GROVE APPLICATION OF BENLATE FOR CONTROL OF POSTHARVEST CITRUS DECAY

G. ELDON BROWN

State of Florida, Department of Citrus
Lake Alfred

AND

L. GENE ALBRIGO

Florida Citrus Experiment Station
Lake Alfred

ABSTRACT

Benlate (benomyl) is an experimental fungicide which provides outstanding control of postharvest decay in Florida citrus. Grove applications of Benlate, which possibly could be used to supplement the required fungicide applied at packing, were evaluated for decay control. Concentrate sprays of Benlate at 10 and 20 X on 'Valencia' orange trees at one week before harvest controlled decay as effectively as the dilute application. Decay control with 20 X sprays at rates of 100 and 250 ppm was not as effective as control with 500 ppm. Benlate and Pinolene, an antitranspirant plastic, were applied to 'Valencia' orange trees before harvest in 1969 and 1970 to improve keeping and peel quality, respectively. Benlate alone or with Pinolene effectively reduced decay of fruit held in storage for 5 and 11 weeks. Stem-end rot caused by *D. natalensis* was reduced in fruit harvested in 1970 from trees sprayed with Benlate a year previously, and the addition of Pinolene with Benlate improved control. Dormant applications of Benlate in February significantly reduced stem-end rot in 'Hamlin' oranges harvested the following November and December.

INTRODUCTION

The problem of postharvest decay in citrus fruit is one that continually plagues Florida shippers and their customers. In many instances, decay caused by one or several fungi that inhabit Florida's citrus groves can be quite devastating. The more important decays are caused by *Diplodia natalensis, Phomposis citri* (stem-end rot, SER), *Penicillium digitatum* (green mold), and *Geotrichum candidum* (sour rot). Other fungi, such as *Alternaria citri* (black rot) and *Colletotrichum gloeosporiodies* (anthracnose), can cause decay under certain conditions (8).

Efforts to reduce this decay to an acceptable level have resulted in a State law requiring all registered packinghouses to apply a fungicide to citrus fruits during the packing process (5). However, decay control with a single postharvest fungicide application is not entirely satisfactory, especially in degreened fruit with which several days elapse between picking and fungicide application or with specialty fruits prone to decay. In recent years, decay control studies have included the experimental use of a preharvest fungicide to supplement the postharvest fungicide application. The experimental fungicide Benlate (benomyl) controls decay with preharvest applications (3, 4), being most effective if applied just before harvest (4).

Further investigations on decay control are herein reported in which Benlate was applied at preharvest as a concentrate spray and as a dilute spray in combination with Pinolene (β-pinene polymer), an antitranspirant plastic film former. Dormant applications of Benlate were also evaluated for decay control.

EXPERIMENTAL METHODS

Sprays were applied to 20 to 30 year-old 'Hamlin' and 'Valencia' trees. Concentrate sprays were applied to plots of single 'Valencia' trees replicated three times while the dilute sprays with Pinolene were applied to plots of three 'Valencia' trees replicated twice. Dormant applications on 'Hamlin' oranges were made on single trees replicated two times. The dilute applications were made with a conventional truck-mounted spray rig, each tree receiving 10 to 15 gallons of spray. Concentrate sprays were applied with a SOLO Model 423 back-pack mistblower. The quantity of Benlate for concentrate application was 75% of the amount used in the dilute application, and it was applied in 1/10 (10X) or 1/20 (20X) the amount of water. Pinolene was applied alone at 1 or 3% (V/V) and in combination with Benlate at 500 ppm (a.i.), a rate used in all experiments unless noted otherwise.

Florida Agricultural Experiment Stations Journal Series No. 3715.

'Hamlin' oranges were degreened for 72 hours, and 'Valencia' oranges receiving concentrate applications of Benlate were degreened for 48 hours. Fruit were washed and waxed, and 160 were selected from each replication for storage in two 4/5-bushel fiberboard cartons.

In certain studies, artificial inoculations of *P. digitatum* (3) and *D. natalensis* were made to 80 fruit from each replication. Fruit were inoculated with a mycelial suspension of *D. natalensis* by dipping the button of the fruit into the suspension before degreening.

