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Climate of Minnesota

PART II. THE AGRICULTURAL AND MINIMUM-TEMPERATURE-FREE SEASONS

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This is the second in a series of publications describing the climate of Minnesota, especially as it relates to agriculture. The first dealt with the probability of occurrence of certain minimum temperatures for the last time in the spring and the first time in the fall (1). This publication is concerned with the agricultural seasons – the average date on which the seasons begin, the length of the seasons, and their duration for a given probability.

Seasons are described in two ways:

1. The division of the year into the agricultural seasons: early spring, late spring, summer, early fall, late fall, and winter.
2. The period free of certain minimum temperatures, of which the so-called freeze-free season is an example.

Source of Data and Station Location

A major portion of the original data for this study was obtained from a climatic study by the U.S. Weather Bureau (7). The remaining data were calculated by the authors. The 75 U.S. Department of Commerce Weather Bureau stations for which temperature data were used in this study are described in table 1 and their locations shown in figure 1.

Temperatures Selected and Calculations Made

Minimum temperatures selected for study were 16°, 20°, 24°, 28°, 32°, 36°, 40°, and 50°F. The original temperature measurements were made with a thermometer housed in a louvered white shelter which stands about 5 feet above ground. The dates on which these temperatures occurred for the last time in the spring and the first time in the fall are all normally distributed except those of 50°F. (1). Once the temperature occurrence variances are determined the probabilities can be calculated. Due to the normal distribution of the spring and fall dates, with the exception of 50°F., and because the spring and fall dates are essentially independent of each other, the periods between the spring and fall dates are also normally distributed. Thus the probability of duration of the minimum-temperature-free periods[1] can be determined, since the variance of each equals the sum of the spring and fall date variances (6).

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The authors wish to acknowledge their indebtedness to the cooperative observers of the U.S. Weather Bureau. Voluntarily and without compensation these men and women, as a result of their daily weather observations, have given Minnesota and the United States climatic records which make studies such as this one possible. They also wish to thank Mr. Robert F. Dale, area climatologist, U.S. Department of Commerce Weather Bureau, Ames, Iowa. for his critical review of this study.

[1]Minimum-temperature-free period is the interval in days between the last occurrence of a particular minimum temperature in the spring and the first occurrence of the same temperature in the fall.

Seasons Defined

The approximate dates of the summer and winter solstices, June 22 and December 22, and the spring and autumnal equinoxes, March 21 and September 23, are sometimes considered as the initiation of the four seasons. Actually these dates refer to certain cardinal positions of the earth in its annual orbit about the sun and are only crude guidelines for the beginning of seasons. Thus some other criterion must be used to define a season and its date of initiation.

A definition of agricultural seasons must rest, of course, upon the plants and the annual growth characteristics they exhibit. However, so few data are available for any quantitative or statistical treatment that it is necessary to find some phenomenon which meets the following criteria:

- It is directly related to plant growth.
- It is easily measured, and therefore preferably a physical factor.
- Its historical record is available.

Climate is evidently the factor sought, since climate is the dominant factor in the physical environment and plant growth is largely a reflection of the physical environment.

For practical application the climatic element or elements used must be observed and recorded almost universally. Only temperature and precipitation meet this requirement. But important as precipitation is, in Minnesota it is usually secondary to temperature in its influence upon crop growth, particularly plant growth initiation and ending.

In the following sections seasons are described in two ways, both based only upon temperature. The first is the partition of the year into six periods termed the agricultural seasons. These are early spring, late spring, summer, early fall, late fall, and winter. The average date of commencement and average duration of each are given. Thus, a general view of Minnesota's agricultural seasons is shown for the first time. This should be of value in defining the climatic limits of crop boundaries.

Secondly, the periods of seasons free of selected minimum temperatures and the probability of duration of each of these periods are presented. This section is valuable in that a means, based upon the probabilities presented, is provided for the long-term planning of agricultural and other temperature-dependent activities.

Local Variations in Climate

Variation in weather with time is largely a matter of the regional climate.[2] Differences in weather from place to place within the same climatic region often are essentially due to local influences. The mechanical mixing of the atmosphere, possible at high altitudes and conducive to homogeneity, is increasingly restricted as the surface of the earth is approached. Thus for measurements close to the earth, such as the air temperature data upon which this study is based, various factors can greatly alter local climates. These are discussed more completely elsewhere (1) (3), but essentially the influence of such features as altitude; topography, including degree and facing direction of slopes; adjacent water bodies; and the kind and condition of the surface are appreciable upon local climates.

Therefore, in attempting to translate the climate as indicated at one station to a neighboring locale, the reader should be aware of the physical features mentioned above and how they might affect the local climate.

The Agricultural Seasons

Newman and Wang (5) define agricultural seasons as follows:

"1. Early spring: cool season perennial crops, such as bluegrass, begin to grow; and cool season annuals, such as spring oats, are planted.

[2]Briefly, weather may be considered as the instantaneous or short-term state of the atmosphere, and climate as the general state of the atmosphere over a number of years.

"2. Late spring: warm season crops, such as dent corn, are planted; and cool season crops grow rapidly.
"3. Summer: warm season crops, such as soybeans, grow rapidly; and cool season annuals, such as small grains, are harvested.
"4. Early fall: cool season crops, such as winter grains, are planted; and warm season crops, such as dent corn, mature rapidly.
"5. Late fall: cool season crops, such as winter grains, grow rapidly; and warm season annuals, such as soybeans, are harvested.
"6. Winter: crop plants are dormant."

