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### THE FREEZING TEMPERATURES OF SOME FRUITS, VEGETABLES, AND CUT FLOWERS.

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#### INTRODUCTION.

There is an ever-increasing demand from those interested in the growing, shipping, and handling of produce for exact data on the freezing points, or the temperatures at which various products freeze.

The extent of damage due to the freezing of produce in transit naturally varies from year to year, but it is usually very heavy, aggregating frequently several hundreds of thousands of dollars during a year. This in general applies not only to such products as apples and potatoes, most of which are grown in the North and harvested and shipped in the late fall and winter, but to products which are grown in the South and Southwest during the winter and shipped to the northern markets. This latter group includes citrus fruits, strawberries, tomatoes, lettuce, string beans, cabbage, cauliflower, eggplant, etc. Cars of these food products often leave the shipping point under refrigeration and in 24 to 36 hours may pass into a zone of freezing temperatures. As they approach the more northern markets they may be exposed to temperatures ranging several degrees below zero. Under some conditions when harvested in warm weather some of these products may be pre-cooled—that is, rapidly cooled to a refrigerating temperature, either immediately before or directly after they are placed in the car for shipment, in order to delay maturity and consequent deterioration. Where pre-cooling is practiced, it is, of course, very important to know the temperatures to which the product can be lowered with absolute safety.

NOTE.—This bulletin gives the results of a portion of the work carried on under the projects "Factors affecting the storage life of vegetables" and "Factors affecting the storage life of fruits."

Knowledge of the exact freezing points of fruits and vegetables is of importance also to the commercial cold-storage man. In most cases fruits and vegetables other than dried or prepared products when placed in cold storage are alive, and the problem is to keep them alive and healthy throughout their storage period. Since various fruits and vegetables freeze at different temperatures, there is more or less doubt in the minds of those interested as to the proper and safe temperatures at which to hold these various products in storage. One of the problems in the storage of many of these products is to hold them at a temperature low enough to slow down the living processes in order to prolong their storage life and yet not allow them to be damaged by actual freezing. Of course, some products, such as berries, may be purposely kept at a freezing temperature and used at once on thawing out, but this subject comes under the head of freezing storage and will not be discussed here. It is therefore essential in commercial work of this kind that accurate data be at hand on the temperatures to which these products can be exposed without injuring their keeping qualities or market value. It should be borne in mind, however, that freezing or freezing injury does not always occur when fruit or vegetable products are exposed to temperatures at or below their true freezing points. This is shown in the studies on Irish potatoes reported in a previous publication,<sup>1</sup> where tubers were cooled as much as 10° F. below their freezing points and again warmed without apparent injury. The commonly known fact that some kinds of products may be actually frozen and then thawed out under certain conditions with no apparent injurious effects constitutes further evidence on this point. On the other hand, some commodities are injured if stored at temperatures well above their actual freezing points. It is evident, therefore, that temperatures just above the freezing point can not be regarded as safe for all types or varieties of fruits and vegetables. It is also noticeable that there are some variations in the freezing points of fruits or vegetables of the same variety and from the same lot, as is shown in the tables that follow. Furthermore, it is quite probable that different individuals of the same variety and strain when grown under different conditions will have somewhat different average freezing points. Attention is therefore called to the fact that the freezing points given in the following tables should be considered as danger points; that is, at or near these temperatures, either above or below them, there is a possibility that the product will be in danger of injury by freezing if exposed for a sufficient length of time. These are temperatures at which it is unsafe to hold produce which is to be used for food if it is desired to maintain it for any length of time in a living condition.

The determinations of the freezing points of a number of fruits and vegetables have been made by the Bureau of Plant Industry in connection with its cold-storage investigations. By freezing point is meant the temperature at which ice crystals begin to form within the product, either fruit or vegetable.

Some 10,000 of these determinations have already been made on many varieties of commercially grown fruits and vegetables, and

<sup>1</sup> Wright, R. C., and Taylor, George F. Freezing injury to potatoes when undercooled. U. S. Dept. Agr. Bul. 916, 15 p., 1 fig., 1 pl. 1921. Literature cited, p. 15.

work is being continued. It has been found in some cases that the freezing points of some varieties are liable to slight variations from year to year, even though the same strain grown in the same locality is used. These variations, however, are probably of more importance in the study of the exact causes and results of freezing injury than from the point of view of the commercial cold-storage and produce man, for the variation of a fraction of a degree hardly warrants any change in the treatment of the produce. It therefore seems advisable to publish the results of these investigations from time to time as obtained, because of the need for such information and because there is no comprehensive publication on the subject.

