in captan, etaconazole, or iprodione at 1,500, 90, and 300 ppm a.i., respectively.
[y] Each value represents the average of 10 fruits, each wounded five times. Decay was evaluated after 6 days at 20 C.
[z] For each fungicide, numbers followed by the same letter within columns are not significantly different ($P = 0.05$, t test).

Table 3. Effects of SOPP detergent on decay control of Bosc pear fruit in packinghouses

Treatment sequence[x]	Percent decay[y] caused by	
	Mucor piriformis	*Penicillium expansum*
Inoculated	51 a[z]	63 bc
Inoculated, SOPP, rinsed	40 a	14 a
Inoculated, rinsed	35 a	21 ab
SOPP, rinsed, inoculated	66 a	81 c

[x] Wounded fruits immersed for 5 min in solutions containing 2.0×10^3 or 1.5×10^4 conidia per milliliter of *P. expansum* and *M. piriformis*, respectively. SOPP was in commercial detergent formulation at 0.09 ± 0.02%, and fruits were exposed for 10–20 sec.
[y] Each value represents the average of 60 fruits, each wounded five times. Decay was evaluated after 5–7 days at 20 C.
[z] Numbers followed by the same letter within columns are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

Table 4. Effects of several Ortho X-77 concentrations in captan on decay control of Anjou pear fruit and captan residues on the fruit surface

Ortho X-77 concentration in captan[w] (% a.i.)	Percent decay[x] caused by		Inhibition zone[y] (mm diameter)
	Botrytis cinerea	*Penicillium expansum*	
0.0	42 a[z]	46 a	20.4 a
0.1	87 b	92 b	8.5 c
0.3	87 b	92 b	7.8 c
0.5	71 b	87 b	13.6 b

[w] Fruits immersed for 3 min in solutions containing 1,500 ppm a.i. of captan combined with the selected Ortho X-77 level and dried, then *P. expansum, B. cinerea,* or *M. piriformis* at 1, 2, and 10 $\times 10^3$ conidia per milliliter was pipetted into wounds.

[x] Each value represents the average of 30 fruits, each wounded five times. Decay was evaluated after 6 days at 20 C.

[y] Each value represents the mean of six fruits, four disks per fruit.

[z] Numbers followed by the same letter within columns are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

Table 5. Effects of Ortho X-77 on fungicide residues on Anjou pear fruit and pH of fungicide solutions

Treatment[x]	Inhibition zone[y] (mm diameter)	pH
Benomyl	3.9 a[z]	5.2
Benomyl + Ortho X-77	0.5 b	5.1
Captan	4.2 a	8.3
Captan + Ortho X-77	0.5 b	7.4

[x] Fruits immersed for 5 min in solutions containing 300 and 1,500 ppm a.i. of benomyl or captan, respectively, alone or combined with 0.5% a.i. of Ortho X-77.

[y] Each value represents the average of six fruits, four disks per fruit.

[z] For each fungicide, numbers followed by the same letter within columns are not significantly different ($P = 0.05$, t test).

maximum decay. This effect on decay was similar to that obtained when Ortho X-77 was added to SOPP.

Increased decay occurred with Ortho X-77 concentrations ranging from 0.1 to 0.5% a.i. At all Ortho X-77 concentrations, captan residue on the fruit was significantly ($P = 0.05$) less than when captan alone was used. A similar effect of reduced fungicide residue on fruit also was measured when Ortho X-77 was added to benomyl. It appeared that concentration of wetting agent in the fungicide formulations was at an optimum, and additional surfactant lowered fungicide retention.

Addition of Ortho X-77 increased the pH of SOPP solution from 10.6 to 11.0 and decreased the pH of captan from 8.3 to 7.4. Eckert and Sommer (2) pointed out that increasing the pH of SOPP solutions would lower the concentration of undissociated phenol and reduce phytotoxicity. However, the effectiveness of SOPP for control of decay is improved only slightly by a pH change that doubles the *o*-phenylphenol concentration. Although hydrolysis of captan is pH-dependent above 7.0, captan half-life increases as pH decreases toward 7.0 (8). Thus, the small pH changes resulting from addition of Ortho X-77 to fungicides in this study appear unlikely to account for the observed increase in decay.

Whereas 50 μg/ml of chlorine was lethal to conidia of *B. cinerea, M. piriformis,* and *P. expansum* after as little as 0.5 min of exposure (6), SOPP treatment did not affect conidial germination. The fungistatic rather than fungicidal nature of SOPP, and perhaps the other fungicides tested in this study, may explain the reduced decay control when fungicide residues were reduced as a result of addition of Ortho X-77.

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