The temperature criteria used to define the seasons for Minnesota were established in the following manner: The average dates of various phenological events were placed into their respective season categories as defined above. Then the temperature criteria suggested by Newman and Wang were fitted to the crop phenological dates at each station. Where their criteria were unsatisfactory, that is, where the minimum temperature occurrence was too early or too late according to the phenological date, new ones had to be found. The temperature criterion for each of the seasons which most nearly fitted the phenological dates at all of the stations was selected as defining the initiation of a particular season. On the whole these agree favorably with those established by Newman and Wang.

At Morris, for example, the average corn and soybean planting dates are May 24 and 25, respectively. The average date of soybean ripening is September 16, and of corn harvesting, October 7. By definition, planting occurs in late spring and ripening and harvesting in late fall. Using Newman and Wang's criteria as a guide, the Minnesota temperature occurrence probability tables (1) show that the event whose date most nearly matches the May 24 and 25 planting dates occurs when less than 20 percent of the minimum temperatures are 32° F. or lower. The average date on which this occurs is May 23. Similarly, for the late fall events it is found that the best fit occurs when more than 10 percent of the minimum temperatures are 32° F. or lower (September 12). Various adjustments were made in the temperature criteria used until the best fit for available phenological data was found for all stations.

Table 2 shows the results obtained for all of the stations for which both phenological dates and temperature occurrence probabilities were available using the temperature criteria finally accepted after a series of trial and error fittings. Agreement between dates of the phenological events and temperature criteria dates is acceptable, though not perfect. It is doubtful that this method can be improved with existing data.

Early and late spring, as defined for St. Paul, appear to be in accord with native vegetation phenological events (table 3)

The obvious advantage to this scheme is that for determining the season commencement dates, it is now possible to make use of the 75 stations for which minimum temperature occurrence probabilities have been computed instead of only the 9 stations for which phenological data are available.

Based upon the results shown in table 2, the following temperature criteria are accepted and used in this study to define the agricultural seasons in Minnesota at each of the 75 stations listed in table 1:

1. Early spring begins when 20 percent or less of the minimum temperatures are 16° F. or lower. In early spring cool season perennial crops, such as bluegrass, begin to grow, and cool season annuals, such as spring oats, are planted.
2. Late spring begins when less than 20 percent of the minimum temperatures are 32° F. or lower. In late spring warm seasoin crops, such as dent corn and soybeans, are planted, and cool season crops grow rapidly.
3. Summer begins when less than 10 percent of the minimum temperatures are 40° F. or lower. In sum-

mer warm season crops, such as soybeans, grow rapidly, and cool season annuals, such as small grains, are harvested.

4. Early fall begins when more than 20 percent of the minimum temperatures are 40° F. or lower. In early fall cool season crops, such as winter grains, are planted, and warm season crops, such as dent corn, mature rapidly.
5. Late fall begins when more than 10 percent of the minimum temperatures are 32° F. or lower. In late fall cool season crops, such as winter grains, grow rapidly, and warm season annuals, such as dent corn and soybeans, are harvested.
6. Winter begins when more than 20 percent of the minimum temperatures are 16° F. or lower. In winter crop plants are dormant.

Commencement Dates of the Agricultural Seasons

Table 4 lists the average commencement date of the six seasons. Early spring, late spring, and summer begin earliest in the extreme southeast and south-central part of the state and are progressively later until the northwest corner is reached (figures 2, 3, and 4).

Early autumn, late autumn, and winter begin earliest in the northwest and move across the state in a southeasterly direction (figures 5, 6, and 7).

The general trend in the progression of the seasons across the state is due to the location of the air mass source regions and also the average direction of movement of the air masses across the state. The warm air mass source region for Minnesota is the Gulf of Mexico and occasionally northern Mexico and southwestern United States. By the time these air masses reach Minnesota they are usually moving in a northeasterly direction. Thus they first cross the southeastern part of the state. With the abatement of winter these masses of warm and frequently moist air sweep farther and farther north, though still moving in a northeasterly direction.

The cold air masses originate in Canada to the northwest and occasionally to the north of Minnesota. Usually these air masses move across the state in a southeasterly direction.

There are several exceptions to the general northwesterly trend of spring and summer and the southeasterly trend of fall and winter. These exceptions are due to one or more of the local features already noted.

Season commencement dates immediately adjacent to the Lake Superior shore are very nearly the same as those in the southeastern counties of Dodge, Goodhue, Olmsted, Steele, and Waseca. This is obviously a local influence and is due to the fact that large water bodies are capable of absorbing and storing much more heat than land surfaces. However, in spite of its great size, the influence of Lake Superior does not extend far inland because of both the prevailing winds from the west and the upland that rises quite abruptly from the Minnesota shore. The restricted influence of the lake is evident in the two Duluth stations (table 4). The city station is nearly at lake level while the airport station is some 800 feet higher.

Spring and summer occur earliest and fall and winter latest in the lower Mississippi Valley and the Twin Cities area. The reason may be attributed partially to a very localized influence of the river and partially to the urban and industrial heat sources and building mass heat reservoirs.

