# A COMPARISON OF TWO METHODS FOR DETERMINING LOW TEMPERATURE INJURY TO ONE YEAR WOOD OF FRUIT PLANTS

by

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# INTRODUCTION

The injury of plants occasioned by winter conditions has been a subject of great interest and importance to plant breeders and fruit growers.

The development of hardy strains has been one of the principal means of combating losses caused by injury from cold, although cultural methods have been adopted to help plants survive the rigor of its climatic environments.

A problem of studying hardiness of plants is to determine when a plant is injured or killed. The process until recently was to place plants or parts of plants under favorable growing conditions following exposure to extreme conditions and observe the resultant growth.

Chandler (1913) observed that different tissues of fruit trees vary in hardiness and also change at different seasons of the year. He has shown that when trees are in an active growing conditions, the cambium, young cortex and sapwood cells are the most tender. When the tissues have matured, the pith in the twigs is the first to be killed by low temperature followed by browning in the sapwood and the outer cell of the cortex. The cambium is most tender in the growing plant, but relatively hardy when it is in winter conditions.

In (1932) Swingle reported a procedure based on the assumption that the release of the electrolytes by the cells of plant tissue placed in water measured by a electrical conductivity procedure constitutes a direct reading of the amount of injury inflicted by a treatment.

He further stated that cold resistance in plants is complex and many factors are important in determining injury at a given time. It can be said that the immediate environment is more important than the genetic constitution in determining resistance. Under certain conditions hardy plants frequently become more susceptible to low temperature injury than more tender plants as a result of the environmental conditions. He further reported that the difference in hardiness between the different portions of the same year growth is generally very much less than the difference between the new years and previous years growth.

In (1941) Filinger and Cardwell developed a method for direct measurement of electrical resistance. They used it in hardiness studies of raspberry canes. The drop in electrical resistance determines the amount of damage to plants. This method of determining the hardiness of plants has some advantages in that the apparatus can be carried to the field to study conditions of plants after adverse weather periods and also it is possible to test the plants without killing or destroying them. The method is also rapid.

This study was an attempt to establish the correlation between the two methods of determining low temperature injury to woody fruit plants.

## REVIEW OF LITERATURE

Eustace (1905) divided winter injury into three categories, root injury, trunk injury and branch injury. He observed that the freezing of the roots causing death or injury occurs in the winter when the temperature is usually low and the ground is bare. Trunk injury, due to freezing causing death or injuries to the cambium tissue of the trunk or limbs when the temperature is so low as to destroy the cambium layer the tree dies. Branch injury usually is the killing back of the new and tender wood from the tip. This form of injury occurs to some extent every year and its extent depends very largely upon whether the wood ripens well or grows late in the fall and contains a large amount of moisture.

The earlier physiologists believed that most of the injury and death of plants due to low temperatures was caused by water freezing in the cells (Meyer and Anderson 1956). Later investigations into the causes of injury by cold suggest that plants are damaged or killed as a result of the ice crystals forming in the intercellular spaces, which may result in desiccation of the protoplasm as well as a possible mechanical deformation.

G. S. Kamp (1918) reported that winter injury on peaches and apples in Indiana, following the hard winter of 1917-1918 that one of the outstanding factors contributing to winter injury was the temperature as influenced by elevation. Also a short, cool, and wet season resulted in failure of trees to ripen their wood, increasing the degree of damage.

Harvey (1918) studied the relation of changes in the proteins to killing the protoplasm in cabbage plants. He found that upon hardening, the proteins change to forms which are less easily precipitated. During the formation of ice there is an increase in acidity sufficient to precipitate the proteins of non-hardy plants but in hardy plants the proteins endure the degree of acidity without precipitation and resulting injury.

Chandler (1918) stated that the maturity of the wood of fruit trees results in increased cold resistance. During his observations following the severe winter of 1917-1918 in New York, he noticed that in every case where the leaves had been removed in summer by insects or spray burning, there was killing of the wood. He indicated also that the slow portion to mature was subjected to more injury.

During the severe winter of 1909-1910, at Fredonia, New York, almost half the fruit buds in Concord vineyard were killed according to Gladwin (1919). The injury was traced to a lack of maturity of the tissues owing to a sudden termination of the growing period by unseasonably low temperatures.

Hooker (1920) reported a high correlation between resistance to low temperatures and pentosan content. He found that plant tissues with high pentosan content lost less water and absorbed more water from the atmosphere than the tissues with low pentosan content.

Angelos (1922) studies showed that when early spring freeze kills the first shoots of grape vines, the second growth is likely to produce partial crop. He noticed that the type of training has some influence on the number of shoots from the second growth and upon the yield.

Wiemer (1929) found that the rate of thawing influences the killing of plants by freezing.

Wellington (1930) indicated that the proportion of the vinefera blood in a given grape hybrid cannot safely make up more than 78-85 per cent of its constitution for areas having minimum winter temperature of -15° or below. Dilution beyond this point is certain to result in lack of winter hardiness.

