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THE FREEZING TEMPERATURES OF SOME FRUITS, VEGETABLES, AND FLORISTS' STOCKS[1]

By R. C. WRIGHT, *physiologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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INTRODUCTION

There is an ever-increasing demand from persons interested in the growing, shipping, and handling of produce for exact data on the freezing points, or the temperatures at which actual ice formation takes place in various products.

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 hundred thousand 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 that are grown in the South and Southwest during the winter and shipped to 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 their freezing point. Under certain conditions when harvested in warm weather some of these products are precooled—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 precooling is practiced, it is, of course, essential to know the temperatures to which the product can be lowered with absolute safety.

[1] This circular is a revision of and supersedes Department Bulletin 1133, The Freezing Temperatures of Some Fruits, Vegetables, and Cut Flowers.

It is of great importance to the commercial cold-storage man to know the exact freezing points of the fruits and vegetables which he handles. In some instances established commercial-storage practices have been changed after the exact freezing points of certain products have been ascertained. 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 them in storage. One of the problems in the storage of many products is to hold them at a temperature low enough to slow down the life processes in order to prolong their storage life and yet not allow them to be damaged by actual freezing, which of course is likely to injure their keeping qualities or market value. With many products this storage temperature is only 1° or 2° above the actual freezing point. Of course some products, such as cherries, strawberries, peas, and lima beans, may be purposely kept in a frozen condition below freezing temperature, but this subject comes under the head of freezing storage and will not be discussed here.

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 potatoes reported in a previous publication,[2] where tubers were cooled as much as 10° F. below their freezing points without actually having become frozen and were again warmed up 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, certain commodities such as tomatoes, bananas, and cucumbers are definitely injured if stored at temperatures many degrees above their actual freezing points. This is usually termed chilling injury. It is evident, therefore, that temperatures just above the freezing point cannot be regarded as safe for all types or varieties of fruits and vegetables. It is also noticeable that there are variations in the freezing points of fruits and 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 danger of injury by freezing if exposed for a sufficient length of time.

It has been found in some cases, as has been pointed out, that the freezing points of some varieties are liable to slight variations. 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 product.

[2] WRIGHT, R. C., and TAYLOR, G. F. FREEZING INJURY TO POTATOES WHEN UNDERCOOLED. U. S. Dept. Agr. Bull. 916. 15 pp., illus. 1921.

The determinations of the freezing points of most of the commercial varieties of fruits, vegetables, and other plant materials have been made by the Bureau of Plant Industry in connection with its cold-storage investigations. This work is being continued.

Except where noted, the products reported upon were American grown and harvested at the usual state of maturity for commercial marketing. The method of determining freezing points has been described elsewhere.[3]

FREEZING POINTS OF FRUITS

Where several varieties of one kind of fruit were investigated the results are given separately to allow comparisions between varieties. The results are given in table 1. In table 2 these are summarized, and in addition there are listed the results of freezing-point determinations on a number of other fruits where only one representative variety of a kind was studied.

APPLES

Freezing-point determinations were made on a number of varieties of summer or early apples and of fall and winter varieties, most of the eastern-grown varieties being produced on the Arlington Experiment Farm, Arlington, Va. The tabulated results by varieties (table 1) 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 28.4° while the latter is 28.5° F. There is very little difference shown between the freezing points of eastern-grown and western-grown fruit.

TABLE 1.—*Average and extreme freezing points of different varieties of certain fruits*

