for the balance of the 71-72 season. During the following season, neither packinghouse 1 nor 3 experienced a reoccurance of the previous seasons' decay problems.

Packinghouse 2 did have a reoccurance of its previous high rate of decay in degreened fruit. Investigation found that the exhaust hood on the pack dump was not functioning and that fumigation of the degreening rooms had not been done during the current season. These were corrected and decay problems were reduced.

From the experience in these three packinghouses, it is apparent that the original packinghouse layout did not take into account what was going to happen to mold spores from fruit that began to decay in degreening. With the introduction of selective fungicides (6), the problem of decay due to resistance becomes even more important in overall fruit handling.

The lessons that can be learned from these packinghouses could be of tremendous advantage in designing future packinghouses. We can summarize these as follows:

1. Separate operations such as dumping fruit and rot grading from fruit that is prepared for degreening.
2. Orient operations where handling decayed fruit will be down wind (either natural or artificial) from other operations. Check the direction of prevailing winds *during* the pack season.
3. Contain spores at dumps with exhaust hoods, sanitizing sprays and total enclosure, if possible.
4. Separate degreening rooms as much as possible from other operations, and provide for simplicity in fumigation and cleaning.
5. Have the final layout of the packinghouse reviewed by a qualified plant pathologist for any potential sources of resistant mold recycling. (9)
6. Assay airborne spores in the packinghouse regularly for resistant molds.

An examination of the layout and operation of the 3 houses studied shows that at least 1 of the above principles has been by-passed in each. Existing packinghouses should review their layout compared to these principles, especially if experiencing high amounts of decay despite the use of fungicides. If in some area a possibility exists for recycling mold spores, then an assay of airborne mold should be run.

Based on the results of this assay, packinghouse management should seek to eliminate or minimize these sources of contamination by:

1. Isolating operations handling decayed fruit.
2. Regularly sanitizing surfaces susceptible to contamination.
3. Assaying regularly for resistant mold and selecting appropriate fungicides.
4. Using a fungicide at the pack line with a mode of action different to the one used during degreening.

By adopting such procedures, losses from decay can be reduced to a minimum.

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DECAY CONTROL OF FLORIDA CITRUS FRUITS WITH IMAZALIL[1]

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Abstract. **Postharvest decay control of Florida citrus fruit treated with imazalil is comparable to benomyl (Benlate) and thiabendazole (TBZ). Imazalil, 1-[2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl] -1H-imidazole, is an experimental fungicide which also controls molds resistant to the benzimidazole fungicides, Benlate and TBZ. Imazalil exhibits** in vitro **activity against all of the common postharvest citrus fungus diseases found in Florida except sour rot,** Geotrichum candidum. **When green mold,** Penicillium digitatum, **develops in citrus fruits treated with imazalil, spourlation is retarded. Consequently, few spores develop to "soil" other fruit in cartons. Imazalil controlled decay of 'Valencia' oranges stored for 11 weeks at 40°F (4.5°C) as effectively as did Benlate. In a simulated marketing period of 1 week at 70°F (21°C) following this cold storage period, decay control from the imazalil and Benlate treatments continued.**

Decay control of Florida citrus fruits continues to be a problem because of the naturally high decay potential, which is frequently compounded by rough and/or delayed handling. Degreening with ethylene, a common commercial practice early in the packing season of many cultivars, adds to the decay problem (8, 9). With the approval of Benlate and TBZ as postharvest citrus fungicides, these problems were partially solved. It has since been found, however, that both green *(P. digitatum) and* blue (*P. italicum*) molds develop strains resistant to these benzimi-

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dazole fungicides (13). Strains resistant to Benlate, TBZ, and other benzimidazole fungicides usually develop in mold populations when fruit treated with benzimidazole fungicides are stored for several weeks (1, 2, 14). Benzimidazole resistant molds usually have cross tolerance (4, 14, 16). Molds resistant to benzimidazole fungicides have been reported from Australia (12, 16, 17), Japan (4), Israel (1), and the United States in California (2, 3), and Florida (14).

A fungicide is needed to apply in combination with, or alternately with, Benlate or TBZ (10). Effectiveness of an experimental citrus fungicide, imazalil, has been recently reported (3, 5, 6, 7, 11).

