Table 2. Effect of winter temperatures on apple powdery mildew of 'Jonathan' trees the following spring.

Year	Minimum temperature during preceding winter (°C)	Terminal mildew[z]
1965	−25	11.6
1966	−12	29.3
1967	−6	11.4
1968	−20	34.0
1969	−30	2.5
1970	−12	11.5
1971	−19	10.1
1972	−22	20.5
1973	−21	29.9
1974	−21	35.8
1975	−12	[y]
1976	−9	17.2
1977	−14	52.2
1978	−18	39.1
1979	−25	<1.0
1980	−24	<1.0

[z]Severity (0.1–1.0) × percent prevalence about 10 days after 1.25 cm green.
[y]Data missing.

of apple shoots during natural winter freezing was also observed by Simons (8). However, the severe injury at the basal part of the terminal bud might not block the transport of water and/or nutrients from shoot to apex for growth of the primordium. Therefore, those buds with the rating of 3 might still be capable of growth. At −23°, the injury rating was 4.3 for mildew-infected buds and 3.1 for healthy buds (Fig. 4) and only 10–20% of those buds could be forced to grow (Table 1). The temperature necessary to achieve this degree of freezing injury of mildew-infected buds was approximately −22°C for all cultivars at the late dormant season (Fig. 3A–3C).

Since 1965, the amount of primary apple powdery mildew present on 'Jonathan' apple trees growing at the Tree Fruit Research Center in Wenatchee, Washington, was estimated in connection with a fungicide-testing program. Data were recorded as severity (scale of 0.1–1.0) times percent prevalence (Table 2). In only 3 of the 16 years (1969, 1979, and 1980) was mildew rated below 10 at this stage of development. In each of these years, minimum temperatures of at least −24° were recorded the preceding winter. Temperatures in this range were also recorded in the winter of 1964–65 when a moderate carryover of mildew was recorded. Thus, while the average terminal mildew following winters warmer than −22° was 26.5%, percent terminal mildew following the 4 winters of −24° or colder was 4.0%.

Burke et al. (3) reviewed the freezing and injury in plants and found that apple flower buds did not deeply supercool and, therefore, did not show a low temperature exotherm during the freezing process. Preliminary observations revealed that freeze injury of either vegetative or reproductive terminal buds of apple trees was similar. Terminal buds seeded with ice during the freezing process injured similarly as those without inoculation. The actual mechanism of cold hardiness of apple terminal buds is not well understood and additional research in this area is necessary. Lateral buds were not studied because they are seldom infected by mildew.

The quantitative data from this study on low temperature injury of mildew-infected apple buds contribute basic information necessary for prediction of primary mildew infection levels early in the season and will allow for corresponding fungicide application schedule adjustments. Survival of mildew-infected buds may be related to the time infection occurs during the growing season, as well as time freezing occurs during winter.

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HortScience 16(6):783–784. 1981.

Effects of Ethylene on Chilling Injury and Subsequent Decay of Conditioned Early 'Marsh' Grapefruit during Low-temperature Storage[1,2]

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Additional index words. growth regulators, *Citrus paradisi,* postharvest physiology

Abstract. **Early Florida 'Marsh' grapefruit (*Citrus paradisi* Macf.) can be safely degreened with 5 ppm C_2H_4 up to 72 hours and then stored for 17 days at 1°C, providing the fruit are conditioned for 7 days at 16° prior to storage.**

Ethylene is used in Florida to degreen early grapefruit for the fresh market. Generally, fruit harvested in September and October require a longer degreening period than those harvested in November and December; usually in December, cool night temperatures are sufficient to degreen fruit on the tree.

Ethylene increases physiological disorders in citrus fruits, including pitting, decay, and, for grapefruit, an unacceptable orange rind color (1, 7, 8). Decay of some citrus cultivars was increased by degreening for only 48 hr with 5, 50, and 120 ppm C_2H_4 (12). Losses in different types of citrus fruits held for 3 weeks at 21°C subsequent to degreening have been related to C_2H_4 concentration and to the duration of exposure (4). Exposure to C_2H_4 for 15 hr is the most satisfactory for several citrus cultivars (10); however, degreening time for Florida grapefruit is often as long as 72 hr, but recent recommendations limit C_2H_4 concentrations to 1–5 ppm (15).