There are several areas where spring and summer occur later and fall and winter occur earlier than in neighboring areas. This is largely caused by local topography or the kind of soil surface. The season commencement dates of a large area surrounding the Meadowlands station in southwestern St. Louis County match those of extreme northwestern Minnesota. The reason rests largely upon the large area of organic (peat) soils surrounding Meadowlands. Such soils are notoriously poor in heat economy. They do not absorb heat readily because of

Table 1. Station index (8)

Index No.	Station name	Location	County	Altitude (feet)
1	Ada	In town	Norman	906
2	Albert Lea	In town	Freeborn	1,235
3	Alexandria	Airport	Douglas	1,421
4	Argyle	In town	Marshall	845
5	Artichoke Lake	Farm site	Big Stone	1,075
6	Babbitt	2 miles southwest	St. Louis	1,615
7	Baudette	In town	Lake of the Woods	1,075
8	Beardsley	In town	Big Stone	1,090
9	Bemidji	Airport	Beltrami	1,392
10	Big Falls	Ranger station	Koochiching	1,220
11	Bird Island	In town	Renville	1,089
12	Brainerd	In town	Crow Wing	1,214
13	Cambridge	In town	Isanti	1,000
14	Campbell	In town	Wilkin	975
15	Canby	In town	Yellow Medicine	1,243
16	Cloquet	Experimental forest	Carlton	1,265
17	Crookston	Northwest School	Polk	883
18	Detroit Lakes	In town	Becker	1,375
19	Duluth	Airport	St. Louis	1,409
20	Duluth	In town	St. Louis	610
21	Fairmont	In town	Martin	1,187
22	Faribault	In town	Rice	1,190
23	Farmington	3 miles north	Dakota	902
24	Fergus Falls	In town	Otter Tail	1,210
25	Fosston	In town	Polk	1,289
26	Grand Marais	U. S. Coast Guard Station	Cook	688
27	Grand Meadow	In town	Mower	1,338
28	Grand Rapids	North Central School	Itasca	1,281
29	Gull Lake Dam	Dam site	Cass	1,215
30	Hallock	In town	Kittson	813
31	Hinckley	In town	Pine	1,035
32	International Falls	Airport	Koochiching	1,179
33	Itasca State Park	State Park	Clearwater	1,500
34	Leech Lake Dam	Dam site	Cass	1,301
35	Little Falls	In town	Morrison	1,115
36	Mahoning Mine	Mine site	St. Louis	1,578
37	Maple Plain	In town	Hennepin	1,030
38	Meadowlands	In town	St. Louis	1,270

Table 1. Station index (8) (continued)

Index No.	Station name	Location	County	Altitude (feet)
39	Milaca	In town	Mille Lacs	1,080
40	Milan	In town	Chippewa	1,005
41	Minneapolis	In town	Hennepin	830
42	Montevideo	In town	Chippewa	900
43	Moorhead	State Teachers College	Clay	940
44	Moose Lake	State Hospital	Carlton	1,085
45	Mora	In town	Kanabec	1,001
46	Morris	West Central School	Stevens	1,130
47	New London	In town	Kandiyohi	1,215
48	New Ulm	In town	Brown	826
49	Park Rapids	In town	Hubbard	1,434
50	Pine River Dam	Dam site	Crow Wing	1,215
51	Pipestone	In town	Pipestone	1,735
52	Pokegama Dam	Dam site	Itasca	1,280
53	Red Lake Falls	In town	Red Lake	1,035
54	Red Lake Indian Agency	Reservation	Beltrami	1,216
55	Redwood Falls	In town	Redwood	1,021
56	Roseau	In town	Roseau	1,047
57	St. Cloud	Airport	Stearns	1,034
58	St. Paul	Airport	Ramsey	920
59	St. Peter	2 miles southwest	Nicollet	825
60	Sandy Lake Dam Libby	Dam site	Aitkin	1,234
61	Springfield	In town	Brown	1,050
62	Tracy	In town	Lyon	1,403
63	Two Harbors	In town	Lake	614
64	Virginia	In town	St. Louis	1,445
65	Wadena	In town	Wadena	1,350
66	Walker	In town	Cass	1,407
67	Warroad	In town	Roseau	1,069
68	Waseca	Experimental farm	Waseca	1,153
69	Wheaton	In town	Traverse	1,018
70	Willmar	State Hospital	Kandiyohi	1,133
71	Winnebago	In town	Faribault	1,110
72	Winnibigoshish Dam	Dam site	Itasca	1,315
73	Winona	In town	Winona	652
74	Worthington	In town	Nobles	1,593
75	Zumbrota	In town	Goodhue	985

Table 2. Average crop phenological dates compared with the temperature-defined agricultural season initiation dates at nine stations (2)