The method of determining freezing points has been described in former papers,<sup>2</sup> and a repetition of this description is not required here.

### FREEZING POINTS OF FRUITS.

Where several varieties of one kind of fruit were investigated the results are given separately to allow comparisons to be made. All temperatures are expressed in degrees Fahrenheit.

*Apples.*—Freezing-point determinations were made for a number of authentic varieties of summer or early apples and of fall and winter varieties, most of which were grown on the Arlington Experiment Farm. The tabulated results given by varieties are shown in Table 1. These results show considerable varietal differences among both summer and winter apples. The average of all summer varieties is practically the same as that of winter varieties, the former being 28.44° F. while the latter is 28.51° F. These results show very little difference between the freezing points of eastern-grown and western-grown fruit.

*Cherries.*—Freezing-point determinations were made for seven varieties of cherries grown on the Arlington Experiment Farm. The average of all varieties was 27.81° F. (Table 1.)

*Grapes.*—Results were obtained from the freezing of seven varieties of grapes, all of which were grown on the Arlington Experiment Farm. The average freezing point of all the varieties was 28.16° F. (Table 1.)

*Oranges.*—The average freezing point of the six varieties of oranges studied was 28.03° F. (Table 1.)

*Peaches.*—Freezing-point determinations were made for 11 varieties of peaches grown near Leesburg, Va., in the Loudoun orchard of the American Fruit Growers (Inc.). Peaches in the hard-ripe stage were utilized for these tests. The average freezing point of all varieties when hard ripe was found to be 29.41° F. (Table 1.)

*Plums.*—Freezing points were obtained for four varieties of plums that were grown in California and purchased on the market and for one variety (Red June) grown at the Arlington Experiment Farm. The variety with the lowest freezing point is Tragedy, with a freezing temperature of 27.21° F. The average freezing point of all varieties is 28.53° F. (Table 1.)

<sup>2</sup> Taylor, George F. Some improvements on the needle type thermocouple for low-temperature work. *In* Jour. Ind. and Eng. Chem., v. 12, p. 797-798, 1 fig. 1920.

Wright, R. C., and Harvey, R. B. The freezing point of potatoes as determined by the thermoelectric method. U. S. Dept. Agr. Bul. 895, 7 p., 1 fig. 1921. Bibliographical footnotes.

Wright, R. C., and Taylor, George F. Freezing injury to potatoes when undercooled. U. S. Dept. Agr. Bul. 916, 15 p., 1 fig., 1 pl. 1921. Literature cited, p. 15.

TABLE 1.—Average and extreme freezing points of fruits.