Dexter, Tottingham and Graber (1930) conducted a series of preliminary experiments which indicated that the degree of resistance of plants to injury by cold may be measured by the diffusion of electrolytes and other substances from chilled or frozen tissues into water after the tissues have thawed. The amount of diffusion was determined with alfalfa roots by conductivity measurements which had been supplemented by colorometric tests for chlorides. It was found that within the limits of the investigation there existed correlations between known hardiness of alfalfa roots and the degree of retention of electrolytes by the tissues after freezing.

Dexter, Tottingham and Graber (1930) continuing their work of measuring the extent of exosmosis of electrolytes from frozen tissues found that tissues grown under different conditions showed the marked influence of environment upon the hardiness process.

They also presented an alternate method for determining low temperature resistance in which electrical conductivity of the tissue itself was determined after freezing, with three varieties of alfalfa of known hardiness. These showed wide varietal differences as well as marked differences in hardiness of individual plants within a given variety.

Dexter (1930) stated that the amount of outward diffusion of electrolytes from tissues exposed to low temperature into distilled water as determined by electrical conductivity measurements indicated a progressive development of hardiness throughou the autumn period in hardy alfalfa varieties, while tender varieties showed no change.

He further explained that colorimetric test for chloride and nitrates in exudate from the frozen roots correlate very well with the conductivity measurements, and regeneration of growth in the greenhouse indicates that the injury by freezing may be estimated by this method.

Anthony, Sudds and Clarke (1937) studied the effects of low temperature on orchards in Pennsylvania and adjoining states. They reported that the degree of maturity was the main cause of winter injury. Hardly any of the injury from the winter of 1935-1936 was due to excessive cold weather alone. Some of the orchards injured have been subjected to temperature 10° F to 20° F lower than during the previous winter without much injury. In most of the northeastern states, fruit trees went into the winter of 1935-1936 poorly matured. The unseasonable freeze in early October injured the leaves and checked the normal maturity process. Some trees were injured because they were too vigorous and others because they were low in vigor. Excess of fertilization, heavy pruning, late cultivation, and spray injury all resulted in more damage to trees.

In comparing the cold hardiness of scion roots from a larger number of apple varieties with "French Crab" seedling roots, to find the most suitable understock from the standpoint of resistance to winter injury; Stuart (1939) discovered that freezing roots at 20° F produced wide differences in electrical conductivity among the varieties. The conductivity of the frozen samples were, however, smaller than those obtained from the boiled sample. He further states that it seems reasonable to consider that these differences in conductivity among the varieties after freezing are due to different amounts of freezing injury. The hardiest roots are less injured and produce the lowest conductivity readings.

Filinger and Cardwell (1941) developed a method for direct measurements of electrical resistance. They used it in hardiness studies of raspberry canes. The drop in electrical resistance noted after freezing the canes was thought to reflect the amount of damage to the canes.

Caplin (1948) used artificial freezing tests on peach fruit buds. He found that the fruit buds of peaches were definitely more hardy than the bark, while leaves were still on the trees in early October. There was a little gain in hardiness at the leaf fall. His results supported the dependability of artificial freezing tests in hardiness studies.

Campbell (1948) observed that more than thirty varieties of peach trees survived the severe winter of 1947 in Kansas. He reported that the temperature dropped from 80° F. to 40° F during a period of 60 hours. Then the temperature fell rapidly to -32° F. After checking the trees at the Horticulture farm, he noticed that many of the peach trees which survived that hard freeze showed minor damage to twigs. The reason for this, according to him, possibly was that the previous long cold period or the slow temperature fall had given maximum hardiness to the peach wood.

Brierley, et al (1937) reported that sever injury or complete killing of Haralson apple trees from low temperature should be reagarded as the combined effects of heavy crop, drought, depleted food reserve and immaturity.

Carrier (1952) noted that segments of current season base canes, between the basal and the terminal six inches, were significantly more frost resistant than the basal at the terminal positions.

Emmert and Howlett (1953) used the electrolytic method for testing the resistance of apple varieties to low temperatures. Their results showed that less electrolytes diffused from the hardy varieties, from the tender varieties.

Snyder (1953) tested the hardiness of the multiflora rose by means of artificial freezing. He then measured the soluble chemical materials leached from the segments of tissues by electrical means to determine the degree of injury. He suggested that the electrolytic test is based on the fact that the greater injury to the cell membrane, the greater the quantity of soluble chemicals which will leach out of the cell. He stated that the method of evaluating the degree of injurty to plant tissues following exposure to low temperature has proved to be satisfactory and rapid. He found also that the canes of the larger diameter are less hardy than canes of the small diameter, but roots are of equal hardiness regardless of size.

Chandler (1954) made a general review of the effect of cold on Horticulture plants. He defined cold resistance as the ability of the plant cells to survive ice formation in the plant tissues. Some plants might die if held 48 hours or more at temperatures little above freezing, while seeds and pollen will later grow even if they are exposed to very low temperatures. The reason is that the latter are too dry to have any ice crystals in their cells. He stated that if the temperature falls is slow, ice tends to form in hardy plants in the intercellular spaces and water moves out of the cells. This movement of water increases the concentration of the cell sap. Also, it is fast enough to prevent ice formation in the cell. Both hardy and tender plants subject to abnormally rapid temperature fall, may be killed by the ice formation in the protoplasm. Chandler also stated that hardiness develops usually in autumn and early winter. This development is due mostly to changes in physical nature of the protoplasm, rather than to an increase in water holding substances in the cell sap.