Kind, variety, state of maturity, and place where grown	Average	Extremes	
		Minimum	Maximum
Apples, summer varieties, eastern-grown:	°F.	°F.	°F.
Yellow Transparent	27.7	27.3	28.2
Red Astrachan	28.6	28.2	28.7
Early Ripe	29.2	28.8	29.5
Red June	29.6	29.3	29.7
Schweitzer	27.4	27.3	27.4
Shoemaker	28.5	27.9	28.0
Benoni	28.8	28.5	29.0
Early Joe	27.8	27.6	28.5
Average	28.4	28.1	28.6
Apples, fall and winter varieties, eastern-grown:			
Baldwin	29.0	28.8	29.4
Ben Davis	29.6	28.2	29.0
Delicious	28.5	28.2	29.1
Grimes Golden	29.0	28.8	29.0
Jonathan	28.2	27.8	28.7
Paragon	28.5	28.4	28.5
Rambo	28.5	28.3	28.9
Stayman Winesap	28.5	28.0	28.9
Winesap	28.2	27.9	28.7
Yellow Newtown	28.0	27.8	28.2
York Imperial	28.3	28.1	28.5
Average	28.5	28.2	28.8
Apples, fall and winter varieties, western-grown:			
Delicious	28.4	28.0	28.9
Gano	28.5	28.3	29.0
Grimes Golden	28.6	28.3	29.0
Jonathan	28.3	28.0	28.7
Rome Beauty	28.9	28.7	29.4
Esopus Spitzenburg	28.7	28.3	29.0
Winesap	28.2	27.9	28.3
Average	28.5	28.2	28.9
Apples, crab:			
Martha	26.7	26.6	26.8
Transcendent	27.5	27.2	28.2
Average	27.1	26.9	27.5
Blackberries:			
Early Harvest	28.5	28.3	28.7
Jumbo	29.1	28.7	29.3
Eldorado	29.2	28.8	29.5
Crystal White	28.4	28.1	28.6
Logan (loganberry)	29.5	29.3	29.7
Cherries, sour, mature, eastern-grown:			
Early Richmond	27.9	27.6	28.3
Montmorency	28.1	27.8	28.6
St. Medard	28.1	27.6	28.6
Average	28.0	27.7	28.5

[3] TAYLOR, G. F. SOME IMPROVEMENTS ON THE NEEDLE TYPE THERMOCOUPLE FOR LOW-TEMPERATURE WORK. Jour. Indus. and Engin. Chem. 12 797–798, illus. 1920.

WRIGHT, R. C., and HARVEY, R. B. THE FREEZING POINT OF POTATOES AS DETERMINED BY THE THERMOELECTRIC METHOD. U. S. Dept. Agr. Bull. 895, 7 pp., illus. 1921.

WRIGHT, R. C., and TAYLOR, G. F. See footnote 2.

TABLE 1.—*Average and extreme freezing points of different varieties of certain fruits*—Continued