Station and crop	Early spring begins	Late spring begins	Summer begins	Early fall begins	Late fall begins	Winter begins
Bird Island	4/5	5/20	6/15	9/2	9/19	10/29
Corn	5/10 Planted*				10/28 Harvested	
Canby	4/7	5/18	6/29	9/4	9/19	10/29
Corn		5/20 Planted			10/21 Harvested	
Crookston	4/18	5/29	6/29	8/5	9/10	10/21
Barley	5/5 Planted					
Corn	5/19 Planted*				10/11 Harvested	
Flax	5/7 Planted	6/28 First bloom	7/4 Full bloom	8/19 Ripe		
Oats	4/27 Planted	6/25 Headed	7/29 Ripe			
Soybeans	5/24 Planted*				9/13 Ripe	
Wheat	4/30 Planted		7/1 Headed			
			8/3 Ripe			
Duluth	4/13	5/31	6/24**	7/29**	9/12	11/3
Oats	4/28 Planted		7/5 Headed	8/7 Ripe*		
Grand Rapids	4/24	6/9	6/30	7/7	8/24	10/12
Oats	5/6 Planted		7/2 Headed	8/4 Ripe*		
Moorhead	4/9	5/21	---	---	9/18	10/26
Corn		5/21 Planted			10/14 Harvested	
Morris	4/13	5/23	6/18	8/19	9/12	10/27
Barley	4/25 Planted					
Corn		5/24 Planted			10/7 Harvested	
Flax	5/1 Planted		6/21 First bloom			
			6/26 Full bloom			
			8/8 Ripe			

Table 2. Average crop phenological dates compared with the temperature-defined agricultural season initiation dates at nine stations (2) (continued)

Station and crops	Early spring begins	Late spring begins	Summer begins	Early fall begins	Late fall begins	Winter begins
Oats	4/22 Planted		6/22 Headed			
			7/23 Ripe			
Soybeans		5/25 Planted			9/16 Ripe	
Wheat	4/23 Planted		6/24 Headed			
			7/26 Ripe			
St. Paul	3/31	5/9	5/31***	9/13***	9/24	11/10
Barley	4/23 Planted					
Corn		5/16 Planted			10/25 Harvested	
Flax	4/24 Planted		6/25 First bloom			
			6/20 Full bloom			
			7/29 Ripe			
Oats	4/25 Planted		6/23 Headed			
			7/22 Ripe			
Soybeans		5/22 Planted		9/23 Ripe		
Wheat	4/23 Planted		6/24 Headed			
			7/26 Ripe			
Waseca	4/5	5/22	6/14	8/26	9/16	10/29
Barley	4/23 Planted					
Corn	5/16 Planted*				10/15 Harvested	
Oats	4/24 Planted		6/22 Headed			
			7/21 Ripe			
Soybeans		5/24 Planted			9/13 Ripe*	
Wheat	4/23 Planted		6/25 Headed			
			7/28 Ripe			

* The dates do not agree with the seasons as defined.

** Estimated dates.

*** Minneapolis data.

poor conductivity of organic materials, and because they may become very dry at the surface. That is, the dry surface layer and the organic material are effective insulators which greatly reduce both the penetration of heat into the soil during the day and the escape of heat at night.

Nor do these organic soils rapidly transmit heat internally due to their usual high water content. Thus the surface of these soils is frequently subject to much greater temperature extremes than inorganic (mineral) soils. In addition, in areas where organic soils occur in depressions, they are subject to the additional hazard of cold air drainage from the surrounding higher elevations.

There are other regions where spring and summer are late and fall and winter early. In the majority of the cases this is due to topographic features inducing a cold air drainage problem. However, there are a few places in Minnesota where the altitude alone may cause a late spring and summer and an early fall and winter. Since air temperature normally decreases with altitude it is possible that spring and summer occur latest and fall and winter earliest in the uplands of extreme northeastern Minnesota. Indeed, in the Misquah Hills of Cook County there may be no summer as defined, for the maximum altitude in Minnesota, 2,230 feet above mean sea level, occurs in this region. However, proof is not possible due to lack of data.

Some areas undoubtedly do not conform to the general pattern as shown in the figures, but they are not evident due to lack of a sufficient number of stations to show the necessary detail. This is true of almost all of northern Minnesota and especially true for the hilly regions of northeastern, southeastern, and southwestern Minnesota.

Although the seasonal dates are determined by frequency of minimum temperature occurrences, the tables and figures show only the *average* commencement date of the seasons. This means that 50 percent of the time the seasons will begin earlier than shown, and 50 percent of the time the seasons will begin later.

Duration of the Agricultural Seasons

The greatest difference in the average duration of the agricultural seasons (table 5 and figures 8 through 15) between the northern and southern parts of the state occurs in summer (figure 10). Generally summer is about 50 days longer in the southern one-fourth than in the northern one-fourth of the state. An extreme difference of 101 days is found between Minneapolis and Cloquet, a distance of about 120 miles (table 5). None of the other seasons exhibits such major geographical differences in season duration. Climatically speaking, summer apparently is the season that largely determines the crop distribution and major agricultural activities, at least as summer is defined in this study. Within each region of nearly equal summer duration other physical factors, such as sunshine, precipitation, and soil, may further limit agricultural endeavors.

In early fall the season duration period is reversed. In the northern one-third of the state early fall lasts nearly a month longer than in the south (figure 11).

The average duration of the period available for the growth of warm season crops, such as corn and soybeans, is shown in figure 13. In figure 14 the average duration of the total period available for some crop growth, early spring through late fall, is shown.