## MATERIALS AND METHODS

The following is the description of the different fruit varieties that were used in the study. The apple varieties were chosen on the basis of their known hardiness. Starking and Golden Delicious have been classified as being medium tender, Jonathan and Mcintosh as medium hardy, while Hibernal and Virginia Crab were considered to be hardy (Emmett and Howlett 1953).

Description of the Apple Varieties

Starking. This variety surpasses most of its orchard associates in all essential tree characteristics. The tree is vigorous, hardy, healthy, productive and very accomodative as to soils. It is one of the cosmopolitan of all apples thriving wherever apples are generally grown on this continent.

Golden Delicious. This variety originated as a chance seedling in West Virginia. The trees, as grown in widely separated regions, are vigorous, healthy and productive with no marked faults.

Jonathan. It has a world wide reputation. The trees are usually hardy, vigorous and productive. It is very accommodating as to the soils and develops fullest perfection in cool climates. The variety is an inviting prey to insects and fungi and the trees must be carefully sprayed.

McIntosh. The trees are vigorous, medium hardy and healthy. Three serious faults detract it from it value as a commerical fruit; its susceptibility to apple scrab, the crop ripens unevenly and the apples seldom hang until sufficiently matured.

Hibernal. This ranks among the best of the Russian apples, and one of the most valuable in rigorous climates in the United States and Canada. The tree is one of the hardiest types, vigorous, healthy and productive. In this country it is used exclusively as a hardy intermediate stock.

Virginia Crab. This variety originated as a chance seedling in a nursery in Iowa in 1869. It is used as a hardy stock variety in certain sections of the country.

## Description of the Grape Varieties

Siebel 9110 (Vitis sp). Vine, vigorous, hardiness not adequatly tested, but not thought to be as winter hardy as concord.

Concord (Vitis Labrusca). Vine vigorous, hardy, healthy and productive over a wide range of conditions. It is the most widely grown of all American varieties.

Beta (Vitis Vulpina). One of the hardiest of grapes. Beta has made a place for itself in Northern Wisconsin and Minnesota. The vines are not only hardy, but also healthy and productive.

## Description of the Peach Varieties

Elberta. The leading peach variety, producing yellow fruit in late season, lacks blossum bud, resistance to low temperatures.

Red Haven. Attractive yellow fruited, mid-season variety, considered hardy in both bud and wood.

Triogem. An early yellow fleshed freestone variety, considered fairly hardy.

## Description of the Cherry Varieties

Early Richmond. The trees are medium in size, medium to below in productivity and relatively hardy. It is valuable as an early variety to lengthen the season for red cherries.

Montomorency. The trees are large, vigorous, very productive, hardy and healthy.

Meteor. Fruit sour. Size, appearance and quality of Montomorency. Tree is very hardy.

The instrument used to measure the electrical resistance of the cuttings and the solution was a "Conductivity Bridge" model R. C. for measurement of resistance and electric conductivity. It is manufactured by the Instrumental Instrument Incorporation.

A device developed at Kansas State University by Fillinger and Cardwell (1941) to provide contact for the whole twigs was used. This consisted of a pair of electrician pliers having parallel acting jaws was held six inches apart by a non-conducting fibre spacing bar. Extensions were fastened to the jaws of the pliers to increase the capacity, and it was through these extensions that portions of needles were inserted. The current passed from one pair of pliers through the cane and was measured with the Conductivity Bridge.

The same model bridge was used for measuring the conductivity reading of the solution. A feeler tube provided with a small rubber bulb to create a vacuum, was fastened to a metal stand and this in turn was connected to the bridge by means of electric wire.

Two household freezers were used to freeze the cuttings artificially. One freezer had the capacity to attain a minimum temperature of 0° F and the second one had the capacity to attain a minimum of -20° F. To bring down the temperature to -40° F in addition to the freezer that could attain a temperature of -20° F, dry ice and acetone were used.

For testing, only the one year old or wood produced during the past growing season from apple , grape , peach and cherry varieties was used.

## Methods

The study was divided into three phases as described below.

Phase I. Twig samples from each of the different apple, grape, peach and cherry varieties were collected from the new year wood. A sample consisted of the basal eight inch portion of the twig.

Forty eight inch samples or cuttings of each variety of the above mentioned fruit trees were divided into four groups of ten and subjected to the following treatments.

| | |
|---|---|
| Group I | Control or Unfrozen |
| Group II | Frozen at 0° F |
| Group III | Frozen at -20° F |
| Group IV | Frozen at -40° F |

The last treatment, that of freezing at -40° F was used for apples only.