| Fruit and varieties.                                     | Temperatures (° F.) |           |          | Fruit and varieties.                  | Temperatures (° F.) |           |          |
|--|---------------------|-----------|----------|---------------------------------------|---------------------|-----------|----------|
|  | Average.            | Extremes. |          |                                       | Average.            | Extremes. |          |
|  |                     | Minimum.  | Maximum. |                                       |                     | Minimum.  | Maximum. |
| <b>Apples, summer varieties:</b>                         |                     |           |          | <b>Oranges—Continued.</b>             |                     |           |          |
| Yellow Transparent.....                                  | 27.72               | 27.29     | 28.16    | Washington Navel....                  | 28.42               | 28.30     | 28.68    |
| Red Astrachan.....                                       | 28.58               | 28.25     | 28.70    | Valencia (California)...              | 27.01               | 26.90     | 27.60    |
| Early Ripe.....  | 29.18               | 28.82     | 29.47    | Satsuma (Owari variety).....          | 28.18               | 27.93     | 28.68    |
| Red June.....  | 29.59               | 29.29     | 29.71    | Average.....                          | 28.03               | 27.86     | 28.34    |
| Sweitzer.....  | 27.38               | 27.32     | 27.41    | <b>Peaches (hard ripe):</b>           |                     |           |          |
| Shoemaker.....   | 28.46               | 27.93     | 28.03    | Belle.....                            | 29.82               | 29.50     | 30.28    |
| Benoni.....  | 28.83               | 28.49     | 29.00    | Elberta.....                          | 29.72               | 29.43     | 30.00    |
| Early Joe.....   | 27.81               | 27.60     | 28.49    | Stevens.....                          | 28.65               | 28.25     | 28.90    |
| Martha (crab).....                                       | 26.70               | 26.62     | 26.76    | Edgemont.....                         | 29.40               | 29.30     | 29.50    |
| Average (not including the crab apple).....              | 28.44               | 28.12     | 28.62    | Williams.....                         | 29.56               | 29.10     | 30.00    |
| <b>Apples, fall and winter varieties, eastern grown:</b> |                     |           |          | Pilleu.....                           | 28.90               | 28.35     | 28.96    |
| Baldwin.....   | 29.04               | 28.84     | 29.43    | Smock.....                            | 29.28               | 29.05     | 29.57    |
| Ben Davis.....   | 28.61               | 28.21     | 28.96    | Salwey.....                           | 29.57               | 29.10     | 29.80    |
| Delicious.....   | 28.48               | 28.16     | 29.10    | Hiley.....                            | 30.02               | 29.90     | 30.24    |
| Grimes.....  | 28.97               | 28.82     | 29.05    | Carman.....                           | 29.57               | 29.30     | 29.95    |
| Jonathan.....  | 28.22               | 27.79     | 28.69    | Champion.....                         | 29.06               | 28.73     | 29.95    |
| Paragon.....   | 28.50               | 28.45     | 28.55    | Average.....                          | 29.41               | 29.09     | 29.74    |
| Rambo.....   | 28.55               | 28.34     | 28.90    | <b>Plums:</b>                         |                     |           |          |
| Stayman Winesap.....                                     | 28.51               | 28.02     | 28.91    | Burbank.....                          | 29.26               | 29.05     | 29.80    |
| Winesap.....   | 28.23               | 27.93     | 28.72    | Wickson.....                          | 29.53               | 29.19     | 29.75    |
| Yellow Newtown.....                                      | 28.00               | 27.80     | 28.20    | Tragedy.....                          | 27.21               | 26.76     | 27.41    |
| York Imperial.....                                       | 28.34               | 28.10     | 28.50    | Red June.....                         | 28.13               | 27.79     | 28.44    |
| Average.....   | 28.49               | 28.22     | 28.82    | Average.....                          | 28.53               | 28.20     | 28.81    |
| <b>Apples, fall and winter varieties, western grown:</b> |                     |           |          | <b>Strawberries:</b>                  |                     |           |          |
| Delicious.....   | 28.36               | 27.98     | 28.86    | American.....                         | 29.70               | 29.66     | 29.75    |
| Gano.....  | 28.55               | 28.26     | 29.05    | Big Late.....                         | 30.03               | 29.25     | 30.05    |
| Grimes.....  | 28.60               | 28.26     | 29.05    | Big Joe.....                          | 29.98               | 29.78     | 30.19    |
| Jonathan.....  | 28.35               | 28.02     | 28.72    | Brandywine.....                       | 29.96               | 29.85     | 30.36    |
| Rome Beauty.....   | 28.92               | 28.72     | 29.38    | Chesapeake.....                       | 30.29               | 29.94     | 30.32    |
| Esopus (Spitzenberg).....                                | 28.69               | 28.26     | 29.05    | Dunlap.....                           | 29.82               | 29.24     | 29.98    |
| Winesap.....   | 28.24               | 27.93     | 28.35    | Excelsior.....                        | 29.94               | 29.28     | 30.04    |
| Average.....   | 28.53               | 28.20     | 28.92    | Early Ozark.....                      | 29.82               | 29.66     | 30.13    |
| <b>Cherries:</b>   |                     |           |          | Early Jersey Giant.....               | 29.82               | 29.43     | 30.22    |
| Early Richmond.....                                      | 27.94               | 27.60     | 28.35    | Gandy.....                            | 29.24               | 28.85     | 29.55    |
| Montmorency.....   | 28.10               | 27.79     | 28.58    | Glen Mary.....                        | 30.08               | 29.53     | 30.16    |
| St. Medard.....  | 28.09               | 27.60     | 28.58    | Howard 17 ( <i>Premier</i> ).....     | 30.23               | 29.58     | 30.38    |
| Royal Nouvelle.....                                      | 28.16               | 27.95     | 28.50    | Hustler.....                          | 30.48               | 30.41     | 30.60    |
| Gloire de France.....                                    | 27.65               | 27.37     | 28.21    | Klondike.....                         | 29.59               | 29.28     | 29.90    |
| Mecker.....  | 26.88               | 26.76     | 27.69    | Kellog ( <i>Kellog's Pride</i> )..... | 30.13               | 29.78     | 30.48    |
| Bigarreau (unknown variety).....                         | 27.83               | 27.83     | 27.83    | Late Jersey Giant.....                | 30.25               | 30.13     | 30.26    |
| Average.....   | 27.81               | 27.56     | 28.25    | Lupton.....                           | 28.84               | 28.82     | 29.10    |
| <b>Grapes:</b>   |                     |           |          | Rewastico.....                        | 30.05               | 30.03     | 30.13    |
| New Concord.....   | 28.39               | 27.93     | 28.68    | Stevens.....                          | 30.18               | 29.37     | 30.42    |
| Ambrosia.....  | 28.21               | 27.83     | 28.63    | Sample.....                           | 30.38               | 29.63     | 30.48    |
| Dracut Amber.....  | 27.88               | 27.77     | 28.10    | Superb.....                           | 30.46               | 29.85     | 30.81    |
| Moores Early.....  | 28.28               | 28.15     | 28.62    | Twilley.....                          | 29.22               | 28.96     | 29.53    |
| Captivator.....  | 27.86               | 27.14     | 28.05    | Average.....                          | 29.93               | 29.56     | 30.13    |
| Campbell (black).....                                    | 27.96               | 27.77     | 28.00    | <b>Blackberries:</b>                  |                     |           |          |
| Mericaedel.....  | 28.54               | 28.40     | 28.54    | Jumbo.....                            | 29.09               | 28.71     | 29.30    |
| Average.....   | 28.16               | 27.85     | 28.37    | Eldorado.....                         | 29.21               | 28.76     | 29.54    |
| <b>Oranges:</b>  |                     |           |          | Crystal White.....                    | 28.40               | 28.12     | 28.63    |
| Temple.....  | 28.64               | 28.34     | 28.82    | Logan ( <i>Loganberry</i> ).....      | 29.51               | 29.32     | 29.75    |
| Pineapple.....   | 27.72               | 27.60     | 27.83    | <b>Raspberries:</b>                   |                     |           |          |
| Florida Seedling.....                                    | 28.20               | 28.10     | 28.43    | Ranere ( <i>St. Regis</i> , red)..... | 30.41               | 30.12     | 30.50    |
|  |                     |           |          | Columbia (black).....                 | 28.76               | 28.24     | 28.79    |
|  |                     |           |          | <b>Cranberries:</b>                   |                     |           |          |
|  |                     |           |          | Searl.....                            | 28.20               | 27.93     | 28.44    |
|  |                     |           |          | Gebhart Beauty.....                   | 26.30               | 26.00     | 26.60    |
|  |                     |           |          | Mammoth.....                          | 26.70               | 26.40     | 26.90    |
|  |                     |           |          | Metallic.....                         | 25.60               | 24.8      | 25.80    |

