Table 1. Tomato fruit firmness as influenced by cultivar and stage of ripeness.

| Harvest date | Days of ripening (20°C) | Fruit firmness | | |
|---|---|---|---|---|
| | | Walter | Fla. MH-1 | Flora-Dade |
| Nov. 30, 1978 | 7 | 3.5b[y] | 2.3a | --- |
| | 14 | 5.4c | 3.6b | --- |
| Dec. 7, 1978 | 7 | 3.7d | 2.4b | 2.1a |
| | 14 | 5.1f | 4.0e | 3.3c |
| May 25, 1979 | 7 | 4.2c | 3.1b | 2.4a |
| | 14 | 5.1f | 4.4e | 3.4c |
| | 21 | 5.5g | 4.8f | 3.8d |
| June 11, 1979 | 7 | 4.0c | --- | 2.5a |
| | 14 | 5.1d | --- | 3.1b |
| | 21 | 5.5e | --- | 4.0c |
| May 30, 1980 | 7 | 4.5[x] | 2.9a | 2.6a |
| | 14 | --- | 4.0c | 3.4b |
| | 21 | --- | 4.9d | 4.0c |
| June 10, 1980 | 7 | 4.6e | 3.0b | 2.5a |
| | 14 | 5.6g | 4.7e | 3.3c |
| | 21 | 5.9h | 5.2f | 4.0d |

[z]The lower the value the firmer the fruit.
[y]Mean separation at 5% level within harvests by Duncan's multiple range test.
[x]Value not included in statistical evaluation.

Table 2. Tomato fruit color as influenced by cultivar and stage of ripening.

| Harvest date | Days of ripening | Tomato fruit color (Hunter a/b values)[z] | | |
|---|---|---|---|---|
| | | Walter | Fla. MH-1 | Flora-Dade |
| May 30, 1980 | 7 | 2.50[y] | 2.63cd[x] | 2.22a |
| | 14 | - | 2.71d | 2.52c |
| | 21 | - | 2.51c | 2.36b |
| June 10, 1980 | 7 | 2.19ab | 2.41de | 2.25bc |
| | 14 | 2.26b | 2.49e | 2.33cd |
| | 21 | 2.11a | 2.38d | 2.24bc |

[z]The higher the value the more intense the color.
[y]Value not included in statistical evaluation.
[x]Mean separation at 5% level within harvests by Duncan's multiple range test.

'Flora-Dade' and 'Florida MH-1' fruits were firmer at 7, 14 and 21 days after incipient color than 'Walter' fruits for all harvests (Table 1). 'Flora-Dade' fruits ripened for 14 or 21 days were as firm as, or firmer than, 'Walter' fruits ripened for 7 days. 'Florida MH-1' fruits ripened for 14 days were as firm as 'Walter' fruits ripened for 7 days except for the December 7, 1978 harvest. The difference in firmness values between 7 and 21 days was greater for 'Florida MH-1' than for 'Walter' or 'Flora-Dade' indicating a faster rate of softening for that cultivar. 'Walter' and 'Florida MH-1' fruits softened more between 7 and 14 days than they did between 14 and 21 days.

The 2 firmer cultivars developed as much red color as 'Walter' indicating that the increased firmness was not due to an overall slower ripening rate (Table 2).

No decay occurred in fruits held 7 to 14 days except at the June 10, 1980 harvest when 2.5% (1 of 40) of 'Flora-Dade' fruits had decayed in the 7-day sample. At 21 days, 9.5% of 'Walter' fruits had decayed with a similar amount for each harvest; 5% of the 'Florida MH-1' fruits had decayed at 21 days for each of the May 25, 1979 and June 10, 1980 harvests. 'Flora-Dade' fruits were without decay at 21 days except for the June 10, 1980 harvest when 5.0% occurred.

The average firmness values after 7 days of ripening for fall and spring harvests respectively were 3.6 and 4.3 for 'Walter' fruits, 2.4 and 3.0 for 'Florida MH-1' fruits and 2.2 and 2.5 for 'Flora-Dade' fruits. The differences between fall and spring values were significant except for 'Flora-Dade'.

The results indicate that ripened fruits of firm cultivars such as 'Flora-Dade' and 'Florida MH-1' could be handled for a 7 to 14 day period and have acceptable firmness.