The eight inch cuttings of the variety to be frozen were placed into ten inch by one inch test tubes, and the tubes were stoppered tightly. These ten tubes were then placed in a beaker containing ethyl alcohol. The beaker was placed in the refrigerator and brought to the desired temperature.

Except for the final temperature the procedure followed was the same for all the twigs frozen at 0° F and -20° F.

For the cuttings to be frozen at -40° F the same procedure was followed until the -20° F temperature was reached. The whole beaker was then placed in a bucket, containing dry ice and acetone, and brought to the minimum temperature of -40° F. The time taken by the cuttings to cool down to the respective temperatures, was found to vary between 5 and 5½ hours. When the samples or cuttings had reached the desired temperatures, as indicated by the thermometer placed in the beaker, the beaker was removed from the refrigerator. The test tubes were then uncorked and the cuttings allowed to return to room temperature. After that, the electric resistance reading of each cutting was recorded by means of the conductivity bridge. Conductivity was calculated by means of the formula:

$$\text{Conductivity} \qquad \frac{1,986,400}{\text{Resistant reading on the bridge}}$$

The same procedure was followed for each of the apple, grape, peach and cherry varieties. As mentioned previously, only the apple varieties were subjected to -40° F.

Phase II. In the second phase the twigs, which were treated at different temperatures mentioned in Phase I and for which the electrical conductivity of the entire twig had been noted, were cut up into one inch pieces, weighed and portions of each twig put in separate flasks. To each flask distilled water, at the rate of five times the weight of the twig, was added. The pieces were left in the water for eighteen hours at room temperature. After completion of 18 hours the distilled water, containing the diffused electrolytes leached from the pieces, was used to measure the electric conductivity.

Phase III. Each flask containing the distilled water and the pieces of the twigs was then boiled for fifteen minutes. Distilled water was added to make up the amount lost by boiling. This was then allowed to stand for sixteen hours. At the end of this time the conductivity reading of the solution was obtained.

It was determined that the higher the conductance reading the greater the degree of freezing injury.

## RESULTS

The procedure of measuring the injury to twigs of different varieties of fruit plants; viz apples, grapes, peaches, and cherries were used as described under Mateials and Methods. The injury caused by various temperature treatment was recorded for individual twigs in the form of electrical conductivity by means of a conductivity bridge, and then analyzed statistically to see if any correlation existed between these procedures. Listed, below, are the results of different procedures and treatments used with the individual varieties of apples, grapes, peaches and cherries respectively as described earlier.

### Apples

The data collected by the measurement of the electric conductivity of twigs of the Starking variety subjected to different temperatures and procedures are presented in Table I.

As will be seen from the table there is no consistency in the results obtained with the different treatments. There was a significant correlation between conductivity readings of the pieces of twigs and that of the pieces of twigs which were boiled in two of the treatments. These included the treatments of control twigs and those frozen at -20° F. Also, there was a significant correlation between the whole twigs and the pieces of twigs frozen at 0° F. There was no further significant correlation observed among the procedures used for different treatments in this variety.

Table I.

The correlation coefficient of conductivity values of twigs of the Starking variety of apple subjected to different temperature treatments and measured by the procedures described in the footnotes.

| Treatment | Procedure* | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 5136 | P > ·10 | NS |
| | BC | 8228 | ·01 > P > ·001 | Sig |
| | CA | 4452 | P > ·10 | NS |
| Frozen at 0° F | AB | 7499 | P < ·02 | Sig |
| | BC | 6065 | ·10 > P > ·05 | NS |
| | CA | 4975 | P > ·10 | NS |
| Frozen at -20° F | AB | 0455 | P > ·10 | NS |
| | BC | 7238 | P < ·01 | Sig |
| | CA | 0224 | P < ·10 | NS |
| Frozen at -40° F | AB | 2734 | P > ·10 | NS |
| | BC | 5407 | P > ·10 | NS |
| | CA | 0397 | P > ·10 | NS |

*A measurements of the electrical conductivity of the whole twig

B measurements of electrical conductivity of the exosmosed solution (one inch pieces of twigs were soaked in distilled water for 18 hours)

C measurements of electrical conductivity of the exosmosed solution (one inch pieces of the same twigs were soaked in distilled water for 16 hours after boiling)

Golden Delicious. The measurement of the electric conductivity readings for the twigs of the Golden Delicious variety given the same temperature treatments and measured by the same three different procedures as the Starking variety are recorded in Table II.

It is evident from the table that as with the previous variety the results were not consistent. The conductivity values determined with the procedure involving the direct measurement of electric conductivity of the whole twigs and the pieces of the twigs of the unfrozen twigs showed a significant correlation. Significant correlation was also observed between the conductivity readings of the pieces of twigs and that of the pieces of twigs which were boiled in two treatments. These included the control twigs and those frozen at $0^\circ$ F. No other significant correlations were observed for this variety regardless of procedure or treatment used.