Isolations for natural latent infections of *D. natalensis* (4) were made from 25 fruit in each replication.

Results and Discussion

Concentrate applications. — Concentrate sprays at 10 and 20 X were compared with a 500 ppm dilute application of Benlate for decay control in 'Valencia' oranges harvested one week after spraying (Table 1). All treatments significantly reduced stem-end rot caused predominately by *D. natalensis.* Decay caused by natural infections of *P. digitatum* was eliminated by all Benlate treatments which also significantly controlled decay in fruit artificially inoculated with *P. digitatum.* Similarly, recovery of latent infections of *D. natalensis* was significantly reduced by the three treatments. In these studies, decay control with concentrate applications of Benlate was equivalent to that obtained with dilute application. 'Valencia' oranges tend to be less prone to decay than are other citrus varieties such as the specialty fruits, and decay of these varieties may not be effectively controlled by concentrate applications. The systemic activity of this material in citrus peel (7) may, however compensate for the noncontinuous coverage resulting from concentrate application.

Decay control with Benlate was further evaluated with 20 X concentrate applications on 'Valencia' oranges at rates equivalent to 500, 250, and 100 ppm dilute (Table 2). Again, significant control of SER was achieved with no significant difference among rates, but less decay control was obtained with the reduced concentrations. A similar reduction in decay control with lower rates was noted with artificial inoculations of *P. digitatum. D. natalensis* was recovered more frequently from latent infections in fruit receiving 250 and 100 ppm than from fruit sprayed with 500 ppm. Benlate, at a rate of 250 or 100 ppm, was not quite as effective as a concentrate application at 500 ppm for control of decay in 'Valencia' oranges.

Applications with Benlate and Pinolene.— Pinolene has been experimentally applied preharvest to citrus to improve peel quality, especially of 'Valencia' oranges to be stored for sale during the summer months (1). In 1969, Benlate was combined with these sprays to also control decay (Table 3). Benlate significantly reduced SER in most treatments while a reduction in *P. digitatum* was not significant due to its low incidence. The addition of 1 or 3% Pinolene did not improve decay control with Benlate. Decay was more prevalent in fruit harvested in July, 12 weeks after treatment application, than in fruit harvested in June. At the July harvest, the fruit tended to be overmature and thus more subject to decay; and Benlate is less effective as the time between application and harvest is extended (4).

Table 1. Influence of preharvest dilute and concentrate applications of Benlate on decay and latent infections of *D. natalensis*.

	Percent			
	Decay*			
Treatments	SER	Mold	Mold (I)**	D. natalensis+
Check	12.3b	1.3a	96.3b	33.3b
10X	1.5a	0.0a	28.3a	2.7a
20X	0.4a	0.0a	27.9a	2.7a
Dilute	1.1a	0.0a	37.5a	1.3a

Values followed by unlike letters are significantly different at the 1% level of probability.

*Decay after four weeks of storage at 70° F.

**Artificially inoculated with *P. digitatum*.

+Isolations for latent infections from fruit harvested four weeks after spraying.

Table 2. Influence of preharvest 20X concentrate applications at different rates of Benlate on decay and latent infections of *D. natalensis*.

	Percent			
	Decay*			
Treatments	SER	Mold	Mold (I)**	D. natalensis+
Check	16.0b	1.8a	62.1b	58.3b
500 ppm	1.8a	0.6a	29.6a	0.0a
250 ppm	3.7a	0.4a	29.6a	5.3a
100 ppm	5.1a	0.8a	45.4ab	16.0a

Values followed by unlike letters are significantly different at the 1% level of probability.

*Decay after four weeks of storage at 70° F.

**Artificially inoculated with *P. digitatum*.

+Isolations for latent infections from fruit harvested four weeks after spraying.

Table 3. Percentage decay after five weeks storage of 'Valencia' oranges sprayed preharvest April 11, 1969 with Pinolene and Benlate.