The Minimum-Temperature-Free Seasons

The season free of a certain minimum temperature may be of more general interest, particularly to industries other than agriculture. The so-called "freeze-free" season, the period when minimum daily temperatures remain above 32° F., is a familiar example. The seasons presented here are those that are free of the following minimum temperatures: 16°, 20°, 24°, 28°, 32°, 36°, 40°, and 50° F. Our interest is in how long these pe-

riods may last and their expected duration for a given probability. Tables 6 through 10 show these probabilities for temperatures 16° to 40° F., respectively. For the season free of 50° F. or lower temperatures, only the average duration period is given (table 10).

The tables are read as in the following example from table 6: At Ada there is a 90-percent chance that minimum daily temperatures will remain above 16° F. for at least 186 days, a 50-percent chance that this period will last 208 days or longer, and a 10-percent chance that it will last 231 or more days.

The reader should interpret these probabilities with caution. For example, in tossing a coin the expectation that "heads" will occur 50 percent of the time is true, either for an individual toss or a series of tosses, but it is not known which of the individual tosses will be heads. A similar situation holds with the duration of seasons of given length. For a season with a 30-percent probability of occurrence it can be expected that the event will occur, on the average, in 3 years out of 10. But there is no way of predicting which years these will be.

The choice of the probability level, 10, 30, or 50 percent, and so on, depends, of course, upon the risk deemed appropriate for the enterprise in question. A 50-percent probability level is not necessarily a favorable one, since one-half of the time the season will be longer and one-half of the time it will be shorter.

Figure 16 shows the average duration that the season will be free of 32° F. or lower temperatures (50-percent probability level, table 8). Maps of the other seasons are not shown due to similarity in configuration.

The average "freeze-free" season in Minnesota varies from a maximum of 167 days at Minneapolis to a minimum of 88 days at Meadowlands in southwestern St. Louis County. The season is nearly as short at Cloquet, 90 days; Big Falls, 95 days; and Itasca State Park, 96 days. In southeastern Minnesota an area of relatively short duration of about 140 days is centered around Grand Meadow, Waseca, and Zumbrota.

The warming influence of Lake Superior is evident, but for reasons already cited it does not extend far inland. Note that figure 16 is a generalized map based upon data from only 75 stations and does not portray the local differences.

Table 3. Comparison of spring phenological dates of native vegetation in St. Paul with the temperature-defined seasons. Phenological data after Hodson (4)

Season commencement date	Average date of phenological event	Event
March 31		EARLY SPRING BEGINS
	April 1-2	Elderberry buds open
	April 9-10	Soft maple in bloom
	April 17-18	Elm in full bloom
	April 18	Lilac buds opening
	April 23	Wealthy apple green tip
	April 27-28	Burr oak leaf tip showing
	April 30	Elm leaf buds breaking open
	May 3-4	Aspen buds opening
	May 5-6	Elderberry in bloom
	May 6	Wealthy apple pink bud stage
May 9		LATE SPRING BEGINS
	May 12-13	Lilac starting to bloom
	May 19	Lilac in full bloom
	May 22-23	Wealthy apple petal fall
	May 24-25	Bridal leaf in bloom
May 31		SUMMER BEGINS

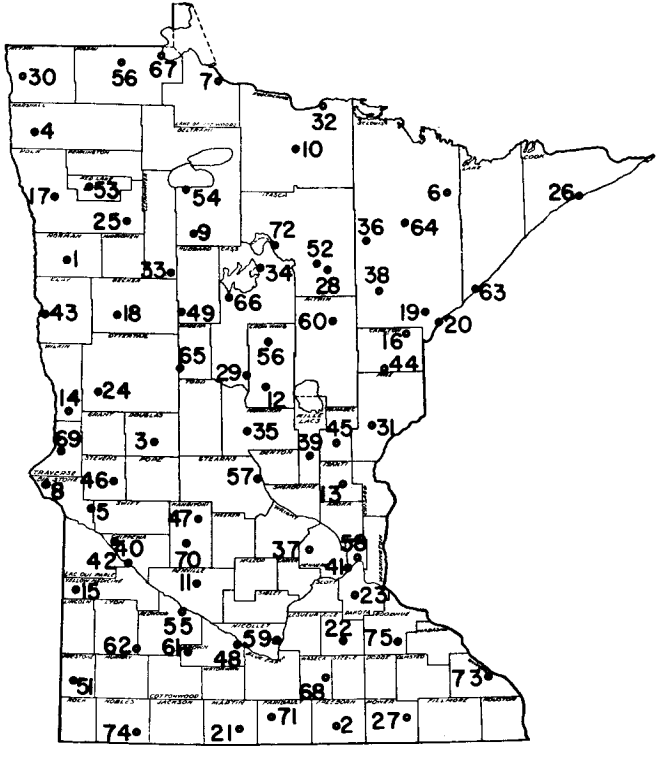

Figure 1. Station locations. See table 1 for station names.