Table II.
The correlation coefficient of conductivity values of twigs of the Golden Delicious variety of apple subjected to different temperature treatments and measured by the procedures described previously.

| Treatment | Procedure | co-r | P 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 6510 | $\cdot05 > P > \cdot02$ | Sig |
| | BC | 7749 | $P < \cdot01$ | Sig |
| | CA | 1812 | $P > \cdot10$ | NS |
| Frozen at $0^\circ$ F | AB | 2308 | $P > \cdot10$ | NS |
| | BC | 6632 | $\cdot05 > P > \cdot02$ | Sig |
| | CA | 2930 | $P > \cdot10$ | NS |
| Frozen at $-20^\circ$ F | AB | 2825 | $P > \cdot10$ | NS |
| | BC | 5092 | $P > \cdot10$ | NS |
| | CA | 5348 | $P > \cdot10$ | NS |
| Frozen at $-40^\circ$ F | AB | 1864 | $P > \cdot10$ | NS |
| | BC | 6190 | $\cdot10 > P > \cdot05$ | NS |
| | CA | 3897 | $P > \cdot10$ | NS |

Ibid.

Jonathan. No significant correlation was found to exist amonstthe three procedures of the control twigs or those frozen at $0^\circ$ F and $-20^\circ$ F as seen in Table III. There was significant correlation between conductivity reading of the pieces of twigs and that of the same pieces of twigs after boiling, frozen at $-40^\circ$ F.

Table III.
The correlation coefficient of conductivity values of twigs of the Jonathan apple variety subjected to different temperatures treatments measured by the procedures described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 3870 | P > ·10 | NS |
| | BC | 2719 | P > ·10 | NS |
| | CA | 2815 | P > ·10 | NS |
| Frozen at 0° F | AB | 1253 | P > ·10 | NS |
| | BC | 1252 | P > ·10 | NS |
| | CA | 0633 | P > ·10 | NS |
| Frozen -20° F | AB | 3685 | P > ·10 | NS |
| | BC | 4892 | P > ·10 | NS |
| | CA | 0991 | P > ·10 | NS |
| Frozen at -40° F | AB | 0314 | P > ·10 | NS |
| | BC | 8438 | ·01 > P > ·001 | Sig |
| | CA | 0534 | P > ·10 | NS |

Ibid.

McIntosh. No significant correlation was observed between any of the procedures regardless of temperature treatments in this variety as shown in Table IV.

Table IV.
The correlation coefficient of conductivity values of twigs of the McIntosh variety of apples subjected to different temperature treatments measured by the procedure as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 3121 | P > ·10 | NS |
| | BC | 0834 | P > ·10 | NS |
| | CA | 0752 | P > ·10 | NS |
| Frozen at 0° F | AB | 0508 | P > ·10 | NS |
| | BC | 4523 | P > ·10 | NS |
| | CA | 0895 | P > ·10 | NS |
| Frozen at -20° F | AB | 3166 | P > ·10 | NS |
| | BC | 4248 | P > ·10 | NS |
| | CA | 1241 | P > ·10 | NS |
| Frozen at -40° F | AB | 0286 | P > ·10 | NS |
| | BC | 6942 | ·10 > P > ·05 | NS |
| | CA | 3873 | P > ·10 | NS |

Ibid.

Hibernal. The results of the electrical conductivity tests of the twigs of this variety subjected to different temperatures and measured by three different procedures is presented in Table V. There was a significant correlation between conductivity readings of the pieces of twigs and the pieces of twigs after boiling in two of the treatments, as shown in the table. These treatments included the unfrozen (control) twigs and those frozen at 0° F. There was also a significant correlation of conductivity values between the whole twigs and the pieces of twigs not frozen. There was no further significant correlation observed amongst the procedures utilized for comparing effects of different temperature treatments.

Table V.
The correlation coefficient of conductivity values of twigs of the Hibernal variety of apple subjected to different temperature treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 6894 | ·05 > P > ·02 | Sig |
| | BC | 7233 | ·01 < P < ·02 | Sig |
| | CA | 5218 | P > ·10 | NS |
| Frozen at 0° F | AB | 2581 | P > ·10 | NS |
| | BC | 6387 | ·05 > P > ·02 | Sig |
| | CA | 2735 | P > ·10 | NS |
| Frozen at -20° F | AB | 3935 | P > ·10 | NS |
| | BC | 5607 | ·10 > P > ·05 | NS |
| | CA | 5133 | P > ·10 | NS |
| Frozen at -40° F | AB | 2611 | P > ·10 | NS |
| | BC | 1072 | P > ·10 | NS |
| | CA | 1236 | P > ·10 | NS |

Ibid.

Virginia Crab. No significant correlation observed amonst the procedures for measuring the electrical conductivity of the twigs of this variety subjected to different temperatures as shown in Table VI.

Table VI
The correlation coefficient of the conductivity values of twigs of the Virginia Crab variety of apple subjected to different temperatures treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 01268 | P > ·10 | NS |
| | BC | 25108 | P > ·10 | NS |
| | CA | 20418 | P > ·10 | NS |
| Frozen at 0° F | AB | 2839 | P > ·10 | NS |
| | BC | 3698 | P > ·10 | NS |
| | CA | 2500 | P > ·10 | NS |
| Frozen at -20° F | AB | 3935 | P > 10 | NS |
| | BC | 5607 | ·10 > P > ·05 | NS |
| | CA | 5133 | P > ·10 | NS |
| Frozen at -40° F | AB | 4175 | P > ·10 | NS |
| | BC | 5751 | ·10 > P > ·05 | NS |
| | CA | 1786 | P > ·10 | NS |

Ibid.