TABLE 1.—Average and extreme freezing points of fruits—Continued.

SUMMARY OF AVERAGES.

| Fruit and varieties.             | Temperatures (°F.) |           |          | Fruit and varieties.                  | Temperatures (°F.). |           |          |
|----------------------------------|--------------------|-----------|----------|---------------------------------------|---------------------|-----------|----------|
|                                  | Average.           | Extremes. |          |                                       | Average.            | Extremes. |          |
|                                  |                    | Minimum.  | Maximum. |                                       |                     | Minimum.  | Maximum. |
| Apples:                          |                    |           |          |                                       |                     |           |          |
| Summer varieties.....            | 28.44              | 28.12     | 28.62    | Grapefruit.....                       | 28.36               | 28.00     | 28.50    |
| Fall and winter.....             | 28.51              | 28.21     | 28.87    | Lemons.....                           | 28.14               | 27.89     | 28.47    |
| Bananas (Jamaica):               |                    |           |          | Oranges.....                          | 28.03               | 27.86     | 28.34    |
| Green.....                       | 29.84              | 29.76     | 29.92    | Peaches (hard ripe).....              | 29.41               | 29.09     | 29.74    |
| { Peel.....                      | 30.22              | 30.10     | 30.58    | Pears (Bartlett):                     |                     |           |          |
| { Pulp.....                      | 29.36              | 29.15     | 29.53    | Hard ripe.....                        | 28.46               | 28.06     | 28.70    |
| Ripe.....                        | 26.00              | 25.45     | 26.50    | Soft ripe.....                        | 27.83               | 27.20     | 28.00    |
| Blackberries:                    |                    |           |          | Pears (unknown Japanese variety)..... | 29.39               | 29.34     | 29.53    |
| Black varieties.....             | 29.15              | 28.73     | 29.42    | Japanese persimmons                   |                     |           |          |
| White varieties.....             | 28.40              | 28.12     | 28.63    | (Tanenashi).....                      | 28.33               | 28.07     | 28.63    |
| Logan ( <i>Loganberry</i> )..... | 29.51              | 29.32     | 29.75    | Plums.....                            | 28.53               | 28.20     | 28.85    |
| Cherries.....                    | 27.81              | 27.56     | 28.25    | Raspberries:                          |                     |           |          |
| Cranberries.....                 | 26.70              | 26.28     | 26.93    | Red varieties.....                    | 30.41               | 30.12     | 30.50    |
| Currants.....                    | 30.21              | 30.18     | 30.25    | Black varieties.....                  | 28.76               | 28.24     | 28.79    |
| Gooseberries.....                | 28.91              | 28.70     | 29.18    | Strawberries.....                     | 29.93               | 29.55     | 30.13    |
| Grapes (eastern).....            | 28.16              | 27.85     | 28.37    |                                       |                     |           |          |

