Table 2. Effects of rates and sources at 2 Fe chelates on fruit size, yield, leaf color, and growth of 'Redhaven' peach trees (1970-1972 averages).

| Treatments | 1970 fruit diam (cm) | Yield (kg)/ tree 1st 3 harvest 1970) | tree Total yield (kg)/ tree (1970) | Rd[z] | Leaf color[z] a (Green) | Leaf color[z] b (Yellow) | Shoot growth (cm) | Cross-sectional area of trunk (cm) |
|---|---|---|---|---|---|---|---|---|
| Control - no fertilizer | 6.02 | 42.33 | 54.72 | 26.0 | 26.0 | 13.0 | 22 | 107 |
| 57 g FeEDDHA | 6.58 | 48.65 | 55.03 | 23.1 | 24.5 | 10.4 | 25 | 108 |
| 113 g FeEDDHA | 6.71 | 57.03 | 64.95 | 23.0 | 24.5 | 9.9 | 24 | 101 |
| 227 g FeEDDHA | 6.71 | 66.68 | 74.05 | 22.5 | 24.1 | 9.3 | 25 | 105 |
| 57 g 157HFe | 6.30 | 44.00 | 48.25 | 24.2 | 25.2 | 11.1 | 23 | 97 |
| 113 g 157HFe | 6.30 | 50.92 | 63.50 | 24.0 | 25.1 | 10.8 | 21 | 102 |
| 227 g 157HFe | 6.53 | 51.77 | 59.51 | 23.5 | 24.7 | 10.2 | 23 | 94 |
| LSD 5% | .10 | 13.05 | 15.20 | .69 | .41 | .88 | ns | ns |
| LSD 1% | .15 | 17.45 | 20.32 | .93 | .55 | 1.17 | | |

[z]Rd = luminous reflectance, a = green, b = yellow. The lower the number, the greener the leaf.

low application rate and 157HFe at all rates did not significantly increase yield of fruit per tree when compared to the non-fertilized trees. Treatments had no significant effect on trunk or shoot growth.

I have previously shown that 'July Elberta' peach trees is more susceptible than 'Sungold' to FeEDDHA-induced Mn deficiency (3, 4). The Mn:Fe ratio changes through the growing season where FeEDDHA is applied (4). The present study suggests that FeEDDHA is more effective than 157HFe in reducing Fe chlorosis of 'Redhaven' peach. The Fe chelates depress the Mn concn of leaves when reducing Fe chlorosis.

### Literature Cited


1. Epstein, E. and O. Lilleland. 1942. A preliminary study of the Mn content of the leaves of some deciduous fruit trees. *Proc. Amer. Soc. Hort. Sci.* 41:11-18.
2. Kochan, W. J. 1962. Iron chelate control of chlorosis in peach trees. *Idaho Agr. Expt. Sta. Bul.* 384.
3. Rogers, E. 1971. Iron-Mn relations of 'Sungold' peaches in western Colorado. *J. Amer. Soc. Hort. Sci.* 96:14-16.
4. ———. 1973. Iron induced Mn deficiency in 'July Elberta' peach trees. *J. Amer. Soc. Hort. Sci.* 98:19-22.
5. Shive, J. W. 1941. Significant roles of trace elements in nutrition of plants. *Plant Physiol.* 16:435-445.
6. Somers, I. I., and J. W. Shive. 1942. The Fe-Mn relation in plant nutrition. *Plant Physiol.* 17:582-602.
7. ———, S. G. Gilbert, and J. W. Shive. 1942. The Fe-Mn ratio in relation to respiratory $CO_2$ and deficiency-toxicity symptoms in soybeans. *Plant Physiol.* 17:317-320.
8. Stebbins, R. L., G. Johnson, and D. K. Johnson. 1963. Response of peach to application of N and chelated Fe in Colorado. *Proc. Amer. Soc. Hort. Sci.* 82:114-119.
9. Twyman, E. S. 1946. The Fe-Mn balance and its effect on the growth development of plants. *New Phytol.* 45:18-24.
10. ———. 1951. The Fe and Mn requirements of plants. *New Phytol.* 50:210-226.
11. Weinstein, L. H. and W. R. Robbins. 1955. The effects of different Fe and Mn nutrient levels on the catalase and cytochrome oxidase activities on green and albino sunflower leaf tissues. *Plant Physiol.* 30:27-32.


