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EVALUATION OF DECAY CONTROL TREATMENTS AND SHIPPING CONTAINERS FOR EXPORT OF GRAPEFRUIT TO JAPAN[1]

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Abstract. **In 5 experimental tests, grapefruit were shipped under commercial conditions, from Florida to Tokyo, Japan, to evaluate 4 fungicide treatments for decay control and 4 experimental shipping containers for physical protection during handling and shipment. The fungicide treatments, sodium o-phenylphenate (SOPP), thiabendazole (TBZ), imazalil and SOPP + TBZ, when used in addition to biphenyl pads, were more effective in controlling stem-end rot and green mold than biphenyl alone. However, none of these materials effectively reduced the incidence of sour rot nor prevented spread of the decay to other fruit in the same carton. Sour rot was a serious decay in the last test with riper fruit. In all tests, the experimental carton that was 1/2-inch (13 mm) deeper than the others reduced the amount of *serious deformation* of the fruit by 50%, as compared to the other types of cartons evaluated that were of standard size but made of heavier boardweight, or differently constructed. There was no difference in carton damage upon arrival among the 5 carton types (4 experimental + 1 standard) used. These results demonstrated that shipping grapefruit in flat packs (without bulge) improves the arrival condition in overseas markets.**

Export of grapefruit from Florida to Japan began in 1971, when Japan liberalized the import restrictions on citrus fruits. Since then, the volume of grapefruit exported to Japan has increased to over 7 million 4/5-bu. cartons per annum with an f.o.b. value in excess of $30 million, with further increases to $50 million anticipated within the next 5 years. This phenomenal growth of a single market has not been without problems of both biological and physical nature, due in part to the long period required for transit (3). Two of these problems are excessive decay in many shipments, especially late in the season, and lack of physical protection to the individual fruit resulting in deformed or flattened fruit due to carton failure and overpacking.

In the spring of 1977, 5 shipping tests with grapefruit were conducted from Tampa, Florida, to Tokyo, Japan, for the purpose of evaluating the effectiveness of 4 fungicide treatments for decay control and 4 new shipping containers for physical protection during handling and shipment.

Materials and Methods

The sources of experimental fruit and the harvesting and handling dates for the 5 test shipments are shown in Table 1. The test grapefruit was obtained in field boxes from commercial packinghouses and transported to the U.S. Horticultural Research Laboratory, Orlando, where it was washed, fungicide treated, waxed, graded, sized and packed in experimental cartons. As required by the Japanese Government, the grapefruit, after packing, was fumigated with ethylene dibromide, at the Florida Division of Plant Industry fumigation station near Bartow, Florida. The cartons were then taken to Tampa, where they were loaded with commercial grapefruit for shipment to Japan. The test cartons were placed in the bottom layers of stacks 8-9 high in the refrigerated holds of the break-bulk ships. The bottom layer location was selected for the test cartons, because fruit and cartons in that location undergo the greatest physical damage.

Table 1. Log of test shipments of Florida grapefruit to Japan, 1977.

Test no.	Fruit source	Cultivar	Date picked	Date packed	Date of arrival inspection	Days elapsed
1	St. Lucie Co.	Ruby	Mar. 22	Mar. 23	Apr. 25	34
2	St. Lucie Co.	Marsh	Mar. 24	Mar. 25	May 11	48
3	St. Lucie Co.	Marsh	Apr. 2	Apr. 4	May 13	41
4	St. Lucie Co.	Marsh	Apr. 11	Apr. 12	May 27	46
5	Palm Beach Co.	Marsh	Apr. 19	Apr. 21	May 28	39

The fungicides tested are listed in Table 2 together with their common or trade names and treatment concentrations. Sodium *o*-phenylphenate (SOPP) + hexamine and thiabendazole (2-(4-thiazolyl)benzimidazole) (TBZ) were applied by recommended procedures (5). An aqueous solution of imazalil (1-[2(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl]-1H-imidazole), an experimental fungicide (4), was sprayed on fruit as it traveled over a roller conveyor. After treatment, all samples were dried and waxed with a solvent wax.