## Grapes

An analysis of data collected by the measurement of the electric conductivity of the twigs of Siebel 9110 variety of grapes subjected to different temperatures and measured by three different procedures are presented in Table VII.

As shown in the table no significant correlation amongst the different procedures used in the measurement of the electrical conductivity subjected to various temperature treatments.

Table VII.
The correlation coefficient of the conductivity values of the canes of the Siebel 9110 variety of grapes subjected to different temperature treatments measured by the procedures described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 53624 | P>·10 | NS |
| | BC | 25894 | P>·10 | NS |
| | CA | 31270 | P>·10 | NS |
| Frozen at 0° F | AB | 25447 | P>·10 | NS |
| | BC | 13487 | P>·10 | NS |
| | CA | 44065 | P>·10 | NS |
| Frozen at -20° F | AB | 00189 | P>·10 | NS |
| | BC | 51032 | P>·10 | NS |
| | CA | 35636 | P>·10 | NS |

Ibid.

Concord. There was a significant correlation between conductivity readings of pieces of canes and the pieces of canes which were boiled, of the canes treatment frozen at -20° F. There was no further significant correlation between the procedures under any other treatment as in Table VIII.

Table VIII.
The correlation coefficient of the conductivity values of the canes of the Concord variety of grapes subjected to the different temperature treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 61903 | ·10>P>·05 | NS |
| | BC | 32397 | P>·10 | NS |
| | CA | 48674 | P>·10 | NS |
| Frozen at 0° F | AB | 12631 | P>·10 | NS |
| | BC | 51066 | P>·10 | NS |
| - | CA | 39360 | P>·10 | NS |
| Frozen at -20° F | AB | 42682 | P>·10 | NS |
| | BC | 63723 | ·05>P>·02 | Sig |
| | CA | 00884 | P>·10 | NS |

Ibid.

<u>Beta</u>. The data collected for the measurement of the electrical conductivity of canes of the Beta variety subjected to different temperature treatments and measured by three different procedures are given in Table IX.

As shown in the table, there was a significant correlation between conductivity readings of the whole canes and the pieces of canes frozen at 0° F and unfrozen control. There was also significant correlation between conductivity readings of the pieces of canes and that of pieces of canes boiled after being frozen at -20° F.

Table IX.
The correlation coefficient of the conductivity values of the canes of the Beta variety of grapes subjected to the different temperature treatment measured by the procedure as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 89403 | P < ·001 | Sig |
| | BC | 35341 | P > ·10 | NS |
| | CA | 22424 | P > ·10 | NS |
| Frozen at 0° F | AB | 88037 | P < ·001 | Sig |
| | BC | 03888 | P > ·10 | NS |
| | CA | 11255 | P > ·10 | NS |
| Frozen at -20° F | AB | 27350 | P > ·10 | NS |
| | BC | 86876 | ·01 > P > ·001 | Sig |
| | CA | 32964 | P > ·10 | NS |

Ibid.

## Peach

The analysis of conductivity values as seen in Table X showed no significant correlation amongst the different procedures used for the measurement of electrical conductivity of twigs of the Elberta variety of peach treated at different temperatures.

Table X.
The correlation coefficient of the conductivity values of the twigs of the Elberta variety of peach subjected to the different temperature treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 53647 | P > ·10 | NS |
| | BC | 47587 | P > ·10 | NS |
| | CA | 10157 | P > ·10 | NS |
| Frozen at 0° F | AB | 53648 | P > ·10 | NS |
| | BC | 20978 | P > ·10 | NS |
| | CA | 20606 | P > ·10 | NS |
| Frozen at -20° F | AB | 12367 | P > ·10 | NS |
| | BC | 15144 | P > ·10 | NS |
| | CA | 11088 | P > ·10 | NS |

Ibid.

Redhaven. The results as interpreted from the Table XI show a significant correlation between the conductivity readings of the pieces of twigs and the pieces of twigs after boiling in the unfrozen or control treatment. There was no further significant correlations in this variety observed among the procedures used to measure conductivity of twigs subjected to the different treatments.

Table XI.
The correlation coefficient of the conductivity values of the twigs of the Redhaven variety subjected to different treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 2[illegible]962 | P > ·10 | NS |
| | BC | 76953 | P < ·01 | Sig |
| | CA | 12708 | P > ·10 | NS |
| Frozen at 0° F | AB | 22164 | P > ·10 | NS |
| | BC | 22359 | P > ·10 | NS |
| | CA | 31837 | P > ·10 | NS |
| Frozen at -20° F | AB | 31857 | P > ·10 | NS |
| | BC | 35658 | P > ·10 | NS |
| | CA | 31837 | P > ·10 | NS |

Ibid.