# An Improved Exotherm Method for Measuring Cold Hardiness of Peach Flower Buds[1]


H. A. Quamme, R. E. C. Layne, H. O. Jackson, and G. A. Spearman
*Research Station, Agriculture Canada, Harrow, Ontario*



*Abstract.* **A method of exotherm analysis is described for determining the cold hardiness of dormant peach flower buds (*Prunus persica* (L.) Batsch). Twig pieces with intact flower buds were placed into thermos bottles and cooled at a constant rate in a programmed cold chamber. A thermocouple was inserted in the node of each twig piece to measure the temperature at which sudden heat release occurred. Thermocouples connected in series made it possible to record exotherms of 5 twig pieces from a cultivar on a single channel of a multipoint recorder. The exotherm method was compared to the $LT_{50}$ method (the temperature at which 50% of the flower buds are killed) using 10 cultivars on one collection date. The mean temperatures at which the exotherms were initiated were significantly correlated with the $LT_{50}$ ($r = +.880$). In addition, the mean temperatures at which exotherms were initiated and the $LT_{50}$ for these cultivars were significantly correlated with the percentage of flower bud mortality averaged over 4 winters ($r = -.667$ and $-.797$, respectively). The exotherm method gives a direct measurement of the temperature at which peach flower buds are killed and offers an opportunity for studying the cold hardiness of individual flower buds not possible with other methods.**



[1]Received for publication February 24, 1975.


Graham (2) and George et al. (1) found that injury to dormant flower primordia of azalea was associated with a sudden release of heat. The temperatures of the exotherms detected on the recorded time-temp profiles were useful in determining the differences in flower bud hardiness of azalea cultivars. Quamme (4) found that a lethal exotherm was present in overwintering flower buds of several *Prunus* species including peach and that exotherm analysis appeared useful for measuring cold hardiness of different peach cultivars. In this paper we describe a method for conveniently measuring flower bud exotherms which was useful in measuring flower bud hardiness of ten peach cultivars on one collection date.

The method used was similar to that previously described (4). Twigs collected from the previous season's growth were cut in pieces to include a node and flower bud. A sharpened thermocouple (24 gauge copper constantan) was inserted into twig pieces at the node below the flower bud (Fig. 1). Insertion of the thermocouple at the base of the flower bud was more convenient than introducing fine thermocouples into the flower primordia through the scales. Often more than one flower bud occurred at a node, but the thermocouple inserted at the base of the node sensed exotherms produced by each flower bud. Sectioning of twig pieces and insertion of the thermocouples were carried out at $-3^{\circ}C$ in a walk-in cooler.

Another improvement to the method previously reported involved increasing the no. of flower buds that could be run per channel on a multipoint recorder by using thermocouples connected in series. Nine thermocouples in series were mounted on a holder made from a cork

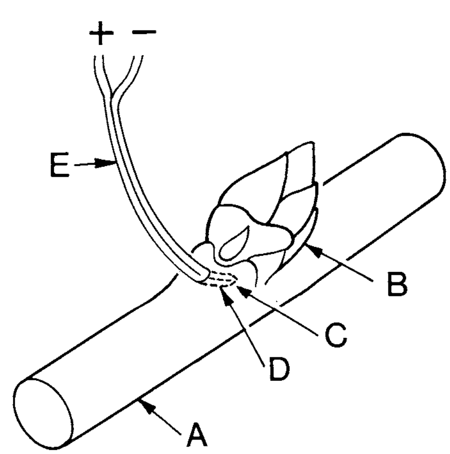


Fig. 1. A diagram illustrating insertion of a thermocouple below a flower bud. A sharpened thermocouple (D) is inserted into the base of the flower bud (B) at the node (C). (E) is the thermocouple lead wire. (A) is the twig piece.

stopper (Fig. 2). Twig pieces were placed on the 5 thermocouples generating a positive signal; the 4 thermocouples generating a negative signal were left at air temp. Freezing in any of the twig pieces produced a deflection on the time-temp plot. The no. of thermocouples that can be connected together can vary, but there must always be one more thermocouple generating a positive signal than negative so that the signals are not cancelled out. In our studies we found that a maximum of 5 positive thermocouples per channel gave good resolution of the exotherms.

Twig pieces mounted on the thermocouple series at $-3^{o}C$ in the cold room were seeded with ice by placing a small drop of ice water on the cut surface of the twig. Twig pieces were placed in thermos bottles and transferred to a programmed freezer for cooling at a rate of $5^{o}C$/hr to $-30^{o}C$. Temp was recorded with a Thermo Electric multipoint recorder (Model FMWST6C) with a range of +5 to $-40^{o}C$, printing rate of 2 sec per point and a chart speed of 6.4 mm (¼ inch)/min. Part of a typical time-temp profile is presented in Fig. 3 to illustrate the initiation temp of the flower bud exotherms. Sudden exotherms were not present on other parts of the time-temp profile.