This study was undertaken to evaluate the effectiveness of imazalil for control of decay of Florida citrus fruits, especially decay caused by strains of green mold resistant to Benlate and TBZ.

Material and Methods

In vitro studies. Imazalil, manufactured by Janssen Pharmaceutica, Belgium, was supplied by the Decco Division of Pennwalt Corporation. For the *in vitro* evaluation, imazalil was added to hot, sterilized potato dextrose agar (PDA). After agitation, the PDA-imazalil medium was poured into sterile, plastic disposable petri dishes (100 x 15 mm). The dishes containing PDA amended with imazalil at 0, 1, 10, 100, and 1,000 parts per million (ppm) were inoculated with the fungi commonly causing decay of Florida citrus fruits. For each comparison, 1 petri dish was inoculated at 4 equidistant locations. Inoculated dishes were incubated at 79°F (26°C) and growth was measured before the mycelium coalesced, usually within 2 to 4 days.

Similar procedures were used to prepare media for evaluating the airborne green mold spore population in the fruit storage room and their degree of resistance to Benlate. Petri dishes with media containing 0, 2, or 20 ppm Benlate and 2 or 20 ppm imazalil were exposed to the storage room atmosphere by removing the lids from the dishes for 1 min. After exposure, dishes were held at 79°F for 4 to 5 days, then the number of colonies of green mold was counted. Comparison of the number of colonies on Benlate-amended medium to the number on the non-amended medium was used as an indication of the level of Benlate-resistant airborne spores.

Fruit treatments. Fruit of both degreened and nondegreened citrus cultivars were treated with Benlate, TBZ, and imazalil. Degreening conditions were those recommended for use in Florida (15). Results of treatments to nondegreened 'Hamlin' oranges and 'Murcott Honey' tangerines are presented as they were typical and represented additional observations with cultivars of 'Pineapple' and 'Valencia' oranges; 'Dancy' tangerines; 'Marsh' grapefruit; 'Temples', and 'Bearss' lemons.

Benlate and TBZ at concn of 600 and 1,000 ppm, respectively, were applied to washed fruit as non-recovery spray treatments over revolving horsehair brushes. Imazalil was applied, usually at a concn of 1,000 ppm, either as a non-recovery spray or as an "in-and-out" dip treatment. The non-recovery spray treatments were applied with a "traveling nozzle" which traverses the brushes carrying the fruit. This is the common commercial method of applying Benlate and TBZ. Sufficient spray was applied to cover the surface of the fruit with a minimum runoff as the fruit revolved on the brushes. In the "in-and-out" dip treatment, the fruit were placed in an expanded metal basket, dipped momentarily in the fungicide, then allowed to drain. After fungicidal treatments, fruit were dried without rinsing and a solvent-type wax was applied. Waxed fruit were packed in 4/5 bu, fiberboard cartons and stored at 70°F.

Storage facility. Prior to the start of the citrus season (September), green mold spores had been eradicated from the storage room by 1% formaldehyde introduced through the water humidification system for 1 day followed by 2 days of airing. Fruit used for this experimental work, together with fruit from other experiments treated with Benlate and TBZ, were held in this storage room.

Results and Discussion

Imazalil was active against all common decay organisms of Florida citrus fruits in *in vitro* studies, except sour rot (Table 1). Imazalil was also effective against strains of green and blue molds resistant to Benlate and TBZ. Results with TBZ were similar to Benlate so they are not presented.

Table 1. Inhibition by imazalil of *in vitro* growth of fungi responsible for postharvest decay of Florida citrus fruits.

Postharvest disease	% Inhibition 1 ppm	% Inhibition 10 ppm
Black rot	35.9	100.0
Anthracnose	16.7	100.0
Stem-end rot		
Diplodia	29.2	100.0
Phomopsis	34.5	100.0
Sour rot[z]	0.0	12.2
Green mold	83.3	100.0
Green mold[y] (benomyl-resistant strain)	100.0	100.0
Blue mold[y] (benomyl-resistant strain)	71.4	100.0

[z]Growth was inhibited with 1,000 ppm imazalil.

[y]Strain grew normally in the presence of 10 ppm Benlate in culture media.