*Strawberries.*—Freezing-point determinations were obtained for 22 authentic varieties of strawberries grown at the Maryland Agricultural Experiment Station. The greatest difference was found between the Lupton, which froze at 28.84° F., and the Hustler, at 30.48° F. The average for all varieties was 29.93° F. (Table 1.)

*Blackberries, raspberries, and cranberries.*—Three varieties of blackberries were frozen, viz, Jumbo, Eldorado, and Crystal White. The two black varieties froze at 29.09° and 29.21° F., respectively, while the white variety froze at 28.4° F. Logan blackberries (eastern grown), froze at 29.51° F. One variety each of red and black raspberries was frozen. The Ranere (*St. Regis*) froze at 30.41° F., while the Columbia froze at 28.76°. Four varieties of cranberries were frozen. Considerable differences were found in the freezing points of some of these varieties. While the Searl variety froze at 28.2° F., the Metallic froze at 25.6°. The results for Gebhart Beauty and Mammoth are intermediate, being 26.3° and 26.7 F., respectively.

*Miscellaneous fruits.*—A number of other fruits and berries were investigated, but only one variety was available in each case. The results are therefore not given separately, but are included in the summary of Table 1 covering the average freezing points of all the fruits studied.

FREEZING POINTS OF VEGETABLES.

While several different kinds of vegetables have been used in the freezing-point determinations, those on which the most extensive variety studies have been centered are Irish potatoes, sweet potatoes, and tomatoes.

*Potatoes.*—Freezing-point determinations were made on 18 different authentic varieties of potatoes. Bulletins 895 and 916 of the United States Department of Agriculture give the results of this study in detail, so they will not be discussed here. The average freezing points of all varieties was 28.92° F. (Table 2.)

TABLE 2.—Average and extreme freezing points of potatoes, sweet potatoes, tomatoes, and other vegetables.