Table 2. Postharvest fungicide treatments used.

	Treatment[z]	Concn. used
1	Control (wash + wax only) (Flavorseal (150)[y,x]	
2	Sodium *o*-phenylphenate[w,x] (SOPP) + hexamine (Dow-hex)[y]	2% + 1%
3	Thiabendazole (TBZ)[y,w]	.12%
4	SOPP + TBZ (Treatment #2 followed by #3)[w]	—
5	Imazalil (Deccozil)[y,v]	.1%

[z]Each test carton and those in the commercial load were packed with 2 biphenyl pads containing approximately 2.3 g biphenyl[y,w] per pad.

[y]Trade names are used for identification, and their use is not to be construed as an endorsement over products not listed.

[x]Approved for use in Japan as a postharvest fungicide or food additive by Ministry of Health and Welfare.

[w]Approved for use in the U.S.A. as a postharvest fungicide by Environmental Protection Agency.

[v]Experimental fungicide not approved for use.

We also evaluated 5 types (1 standard + 4 experimental) of shipping containers (Table 3). Inside dimensions of all types were 17 x 10-5/8 x 9-5/8 inches (1 inch = 25 mm), except Type B, which was 1/2 inch higher. Types A, B, C, and D were two-piece, full-telescope, fiberboard

[1]This paper reports the results of research only. Mention of a pesticide/fungicide in this paper does not constitute recommendation for use by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

cartons with half-slotted bodies and covers; type E had side-slotted tray design with double side walls and no joint on the bottom surface of the body. Container types A, C, D, and E, when packed with fruit, had the allowable 1/2-inch bulge as described by Florida Department of Citrus regulation (1). The 1/2-inch-deeper carton (Type B) was packed flat without bulge. Each test consisted of 4 cartons each of size 32 fruit for each fungicide treatment and carton type. During transit, temperature for all ships was about 50-52°F (10-11°C) with about 90% relative humidity.

Table 3. Descriptions, identification letters, and specifications for the 5 types of shipping containers used in the 5 test shipments from Florida to Tokyo, 1977.

Type of carton[z]	Identification letter	Paperboard weight Cover	Body
		(lb/1000 ft²)[y]	
Standard:			
Fiberboard, full telescope	A	42-33-42	90-33-90
Experimental:			
Fiberboard, full telescope[x]	B	42-33-42	90-33-90
Fiberboard, full telescope	C	42-33-42	69-40-90
Fiberboard, full telescope	D	42-33-42	69-40-69
Fiberboard, full telescope	E	42-33-42	69-33-69[w]

[z]Waterproof adhesives were used throughout in bodies and covers of all shipping containers.
[y]1 lb/1000 ft² = 1 kg/237 m².
[x]Carton was 1/2-inch deeper than standard carton: 17 x 10-5/8 x 10-1/8 inches vs 17 x 10-5/8 x 9-5/8 inches.
[w]Body was side-slotted tray design that resulted in double sidewalls.

Test fruit was unloaded in Tokyo, Japan, and then inspected for decay, physiological peel injury, and deformation. The cartons were also measured to determine changes in size or configuration, such as side bulge, end bulge, and bottom sag. The biphenyl pads were removed after the arrival inspection. Test fruit was then held at about 75°F (24°C) and reinspected after 1 and 2 weeks. Decays were classed according to the kind of decay or causal organism, if known.

Results and Discussion

Decay-control treatments. The 4 fungicide treatments (SOPP, TBZ, SOPP + TBZ and imazalil) when used in addition to biphenyl pads, were more effective in controlling total decay than biphenyl alone (Fig. 1). The control fruit (biphenyl pads only) averaged 3% total decay on arrival, 6.1% after 1 week, and 11% after 2 weeks. The most effective treatment was SOPP + TBZ which limited decay to 0.8%, 1.7% and 2.7%, respectively. With TBZ, imazalil and SOPP, levels of decay were intermediate; SOPP was slightly less effective than the other 2 treatments. Untreated controls were not possible because all test cartons were exposed to biphenyl vapors from commercial cartons during shipment.

