BENLATE, AN EXPERIMENTAL POSTHARVEST CITRUS FUNGICIDE

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Abstract

Benlate (DuPont 1991) has provided outstanding control of postharvest decay of fresh citrus fruit. Nearly complete control of green mold and stem-end rot has been obtained. Benlate is an experimental fungicide which has been under study at the Florida Citrus Experiment Station for 2 years. Decay control with Benlate has been better than that obtained with sodium o-phenylphenate (Dowicide A), diphenyl pads in ventilated cartons, or a combination of these 2 fungicides. Benlate decay control has been equal to and, in some instances, superior to decay control with Mertect 260 (thiabendazole), a newly approved fungicide for postharvest use on citrus fruit. Benlate, although essentially insoluble in water, controlled decay when fruit were dipped in an aqueous suspension of this fungicide. An in-and-out dip which completely wet the fruit controlled decay as effectively as longer dip treatments. Benlate has very little odor and is nonirritating to the eyes or skin.

Introduction and Literature Review

Decay losses result in a competitive disadvantage for Florida citrus fruit, both in the domestic and world markets. Specialty citrus fruits such as 'Temples' and 'Dancy' tangerines and fruit which have been degreened with ethylene are commonly more subject to postharvest decay than properly handled, nondegreened oranges and grapefruit. Better fungicides are needed to improve the keeping quality of Florida citrus fruit.

Most decay of Florida citrus fruit is caused by 4 fungi: *Diplodia natalensis* P. Evans and *Phomopsis citri* Faw. which cause stem-end rot; *Penicillium digitatum* Saac., green mold and *Geotrichum candidum* Ferr., sour rot. The latter fungus most frequently causes decay of 'Dancy' tangerines, 'Ponkans' and 'Temples.'

Experiments with Benlate have been in progress at the Florida Citrus Experiment Station for the past 2 years. Chemically, Benlate is methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (1). This fungicide was first distributed for experimental work as Fungicide 1991. Brown (2) reported that Benlate sprayed on citrus trees one week or longer before harvest effectively controlled postharvest decay. Harding (3) found that a wax emulsion containing Benlate reduced mold decay in inoculated fruit of several citrus cultivars. Gutter (4, 5), in Israel, found Benlate to be superior to other fungicides tested for postharvest green mold control of artificially inoculated 'Shamouti and "Valencia oranges and 'Eureka' lemons.

Experimental Methods

Commercial procedures were followed as closely as possible. Concentration of Benlate and duration of treatment were varied. Benlate was compared with the Food and Drug Administration-approved postharvest citrus fungicides Mertect 260 (thiabendazole or TBZ), Dowicide A (sodium o-phenylphenate) and diphenyl (biphenyl).

Most of the fruit used in this experimental work were obtained from the Citrus Experiment Station groves, but commercially grown fruit were used when comparable fruit were not available from the Experiment Station. Fruit for all experiments were distributed at random into the desired number of lots for each experiment. Culls and off-grade fruit were removed before packing. Lot size was usually 80 to 100 fruit but varied from 35 for 'Marsh' grapefruit to 125 fruit for 'Dancy' tangerines. Fruit size determined the number of fruit per lot in most instances. Over 16,000 fruit in 84 experiments were treated with Benlate.

Benlate is essentially insoluble in water. Fruit were dipped in aqueous suspensions of 500 and 1,000 ppm of active material. Treating time varied from an in-and-out dip that completely wet the fruit to a 2-minute dip. Fruit were not rinsed following treatment. Mertect

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260 was applied in the same manner (7). Dowicide A and diphenyl were applied using commercial practices (6). All fungicidal treatments were applied at the ambient temperature of the laboratory which was usually between 70° and 80°F.

Fruit were washed before fungicidal treatments except when the fungicide was applied before and again after degreening, the fruit were washed before the second treatment. All lots were dried and polished on horsehair brushes and waxed with nonfungicidal Flavorseal, then packed in 4/5-bushel, ventilated, telescope-type, fiberboard cartons and held at 70°F except in cold-storage experiments where the holding temperature was 40°F. Fruit in 5 experiments were punctured by rolling each fruit over 21 wire nail points protruding 1/16 to 3/16 inch through a board.

Benlate was tested on 'Hamlin,' 'Pineapple,' 'Valencia' and navel (variety unknown) oranges; 'Marsh' and 'Ruby Red' grapefruit; 'Robinson' and 'Dancy' tangerines; 'Bearss' lemons; 'Ponkans;' 'Murcotts;' 'Temples' and 'K-Early' tangelos. Experiments were usually repeated 4 times. Decay classified as stem-end rot, mold or miscellaneous was recorded at 1, 2, 3 and, in most instances, 4 weeks from the picking date. Percentage decay for the comparable lots was averaged to obtain figures used in this paper. All fruit were examined for evidence of peel injury.

Results and Discussion

All data cannot be reported in this paper, but enough will be presented to show the decay control that can be expected with Benlate.