On Feb. 21, 1974 twigs from 10 peach cultivars were collected and

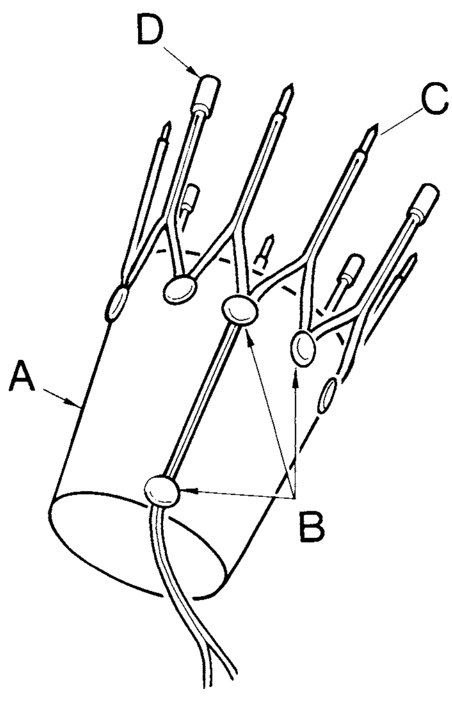


Fig. 2. The configuration of the multiple thermocouples in series used for measuring exotherms. (A) is the cork stopper on which the thermocouples are mounted with thumb tacks (B). (C) is a sharpened thermocouple where a twig piece is mounted. (D) is aluminum foil used to dampen out temperature variation on the thermocouples producing the negative signal.

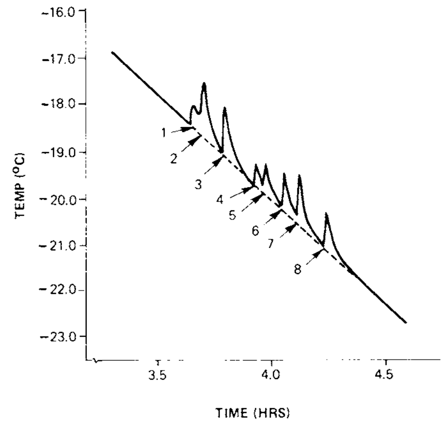


Fig. 3. A part of a typical time-temp profile of 'Loring' peach flower bud showing the initiation of the exotherms (numbered arrows). Where two or more exotherms were superimposed, the temp at which the exotherm was initiated was determined from the extrapolated base line (dashes).

stored at $-3^{o}C$. Natural flower bud mortality of the 10 peach cultivars at the time of collection ranged from 5 to 30%. Exotherm measurements were made on Feb. 25, 26 and 27. Three twigs of each cultivar were sectioned and 5 twig pieces were taken at random from the pooled sample for each exotherm analysis. Two analyses were performed on each date.

On the same dates that exotherm measurements were made, samples of 3 intact twigs of each cultivar were placed in a cooling apparatus (5) and frozen at the same cooling rate ($5^{o}C$/hr) that was used for exotherm analyses. These twigs were removed from the cooling apparatus at 4 temp, $-18^{o}$, $-20^{o}$, $-22^{o}$, and $-24^{o}C$. The temp was monitored in one twig of one of the samples removed at each test temp. After removal, the twigs were thawed at $3^{o}C$, incubated in a water-saturated atmosphere for 2 days and sectioned to observe the no. of dead flower buds. The temp at which 50% of the flower buds were killed ($LT_{50}$) was calculated using the technique described by Proebsting et al. (3).

The cultivars studied in these tests (Table 1) represented the range in cold hardiness of peach cultivars available in the Harrow germplasm collection. The cold hardiness of cultivars studied in these tests ranged from those that are frequently injured but which do survive in southern Ontario ('Loring' and 'Glohaven') to those which are very winter hardy and sustain injury only in severe winters such as 1971-72, ('Harrow Blood' and 'Siberian C'). Natural flower bud mortality was determined by sectioning and counting the number of dead flower buds in March or April before flower bud expansion. Correlations were calculated between mean natural flower bud mortality for 4 years, the mean temp at which flower bud exotherms were initiated and $LT_{50}$. The mean natural bud mortality was significantly negatively correlated with the mean initiation temp of the exotherm (r = –.664) and $LT_{50}$ (r = –.797). A highly significant positive correlation was also observed between initiation temp of the exotherm and $LT_{50}$ (r = +.880).