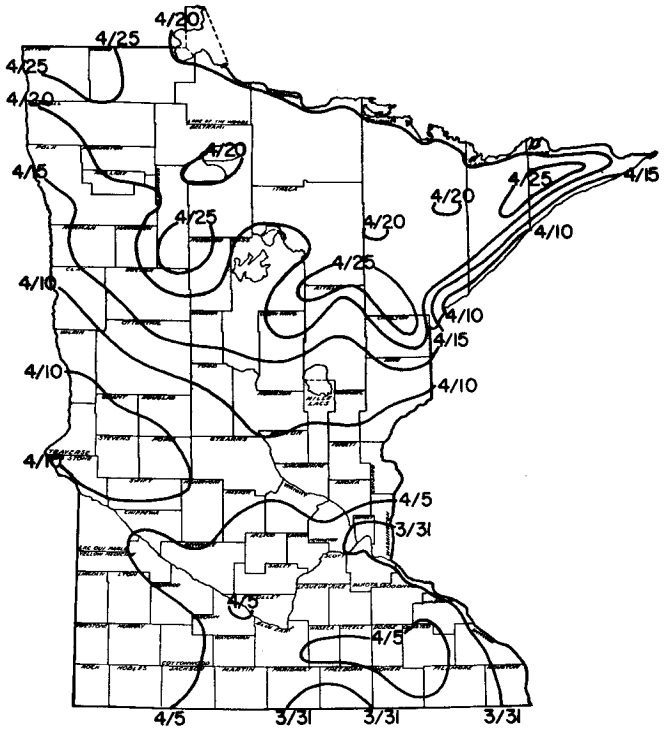

Figure 2. Average commencement date of early spring — date on which 20 percent or less of the minimum temperatures are 16° F. or lower. In early spring cool season perennial crops, such as bluegrass, begin to grow, and cool season annuals, such as spring oats, are planted.

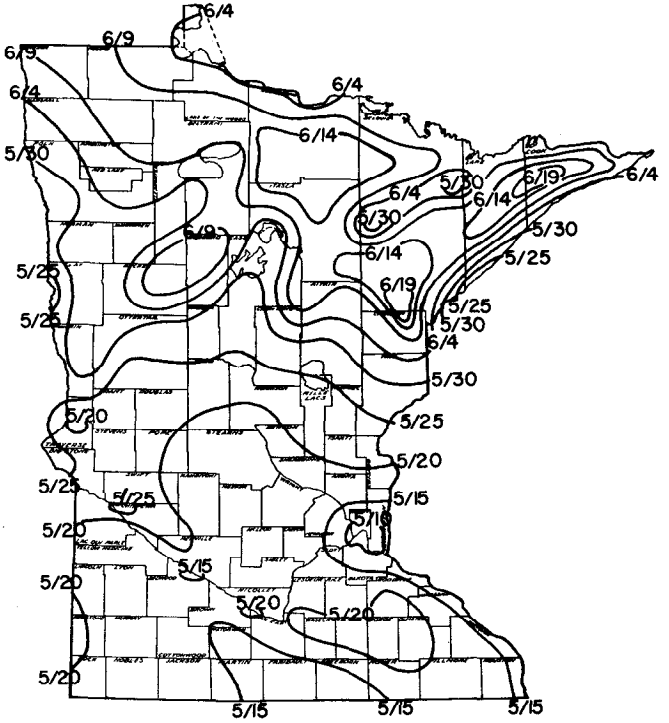

Figure 3. Average commencement date of late spring — date when less than 20 percent of the minimum temperatures are 32° F. or lower. In late spring warm season crops, such as dent corn and soybeans, are planted, and cool season crops grow rapidly.

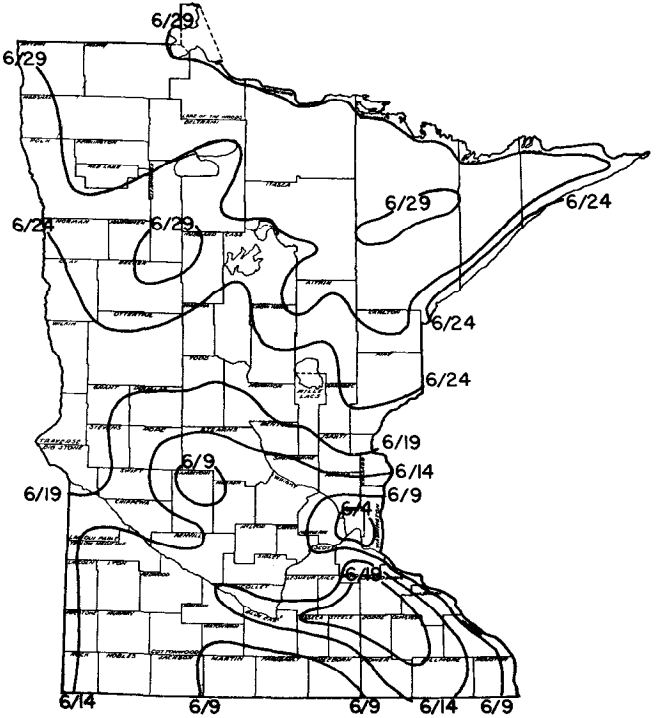

Figure 4. Average commencement date of summer — date on which less than 10 percent of the minimum temperatures are 40° F. or lower. In summer small grains are harvested, and warm season crops, such as dent corn and soybeans, grow rapidly.