Decay of nondegreened 'Hamlin' oranges, treated with Benlate or imazalil, is shown in Table 2. Benzimidazole-resistant spores were not present in the storage room this early in the citrus season. Imazalil was as effective as Benlate against both green mold and stem-end rot.

Table 2. Decay of nondegreened 'Hamlin' oranges treated with Benlate and imazalil.

Treatment	Avg. % decay[z,y] Stem-end rot	Green mold	Other	Total
Check	5.0 a	10.3 a	0.0 a	15.3 a
Benlate, 600 ppm[x]	0.0 b	2.3 b	0.0 a	2.3 b
Imazalil, 1,000 ppm[x]	0.7 b	0.3 b	0.7 a	1.7 b

[z]Average decay in 300 fruit per treatment in 3 experiments after 4 weeks storage @ 70°F.

[y]Data followed by the same letter in each column do not differ at a probability level of 5%.

[x]Nonrecovery spray.

Lack of control of green mold with Benlate and TBZ later in the season indicated that a population of benzimidazole-resistant mold spores had accumulated in the storage room. PDA plates amended with Benlate and imazalil were exposed showing the presence of green molds which grew on the plates containing 2 and 20 ppm Benlate but at a slower rate than on the non-fungicidal plate (Fig. 1). PDA plates with 2 and 20 ppm imazalil exposed at the same time, were free of mold growth indicating that molds, whether or not from Benlate-resistant strains, will not grow in the presence of imazalil.

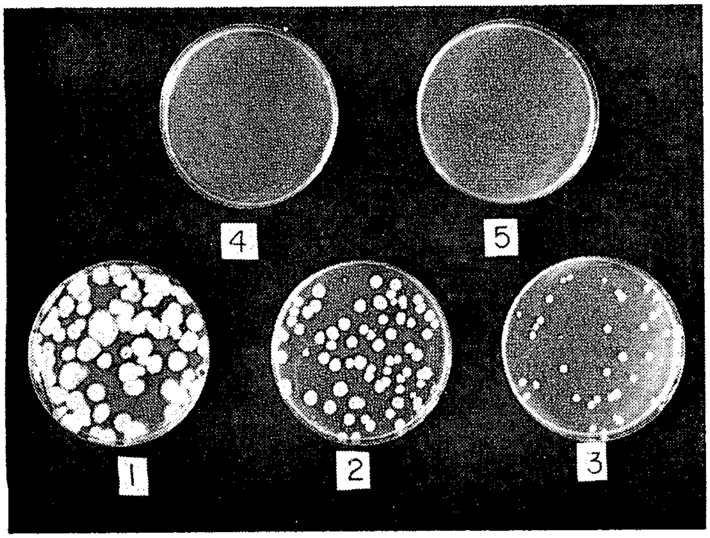

Fig. 1. Green mold growth on PDA plates amended with Benlate or imazalil, 3 days after inoculation. Exposure time was 1 min. Plates contained: 1. no fungicide; 2. Benlate, 2 ppm; 3. Benlate, 20 ppm; 4. Imazalil, 2 ppm; 5. Imazalil, 20 ppm.

Benlate did not control green mold decay of 'Murcott Honey' tangerines after a high level of Benlate-resistant green mold spores developed in the storage room (Table 3). Green mold decay of imazalil-treated fruit, however, was very low for the same storage condition. Stem-end rot was controlled equally well by both imazalil and Benlate (Tables 2, 3) with no evidence of resistance developing.

Table 3. Decay of nondegreened 'Murcott Honey' tangerines treated with Benlate and imazalil and stored in the presence of benzimidazole-resistant green mold spores.

Treatment	Avg. % decay[z,y] Stem-end rot	Green mold	Other	Total
Check	3.8 a	7.5 a	0.5 a	11.8 a
Benlate, 600 ppm[x]	1.0 b	10.5 a	0.8 a	12.3 a
Imazalil, 1,000 ppm[w]	0.8 b	1.0 b	0.8 a	2.6 b

[z]Average decay in 400 fruit per treatment in 4 experiments after 4 weeks storage @ 70°F.
[y]Data followed by the same letter in each column do not differ at a probability level of 5%.
[x]Nonrecovery spray.
[w]'In-and-out' dip.