| Kind and variety.       | Temperatures (° F.). |              |              | Kind and variety.             | Temperatures (° F.). |              |              |
|-------------------------|----------------------|--------------|--------------|-------------------------------|----------------------|--------------|--------------|
|                         | Average.             | Extremes.    |              |                               | Average.             | Extremes.    |              |
|                         |                      | Minimum.     | Maximum.     |                               |                      | Minimum.     | Maximum.     |
| <b>Potatoes:</b>        |                      |              |              | <b>Potatoes (ripe)—Contd.</b> |                      |              |              |
| Triumph.....            | 29.20                | 29.00        | 29.33        | Greater Baltimore....         | 30.62                | 30.20        | 30.81        |
| Early Prospect.....     | 28.80                | 28.72        | 29.30        | Columbia.....                 | 30.31                | 30.29        | 30.77        |
| Irish Cobbler.....      | 29.67                | 29.60        | 29.72        | Delaware Beauty.....          | 30.02                | 29.95        | 30.33        |
| First Early.....        | 29.00                | 28.88        | 29.00        | Livingston's Globe....        | 30.58                | 30.32        | 30.88        |
| New Early Standard.     | 28.97                | 28.74        | 29.12        | Livingston's Acme....         | 30.46                | 30.41        | 30.74        |
| Ehnoia.....             | 29.17                | 29.01        | 29.30        | <b>Greenhouse varieties—</b>  |                      |              |              |
| Spaulding No. 4.....    | 29.33                | 29.21        | 29.32        | Carter's Sunrise.....         | 30.58                | 30.06        | 30.85        |
| Green Mountain.....     | 28.50                | 28.38        | 28.55        | Stirling Castle.....          | 30.54                | 30.41        | 30.60        |
| Gold Coin.....          | 28.63                | 28.40        | 28.70        | <b>Average.....</b>           | <b>30.38</b>         | <b>30.20</b> | <b>30.67</b> |
| Rural New Yorker....    | 28.70                | 28.46        | 28.75        | <b>Potatoes (green):</b>      |                      |              |              |
| Russet Rural.....       | 28.32                | 28.30        | 28.48        | Bonny Best.....               | 30.57                | 30.38        | 30.83        |
| U. S. Seedling No.      |                      |              |              | Earliana.....                 | 30.24                | 29.77        | 30.58        |
| 38774.....              | 28.77                | 28.65        | 28.83        | John Baer.....                | 30.53                | 30.48        | 30.58        |
| Up-to-date.....         | 29.10                | 29.10        | 29.10        | Early Michigan.....           | 30.70                | 30.53        | 30.77        |
| Producer.....           | 28.70                | 28.73        | 28.79        | Red Rock.....                 | 30.58                | 30.34        | 30.67        |
| Oregon White Rose....   | 28.71                | 28.60        | 28.80        | Stone.....                    | 30.15                | 30.10        | 30.38        |
| British Queen.....      | 29.27                | 29.22        | 29.30        | <b>Greenhouse varieties—</b>  |                      |              |              |
| Garnet Chile.....       | 28.16                | 28.00        | 28.28        | Carter's Sunrise.....         | 30.29                | 30.20        | 30.59        |
| American Giant.....     | 29.64                | 29.48        | 29.68        | Stirling Castle.....          | 30.11                | 29.90        | 30.15        |
| <b>Average.....</b>     | <b>28.92</b>         | <b>28.80</b> | <b>29.02</b> | <b>Average.....</b>           | <b>30.40</b>         | <b>30.21</b> | <b>30.57</b> |
| <b>Sweet potatoes:</b>  |                      |              |              | <b>Sweet corn:</b>            |                      |              |              |
| Big Stem.....           | 28.05                | 27.48        | 28.72        | Crosby.....                   | 29.07                | 28.82        | 29.43        |
| Dooley.....             | 28.46                | 27.93        | 28.91        | Country Gentlemen....         | 29.11                | 28.63        | 29.43        |
| Early Carolina.....     | 28.59                | 28.40        | 28.96        | Howling Mob.....              | 28.00                | 27.89        | 28.16        |
| Georgia.....            | 28.05                | 27.79        | 28.58        | Golden Bantam.....            | 29.61                | 29.25        | 29.85        |
| Gold Skin.....          | 28.47                | 28.21        | 28.63        | <b>Average.....</b>           | <b>28.95</b>         | <b>28.65</b> | <b>29.22</b> |
| Improved Big Stem....   | 28.76                | 28.26        | 29.00        | <b>Onions:</b>                |                      |              |              |
| Miles.....              | 28.34                | 28.16        | 28.54        | Yellow Danvers.....           | 30.10                | 29.61        | 30.17        |
| Nancy Hall.....         | 28.10                | 27.54        | 28.35        | White Globe.....              | 30.20                | 29.75        | 30.41        |
| Mullihan.....           | 27.64                | 27.46        | 27.93        | Texas Bermuda.....            | 29.96                | 29.71        | 30.13        |
| Pierson.....            | 28.68                | 28.02        | 28.72        | <b>Average.....</b>           | <b>30.09</b>         | <b>29.69</b> | <b>30.24</b> |
| Porto Rico.....         | 28.34                | 27.87        | 28.68        | <b>Lettuce:</b>               |                      |              |              |
| Pumpkin.....            | 28.98                | 28.68        | 29.09        | May Queen.....                | 30.49                | 30.38        | 30.60        |
| Red Brazil.....         | 28.40                | 28.30        | 28.63        | Way Ahead.....                | 31.54                | 31.25        | 31.77        |
| Red Bermuda.....        | 28.17                | 27.98        | 28.63        | Prize Head.....               | 31.57                | 31.45        | 31.77        |
| Red Jersey.....         | 28.52                | 28.30        | 28.77        | <b>Average.....</b>           | <b>31.20</b>         | <b>31.03</b> | <b>31.38</b> |
| Southern Queen.....     | 28.56                | 28.25        | 28.82        | <b>Carrots:</b>               |                      |              |              |
| Triumph.....            | 28.43                | 28.26        | 28.72        | Danvers.....                  | 29.61                | 29.43        | 29.65        |
| Yellow Belmont.....     | 28.57                | 28.49        | 28.82        | Chauntenay.....               | 29.53                | 29.42        | 29.70        |
| Yellow Jersey.....      | 28.97                | 28.26        | 29.05        | <b>Average.....</b>           | <b>29.57</b>         | <b>29.42</b> | <b>29.68</b> |
| Yellow Strasburg....    | 28.72                | 28.30        | 29.00        | <b>Peas:</b>                  |                      |              |              |
| <b>Average.....</b>     | <b>28.44</b>         | <b>28.10</b> | <b>28.72</b> | Early Alaska.....             | 28.93                | 28.26        | 29.19        |
| <b>Tomatoes (ripe):</b> |                      |              |              | Hosford's Market              |                      |              |              |
| Bonny Best.....         | 30.60                | 30.48        | 30.68        | Garden.....                   | 30.93                | 30.73        | 30.99        |
| Olney Special.....      | 30.59                | 30.34        | 30.67        | Laxtonian.....                | 30.23                | 30.03        | 30.56        |
| Earliana.....           | 30.52                | 30.43        | 30.77        | <b>Average.....</b>           | <b>30.03</b>         | <b>29.67</b> | <b>30.25</b> |
| John Baer.....          | 30.57                | 30.24        | 30.90        |                               |                      |              |              |
| Landreth.....           | 30.45                | 30.34        | 30.72        |                               |                      |              |              |
| Early Michigan.....     | 30.67                | 30.19        | 30.85        |                               |                      |              |              |
| Marvel.....             | 30.03                | 29.90        | 30.38        |                               |                      |              |              |
| Bloomdale.....          | 29.99                | 29.90        | 30.53        |                               |                      |              |              |
| Red Rock.....           | 30.55                | 30.48        | 30.62        |                               |                      |              |              |
| Trucker's Favorite....  | 30.06                |              |              |                               |                      |              |              |
| New Glory.....          | 29.78                | 29.63        | 30.38        |                               |                      |              |              |
| Stone.....              | 30.31                | 30.10        | 30.58        |                               |                      |              |              |