Phomopsis stem-end rot (*Phomopsis citri* Fawc.) and green mold rot (*Penicillium digitatum* Sacc.) were the most prevalent decays and, under normal conditions, are the most prevalent decays of fully ripe Florida grapefruit on the market (6). The development of these 2 kinds of decay was significantly reduced by all 4 fungicides in all of the tests (Fig. 1). The miscellaneous decays observed included anthracnose (*Colletotrichum gloeosporioides* (Penz.) Sacc., sour rot (*Geotrichum candidum* Lk. ex Pers), and decays caused by *Alternaria citri* Ell. & Pierce,

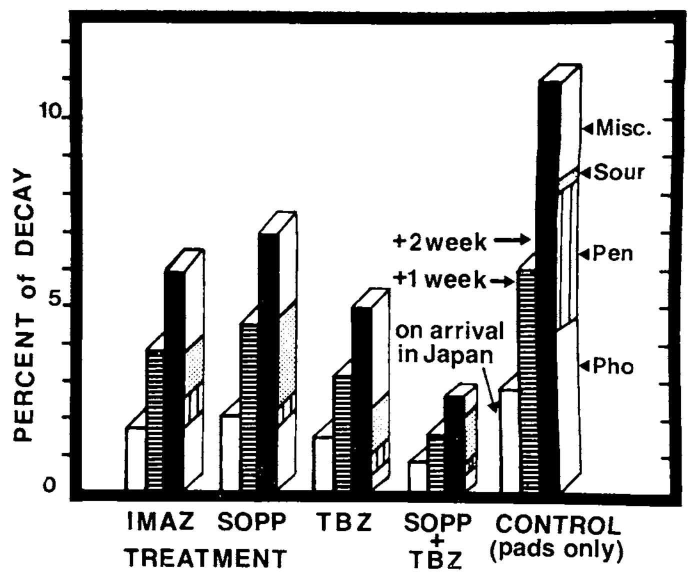

Fig. 1. Effect of several fungicide treatments on decay of Florida grapefruit exported to Japan. Total decay on arrival and after 1 and 2 weeks, and kinds of decay after 2 weeks (average of 5 tests—1977).

Fusarium sp., and others. These miscellaneous decays were not significantly controlled by the fungicide treatments.

The fact that the incidence of sour rot was lower in the control than in the other treatments may be explained by the fact that both *P. digitatum* and *G. candidum* infect through peel injuries at harvest. *Penicillium digitatum* is the more aggressive of the two, so *if it is controlled*, sour rot is allowed to develop.

Sour rot was infrequent in the first 4 tests; but was the most prevalent decay in test 5. None of the treatments was effective in reducing its incidence or preventing spread to other fruit in the same carton. In test 5, 5 or more fruit per carton in 25% of the cartons developed sour rot by the last inspection, regardless of treatment. In addition to the fruit loss due to this watery soft rot, the bottoms of the cartons became wet and deteriorated due to leakage from the rotted fruit. As much as 3% of this test fruit exhibited blossom-end clearing, which indicated that considerable internal bruising had occurred. Blossom-end clearing is a disorder that develops in fruit that has been dropped or handled roughly at harvest. There was also a 2-day delay, with 85°F weather (Table 1) between harvest and fungicide treatment that was conducive to sour rot development, in addition to the probable rough handling. Normally some control can be expected with SOPP treatment (5); however, under the conditions of this test none was attained.

Physiological rind breakdown (aging and pitting) and chilling or chemical injury were negligible in all tests, and were not affected by any treatment.

Biphenyl has been approved for use by Japan since 1971, and has been used by the Florida packers since that time for all grapefruit shipments. On May 1, 1977, SOPP was also approved by the Japanese Government for use on imported citrus fruit, and TBZ is also being considered for approval. Our results clearly indicate that SOPP should be used in conjunction with biphenyl for all Florida grapefruit shipped to Japan. If and when TBZ is approved, its use should also be considered instead of, or in addition to, one of these fungicides, depending on the needs for decay control.