Kind, variety, state of maturity, and place where grown	Average	Extremes	
		Minimum	Maximum
Cherries, sweet, mature, eastern-grown:	°F.	°F.	°F.
Corey	24.9	23.9	25.8
Mary Hall	24.5	24.5	24.6
Average	24.7	24.2	25.2
Cherries, sweet, California:			
Black Tartarian, mature	24.2	23.5	25.1
Black Tartarian, immature	25.8	25.4	26.6
Bing, mature	24.1	23.4	24.8
Bing, immature	25.3	24.6	26.4
Average, mature	24.2	23.5	24.7
Average, immature	25.6	25.0	26.5
Cranberries:[1]			
Searl, Wisconsin	28.2	27.9	28.4
Gebhart Beauty, Wisconsin	26.3	26.0	26.9
Mammoth, Wisconsin	26.7	26.4	26.9
Metallic Bell, Wisconsin	25.6	24.8	25.8
Chipman, Massachusetts	26.9	26.0	27.4
Perry Red, Massachusetts	27.9	26.6	28.0
Early Black, Massachusetts	28.1	27.6	28.7
McFarlin, Massachusetts	29.0	28.4	29.4
Shaw Success, Massachusetts	25.0	24.6	25.7
Howes, Massachusetts	28.2	27.5	28.4
Pride, Massachusetts	27.0	26.6	27.7
Wales Henry, Massachusetts	28.7	27.9	28.0
Average	27.3	26.7	27.6
Grapes: American or euvitis type:			
Earl Concord	28.4	27.9	28.7
Ambrosia	28.2	27.8	28.6
Dracut Amber	27.9	27.8	28.1
Moore Early	28.3	28.1	28.6
Captivator	27.9	27.1	28.0
Campbell Early	28.0	27.8	28.0
Mericadel	28.5	28.4	28.5
Caco	27.3	27.2	27.4
Catawba	26.7	26.2	27.7
Concord	27.2	27.2	27.2
Delaware	24.6	24.2	25.4
Average	27.5	27.2	27.8
Grapes, European or vinifera type:			
Ohanez (Almeria), mature, California	25.6	25.2	26.1
Ohanez (Almeria), mature, Spain	25.6	24.6	26.7
Ohanez (Almeria), immature, Spain	26.1	25.1	27.2
Ohanez (Almeria), mature, Argentina	22.7	21.9	24.9
Ohanez (Almeria), mature, South Africa	25.8	25.1	26.4
Emperor, California	24.6	24.1	24.8
Emperor, Argentina	23.7	23.0	24.0
Emperor, South Africa	26.1	25.4	26.8
Malaga	24.6	24.6	24.8
Muscat	25.2	24.5	25.7
Olivette Blanche (Lady Finger)	25.0	24.5	25.8
Ribier	24.8	23.7	25.7
Sultanina (Thompson Seedless)	23.6	22.9	24.7
Grapes, European or vinifera type—Continued.			
Henab Turki, South Africa	26.1	25.9	26.5
Rasin Blanc, South Africa	24.9	24.2	25.8
Prune de Cazouls, South Africa	26.4	25.6	27.2
Barlinka, South Africa	25.6	24.4	26.8
Waltham Cross, South Africa	25.5	25.2	25.8
Average, mature:			
California	24.8	24.2	25.4
Spain	25.6	24.6	26.7
Argentina	23.2	22.4	24.4
South Africa	25.8	25.1	26.5
Oranges:			
Washington Navel, California:			
Flesh	28.4	28.3	28.7
Rind	27.4	26.9	28.4
Valencia, California, flesh	27.0	26.9	27.6
Pineapple, Florida, flesh	27.7	27.6	27.8
Seedling, Florida, flesh	28.2	28.1	28.4
Temple, Florida, flesh	28.6	28.3	28.8
Valencia, Florida:			
Flesh	28.3	27.9	28.9
Rind	27.4	26.9	28.1
Average:			
Flesh	28.0	27.8	28.4
Rind	27.4	26.9	28.2
Peaches, hard ripe:			
Belle	29.8	29.5	30.3
Elberta	29.7	29.4	30.0
Stevens	28.6	28.2	28.9
Edgemont	29.4	29.3	29.5
Williams	29.6	29.1	30.0
Bilyeu	28.9	28.3	29.0
Smock	29.3	29.0	29.6
Salwey	29.6	29.1	29.8
Hiley	30.0	29.9	30.2
Carman	29.6	29.3	29.9
Champion	29.1	28.7	29.9
Earl Rose	28.5	28.2	28.7
J. H. Hale	29.6	29.1	30.1
Average	29.4	29.0	29.7
Pears:			
Bartlett, hard ripe	28.5	28.1	28.7
Bartlett, soft ripe	27.8	27.2	28.0
Beurre Bosc, hard ripe	27.8	26.9	28.7
Anjou, hard ripe	26.9	26.4	27.1
Anjou, soft ripe	27.2	26.7	27.9
Kieffer, hard ripe	27.9	27.8	28.2
Kieffer, soft ripe	28.1	27.6	28.8
Winter Nelis, hard ripe	27.2	27.1	27.5
Winter Nelis, soft ripe	27.5	27.1	28.1
Average, hard ripe	27.7	27.2	28.0
Average, soft ripe	27.7	27.1	28.2
Plums:			
Damson, eastern grown	25.9	25.6	26.3
Burbank, California	29.3	29.0	29.8
Wickson, California	29.5	29.2	29.7
Tragedy, California	27.2	26.8	27.4
Red June, eastern-grown	28.1	27.8	28.4
Average	28.0	27.7	28.3

[1] This product is liable to be injured if stored at temperatures somewhat above its actual freezing point. For a discussion of the proper storage temperature see the following publications: ROSE, D. H., WRIGHT, R. C., and WHITEMAN, T. M. THE COMMERCIAL STORAGE OF FRUITS, VEGETABLES, AND FLORISTS' STOCKS. U. S. Dept. Agr. Circ. 278, 40 pp. 1933.

