HORTSCIENCE 26(4):397-399. 1991.

Thiabendazole and Imazalil Applied at 53C Reduce Chilling Injury and Decay of Grapefruit

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Additional index words. Citrus paradisi, citrus, postharvest disorders

Abstract. **The fungicides thiabendazole (TBZ) or imazalil were applied at 1 g·liter^{-1} at 24 or 53C to 'Marsh' and 'Redblush' grapefruit *(Citrus paradisi* Macf.) to reduce fruit susceptibility to chilling injury (CI) and decay. Generally, there was more CI and decay on 'Marsh' grapefruit than on 'Redblush'. Severity of CI was lower in grapefruit that had been dipped at 53C than at 24C. Fruit dipped in fungicides had less CI than fruit dipped in water alone. Imazalil was more effective in reducing CI than TBZ. Fungicides reduced decay at both temperatures, and imazalil was better than TBZ. Chemical names used: 2-(4-thiazolyl)benzimidazole (thiabendazole, TBZ); 1-[2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl] *-1H* -imidazole (imazalil).**

Grapefruit, like many other tropical and subtropical fruits, develop chilling injury (CI) when stored at temperatures below 10 to 12C (Chace et al., 1966; Grierson, 1974; Pantastico et al., 1968). The storage time required for CI development varies from less than 3 weeks to more than 12 weeks, depending on the harvest date (Purvis and Grierson, 1982; Purvis et al., 1979). Generally, early and late-season Florida grapefruit are more susceptible to CI than midseason fruit (Grierson, 1974; Grierson and Hatton, 1977).

Among the many factors that have been investigated for their potential to reduce CI incidence on grapefruit is the fungicide thiabendazole (TBZ) (Chalutz et al., 1985; Kokkalos, 1974; Schiffman-Nadel et al., 1972; Wardowski et al., 1975). Wild and Hood (1989) recently reported that dipping 'Valencia' oranges in water at 53C or suspensions of TBZ or benomyl at 53C reduced CI even more.

Preliminary, unpublished work at our laboratory showed that solutions of imazalil at ambient temperature reduced CI in late-season grapefruit. Based on these findings, we tested the response of grapefruit to TBZ and imazalil at ambient and elevated temperatures with the objective of reducing its susceptibility to CI and decay.

Interior 'Marsh' (white-fleshed) and coastal Indian River 'Redblush' (red-fleshed) grapefruit were obtained from two commercial packinghouses for four separate tests (replications) of each cultivar in May 1989 (late season). On each occasion, freshly harvested size 40 fruit (10 ± 1.3 cm in diameter) (within 24 h) were hand-selected and transported to the U.S. Horticultural Research Laboratory, Orlando, Fla. Fruit were washed with a nonfungicidal soap (Mold Strip 25; Fresh Mark Chemical, Ocoee, Fla.), randomly divided into 120-fruit lots, and dip-treated for 2 min as follows: a) water at ambient temperature, 24C, or at b) 53C; c) TBZ at 1 g·liter^{-1} at 24C or at d) 53C; or e) imazalil at 1 g·liter^{-1} at 24C or at f) 53C. Following treatment, all fruit were waxed with Flavorseal solvent wax (FMC Corp., Lakeland, Fla.), packed in fiberboard citrus cartons, and stored 6 weeks at 5C and 86% ± 5% relative humidity (RH), and then held an additional 2 weeks at 20C and 90% ± 2% RH. The fruit were then evaluated for CI (expressed as CI index) and decay.

At evaluation, all fruit were inspected for visible symptoms of CI, i.e., pitting and rind scald. Fruit were classified into one of five CI categories, depending on the surface area affected, where 1 = 0%, 3 = below 5%, 5 = 5% to 25%, 7 = 26% to 50%, and 9 = more than 50%. A CI index was calculated by summing the products of the number of fruit in each category by the value of each category and then dividing this sum by the total number of fruit evaluated. Decayed fruit were removed at each inspection, and the primary decay-causing organism was determined. Data for CI injury and decay were analyzed as a randomized complete block design with factorial treatments (2 cultivars × 2 dip temperatures × 3 fungicides) with four harvest dates (blocks) using the analysis

Received for publication 21 May 1990. Mention of a trademark, warranty, proprietary product, or vendor does not constitute a guarantee by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable. We gratefully acknowledge Roxanne Wiseman and Cathy Carroll for technical assistance in this work. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

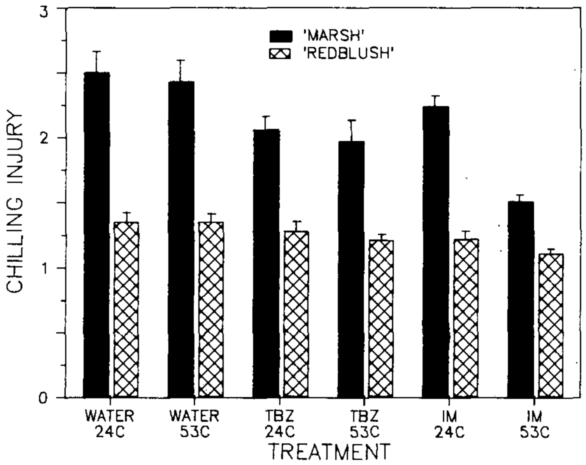

Fig. 1. Effect of dip treatment on incidence of chilling injury of grapefruit stored 6 weeks at 5C plus 2 weeks at 20C. Vertical lines represent SE of the means.