Grapefruit develop chilling injury (CI) when exposed to temperatures below 10°C. CI is evident in 2 forms: rind pitting, which prevails at about 4°, and brown staining of the rind, which is common near 0° (11). The recommended storage temperature for grapefruit is 10° for mid- and late-season fruit and 16° for early fruit (2, 11). Grapefruit have varying susceptibility to CI throughout the harvesting season when exposed to temperatures below 10° (3, 4, 6, 13). These reports indicate that resistance to CI in grapefruit increases from the early picking season (September and October), but decreases from midseason (February and March) to late in the season (May and June). Postharvest application of the fungicides benomyl and thiabendazole reduced CI in Florida grapefruit (14). Commercially, early degreened fruit would not be stored, but

[1]Received for publication April 24, 1981.
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[2]Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.
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[4]The authors gratefully acknowledge the assistance of Victor Chew, USDA Statistician, University of Florida, for conducting the statistical analyses, and the Florida Citrus Commission for supplying the fruit.

Table 1. Effects of ethylene on decay of early 'Marsh' grapefruit (1978) conditioned at 16°C for 7 days prior to storage at 1°.[z]

Conditioning, storage, and ethylene treatment[y]	Decay (%)		
		After holding at 21°	
	After storage	7 Days	14 Days
24 days at 16°C			
0 hr	0	0	0
24 hr	0.2	0.3	0.5
48 hr	0.2	0.2	0.3
72 hr	0.3	0.3	0.3
24 days at 1°[x]			
0 hr	0	0.2	0.3
24 hr	0	0.3	1.0
48 hr	0	0.8	5.8
72 hr	0	2.4	6.5
7 days at 16° + 17 days at 1°			
0 hr	0	0	0.3
24 hr	0	0.2	0.6
48 hr	0	0.3	0.5
72 hr	0.2	0.3	0.5

[z]Each value represents 689 fruit from a single grove harvested on October 23, November 7, November 20, and December 4.

[y]Ethylene dispensed at 5 ppm at 29° and a relative humidity of 90 to 95%.

[x]Regression analyses ($P < .05$) showed that fruit stored constantly at 1° for 24 days and then held for 7 and 14 days at 21° were progressively affected by C_2H_4 exposure time.

it may be shipped for considerable distances; therefore, CI can be an important factor. Temperature conditioning of grapefruit to reduce CI prior to low-temperature storage was first noted in 1921 with recommendations made in 1926 (9). Although further research has been done, conditioning procedures are not used commercially.

The purpose of this study was to determine the effects of C_2H_4 on CI of early grapefruit which were conditioned prior to low-temperature storage.

Early 'Marsh' grapefruit were harvested 4 times (October 23, November 7, November 20, and December 4) from a single grove in the Indian River District of Florida during the 1978–79 season. Fruit were placed in the C_2H_4 room for degreening on the day of harvest. Standard degreening procedures were used (5). Fruit that were not degreened were washed, treated with 1000 ppm thiabendazole, waxed with Flavorseal 93, graded, replicated into lots of 3 cartons, and placed in the respective conditioning and storage rooms.

Ethylene was dispensed at 5 ppm into a room maintained at 29°C and at a relative humidity of 90 to 95%. Fruit were kept in the room for the prescribed 24, 48 and 72 hr and then washed, treated with thiabendazole, waxed, graded, and placed in conditioning and storage rooms with fruit that had not been degreened. Conditioning was for 7 days at 16° and 80–92% relative humidity. Storage was at 1° and 88–92% relative humidity or 16° and 80–92% relative humidity for 24 days. Fruit were inspected at the end of storage and after additional 7 and 14 days at 21°.

CI was classified as either rind pitting or brown staining, but these forms were combined as total CI. The amount of rind surface affected with CI was tabulated as slight (up to 20 mm), moderate (20–35 mm), and severe (over 35 mm). Decayed fruit were classified according to types of decay, but not counted for CI.

No CI developed in grapefruit during storage for 24 days at 16°C or 7 days at 16° plus 17 days at 1°, regardless of C_2H_4 treatment. Fruit degreened for 0 and 24 hr had no CI. However, degreening for 48 and 72 hr and then storing for 24 days at 1° resulted in 2.2 and 13.4% CI, respectively (data not shown).

Fruit that were degreened for 48 and 72 hr and then stored for 24 days at 1°C had 6.9 and 20.4% CI, respectively, after holding for 7 days at 21°. Similar fruit developed only 0.5% CI from 24-hr exposure to C_2H_4. Some reduction in CI of the fruit held at 21° for 14 days was noted, because decayed fruit were not included in the count. Brown staining accounted for 98% of the CI, of which 55, 33 and 12% were slight, moderate, and severe, respectively.

The extent of decay after storage was negligible (Table 1). At 21°C, decay increased most rapidly in fruit that had displayed CI from constant storage for 24 days at low temperature. Most of the decay was caused by *Penicillium digitatum* Sacc. or green mold (70.1%). This fungus enters through injury, such as the CI in this study.

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