TABLE 1.—*Average and extreme freezing points of different varieties of certain fruits*—Continued

Kind, variety, state of maturity, and place where grown	Average	Extremes	
		Minimum	Maximum
	°F.	°F.	°F.
Raspberries:			
Ranere (St. Regis)	30.4	30.1	30.5
Latham	29.8	29.7	29.8
Chief	30.0	29.0	30.1
Potomac	30.7	30.6	30.9
Columbian	28.8	28.2	28.8
Average	29.9	29.5	30.1
Strawberries:			
Big Late	30.0	29.2	30.0
Joe (Big Joe)	30.0	29.8	30.0
Blakemore	29.9	29.7	30.5
Brandywine	30.0	29.8	30.4
Chesapeake	30.3	29.9	30.3
Strawberries—Continued.			
Dorsett	29.8	29.5	30.1
Dunlap	29.8	29.2	30.0
Excelsior	29.9	29.3	30.0
Gandy	29.2	28.8	29.5
Glen Mary	30.1	29.5	30.2
Howard 17 (Premier)	30.2	29.6	30.4
Klondike	29.6	29.3	29.9
Kellogg (Kellogg's Pride)	30.1	29.8	30.5
Lupton	28.8	28.8	29.1
Redheart	30.3	29.6	30.7
Sample	30.4	29.6	30.5
Average	29.9	29.5	30.1

TABLE 2.—*Summary of average and extreme freezing points of fruits*

Kind, variety, etc.	Average	Extremes	
		Minimum	Maximum
	°F.	°F.	°F.
Avocados,[1] Collinson	27.2	27.0	27.4
Apples: [2]			
Summer varieties	28.4	28.1	28.6
Fall and winter	28.5	28.2	28.8
Crab	27.1	26.9	27.5
Bananas: [1]			
Peel, immature	29.8	29.8	29.9
Pulp, immature	30.2	30.1	30.6
Peel, mature	29.4	29.1	29.5
Pulp, mature	26.0	25.4	26.5
Blackberries: [2]			
Black varieties	28.9	28.6	29.2
White variety	28.4	28.1	28.6
Logan (loganberry)	29.5	29.3	29.7
Blueberry, Rubel	27.4	26.9	27.9
Cherries: [2]			
Sour mature, eastern-grown	28.0	27.7	28.5
Sweet mature, eastern-grown	24.7	24.2	25.2
Sweet mature, California	24.2	23.5	24.7
Sweet immature, California	25.6	25.0	26.5
Citrus: [2]			
Grapefruit, flesh [1]	28.4	28.0	29.0
Grapefruit, rind	28.4	28.0	28.6
Kumquat	28.5	27.9	28.8
Lemon, flesh,[1] California	28.1	27.9	28.5
Lemon, rind, California	28.2	27.9	28.4
Lime, Persian [1]	29.3	29.1	29.5
Orange, flesh [1]	28.0	27.8	28.4
Orange, rind	27.4	26.9	28.2
Citrus—Continued.			
Tangerine, flesh	29.2	28.8	29.4
Satsuma, Owari, flesh	28.2	27.9	28.7
Coconuts: [1]			
Flesh	25.5	23.5	27.0
Milk	30.4		
Cranberries [1 2]	27.3	26.7	27.6
Currants	30.2	30.2	30.2
Figs, Mission, fresh, California	27.1	26.3	27.6
Gooseberries	28.9	28.7	29.2
Grapes: [2]			
American type	27.5	27.2	27.8
European type	24.9	24.3	25.5
Mango, Faizanson [1]	29.8	29.7	30.0
Olives, fresh,[1] green	28.5	27.7	29.4
Papaya	30.1	29.9	30.4
Peaches, hard ripe	29.4	29.0	29.7
Pears,[2] hard ripe	27.7	27.2	28.0
Pears,[2] soft ripe	27.7	27.1	28.2
Persimmon, Tanenashi	28.3	28.1	28.6
Pineapples, immature	29.1	28.7	29.8
Pineapples, eating ripe	29.9	29.6	30.2
Plums [2]	28.0	27.7	28.3
Quince	28.1	28.0	28.4
Raspberries [2]	29.9	29.5	30.1
Strawberries [2]	29.9	29.5	30.1
Chestnuts, Italy	23.8	23.0	24.2
Pecans, Schley	19.6	19.2	19.9
Walnuts, Persian (English)	20.0	19.0	22.1

[1] See footnote 1, table 1.
[2] See table 1 for freezing points of different varieties.

CHERRIES

Freezing-point determinations were made on three sour and two sweet varieties of cherries grown on the Arlington Experiment Farm and two varieties of sweet cherries from California. Special interest is attached to the freezing points of the sweet varieties (table 1). Determinations were made on both fully mature black fruit of the two California varieties and on bright-red fruit which, although immature, is often shipped to eastern markets. The immature bright-red cherries were quite sour, whereas the mature dark-red to black fruit was sweet and of good eating quality.