### Literature Cited


1. Crill, P., J. W. Strobel, D. S. Burgis, H. H. Bryan, C. A. John, P. H. Everett, J. A. Bartz, N. C. Hayslip, and W. W. Deen. 1971. Florida MH-1, Florida's first machine harvest fresh market tomato. Fla. Agr. Expt. Sta. Cir. S212.
2. Geraldson, C. M., A. J. Overman, and J. P. Jones. 1965. Combination of high analysis fertilizer, plastic mulch and fumigation for tomato production on old agricultural land. Proc. Soil & Crop Sci. Soc. Fla. 25:18–24.
3. Hall, C. B. 1964. Firmness and color of some tomato varieties during ripening and according to harvest dates. Proc. Amer. Soc. Hort. Sci. 84:507–512.
4. Hamson, A. R. 1952. Measuring firmness of tomatoes in a breeding program. Proc. Amer. Soc. Hort. Sci. 60:425–433.
5. Hicks, J. R., P. H. Everett, and R. H. Dougherty. 1972. Consumer acceptance of machine harvested 'Florida MH-1' tomatoes and taste panel comparisons of 'Florida MH-1' and 'Walter' tomatoes. Proc. Fla. State Hort. Soc. 85:184–186.
6. Hicks, J. R. and N. C. Hayslip. 1975. Fresh market tomatoes harvested red-ripe. HortScience 10:2.
7. Hicks, J. R., N. C. Hayslip, and R. K. Showalter. 1975. Consumer preferences in buying pink and red-ripe tomatoes. HortScience 10:11–12.
8. McCollum, J. P. 1956. Sampling tomatoes for composition studies. Proc. Amer. Soc. Hort. Sci. 68:587–595.
9. Volin, R. B. and H. H. Bryan. 1976. 'Flora-Dade', a fresh market tomato with resistance to Verticillium wilt. Fla. Agr. Expt. Sta. Cir. S-246.




*HortScience* 16(6):781–783. 1981.

# Effect of Low Temperature on Survival of Apple Buds Infected with the Powdery Mildew Fungus[1]

**R. A. Spotts, R. P. Covey,[2] and P. M. Chen**
*Mid-Columbia Experiment Station, Oregon State University, Hood River, OR 97031*

*Additional index words. Malus domestica, Podosphaera leucotricha*, freezing injury

***Abstract.*** **The lowest survival temperatures were determined quantitatively for dormant terminal buds of 'Newtown', 'Golden Delicious' and 'Rome Beauty' apples (*Malus domestica* Borkh.) that were either healthy or infected with powdery mildew (*Podosphaera leucotricha* (Ell. & Ev) Salm.). Irrespective of cultivar, all mildew-infected buds were more susceptible to freezing injury than healthy buds. Survival of mildew-infected buds at about −22°C was similar to survival of healthy buds at −26°. Field data on 'Jonathan' showed that terminal mildew infection following winters warmer than −22° was 26.5%, but was only 4.0% following winters −24° or colder.**

The apple powdery mildew fungus overwinters as mycelium in vegetative and fruit buds (1, 2, 5, 10). *Podosphaera leucotricha*, an obligate parasite, survives only in association with living host tissue. Following severe winters, mildew severity is low (6, 9). Previous work has shown that low temperatures do not directly affect the fungus mycelium but that mildew-infected buds were more likely to be injured by exposure to low temperature than were healthy buds (4, 6). This study was conducted to determine quantitatively the lowest survival temperatures of healthy and mildew-infected buds of selected apple cultivars.

[1]Received for publication July 9, 1981. Oregon State Agricultural Experiment Station Technical Paper No. 5910.
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.
[2]Tree Fruit Research Center, Wenatchee, WA 98801.

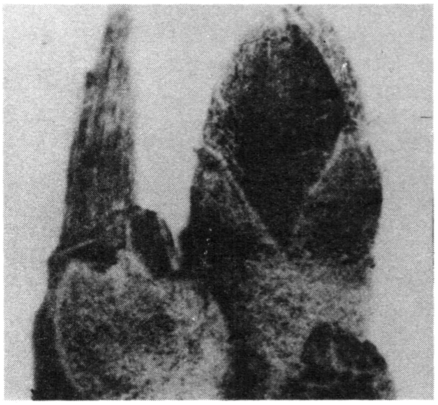

Fig. 1. Powdery mildew-infected (left) and healthy (right) apple terminal buds.

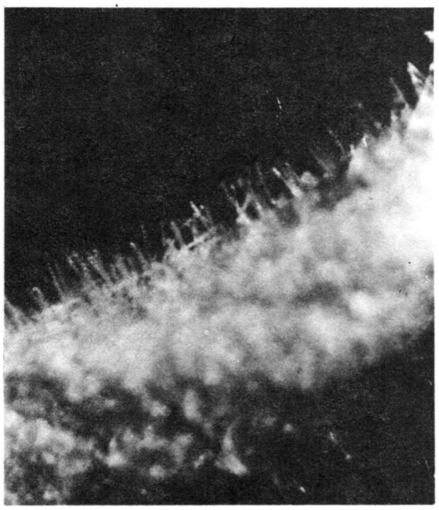

Fig. 2. Conidia of *P. leucotricha* (30×) on leaf tissue of opening bud.