'Hamlin' oranges.—Decay of degreened 'Hamlin' oranges was almost completely controlled by Benlate (Table 1). Benlate applied before and after degreening eliminated decay in fruit during 4 weeks of storage in 4 comparable experiments. A 2-minute dip in 1,000 ppm Benlate after degreening was a little more effective than an in-and-out dip in the same suspension. Dowicide A-hexamine did not control decay. Mertect 260 was slightly less effective than Benlate.

Benlate applied to nondegreened 'Hamlins' also gave excellent control of decay.

'Dancy tangerines.—Benlate applied before and after degreening reduced decay at 3 weeks from picking from 22.1% to 2.6% (Table 2). An in-and-out dip in Benlate after degreening resulted in 69% decay control. Dowicide A-hexamine did not give effective control of decay.

Average decay of nondegreened 'Dancy' tangerines was 17.1% after 3 weeks storage. Benlate applied as an in-and-out dip reduced decay to 4.2% for the same holding period.

'Pineapple' oranges.—Benlate, Mertect 260 and Dowicide A-hexamine effectively controlled decay of nondegreened 'Pineapple' oranges (Table 3). At 3 weeks from picking, fruit treated with Benlate had no decay. After a 4-week holding period, decay control with both Benlate and Mertect 260 was 99%; decay control with Dowicide A-hexamine was 93%.

'Marsh' grapefruit.—Benlate and Mertect 260 were equally effective in controlling decay of nondegreened 'Marsh' grapefruit (Table 4). Decay control with either Benlate or Mertect

Table 1. Decay control of degreened 'Hamlin' oranges with Dowicide A-hexamine, Mertect 260, or Benlate.

Treatment	Avg. % total decay* Weeks after picking** 2	3	4
Check	5.0 b	9.0 b	12.3 b
Dow-hex 2%, 2 min. flood after degreening	2.8 ab	8.0 b	11.3 b
Mertect 260, 1,000 ppm, in & out dip before and after degreening	0.5 a	0.8 a	1.0 a
Mertect 260, 1,000 ppm, 2 min. dip after degreening	0.3 a	0.8 a	0.8 a
Benlate, 1,000 ppm, in & out dip before and after degreening	0 a	0 a	0 a
Benlate, 1,000 ppm, in & out dip after degreening	0.8 a	0.8 a	1.0 a
Benlate, 1,000 ppm, 2 min. dip after degreening	0 a	0.3 a	0.3 a

*Average of 4 experiments held at 70° F.

**Data followed by the same letters do not differ at a probability level of 5%.

Table 2. Comparison of decay control with Dowicide A-hexamine or Benlate applied to degreened 'Dancy' tangerines.

Treatment	Avg. % total decay* Weeks after picking 1	2	3**
Check	5.5 b	17.5 b	25.4 b
Dow-hex 2%, 2 min. flood after degreening	3.2 ab	11.7 ab	23.2 b
Benlate, 1,000 ppm, in & out dip before and after degreening	0.3 a	1.2 a	2.6 a
Benlate, 1,000 ppm, in & out dip after degreening	1.4 a	4.8 a	6.8 a

*Average of 3 experiments held at 70° F.

**Data followed by the same letters do not differ at a probability level of 5%.

Table 3. Comparison of Dowicide A-hexamine, Mertect 260, or Benlate applied to nondegreened 'Pineapple' oranges for control of decay.

	Avg. % total decay*		
	Weeks after picking		
Treatment	2	3	4**
Check	12.3 b	16.8 b	21.5 b
Dow-hex 2%, 2 min. flood	0.8 a	1.0 a	1.5 a
Mertect 260, 1,000 ppm, in & out dip	0 a	0.3 a	0.3 a
Benlate, 1,000 ppm, in & out dip	0 a	0 a	0.3 a

*Average of 4 experiments held at 70° F.

**Data followed by the same letter do not differ at a probability level of 5%.

260 was 90% during a holding period of 4 weeks compared with 70% decay control with Dowicide A-hexamine.

Benlate treatment of cold-storage 'Valencia' oranges. — Nondegreened 'Valencia' oranges, dipped for 2 minutes in 1,000 ppm Benlate, were held for 10 weeks at 40°F plus an additional 6 days under simulated marketing conditions at 70°F. After 10 weks storage, the Benlate-treated fruit had a decay loss of 0.3% compared with 7.5% in the check fruit. After these fruit were held for 6 additional days at 70°F, the check had a loss of 21.9% compared with 4.0% for the Benlate-treated fruit. Dowicide A-hexamine did not control decay as effectively as Benlate (Fig. 1).

Residual activity. — Benlate-treated fruit were found to be very resistant to decay following injury. 'Valencia' oranges were dipped for 2 minutes in a 1,000 ppm Benlate suspension then dried and waxed. The following day, one carton of untreated and a second carton of Benlate-treated fruit were punctured as described in Experimental Methods. Three weeks from picking, the Benlate-treated fruit had a decay loss of 4.0% compared with 71.0% for untreated fruit.

Table 4. Decay of nondegreened 'Marsh' grapefruit treated with Dowicide A-hexamine, Mertect 260 or Benlate.