GRAPES

Results were obtained from 11 varieties of American grapes, labrusca type, and 7 varieties of European grapes, vinifera type, all American grown. While the average freezing point of the American grapes grown at Arlington Farm or at the National Agricultural Research Center, Beltsville, Md., was 27.5° F., it will be noted (table 1) that the freezing point of the Delaware variety, 24.6°, is considerably below that of the other varieties of both American and European types due probably to the greater sugar content. In addition, there were studied two varieties of vinifera-type grapes grown in Argentina and South Africa to compare with the same varieties grown in California, and also five other commercial varieties from South Africa. It will be noted that the American and South African grown Almeria grapes had about the same freezing point, while the same variety from Argentina froze at several degrees lower. On the other hand, the Emperor variety from South Africa froze at higher temperatures than those from either California or Argentina. The lowest freezing point was 22.7° in the Almeria from Argentina.

All the vinifera grapes studied came from commercial shipments on the market and were all American grown and mature except where noted.

ORANGES

The average freezing points of oranges grown both in California and Florida were determined.

PEACHES

Freezing-point determinations were made on 13 varieties of peaches commercially grown in nearby Virginia or Maryland. Peaches in the hard-ripe stage were utilized for these tests.

PEARS

Studies were made on five commercial varieties of pears, all California grown except the Kieffer variety. They were tested both in the hard-ripe or shipping-ripe stage of maturity and in the soft-ripe or eating-ripe stage.

PLUMS

Freezing points were obtained for three varieties of plums grown in California and purchased on the market and for two varieties grown at Arlington Farm. The variety with the lowest freezing point is Damson.

STRAWBERRIES

Freezing-point determinations were obtained for 16 varieties of strawberries grown at the Maryland Agricultural Experiment Station and at the National Agricultural Research Center. The greatest difference was found between Lupton, which froze at 28.8° F., and Redheart, which froze at 30.3°.

BLACKBERRIES, RASPBERRIES, AND CRANBERRIES

Four varieties of blackberries, one of Logan blackberries (eastern grown), and five of raspberries were studied. Four of the varieties of cranberries frozen were grown in Wisconsin and eight in Massachusetts. Considerable differences were found in the freezing points of some of these varieties. While the McFarlin variety, for instance, froze at 29°, Shaw's Success froze at 25°.

MISCELLANEOUS FRUITS

A number of other fruits and berries were investigated, but only one variety was available in each case. The results are included in table 2, covering the average freezing points of all the fruits studied. Three kinds of nuts were frozen, viz, Italian chestnuts, Persian (English) walnuts, and pecans.

FREEZING POINTS OF VEGETABLES

Although several different kinds of vegetables have been used in the freezing-point determinations, those on which the most extensive varietal studies have been centered are potatoes, sweetpotatoes, and tomatoes. These results are found in table 3.

TABLE 3.—*Average and extreme freezing points of several different varieties of potatoes, sweetpotatoes, tomatoes, and certain other vegetables*