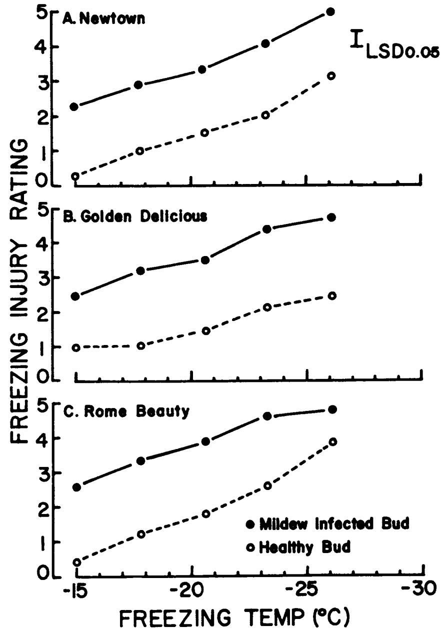


Fig. 3. Freezing injury of terminal buds of 3 apple cultivars as evaluated by the visual observation method. Apple terminal buds were at the late dormant stage.

Terminal buds were cut from uniform, mature trees of 3 apple cultivars ('Newtown' on seedling rootstock, 'Golden Delicious' on Malling Merton (MM) 106, and 'Rome Beauty' on MM 106) at the Mid-Columbia Experiment Station, Hood River, Oregon, during February, 1981. To determine the accuracy of visual classification of buds as "healthy" or "infected," 50 terminal buds, appearing "healthy" and 50 appearing "infected" (Fig. 1) of each cultivar were excised with 10 cm of stem attached, the cut ends placed in water, and the buds forced in a growth chamber at 20±1°C, 50±10% relative humidity, and 12 hr photoperiod. When 5 to 10 mm of green tissue was exposed, each bud was examined with a stereomicroscope at 30× for *P. leucotricha* conidia (Fig. 2). Sporulation was observed on 98, 94, and 96% of "infected" 'Golden Delicious', 'Newtown', and 'Rome Beauty', respectively. No mildew was observed on 100, 96, and 100% of "healthy" 'Golden Delicious', 'Newtown', and 'Rome Beauty', respectively.

To determine the lowest survival temperature (LST) of apple terminal buds, both healthy and mildew-infected buds were excised from the terminal shoots with about 5 mm of the stem attached to the buds. The freezing test was a modification of the method of Proebsting and Sakai (7) who reported that peach flower buds excised with about 1 mm of vascular traces had the same death point as those buds with more stem tissue attached. For each temperature, 10 excised buds and a thermocouple were wrapped together in aluminum foil and placed in a thermos bottle containing an ice cube. When the bud temperature equilibrated to about 2°C, the thermoses were placed into a −34.4° freezer. The freezing rate was estimated about 5°/hr. When desired test temperature was reached, the thermos bottle with frozen buds was removed from the freezer and incubated at 3° overnight to allow slow thawing. Buds were then incubated in a moisture-saturated chamber at 20° for 3 days.

Bud viability was visually evaluated by the degree of tissue browning of bud primordia and surrounding tissue. A rating scale from 0 to 5 was used for the degree of tissue browning with 0 as no browning; 1 as 20% of surrounding tissue browned but primordia green; 2 as 40% of surrounding tissue browned but primordia green; 3 as 60% of surrounding tissue browned with some browned primordia; 4 as 80% of surrounding tissue browned with mostly browned primordia; and 5 as all primordia and surrounding tissue browned. Ratings were made for each of the 5 temperature readings. The mean score of 10 buds from either healthy or mildew-infected terminal shoots was plotted against its corresponding freezing temperature. The LST of the terminal bud was arbitrarily defined as the temperature at which the mean score was rated at 2.5.

The LST of healthy vs. infected terminal buds was estimated as −25°/−16°C, −27.8°/−14.5°, and −22.8°/−14.5° for 'Newtown', 'Golden Delicious', and 'Rome Beauty', respectively (Fig. 3A–3C). Irrespective of cultivar, all the mildew-infected terminal buds were more susceptible to freezing injury than healthy buds.