Treatments	Harvest date	Storage temperature 40* SER	40* Mold	70 SER	70 Mold
Check	June 11	4.1b	1.0ab	3.3ab	1.5ab
Benlate		0.0a	0.7ab	0.0a	0.7ab
Pinolene (1%)		3.2b	1.6ab	3.3ab	3.3b
Pinolene (3%)		3.5b	2.9b	5.3b	2.7ab
Benlate + Pinolene (1%)		0.0a	0.7ab	0.0a	0.0a
Benlate + Pinolene (3%)		0.0a	0.0a	0.0a	0.6ab
	July 9	40*		70	
Check		8.2bc	2.6ab	10.7c	3.2a
Benlate		1.3ab	1.3ab	2.9ab	1.7a
Pinolene (1%)		11.0c	2.9b	13.2c	6.3a
Pinolene (3%)		7.2abc	1.3ab	8.7bc	6.5a
Benlate + Pinolene (1%)		1.3ab	1.3ab	0.7a	2.5a
Benlate + Pinolene (3%)		0.3a	0.0a	3.4**	3.4**

Values followed by unlike letters are significantly different at the 5% level of probability.

*Fruit were removed after four weeks and held one week at 70° F.

**Fruit from one replication were inadvertantly harvested.

The same treatments were again applied to these trees the following year except only 4 weeks elapsed between application and harvest (Table 4). Fruit were stored 11 weeks; and decay, especially that caused by *P. digitatum,* was more prevalent than in the previous year. Again, Benlate significantly reduced both SER and green mold with no additional benefit from Pinolene. A significant reduction in SER was obtained with the 3% application of Pinolene which perhaps physically interferred with sporulation of the SER fungi. In this experiment, SER was caused almost exclusively by *P. citri* which is normally more prevalent than *D. natalensis* in late season fruit held in cold storage.

Samples of 50 fruit were picked from each replication in March of 1970 before the treatments were applied the second time to see if any differences in decay persisted from the treatments applied approximately a year previously (Table 5). These fruit were degreened; and SER, which under these conditions were predominately caused by *D. natalensis,* was significantly reduced with Benlate; but Benlate was even significantly more effective if applied with 1 or 3% Pinolene. A similar response was revealed when isolations for latent infections of *D. natalensis* were made from additional fruit picked from the six treatments. Since Pinolene has been reported to reduce the rate of deterioration of carbaryl on tomato foliage (2), it may be acting in a similar fashion with Benlate. Improvement in decay control with Pinolene is not apparent in fruit harvested shortly after application; but Pinolene may retard deterioration of Benlate on the deadwood and button the following season, thereby influencing sporulation and consequent infection.

Dormant applications.—Several rates of Benlate were applied to 'Hamlin' orange trees in February before bloom. SER caused by *D. natalensis* was significantly reduced by most

Table 4. Percentage decay after 11 weeks storage of 'Valencia' oranges sprayed preharvest April 23, 1970 with Pinolene and Benlate.*

Treatments	SER	Mold
Check	15.4b	16.0b
Benlate	2.2a	0.3a
Pinolene (1%)	13.8b	16.0b
Pinolene (3%)	6.8a	19.5b
Benlate + Pinolene (1%)	3.2a	0.8a
Benlate + Pinolene (3%)	1.5a	0.6a

Values followed by unlike letters are significantly different at the 5% level of probability.

*Fruit were harvested May 20, 1970 and stored for nine weeks at 40° F plus two weeks at 70° F.

Table 5. Influence of Benlate and Pinolene applied April 11, 1969 on SER and latent infections of D. natalensis in fruit picked March 20, 1970.

Treatments	Percent SER	Percent D. natalensis
Check	10c	82bc
Benlate	5b	70bc
Pinolene (1%)	6b	92c
Pinolene (3%)	12c	80bc
Benlate + Pinolene (1%)	2a	50ab
Benlate + Pinolene (3%)	1a	22a

Values followed by unlike letters are significantly different at the 5% level of probability.