Kind, state of maturity, and variety	Average	Extremes	
		Minimum	Maximum
	°F.	°F.	°F.
Cantaloups, eating ripe:			
Rocky Ford, flesh	29.1	28.2	29.7
Rocky Ford, rind	28.6	27.9	29.6
Tip Top, flesh	29.0	28.7	29.4
Tip Top, rind	28.3	28.2	28.8
Average, flesh	29.0	28.4	29.5
Average, rind	28.4	28.0	29.2
Carrots:			
Danvers	29.6	29.4	29.7
Chantenay	29.5	29.4	29.7
Average	29.6	29.4	29.7
Corn, sweet, milk stage:			
Crosby	29.1	28.8	29.4
Country Gentleman	29.1	28.6	29.4
Howling Mob	28.0	27.9	28.2
Golden Bantam	29.6	29.2	29.8
Average	28.9	28.6	29.2
Lettuce:			
May Queen	30.5	30.4	30.6
Way Ahead	31.5	31.2	31.8
Prize Head	31.6	31.4	31.8
Iceberg	31.2	30.8	31.4
Average	31.2	31.0	31.4
Onions:			
Yellow Danvers	30.1	29.6	30.2
White Globe	30.2	29.7	30.4
Texas Bermuda	30.0	29.7	30.1
Peas:			
Early Alaska	28.9	28.3	29.2
Horsford Market Garden	30.9	30.7	31.0
Laxtonian	30.2	30.0	30.6
Average	30.0	29.7	30.2
Potatoes: [1]			
Triumph	29.2	29.0	29.3
Irish Cobbler	29.7	29.6	29.7
Spaulding No. 4	29.3	29.2	29.3
Green Mountain	28.5	28.4	28.5
Gold Coin	28.6	28.4	28.7
Rural New Yorker No. 2	28.7	28.5	28.7
Russet Rural	28.3	28.3	28.5
Up-to-Date	29.1	29.1	29.1
Oregon White Rose	28.7	28.6	28.8
British Queen	29.3	29.2	29.3
Garnet Chili	28.2	28.0	28.3
American Giant	29.6	29.5	29.7
Katahdin	29.2	29.0	29.6
Average	28.9	28.8	29.0
Sweetpotatoes: [1]			
Big Stem	28.0	27.5	28.7
Dooley	28.5	27.9	28.9
Gold Skin	28.5	28.2	28.6
Sweetpotatoes—Continued.			
Improved Big Stem	28.8	28.3	29.0
Nancy Hall	28.1	27.5	28.3
Mullihan	27.6	27.5	27.9
Pierson	28.7	28.0	28.7
Porto Rico	28.3	27.9	28.7
Pumpkin	29.0	28.7	29.1
Red Brazil	28.4	28.3	28.6
Red Bermuda	28.2	28.0	28.6
Red Jersey	28.5	28.3	28.8
Southern Queen	28.6	28.2	28.8
Triumph	28.4	28.3	28.7
Yellow Belmont	28.6	28.5	28.8
Yellow Jersey	29.0	28.3	29.0
Yellow Strasburg	28.7	28.3	29.0
Average	28.5	28.1	28.7
Tomatoes, ripe: [1]			
Bonny Best	30.6	30.5	30.7
Earliana	30.5	30.4	30.8
John Baer	30.6	30.2	30.9
Landreth	30.4	30.3	30.7
Marvel	30.0	29.9	30.4
Bloomdale	30.0	29.9	30.5
Red Rock	30.5	30.5	30.6
New Glory	29.8	29.6	30.4
Stone	30.3	30.1	30.6
Greater Baltimore	30.6	30.2	30.8
Columbia	30.3	30.3	30.8
Delaware Beauty	30.0	29.9	30.3
Livingston Globe	30.6	30.3	30.9
Marglobe	30.7	30.7	30.8
Livingston Acme	30.7	30.4	30.7
Greenhouse varieties:			
Carter Sunrise	30.6	30.1	30.8
Stirling Castle	30.5	30.4	30.6
Average	30.4	30.2	30.7
Tomatoes, green: [1]			
Bonny Best	30.6	30.4	30.8
Earliana	30.2	29.8	30.6
John Baer	30.5	30.5	30.6
Red Rock	30.6	30.3	30.7
Stone	30.1	30.1	30.4
Marglobe	30.6	30.5	30.8
Greenhouse varieties:			
Carter Sunrise	30.3	30.2	30.6
Stirling Castle	30.1	29.9	30.1
Average	30.4	30.2	30.6
Watermelons: [1]			
Dixie Belle, flesh	29.0	28.9	29.1
Dixie Belle, rind	28.8	28.6	28.9
Irish Grey, flesh	29.4	29.0	29.8
Irish Grey, rind	28.8	28.5	29.1
Average, flesh	29.2	28.9	29.4
Average, rind	28.8	28.5	29.0

[1] This product is liable to be injured if stored at temperatures somewhat above its actual freezing point. For a discussion of the proper storage temperature see publication cited in footnote to table 1.

POTATOES

Freezing-point determinations were made on 13 different commercial varieties of potatoes.

SWEETPOTATOES

The results of freezing 17 more or less common varieties of sweetpotatoes are presented in table 3. The variety with the lowest freezing point was Mullihan, one of the less known varieties, which froze at 27.6° F. The highest freezing points were found with Pumpkin and Yellow Jersey varieties, both of which froze at 29.0°.