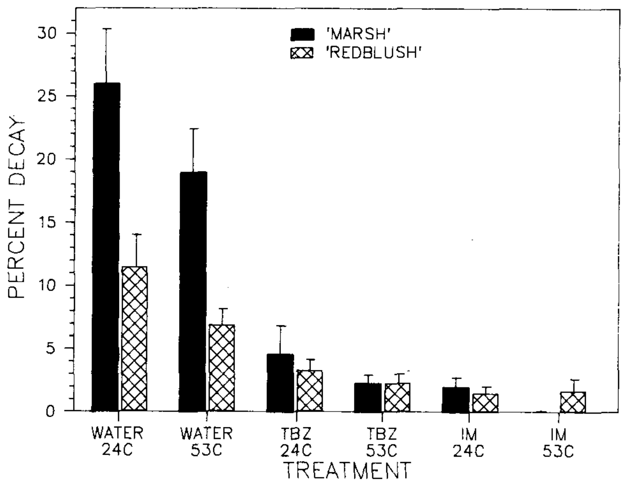

Fig. 2. Effect of dip treatment on decay o fgrapefruit stored 6 weeks at 5C plus 2 weeks at 20C. Vertical lines represent SE of the means.

Table 1. Analysis of variance of a 2 × 2 × 3 factorial examining the effect of cultivar, dip temperature, and fungicide on chilling injury and decay after 6 weeks at 5C plus 2 weeks at 20C of late-harvested 'Marsh' and 'Redblush' grapefruit.

Source	df	Chilling injury index mean squares	Decay mean squares
Cultivar (C)	1	8.97***	252.1*
Dip temp (T)	1	0.37**	96.3
C × T × fungicide (F)	2	0.11	0.3
Orthogonal contrasts			
Water (W) vs. F	1	0.65***	704.2***
TBZ vs. imazalil (IM)	1	0.62**	1275.1***
C × W vs. F	1	0.16	155.0
C × TBZ vs. IM	1	0.23*	312.5**
T × W vs. F	1	0.35*	20.2
T × TBZ vs. IM	1	0.01	36.1*
Error	36	0.05	39.1

***, **, *Significant at $P > F < 0.001$, 0.01, or 0.05, respectively.

of variance (ANOVA) procedure (SAS Institute, 1988).

The analysis showed a highly significant ($P < 0.001$) overall effect of cultivar on CI, as there was much more CI on 'Marsh' than on 'Redblush' grapefruit (Table 1, Fig. 1). The effect of dip temperature on CI was highly significant ($P < 0.01$). Fruit dipped at 53C had less CI than fruit dipped at 24C. Fungicide treatment significantly reduced ($P < 0.001$) CI. Imazalil was significantly more ($P < 0.01$) effective in reducing CI than TBZ. Although our findings agree with the findings of Wild and Hood (1989), the reduction in CI we found was not as large as that found in their study with 'Valencia' oranges. We may not have obtained the reduction in CI through the use of TBZ that Wild and Hood (1989) and others have observed because they stored their fruit for much longer periods than we did. Our fruit were stored for 6 weeks at 5C plus 2 weeks at 20C, which equals the maximum time that Florida grapefruit would be commercially stored and marketed. Chalutz et al. (1985), Kokkalos (1974), Schiffmann-Nadel et al. (1972), Wardowski et al. (1975), and Wild and Hood (1989) held their grapefruit for 17, 20, 13, 9.5, and 15 weeks, respectively, before rating for CI.

About 60% of the decayed areas on stored fruit were due to stem-end rot, 20% to penicillium rot, and the remainder to miscellaneous rots. Overall, significantly more ($P < 0.05$) decay was found in 'Marsh' grapefruit than in 'Redblush' (Table 1, Fig. 2). As expected, fungicides significantly reduced ($P < 0.001$) decay. Significantly less ($P < 0.001$) decay was found in imazalil-treated fruit than in TBZ-treated fruit. Decay incidence generally followed CI in terms of treatment effect.

Results of this study confirm the benefits of high-temperature fungicide treatments for maintaining grapefruit quality and indicate some benefits of high-temperature fungicide treatments for reducing CI. However, the temperature of the water has to be carefully controlled because water at 58C for 2 min resulted in damage to the peel and water at 40C and below was without effect (data not shown). The practical implication of high-temperature fungicide treatments is the possibility of storage of grapefruit for extended periods at temperatures below those presently used (10 to 15.5C).

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