Packaging tests. During the 5 export test shipments, cartons that were deeper than others by 1/2-inch (Treatment B) offered more protection to grapefruit than the standard and other experimental types of containers tested.

For the 5 shipments, serious deformation was significantly lower for fruit packed in the deep cartons and averaged 12.1% as compared to 23.5 to 25.5% for fruit shipped in the other containers (Table 4). Thus, data from these commercial shipments agree with data from laboratory tests conducted by Hale in 1973 (2), in that the overall appearance of grapefruit was related to fruit-pack heights. The higher the fruit is bulged when packed, the more serious is the deformation at subsequent unloading.

Container types B and C maintained original size and shape slightly better than the other shipping containers (Table 5). However, the differences in the amounts of bottom sag, end bulge, and side bulge among the 5 types of containers were not statistically significant.

Table 4. Percentage of grapefruit seriously deformed in 5 types of shipping containers on arrival at Tokyo, 5 test shipments, 1977.

Carton identification letter	Seriously deformed[z]
Standard:	
A	24.5
Experimental:	
B	12.1[y]
C	25.5
D	23.5
E	24.0

[z]Seriously deformed fruit is defined as fruit with total aggregate flattened or indented surface area more than 2 inches in diameter.
[y]Statistically significant difference from all other treatments at the 1% level.

Table 5. Amount of physical damage to 5 types of shipping containers during 5 test shipments from Florida to Tokyo, 1977.

Carton identification letter	Type of carton damage		
	Bottom sag	Side bulge	End bulge
		Inches	
Standard:			
A	0.8	0.8	0.6
Experimental:			
B	0.7	0.7	0.5
C	0.7	0.8	0.4
D	0.8	0.9	0.6
E	0.9	0.8	0.7

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INTERNAL FREEZE DAMAGE IN FLORIDA GRAPEFRUIT HELD IN FLORIDA AND SIMILAR FRUIT SHIPPED AND HELD IN JAPAN DURING LATE SPRING 1977

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Abstract. **Grapefruit from five USDA experimental shipments to Japan were cut and inspected to determine if internal drying increased after harvest and during transit to Japan. Off-grade fruit increased from 3% at packing to 30% on arrival due to internal freeze damage, based on the extent of damage to comparable fruit cut in Florida at time of packing. Granulation also contributed to the dryness of some of the lots of fruit. Commercial grapefruit, consisting of 168 cartons and 18 brands from 4 shipments that arrived in Japan during April and May 1977, were similarly tested. Fruit that went through frozen-fruit separators at the packinghouse averaged 32% U.S. No. 2 or below; and fruit not separated averaged 42%. Fruit classified as U.S. No. 2 and below, according to packinghouse lots, ranged from 0 to 71%. The larger the size of the fruit, the less was the internal freeze damage.**

Subfreezing temperatures on January 20 and 21, 1977, seriously damaged citrus groves throughout the State of Florida. Immediately after the freeze, a 10-day embargo was imposed to prevent the shipment of damaged or unwholesome fruit as prescribed by the Florida citrus code (1). During the embargo, much of the seriously frozen fruit dropped from the trees and some drying, particularly at the stem end, affected fruit that remained on the trees. The extent of freeze damage to these remaining fruit was difficult to assess without cutting the fruit. Dried fruit can be separated in the packinghouse by specific gravity or water flotation (4). The purposes of these investigations were to determine 1) if the level of internal freeze damage (drying) at picking increased during storage (simulated transit) or during actual transit to Japan, the largest importer of Florida grapefruit, and 2) to survey, after arrival in Japan, the extent of internal freeze damage in commercially shipped grapefruit.

Materials and Methods

All fruit were cut and examined by the official procedure prescribed to grade Florida citrus for internal dryness or freeze damage (3). The fruit were inspected and graded according to U.S. standards for Florida grapefruit (2). Tabulations were made of individual fruit that met one of these three categories: U.S. No. 1, U.S. No. 2, or below U.S. No. 2; however, fruit shipped to Japan must