TOMATOES

The freezing-point temperatures of 17 commercially grown varieties of tomatoes are presented in table 3. These tomatoes were all grown under the same conditions at Arlington Farm. Determinations were made on both field-ripened and mature-green tomatoes such as are usually shipped to distant markets. The lowest freezing point (29.8° F.) of ripe tomatoes was found in the New Glory variety. The Marglobe and Livingston Acme varieties both froze at 30.7°, the highest freezing point in any of the varieties studied. There was no difference in the average freezing points of ripe and mature green tomatoes.

SWEET CORN

Four varieties of sweet corn were studied, all in the milk stage. The freezing point varied considerably with the age of the product, and there was also considerable variation among varieties (table 3).

MISCELLANEOUS VEGETABLES

The freezing points of three varieties of onions, four of lettuce, two of carrots, two of cantaloups, two of watermelons, and three of peas are also given in table 3. The freezing points of several other kinds of vegetables where only one variety of each was studied are given in table 4, together with the average freezing point of all of the vegetables listed by varieties in table 3.

FREEZING POINTS OF FLORISTS' STOCKS

The freezing points of cut flowers, plants, bulbs, corms, and tubers that are commonly held in cold storage or shipped in quantities were similarly determined. The determinations made for 15 kinds of cut flowers, 8 of bulbs, corms, and tubers, and 10 of plants are presented in table 5. The freezing points of cut flowers were determined on petals alone, and of plants on leaves alone. The freezing points of the petals of cut flowers varied from 27.5° F. in Easter lilies to 30.8° in the orchid. The leaves of rose and peony plants froze at lower temperatures than petals borne on the same stems, whereas leaves of Easter lilies froze at a higher temperature than the petals. The fronds of dagger ferns, which are commonly shipped in large quantities and stored during the winter, froze at the relatively low temperature of 23.6°. Holly leaves such as are used in large quantities in sprays or wreaths for Christmas decoration froze at 26.3°. The foliage of neither holly nor dagger fern was apparently injured by freezing, as is often the case with less hardy plant material. *Asparagus plumosus* foliage, which is shipped in considerable quantities, also froze at a relatively low temperature, 24.2°. The leaves of sansevieria plants, which are frequently shipped in large quantities for potting as ornamentals froze at the relatively high temperature of 31.0°. Among the

bulbs studied, tulips froze at 25.4°, and Paper White narcissus froze at close to 29°.

TABLE 4.—*Summary of average and extreme freezing points of different vegetables*

Kind and variety	Average	Extremes	
		Minimum	Maximum
	°F.	°F.	°F.
Artichoke:			
Globe	29.1	29.1	29.1
Jerusalem	27.5	27.2	27.9
Asparagus	29.8	29.4	30.1
Beans:			
Snap or green	29.7	29.6	30.1
Snap, pods	30.2	29.9	30.4
Lima	30.1	29.8	30.3
Lima, pods	30.8	30.7	31.0
Beet	26.9	26.7	27.2
Brocoli, Italian	29.2	28.7	29.4
Cabbage (early) Jersey Wakefield	31.2	31.1	31.3
Carrots [1]	29.6	29.4	29.7
Cauliflower	30.1	29.9	30.1
Celery	29.7	29.7	30.0
Chayote	30.0	29.7	30.4
Chicory, curled	30.7	30.5	31.0
Corn, sweet, milk stage	28.9	28.6	29.2
Cucumber [2]	30.5	30.3	30.6
Dandelion greens	29.8	29.5	30.1
Eggplant [2]	30.4	30.2	30.7
Endive, curled	30.9	30.5	31.3
Endive, Belgian, imported	30.7	30.5	30.9
Escarole, broad-leaved endive	30.5	30.0	30.7
Fennel, Florence	29.0	28.5	29.7
Garlic	25.4	24.6	25.7
Horseradish	26.4	25.2	27.6
Kohlrabi	30.0	29.7	30.2
Leek	29.2	28.5	29.8
Lettuce [1]	31.2	31.0	31.4
Muskmelons, eating ripe: [1 3]			
Cantaloup, flesh	29.0	28.4	29.5
Cantaloup, rind	28.4	28.0	29.8
Honey Dew, flesh	29.0	28.7	29.3
Honey Dew, rind	28.8	28.3	29.8
Mushroom, cultivated	30.2	29.9	30.4
Okra	30.1	30.0	30.2
Onions, mild	30.0	29.7	30.1
Onions, strong [1]	30.1	29.7	30.3
Onion sets, Yellow Strassburg	29.5	29.0	29.9
Parsnip	29.9	28.4	29.3
Peas, green [1]	30.0	29.7	30.2
Peas, pods	30.0	29.9	30.4
Peppers, green	30.1	29.9	30.3
Potatoes [1 2]	28.9	28.8	29.0
Pumpkin, Connecticut Pie [2]	30.1	30.0	30.3
Radish, French Breakfast	27.3	26.9	27.9
Rhubarb	28.4	27.5	29.3
Romaine	30.5	30.1	30.8
Rutabaga, American Purple Top	29.5	28.4	29.9
Salsify	28.4	28.1	28.7
Spinach	30.3	30.2	30.5
Squash: [2]			
Summer (cymling)	29.3	29.1	29.6
Winter, Hubbard	29.3	28.9	29.5
Italian, Cocazelle	30.9	30.5	31.3
Sugar beet	28.5	28.1	29.2
Sweetpotatoes [1 2]	28.5	28.1	28.7
Tomatoes, ripe [1 2]	30.4	30.2	30.7
Tomatoes, mature-green [1 2 3]	30.4	30.2	30.6
Turnips, Purple Top White Globe	30.5	30.2	31.1
Watermelon, flesh	29.2	28.9	29.4
Watermelon, rind	28.8	28.5	29.0