Quamme (4) previously reported on the relationship between mean initiation temp of flower bud exotherms and the $LT_{50}$ in 'Elberta' and 'Siberian' peach throughout the winter season. He also reported on the relationship between the mean initiation temp of exotherms and the rated flower bud hardiness of 5 cultivars on 3 dates. Those experiments and this study illustrate that exotherm analysis is a useful technique for measuring the cold hardiness of dormant peach flower buds. One advantage of the exotherm method is that it measures the exact killing temp of individual buds. This can be particularly useful in studies which attempt to relate flower bud hardiness to environmental stress. Exotherm measurements are also useful in studying differences in flower bud hardiness on a single branch or for evaluating the localized effect of a disease or treatment on flower bud hardiness. It requires less labor and plant material than $LT_{50}$ measurements.

A disadvantage is that the number of simultaneous measurements is limited by the type of multipoint recorder used. With the type of recorder used in this study only 12 of the 24 available

Table 1. Comparison of the natural mortality of 10 peach cultivars with the mean initiation temp of the exotherm and $LT_{50}$.

| Cultivar | Natural mortality (% buds killed) | | | | Mean | Initiation temp of the exotherm (°C) | $LT_{50}$ (°C) |
|---|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | 1974 | | | |
| Harrow Blood | 13.0 | 10.0 | 65.7 | 21.3 | 27.5 | –21.7 | –22.0 |
| Siberian C | 8.5 | 4.5 | 58.1 | 27.4 | 24.6 | –21.0 | –21.8 |
| Babygold 5 | 25.4 | 20.3 | 95.0 | 9.0 | 37.4 | –19.9 | –21.4 |
| Madison | 27.4 | 9.6 | 100.0 | 20.4 | 39.4 | –20.2 | –21.1 |
| Redhaven | 21.0 | 21.6 | 100.0 | 15.0 | 39.4 | –19.5 | –21.0 |
| Veteran | 70.2 | 22.7 | 88.3 | 4.4 | 46.4 | –20.7 | –21.5 |
| Olinda | 66.5 | 42.3 | 100.0 | 16.0 | 56.2 | –20.1 | –21.2 |
| Earlired | 32.3 | 44.6 | 100.0 | 54.0 | 57.7 | –18.7 | –19.5 |
| Loring | 62.1 | 20.2 | 100.0 | 61.9 | 61.1 | –19.5 | –20.0 |
| Glohaven | 53.0 | 39.5 | 100.0 | 53.4 | 61.5 | –20.1 | –20.6 |

channels were used because it was difficult to resolve exotherms when more channels were used. This limited the number of samples run to 60 each time; 5 twig samples × 12 channels. Because exotherms appear on the time-temp profile as a sudden deflection, it may be possible to develop computer instrumentation to detect and record exotherm temperatures with a greater number of channels. This would enhance the usefulness of exotherm analysis for routine screening of peach progenies for flower bud hardiness.


### Literature Cited

1. George, M. F., M. J. Burke, and C. J. Weiser. 1974. Supercooling in overwintering azalea flower buds. *Plant Physiol.* 54:29-35.
2. Graham, R. 1971. Cold injury and its determination in selected *Rhododendron* species. MS thesis, University of Minnesota, St. Paul.
3. Proebsting, E. L., Jr., H. H. Mills, and T. S. Russell. 1966. A standardized temperature survival cure for dormant Elberta peach fruit buds. *Proc. Amer. Soc. Hort.* 89:85-90.
4. Quamme, H. A. 1974. An exothermic process involved in freezing injury to flower buds of several *Prunus* species. *J. Amer. Soc. Hort. Sci.* 99:315-318.
5. Weaver, G. M., and H. O. Jackson. 1969. Assessment of winterhardiness in peach by a liquid nitrogen system. *Can. J. Plant Sci.* 49:459-463.


# Carry Over Effect of Ethephon on Fruit Shape of 'Delicious' Apples[1]


M. W. Williams[2]
*U.S. Department of Agriculture and Washington State University, Wenatchee*



*Abstract.* **(2-Chloroethyl)phosphonic acid (ethephon) applied to 'Delicious' apples before harvest to improve fruit quality can change fruit shape (length/diameter ratio) the next year. The change is magnified when ethephon follows a summer application of succinic acid-2,2-dimethylhydrazide (SADH) and is most evident on low vigor trees.**


Apples have characteristic shapes that are important in marketing of the fruit. The elongated shape and the 5 lobes at the calyx end of 'Delicious' apples are especially distinctive and have aesthetic and economic value. A length/diameter (L/D) ratio of ca. 1.0 is desirable for good marketability of the fruit. 'Delicious' fruit with a L/D ratio of less than 0.88 are often rejected from the extra fancy grade. Therefore, cultural and chemical treatments that adversely affect fruit shape should be avoided.