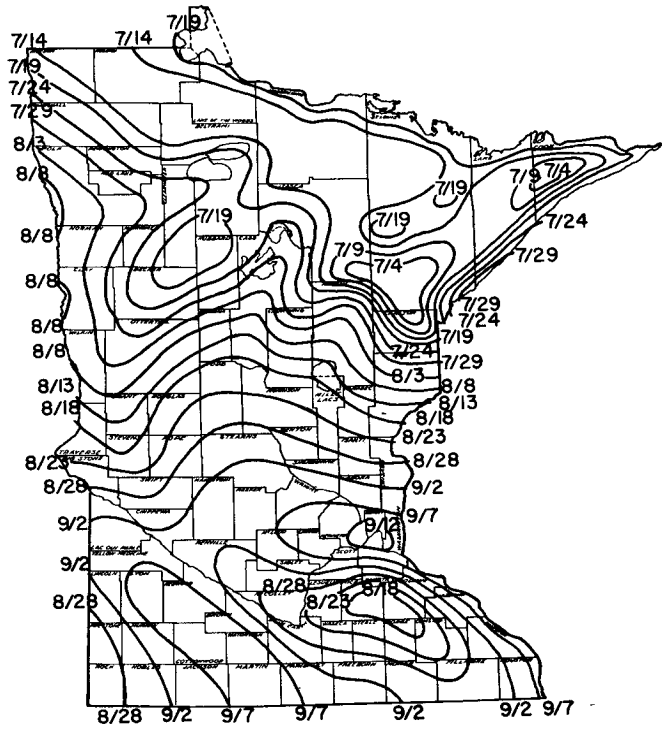

Figure 5. Average commencement date of early fall — date on which more than 20 percent of the minimum temperatures are 40° F. or lower. In early fall cool season crops, such as winter grains, are planted, and warm season crops, such as dent corn and soybeans, mature rapidly.

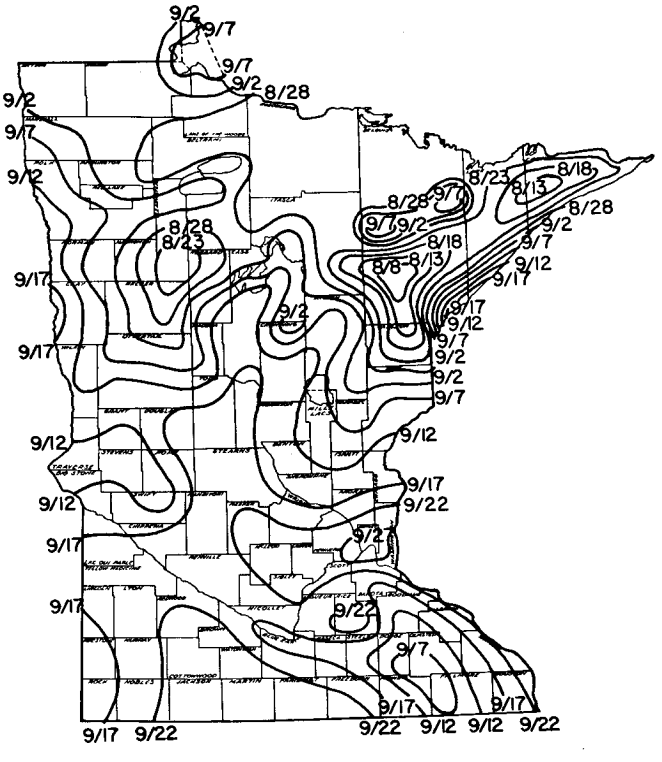

Figure 6. Average commencement date of late fall — date on which more than 10 percent of the minimum temperatures are 32° F. or lower. In late fall warm season annuals, such as dent corn and soybeans, are harvested, and cool season crops, such as winter grains, grow rapidly.

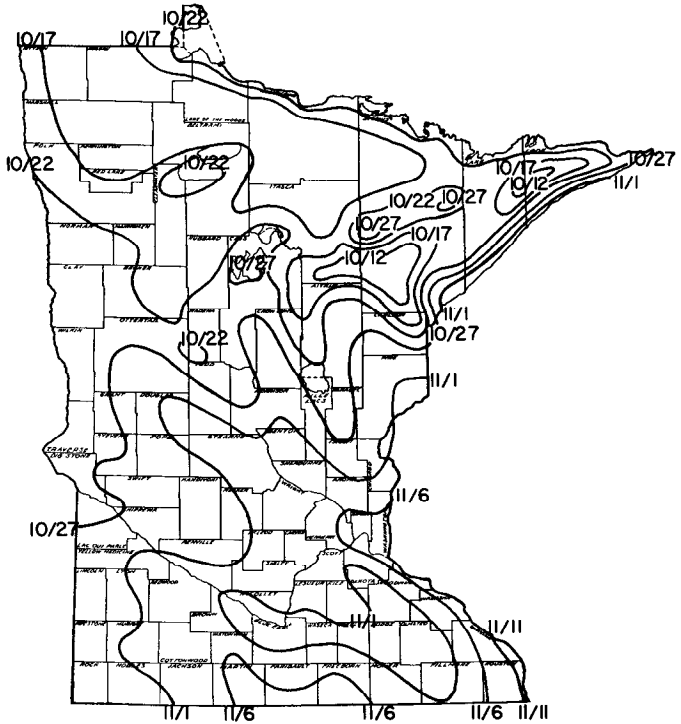

Figure 7. Average commencement date of winter — date on which more than 20 percent of the minimum temperatures are 16° F. or lower. In winter crop plants are dormant.