Table 1. Survival of healthy and mildew-infected 'Newtown' terminal buds exposed to low temperatures as evaluated by the bud-breaking method[z].

| Freezing temp (°C) | Bud survival (%) Healthy | Infected |
|---|---|---|
| −15 | 92 | 78 |
| −18 | 100 | 55 |
| −20.6 | 50 | 90 |
| −23.3 | 20 | 10 |
| −26 | 10 | 0 |

[z]The terminal shoots (15-cm length) were thawed at 3°C overnight after each freezing temperature, inserted in a flask containing water, and incubated in a growth chamber for bud growth.

In order to verify the LST of terminal buds as determined by the visual observation technique, one freezing test was performed in late winter of 1981 (February 27) when the buds were presumably deacclimated to a certain extent and could be forced into growth at room temperature. In addition to 10 excised 'Newtown' buds, each thermos bottle contained 10 terminal 'Newtown' shoots (about 15 cm in length) wrapped in aluminum foil. After the freezing test, the excised buds were visually evaluated to determine their LST while the shoots were inserted into flasks with water and incubated in a growth chamber to determine the number of terminal buds capable of growth.

By February 27, healthy 'Newtown' buds deacclimated to LST −20.6°C while mildew-infected buds remained at LST −18° (Fig. 4). The survival evaluation by the bud breaking method indicated that both healthy and mildew-infected terminal buds had at least 50% or more buds capable of growth at −20.6° (Table 1). It was apparent that the visual observation method could not determine less than 2–3° LST. The most susceptible region of the terminal bud was at the base of the shoot apex, especially in the pith tissue underneath the bud primordium. This injury pattern

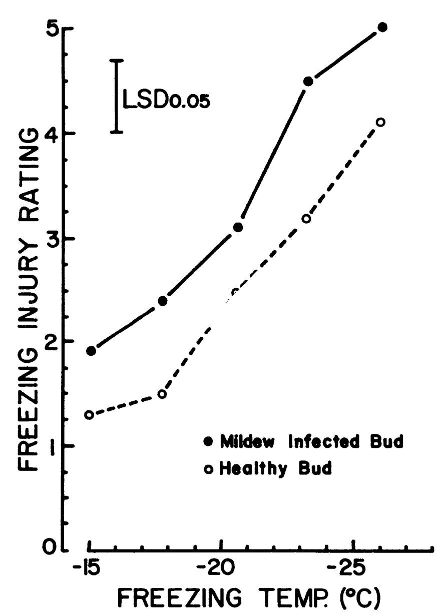


Fig. 4. Freezing injury of terminal buds of 'Newtown' apple as evaluated by the visual observation method. Buds were at the rapid deacclimating stage.

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.

### Literature Cited


1. Berwith, C. E. 1936. Apple powdery mildew. Phytopathology 26:1071–1073.
2. Burchill, R. T. 1958. Observations on the mode of perennation of apple mildew. Rpt. Agr. Hort. Res. Sta. Bristol, 1957. p. 114–123.
3. Burke, M. J., L. V. Gusta, H. A. Quamme, C. J. Weiser, and P. H. Li. 1976. Freezing and injury in plants. Annu. Rev. Plant Physiol. 27:507–528.
4. Covey, Jr., R. P. 1969. Effect of extreme cold on the overwintering of *Podosphaera leucotricha*. Plant Dis. 53:710–711.
5. Kosswig, M. Von. 1959. Bemerkungen zur Biologie und Bekämpfung des Erregers des Apfelmehltaus Podosphaera leucotricha (Ell. et Ev.) Salm. Z. F. Pflanzenkrankh. u. Pflanzensch. 66:263–272.
6. Luepschen, N. S. 1979. Apple mildew research 1979: winter bud mortality, fungicide effectiveness, and tree responses to control programs. Colo. State Univ. Expt. Sta. Prog. Rpt. 13.
7. Proebsting, Jr., E. L. and A. Sakai. 1979. Determining $T_{50}$ of peach flower buds with exotherm analysis. HortScience 14:597–598.
8. Simons, R. K. 1972. Winter injury on young developing apple shoots. HortScience 7:401–402.
9. Sprague, R. 1955. A restudy of apple powdery mildew in eastern Washington. Washington Agr. Expt. Sta. Bul. 560.
10. Woodward, R. C. 1927. Studies on *Podosphaera leucotricha* (Ell. & Ev.) Salm. I. The mode of perennation. Trans. Brit. Mycol. Soc. 12:173–204.


*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]

**T. T. Hatton and R. H. Cubbedge**[3,4]
*U.S. Department of Agriculture, Agricultural Research Service, Orlando, FL 32803*

*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.
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.
[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.
[3]Research Horticulturist and Biological Laboratory Technician.
[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.