Green mold growing on imazalil-treated fruit, produces a white mycelium which sporulates very slowly on the surface of the fruit (Fig. 2). In the small number of instances when imazalil-treated fruit developed green mold, sporulation was reduced or even prevented. A similar observation was made in California (3). Inhibition of sporulation is highly desirable because it prevents sound fruit in a carton or other container from being "soiled" by mold spores.

Data not presented in this paper showed that sour rot of degreened 'Dancy' tangerines was not controlled by imazalil, confirming the *in vitro* results.

In a cold storage experiment with nondegreened 'Valencia' oranges stored at 40°F in a room without Benlate-resistant molds, both Benlate and imazalil effectively controlled decay (Fig. 3). After a storage period of 11 weeks at 40°F, fruit were moved to the storage room containing Benlate-resistant mold spores for a simulated marketing period of 1 week at 70°F. Both fungicides continued to retard spoilage at 70°F but decay loss in the imazalil-treated fruit was less than with Benlate.

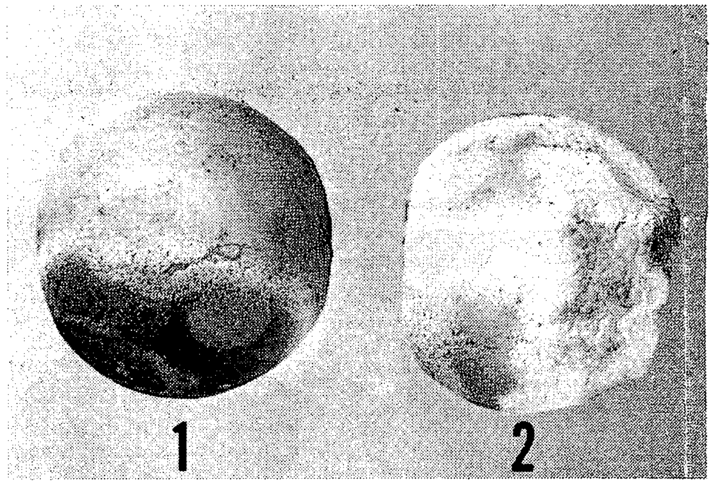

Fig. 2. Comparison of sporulation by green mold on 'Valencia' oranges without fungicidal treatment (1) and treated with imazalil (2). Note the nonsporulating mycelium on the surface of the imazalil-treated fruit.

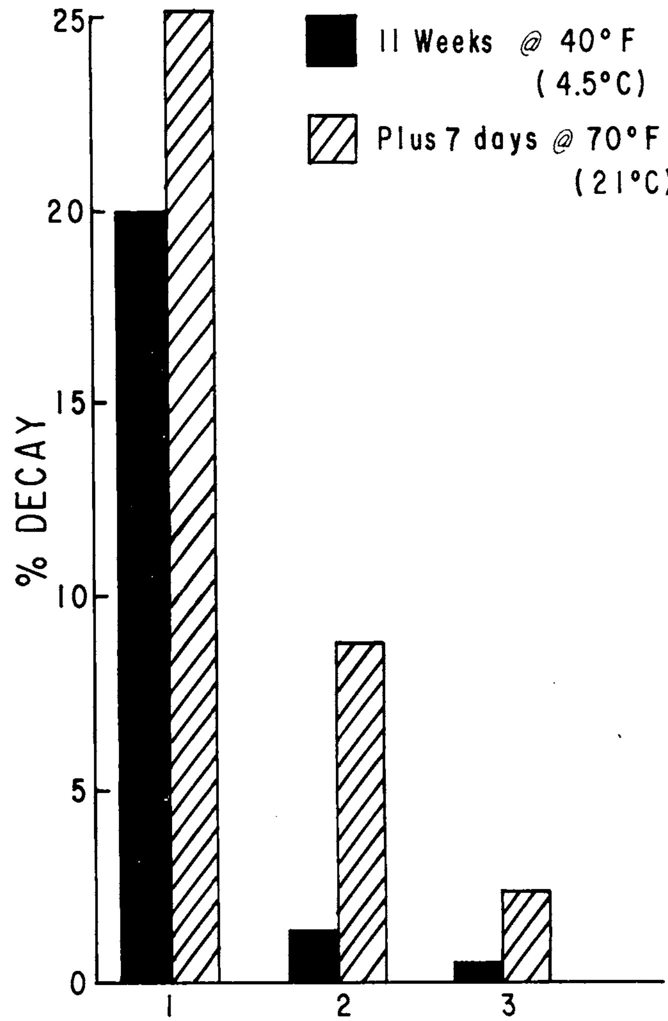

Fig. 3. Decay of nondegreened 'Valencia' oranges stored for 11 weeks at 40°F, then held for 7 more days at 70°F. Treatments were: 1. Check, 2. Benlate, 600 ppm, and 3. imazalil, 1,000 ppm.