*Fruit were degreened 48 hours and stored four weeks at 70° F.

treatments in fruit harvested and degreened in November and December (Table 6). Decay caused by *P. digitatum* was not affected. Though residue analyses for Benlate were not conducted, mature fruit from all treatments were artificially inoculated after harvest with *P. digitatum* and *D. natalensis* to compare host susceptibility which could be influenced by translocation of this material into the fruit during formation. Fruit from all treatments were equally susceptible to decay by these two organisms. However, there was a tendency for fruit from the sprayed trees to develop symptoms less rapidly; and the effect was inverse to fungicide concentration, thus suggesting some fungitoxicity. Another perhaps more plausible explanation could again be that SER was reduced because Benlate suppressed sporulation of *D. natalensis* from the deadwood.

Table 6. Influence of dormant applications of Benlate on postharvest decay of 'Hamlin' oranges after three weeks storage at 70° F.*

	Percent			
	November 24, 1969		December 15, 1969	
Treatments	SER	Mold	SER	Mold
Check	47.5c	2.2a	35.9b	1.7a
2,000 ppm Benlate	10.9a	6.2a	5.9a	3.4a
1,500 ppm Benlate	15.6ab	2.5a	11.7a	2.5a
1,000 ppm Benlate	18.4ab	3.4a	15.0a	5.0a
500 ppm Benlate	29.3bc	0.6a	19.2a	4.2a

Values followed by unlike letters are significantly different at the 5% level of probability.

*Sprays were applied February 19, 1969.

Preliminary studies to date indicate this to be true. Benlate has been shown to control brown rot (*Monilinia fructicola*) of peaches by suppressing sporulation from infected peach peduncles and mummified fruit (6).

Annual grove applications of Benlate for control of postharvest decay could possibly eradicate the SER fungi from the deadwood or at least reduce sporulation. Applications other than at preharvest for control of certain other citrus diseases may also be beneficial for the same reason. The activity of Benlate as an eradicant or antisporulant may, in some cases, be enhanced with the use of spray adjuvants such as Pinolene.

LITERATURE CITED

1. Albrigo, L. G. and G. E. Brown. 1970. Peel and internal quality of oranges as influenced by grove application of Pinolene and Benlate. Proc. Fla. State Hort. Soc. 83: In press.

2. Blazquez, C. H., A. D. Vidyarthi, T. D. Sheehan, M. J. Bennett, and G. T. McGrew. 1970. Effect of Pinolene (β-pinolene polymer) on carbaryl foliar residues. J. Agr. Food Chem. 18: 681-684.

3. Brown, G. E. 1968. Experimental fungicides applied preharvest for control of postharvest decay in Florida citrus fruit. Plant Dis. Reptr. 52: 844-847.

4. Brown, G. E. and A. A. McCornack. 1969. Benlate, an experimental preharvest fungicide for control of postharvest citrus fruit decay. Proc. Fla. State Hort. Soc. 82: 39-43.

5. Florida Citrus Commission Regulation 105-1.43. 1968. Fungicide or fungistat treatment required for fresh citrus fruit.

6. Kable, P. F. 1970. Eradicant action of fungicides applied to dormant peach trees for control of brown rot (**Monilinia fructicola**). J. Hort. Sci. 45: 143-152.

7. Ogawa, J. M., H. J. Su, Y. P. Tsai, and I. M. Lee. 1969. Postharvest decay development as affected by symtemic ativity of benomyl in bananas, oranges, and pineapples. Phytopathology 59: 1043 (Abstr.).

8. Smoot, J. J. and C. F. Melvin. 1967. Postharvest decay of specialty hybrid citrus fruits in relation to degreening time. Proc. Fla. State Hort. Soc. 80: 246-250.

DECAY CONTROL OF FLORIDA CITRUS FRUITS WITH PACKINGHOUSE APPLICATIONS OF THIABENDAZOLE

JOHN J. SMOOT AND C. F. MELVIN
Horticultural Field Station USDA
Orlando

ABSTRACT

During the 1969-1970 harvest season, samples of various citrus fruits were collected weekly from five commercial packinghouses. Untreated samples and samples treated with thiabendazole (TBZ) were held for decay development. The three following methods of applying TBZ at a rate of approximately 1,000 ppm were evaluated: (1) recirculating flood (two houses), (2) noncirculating spray (two houses), and (3) TBZ in water wax (one house). In three additional tests Valencia oranges were treated at the various packinghouses, and comparable fruit