Triogem. The results show no significant correlation amongst the different procedures used for the measurement of electrical conductivity of the twigs treated at various temperatures as seen in Table XII.

Table XII.

The coefficient of correlation of the conductivity values of the twigs of the Triogem variety subjected to different treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 07388 | P >·10 | NS |
| | BC | 13741 | P >·10 | NS |
| | CA | 08309 | P >·10 | NS |
| Frozen at 0° F | AB | 17876 | P >·10 | NS |
| | BC | 46093 | P >·10 | NS |
| | CA | 15194 | P >·10 | NS |
| Frozen at -20° F | AB | 48138 | P >·10 | NS |
| | BC | 09401 | P >·10 | NS |
| | CA | 05628 | P >·10 | NS |

Ibid.

## Cherry

The results as analyzed for the correlation amongst the procedures to measure the electrical conductivity of Early Richmond variety, subjected to different temperature treatments as shown in Table XIII. They indicate that for the unfrozen twigs of this variety there was significant correlation between the pieces of twigs and the pieces of twigs boiled; whereas no other significant values obtained for correlation were observed.

Table XIII.
The correlation coefficient of the conductivity values of the twigs of the Early Richmond variety subjected to different treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 59053 | ·10 > P > ·05 | NS |
| | BC | 68281 | ·05 > P > ·02 | Sig |
| | CA | 35043 | P > ·10 | NS |
| Frozen at 0° F | AB | 35690 | P > ·10 | NS |
| | BC | 05328 | P > ·10 | NS |
| | CA | 33761 | P > ·10 | NS |
| Frozen at -20° F | AB | 30199 | P > ·10 | NS |
| | BC | 02861 | P > ·10 | NS |
| | CA | 08678 | P > ·10- | NS |

Ibid.

Montmorency. Table XIV shows a significant correlati on existed between the procedures of measuring conductivity of the pieces of twigs and the pieces of twigs after boiling, as well as, between the pieces of twigs and the whole twigs frozen at 0° F. No significant correlation was otherwise observed.

Table XIV.
The correlation coefficient of the conductivity values of the twigs of the Montmorency variety subjected to different treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Result |
|---|---|---|---|---|
| Unfrozen (control) | AB | 60837 | ·10 > P > ·05 | NS |
| | BC | 37789 | P > ·10 | NS |
| | CA | 32159 | P > ·10 | NS |
| Frozen at 0° F | AB | 50839 | P > ·10 | NS |
| | BC | 82711 | ·01 > P > ·001 | Sig |
| | CA | 32159 | ·01 > P > ·001 | Sig |
| Frozen at -20° F | AB | 00920 | P > ·10 | NS |
| | BC | 34257 | P > ·10 | NS |
| | CA | 55453 | ·10 > P > ·05 | NS |

Ibid.

Meteor. No significant correlation existed between any of the procedures of measuring electrical conductivity of twigs treated at different temperatures.

Table XV.
The correlation coefficient of the conductivity values of the twigs of the Meteor variety subjected to different treatments measured by the procedures as described previously.

| Treatment | Procedure | co-r | P at 5% level | Results |
|---|---|---|---|---|
| Unfrozen (control) | AB | 29383 | P > ·10 | NS |
| | BC | 31460 | P > ·10 | NS |
| | CA | 37446 | P > ·10 | NS |
| Frozen at 0° F | AB | 39886 | P > ·10 | NS |
| | BC | 40039 | P > ·10 | NS |
| | CA | 22475 | P > ·10 | NS |
| Frozen at -20° F | AB | 57381 | ·10 > P > ·05 | NS |
| | BC | 17998 | P > ·10 | NS |
| | CA | 32442 | P > ·10 | NS |

Ibid.

## DISCUSSION OF THE RESULTS

The injury of plants occasioned by winter conditions has been a subject of great interest and importance to fruit plan breeders and growers.

Determination of the degree of hardiness has necessitated field trials commonly requiring extended periods of time; during which weather conditions may be too mild to test the relative hardiness in one season, while so severe in the next that hardy as well as tender varieties and strains are severly injured. It is quite evident that a rapid means of measuring relative degree of resistance to cold, of strains and varieties of plants grown with various cultural procedures, would hasten the progress in the work of the plant breeders, as well as, facilitate investigations of the physical and chemical nature of hardening processes and its relations to the resistance of the plants to low temperatures and other climatic conditions.

It seems to be generally accepted that the injury or killing of tissue, by cold or by any other means, involves the disorganization of the essential processes of life. With such disorganization, it is well recognized that the cell loses its capacity to regulate the diffusion of its soluble contents.

Upon this basis it was assumed (Chandler, 1913) that the degree of injury from low temperature to overwintering, and other plant structure might be corrected with the exosmosis of electrolytes and other materials following exposure to cold. Such outward diffusion of electrolytes can readily be estimated by conductivity measurements.

Investigation in this study was devoted to seeing if there was any correlation in determining hardiness of plants between the procedures known as exosmosis method as suggested by Swingle (1932) and others and the direct measurement of the conductivity by Filinger and Cardwell (1941).