Conclusion

Imazalil is not yet approved by the Environmental Protection Agency. This fungicide has shown considerable potential as a postharvest fungicide for the control of major decays of Florida citrus fruits, except sour rot. The fungicidal effect of imazalil persists during long term cold storage and a simulated marketing period. The property of imazalil to control strains of green mold resistant to benomyl as well as to arrest mold sporulation makes it a desirable postharvest citrus fungicide.

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PHOSPHINE AS A FUMIGANT FOR GRAPEFRUIT INFESTED BY CARIBBEAN FRUIT FLY LARVAE[1,2]

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Abstract. **Both hatch of eggs and pupation of larvae of the Caribbean fruit fly,** Anastrepha suspensa **(Loew), were reduced or prevented by fumigation with phosphine gas generated from magnesium phosphide containing paper covered flat packets (Fumi-cels®). Fruit flies infesting 'Marsh' seedless grapefruit were controlled when fruit in refrigerated semi-trailer vans was fumigated at 13°C for 96 hr or fruit under a tarpaulin was fumigated at ambient temp for 48 hr. There was no apparent injury to fruit fumigated under these conditions.**

The Caribbean fruit fly, *Anastrepha suspensa* (Loew), a pest of fruit in Florida the past 12 years (Weems, 1966), commonly infests guava, *Psidium guajava* L., tropical almond, *Terminalia catappa*, L., Surinam cherry, *Eugenia uniflora* L., and other tropical and subtropical fruits. Until 1974, citrus had only occasionally been reported as infested. However, in June of that year, Japanese quarantine officials found a total of 14 larvae of the Caribbean fruit fly infesting 11 Florida grapefruit among over 3.5 million kg transported to Japan on 5 ships that had left the United States between April 4 and May 27. All further shipments of Florida grapefruit were then discontinued until schedules for fumigation with ethylene dibromide (EDB) were approved by the Japanese Ministry of Agriculture in consultation with officials of the U. S. Department of Agriculture. Shipments were resumed in February 1975, and that spring over 5 million boxes of grapefruit that were to be shipped to Japan, the equivalent of about 100 million kg, were fumigated with ethylene dibromide in semi-trailer vans or in overseas containers.

Meanwhile, research was initiated at Miami to find other treatments for fruit fly larvae. One possibility is phosphine. Phosphine generated from aluminum phosphide (Phostoxin®) has been commercially available for several years as a fumigant for insect pests of grain and other stored products (Lindgren and Vincent, 1966). However, Phostoxin has not been used to control insect pests of fresh fruit and vegetables because it could be phytotoxic and because such a long fumigation is required. For example, at some conditions (lower temp), phosphine can take as much as 2 days just to evolve to its maximum concn in an enclosed space. However, a new formulation has recently been developed that uses magnesium phosphide (Fumi-cel®) as the material for the generation of phosphine gas. The magnesium phosphide is formulated as a flat, paper-covered packet. Each standard size Fumi-cel (26 x 17.5 x 0.5 cm) contains enough magnesium phosphide to develop 33 g of phosphine (PH_3) for treatment of 28 to 44.8 m^3. Smaller Fumi-cels (7.5 x 6.5 x 0.5 cm) generating 3.3 g of phosphine formulated for use in research can be used to treat 2.8 m^3 spaces.

[1]This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by USDA, nor does it imply registration under FIFRA as amended. Mention of a trade name does not constitute a recommendation for use by the U.S.D.A.

[2]The authors wish to acknowledge assistance in this research from the Florida Citrus Commission, Phostoxin Sales, Inc., Alhambra, California, and Degesch, Frankfort, Germany.