Treatment	Avg. % total decay* 4 weeks after picking**
Check	7.3 b
Dow-hex 2%, 2 min. flood	2.2 a
Mertect 260, 500 ppm, 1 min. dip	0.7 a
Benlate, 500 ppm, 1 min. dip	0.7 a

*Average of 4 experiments held at 70° F.

**Data followed by the same letter do not differ at a probability level of 5%.

Table 5. Decay in nondegreened 'Valencia' oranges as affected by residual fungicidal activity of Dowicide A-hexamine, Mertect 260 or Benlate.

Treatments	Avg.* % total decay**
Check	63.4 c
Dow-hex 2%, 2 min. flood	24.3 ab
Mertect, 500 ppm, in & out dip	43.5 bc
Mertect, 1,000 ppm, in & out dip	25.0 ab
Benlate, 500 ppm, in & out dip	0 a
Benlate, 1,000 ppm, 2 min. dip	0.3 a

*Average of 4 experiments.

**Data followed by the same letters do not differ at a probability level of 5%.

Note: Fruit were held for 4 weeks after treatment, then sound fruit were injured but not inoculated and held for one additional week to obtain these decay figures. Storage temperature was 70° F.

This same effect was observed with 'Valencia' oranges injured in the same way 4 weeks after the fruit were dipped in Benlate (Table 5). Check fruit had a decay loss of 63.4%, all due to green mold, one week after being injured,

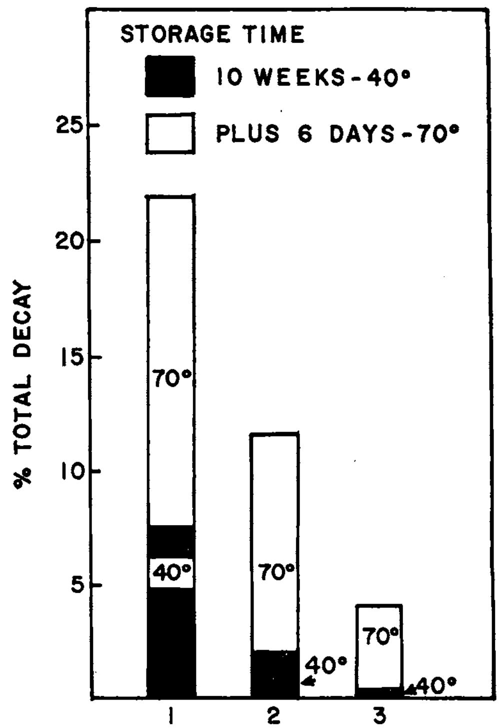

Figure 1.—Decay of 'Valencia' oranges held for 10 weeks at 40° F, then 6 additional days at 70° F. 1) No fungicidal treatment; 2) Dowicide A-hexamine treated; 3) Benlate treated.

while practically no decay developed in Benlate-treated fruit. Mertect 260 and Dowicide A-hexamine treatments provided less residual decay control.

No change in degreening rate was noted due to dipping either 'Hamlin' oranges or 'Dancy' tangerines in Benlate before degreening. No peel injury was observed due to Benlate treatments. Gloss was not affected by any of the Benlate treatments.

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PARAMETERS CONTROLLING THE USE OF 2-AMINOBUTANE FUMIGATION FOR DECAY CONTROL IN FRESH AND CANNERY CITRUS FRUIT

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ABSTRACT

Parameters for maximum decay control with 2-aminobutane (2AB) fumigation were determined in simulated shipping tests with 'Hamlin' and 'Valencia' oranges, 'Temples,' and 'Dancy' tangerines. The fumigation chamber must be at least three-quarters full. The most effective treatment was to evaporate a single initial charge of 2AB over a period determined by treatment temperature. Optimum duration varied inversely with temperature. Three hours was adequate at 85°F, but 24 hours was required at 40°F. Optimum dosage of 2AB varied inversely with temperature from 1 ml/ft^3 at 85°F to 2 ml/ft^3 at 40°F. Use of "Quick Color" (1,1,1-trichloroethane + methylene dichloride) to eliminate fire hazard had no consistent effect on decay control. No phytotoxicity was encountered in fumigation treatments with 2-aminobutane (2AB) resulting in legally acceptable residues (below 20 ppm). In experiments with mechanically harvested oranges, 2AB vapor was tried in a manner comparable to in-truck fumigation with ethylene dibromide (EDB) for fruit fly sterilization. Decay control was excellent, and the method is considered to have potential for controlling decay in mechanically harvested loads that cannot be processed immediately. Label registration to permit commercial use of the fumigation method has not been obtained.

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INTRODUCTION

Eckert and Kolbezen first reported the possibilities of using 2-aminobutane (2AB) for control of decay in citrus fruit (1, 2). Their exploratory studies of its use in vapor form were, however, largely discontinued in favor of methods using aqueous applications of salts of 2AB. A series of papers from this laboratory have dealt with use of 2AB as a fungicidal fumigant (4, 5, 8, 9, 10). These were originally undertaken seeking a replacement for diphenyl as a vapor phase fungicide. As research at the Citrus Experiment Station progressed, it became apparent that 2AB could be applied either before