It was found as shown above there was no consistency in the results of the procedures used on apple twigs of different varieties receiving varying temperature treatments.

The varieties were chosen on the basis of known hardiness to cold; which was later confirmed by the measurements of the electric conductivity, after the twigs were subjected to different temperature treatments, supporting the observations made by Filinger and Cardwell (1941) that the higher the resistance reading, the greater the amount of injury.

Although, there was some significant correlation between the procedures of some varieties under some treatments, the overall correlation between the different procedures used for measuring the conductivity of twigs of varieties of apples, grapes, peaches and cherries were inconsistent. Suggesting little real relationship.

The reasons for these results may be as stated by Swingle (1932), that cold resistance in plants is complex and many factors are important in determining injury at a given time. The immediate environment is more important than the genetic constitution in determining resistance. The difference in hardiness between the different positions of the same years growth is generally very much less than difference between the new years and previous years growth.

Though there was little significant correlation between the two procedures of Swingle and Filinger and Cardwell, the conclusion drawn by both that higher resistance reading indicates the greater amount of injury seemed to be confirmed by this study, the lower the temperature the higher the conductivity readings.

Another factor that was observed during the study was that the degree of injury due to cold is affected by the diameter of the wood; the thicker the wood the less the injury, as indicated by the readings obtained during the study. This may have affected one method more than another.

The Correlation Coefficient is a measure of the degree in which two variables follow the same trend or opposite ones. In this study a positive relationship was observed in all cases although this relationship was not consistently significant. Small samples may result in accidents of sampling; therefore if 100 samples were used rather than 10 the results may have been more dependable. It is obvious that other factors are present as evidenced by lack of relationship between the conductivity values. These may be of physical-chemical nature and merit further study. The effect of twig diameter should receive attention.

It is possible that differential injury occurs as a result of low temperature exposure. If so, the release of electrolytes may differ greatly within the twigs. This possibly would be reflected by different conductivity readings for whole twigs and piece twigs subjected to the same temperature treatments.

## SUMMARY

There were significant correlations between some procedures noted for some cherry, peach, grape and apple varieties. In general however, no definite pattern evolved relative to temperature treatment and test procedure relationships. It is obvious that factors not measured by this experiment entered in it.

The electrical conductivity readings obtained corresponded quite well to those obtained by oth r workers using the same varieties. With lower temperature treatments the conductivity readings increased suggestions on increase in twig injury.

A wide varietal response to different temperature treatments were noted, as well as the expected difference between species.

These studies should be continued in an effort to discover what factors the two methods the direct reading of whole twig method and the piece twig solution method measure.

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A COMPARISON OF TWO METHODS FOR DETERMINING
LOW TEMPERATURE INJURY TO ONE YEAR
WOOD OF FRUIT PLANTS

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An ABSTRACT OF A MASTER'S THESIS

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## AN ABSTRACT

The purpose of this study was to determine if there was significant correlation between two methods of low temperature injury to overwintering wood of fruit plants subjected to different low temperatures.

The two methods of determining injury to twigs were based on the previous studies of Filinger and Cardwell (1941) who used direct method of measuring electric conductivity passed through intact twigs and Swingle (1932) who used what is called the exosmosis method of measuring the electrical conductivity of the water solutions in which one inch pieces of the twigs were soaked.

Forty twigs of the apple varieties and thirty twigs each of the grape, peach and cherry varieties were used for each treatment. The basal eight inch portion of the twigs was put in test tubes which were then stoppered and placed in beakers containing ethyl alcohol. Artificial methods of freezing were employed as a means of achieving the required temperatures.

The degree of injury was then measured by the electrical conductivity readings obtained with the conductivity bridge. The test was based upon the assumption that the release of electrolytes by cells when measured by the electrical conductivity gives a direct reading of the amount of injury inflicted by a given temperature treatment.

Twigs of the apple varieties were subjected to one of the following temperature treatments. Unfrozen or control, 0° F, -20° F and -40° F. The period of freezing varied between 5 and 5½ hours.

A electrical resistance reading of each individual whole twig was recorded directly after the twigs were allowed to thaw at room temperature and the electrical conductivity calculated.

The same twigs were then cut into one inch pieces and weighed and a portion of each twig was put in a separate flask. To each flask distilled water at the rate of five times the weight of the pieces was added. The pieces were left in water for 18 hours. After the completion of this time, the distilled water containing the diffused electrolytes leached from the pieces was used to measure the electrical conductivity.

The flasks containing distilled water and the pieces were then boiled, after fifteen minutes distilled water was added to make up the amount lost by boiling. The pieces were left in water for 16 hours and after the completion of this time the electrical conductivity reading of the solution was recorded.

From the conductivity readings obtained for individual twigs by these methods, the coefficient of correlation amongst the method was calculated.

It can be assumed that the methods had in common the higher the conductivity reading the greater the amount of injury to the twigs.

No definite pattern of relationship was observed. With few exceptions there was no significant correlation between any two methods subjected to any temperature treatment.