[1] See table 3 for freezing points of different varieties.
[2] See footnote 1, table 1.
[3] This same group of varieties when vine ripened averaged 30.5° F.

TABLE 5.—*Average freezing points of certain cut flowers, bulbs, corms, tubers, and plants*

Kinds	Average	Extremes	
		Minimum	Maximum
	°F.	°F.	°F.
Cut flowers (petals):			
Anemone	28.1	28.0	28.2
Carnation	28.4	27.9	28.7
Chrysanthemum	28.4	28.0	28.7
Gardenia	28.3	28.3	28.3
Gladiolus	28.7	28.7	28.7
Heath (heather)	28.7	28.7	28.7
Hyacinth	28.7	28.5	29.0
Lily, Easter	27.5	------	------
Narcissus, Sir Watkin	30.1	30.0	30.9
Orchid (*Cattleya*)	30.8	30.1	31.1
Peony	29.0	------	------
Poinsettia	29.2	29.0	29.5
Ranunculus	28.6	28.2	28.9
Rose	30.4	------	------
Tulip	28.0	27.7	28.2
Bulbs, corms, and tubers:			
Dahlia	28.3	28.0	28.7
Gladiolus	26.8	26.5	27.0
Hyacinth	28.7	28.5	29.2
Bulbs, corms, and tubers—Con.			
Lily, Calla	27.5	27.5	27.5
Lily, Regal	27.1	27.0	27.8
Narcissus, Paper White:			
Dormant	28.9	28.2	29.3
Sprouting	29.4	29.1	29.9
Narcissus, Sir Watkin	26.1	25.8	26.3
Tulip	25.4	24.9	25.4
Plants (leaves):			
Asparagus plumosus nanus	24.2	23.5	24.8
Carnation	27.4	27.4	27.4
Chrysanthemum	28.7	28.7	28.7
Fern, Oregon Dagger	23.6	23.6	23.6
Gladiolus	26.8	26.8	26.8
Holly, eastern grown	26.3	23.9	27.0
Lily, Easter	29.2	------	------
Peony	28.4	------	------
Rose	28.3	------	------
Sansevieria laurentia	31.0	31.0	31.0

SUMMARY

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 conditions may be actually frozen and afterwards thawed out without apparent injury, while, on the other hand, some products are injured by chilling 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. Sometimes this is due to different degrees of maturity.

In view of these facts, the freezing points given in this circular 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. The temperatures given are those at which it is unsafe to hold produce because of the danger of freezing.

The freezing points of 34 commercial kinds of fruits, 45 of vegetables, 15 of cut flowers, 8 of bulbs, corms, or tubers, and 10 of plants or florists' greens are given. Additional data are also given for a number of different varieties of these kinds.

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This circular is a contribution from

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Division of Fruit and Vegetable Crops and Diseases.	E. C. AUCHTER, *Principal Horticulturist, in Charge.*

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