Spring applications of ethephon are used on young trees to promote flowering (4). Summer applications of this chemical are used to advance fruit maturity and to increase red color and overall dessert quality (1, 2, 3). In some future instances, a fruiting tree may be treated with ethephon in both spring and summer. SADH may be used on the same tree either in the spring to promote bloom or in the summer to retain fruit firmness and increase red color. We reported earlier that SADH could reduce the L/D ratio of 'Delicious' apples (5) when applied at high concn or late in the season.

This paper deals with the effect of spring and summer applications of ethephon and the combination of ethephon and SADH on fruit shape.

Fruit samples were collected from treated and control trees in several orchards. The trees were treated the previous year with various concn and timings of single or multiple applications of ethephon and SADH (see tables). Representative limbs on 10 treated and 10 control trees were selected, and 20 fruit of various sizes were harvested in order down the limb. Length and diam of each fruit were measured, and the L/D ratio was determined. Typical fruit of different ratios are shown in Fig. 1.

Minimal amounts of ethephon and SADH applied in the spring either alone or in combination did not affect fruit shape the following year. High rates of SADH (2000 ppm) applied in the spring to low- or moderate-vigor trees (orchard A) slightly affected fruit shape the following year (Table 1). No effect was observed on fruit from orchard B, where the trees were in good vigor (Table 1). Trees with more than 29 cm of terminal growth are considered to have good vigor.

Ethephon applied alone in the summer at the 300- and 450-ppm concn caused flattening of fruit the following year (Table 2). The 150-ppm concn did not affect fruit shape.

Table 1. Effect of spring applications of ethephon and high rates of SADH on length/diam (L/D) ratio of 'Delicious' apples.

| *Orchard* and treatment | Avg L/D ratio: Weeks applied after bloom 4 | 5 | 6 |
|---|---|---|---|
| *Orchard A* (poor, low vigor) | | | |
| Control | 0.94 | 0.94 | 0.94 |
| Ethephon (300 ppm) | 0.95 | 0.94 | 0.95 |
| Ethephon (150 ppm) + SADH (1000 ppm) | 0.96 | 0.94 | 0.94 |
| SADH (2000 ppm) | 0.90* | 0.91* | 0.90* |
| *Orchard B* (good vigor) | | | |
| Control | – | 0.97 | – |
| Ethephon (450 ppm) | – | 0.97 | – |
| Ethephon (300 ppm) + SADH (1000 ppm) | – | 0.97 | – |
| SADH (2000 ppm) | – | 0.97 | – |

*Significantly different from control at the 5% level (LSD = 0.03).

In one orchard, ethephon was applied at different times following a summer (70 days after bloom) application of SADH. Fruit shape was significantly affected the following year by all preharvest ethephon treatments applied between 104 and 125 days after bloom. The latest application caused the most severe flattening of the fruit (Table 3).

A trial was conducted to determine the effect of spring and summer applications of ethephon and SADH on fruit

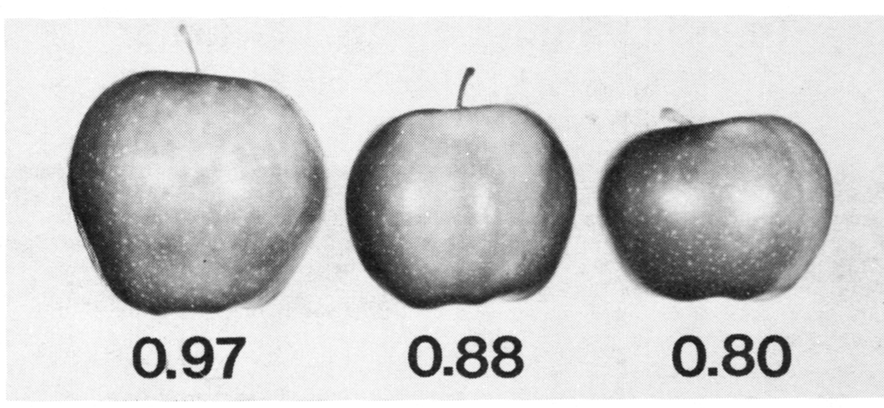


Fig. 1. Length/diameter ratios of typical 'Delicious' apples from trees treated previous season with ethephon and SADH. Fruit on left is untreated.


[1]Received for publication May 5, 1975.


[2]Plant Physiologist and Research Leader. I greatly appreciate the assistance of Harlin D. Billingsley, Agr. Research Tech., in collecting the data for this paper.