## SUMMARY OF AVERAGES.

|                       |       |       |       |                      |       |       |       |
|-----------------------|-------|-------|-------|----------------------|-------|-------|-------|
| Beans (snap).....     | 29.74 | 29.65 | 30.06 | Lettuce.....         | 31.20 | 31.03 | 31.38 |
| Cabbage (Early Jersey |       |       |       | Onions (dry).....    | 30.09 | 29.69 | 30.24 |
| Wakefield).....       | 31.18 | 31.06 | 31.34 | Peas (green).....    | 30.03 | 29.67 | 30.25 |
| Carrots.....          | 29.57 | 29.42 | 29.68 | Potatoes.....        | 28.92 | 28.80 | 29.02 |
| Cauliflower.....      | 30.08 | 29.95 | 30.15 | Potatoes, sweet..... | 28.44 | 28.10 | 28.72 |
| Corn, sweet.....      | 28.95 | 28.65 | 29.22 | Tomatoes (ripe)..... | 30.38 | 30.20 | 30.67 |
| Eggplant.....         | 30.41 | 30.17 | 30.69 | Turnips.....         | 30.23 | 30.16 | 30.48 |
| Kohl-rabi.....        | 30.02 | 29.74 | 30.22 |                      |       |       |       |

*Sweet potatoes.*—The results of freezing 20 more or less common varieties of sweet potatoes are presented in Table 2. The varieties with the lowest freezing points are Big Stem and Georgia, both of which froze at 28.05° F. The highest freezing points were found with Pumpkin and Yellow Jersey varieties, which froze at 28.98° and 28.97° F., respectively. The average of all varieties was 28.44° F.

*Tomatoes.*—The freezing temperatures of 19 commercially grown varieties of tomatoes were determined and are presented in Table 2. These tomatoes were all grown under the same conditions at the Arlington Experiment Farm. Determinations were made on both ripe and practically full-grown green specimens, such as are usually picked for shipment from the Southern States to the northern markets. With the ripe tomatoes the lowest freezing point (29.78° F.) was found in connection with the New Glory variety. The Early Michigan variety froze at 30.67° F., which represents the highest freezing point of all the varieties studied. There was no appreciable difference in the average freezing points of ripe and green tomatoes, the averages being 30.38° and 30.40° F., respectively.

*Sweet corn.*—The freezing point of sweet corn varied considerably with the age of the product. There was also considerable variation between varieties. Four varieties were studied. (See Table 2.)

*Miscellaneous vegetables.*—The freezing points of three varieties of onions, three varieties of lettuce, two varieties of carrots, and three varieties of peas, and of at least one variety each of beans, cabbage, cauliflower, eggplant, kohlrabi, and turnips are also presented in the body or in the summary of Table 2.

#### FREEZING POINTS OF CUT FLOWERS.

Requests have been received for information on the freezing points of such cut flowers as are commonly held in cold storage or shipped in quantities. Determinations were made for peonies, roses, and Easter lilies, and these are presented in Table 3. Results are shown for both petals and leaves. With peonies and roses the petals freeze at temperatures higher than do the leaves. Rose petals froze at 30.04° F., while peony petals did not freeze until a temperature of 29.05° was reached. In the case of Easter lilies the leaves froze before the petals, the latter not succumbing until the temperature reached 27.50° F.

TABLE 3.—Average freezing points of the petals and leaves of cut flowers.

| Scope of inquiry.             | Peony.  |         | Rose.   |         | Easter lily. |         |
|-------------------------------|---------|---------|---------|---------|--------------|---------|
|                               | Petals. | Leaves. | Petals. | Leaves. | Petals.      | Leaves. |
| Number of determinations..... | 12      | 8       | 6       | 6       | .....        | .....   |
| Freezing point.....° F.       | 29.05   | 28.39   | 30.04   | 28.27   | 27.50        | 29.20   |

#### RECAPITULATION.

Freezing or freezing injury does not always occur when fruit or vegetable products are exposed to temperatures at or below their actual freezing points. Under certain conditions many of these products can be undercooled; that is, cooled to a point below the true freezing temperature of each and again warmed up without freezing and without apparent injury. Certain products under certain con-

ditions may be actually frozen and then thawed out without apparent injury, while, on the other hand, some products are injured if stored at temperatures well above their actual freezing points. Evidence seems to show that different individuals of the same variety and strain when grown under different conditions will have somewhat different freezing points, and that there are also some variations in the freezing points of products of the same variety and from the same lot.

In view of these facts the freezing points given in this bulletin should be considered only as danger points at or near which, either above or below, there is a possibility of freezing injury if exposed for a sufficient length of time. These are temperatures at which it is unsafe to hold produce for any length of time, as serious danger of frost injury exists.

*Fruits.*—The average of the freezing points of 9 varieties of summer apples was found to be 28.44° F., while the average for 14 varieties of fall and winter apples was 28.49° and 28.53° F. for eastern-grown and western-grown fruit, respectively, showing very little difference between the results for apples of the same varieties.

The freezing points of 7 varieties of cherries averaged 27.81° F.; 7 varieties of grapes, 28.16°; 6 varieties of oranges, 28.03°; 11 varieties of peaches, 29.41°; 4 varieties of plums, 28.53°; 22 varieties of strawberries, 29.93°; blackberries, 29.15°; white blackberries, 28.4°; Logan blackberries, 29.51°; red raspberries, 30.41°; black raspberries, 28.76°; cranberries, 26.7°; green bananas, peel 29.84°, pulp 30.22°; ripe bananas, peel 29.36°, pulp 26°; currants, 30.21°; gooseberries, 28.91°; grapefruit, 28.36; hard-ripe Bartlett pears, 28.46°; soft-ripe Bartlett pears, 27.83°; Japanese pears (unknown variety), 29.39°; and Japanese persimmons (Tanenashi), 28.33°.

Fruits freezing above 30° F. are green bananas (pulp), currants, and red raspberries. Those freezing between 29° and 30° F. are green bananas (peel), ripe bananas (peel), blackberries, Logan blackberries, peaches, Japanese pears, and strawberries. Those freezing between 28° and 29° F. are apples, blackberries (white), gooseberries, grapes, grapefruit, lemons, oranges, Bartlett pears (hard ripe), Japanese persimmons (Tanenashi), plums, and raspberries (black). Those freezing between 27° and 28° F. are cherries and Bartlett pears (soft ripe). Cranberries and ripe bananas (pulp) freeze between 26° and 27° F.

*Vegetables.*—The average freezing point of 18 varieties of potatoes was 28.92° F.; for 20 varieties of sweet potatoes, 28.44°; and for 19 varieties of tomatoes (ripe), 30.38°. The freezing points of other vegetables investigated were beans (snap), 29.74°; cabbage, 31.18°; carrots, 29.57°; cauliflower, 30.08°; sweet corn, 28.95°; eggplant, 30.41°; kohlrabi, 30.02; lettuce, 31.2°; onions (dry), 30.09°; peas (green), 30.03°; and turnips, 30.23°.

Two vegetables froze above 31° F., viz, cabbage and lettuce. Those freezing between 30° and 31° F. were cauliflower, eggplant, kohlrabi, onions, peas, tomatoes, and turnips. Those freezing between 29° and 30° F. were beans and carrots. Sweet corn, potatoes, and sweet potatoes froze between 28° and 29° F.

*Cut flowers.*—Determinations of the freezing points of the petals and leaves of Easter lilies, peonies, and roses show that Easter lily petals freeze between 27° and 28° F.; rose leaves and peony leaves, between 28° and 29°; peony petals and Easter lily leaves, between 29° and 30°; and rose petals, between 30° and 31°.