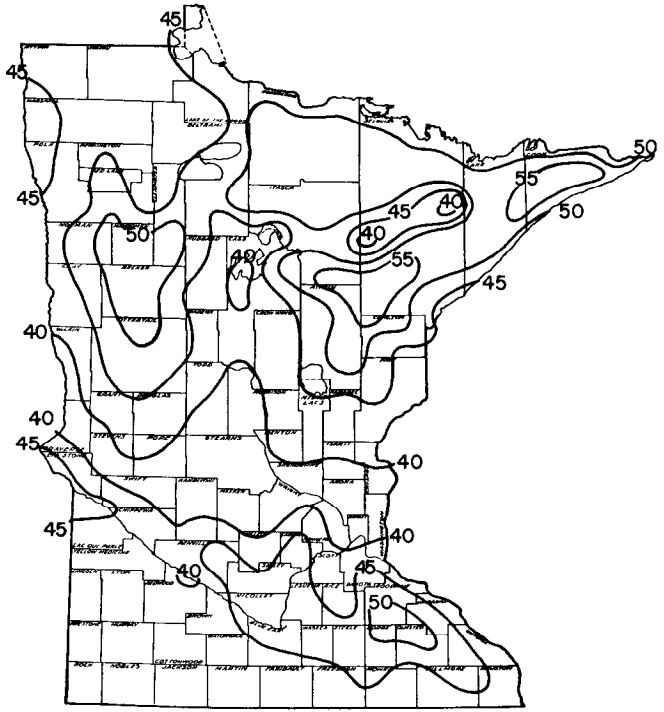

Figure 8. Average duration in days of early spring — 20 percent or less of the minimum temperatures are 16° F. or lower. In early spring cool season perennial crops, such as bluegrass, begin to grow, and cool season annuals, such as spring oats, are planted.

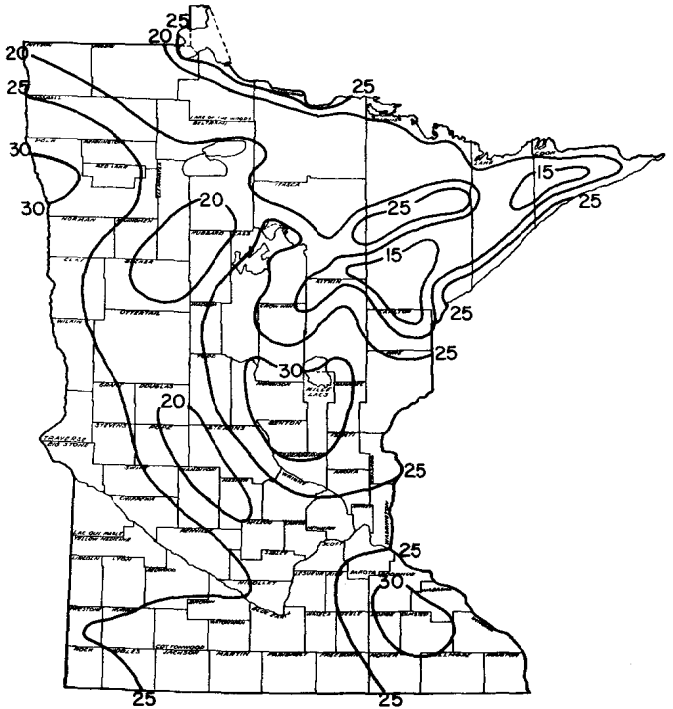

Figure 9. Average duration in days of late spring — less than 20 percent of the minimum temperatures are 32° F. or lower. In late spring warm season crops, such as dent corn and soybeans, are planted, and cool season crops grow rapidly.

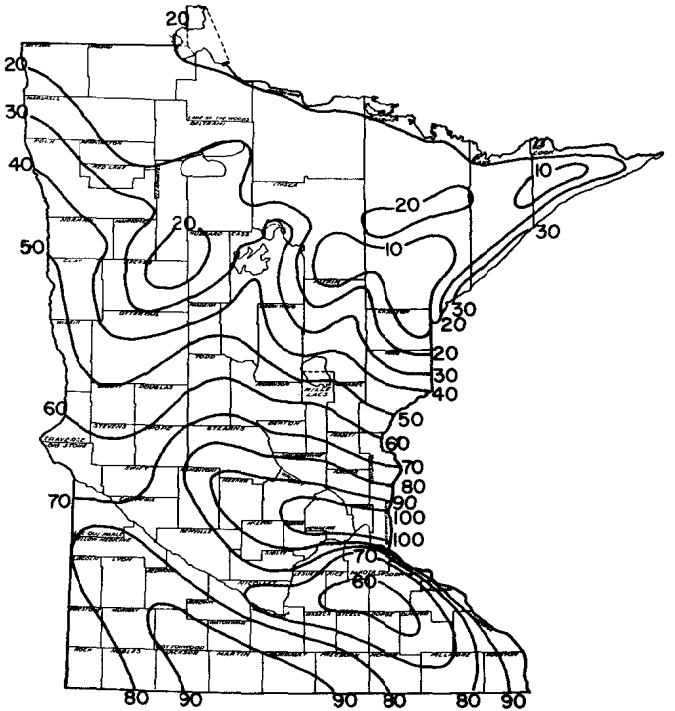

Figure 10. Average duration in days of summer — less than 10 percent of the minimum temperatures are 40° F. or lower. In summer small grains are harvested, and warm season crops, such as dent corn and soybeans, grow rapidly.

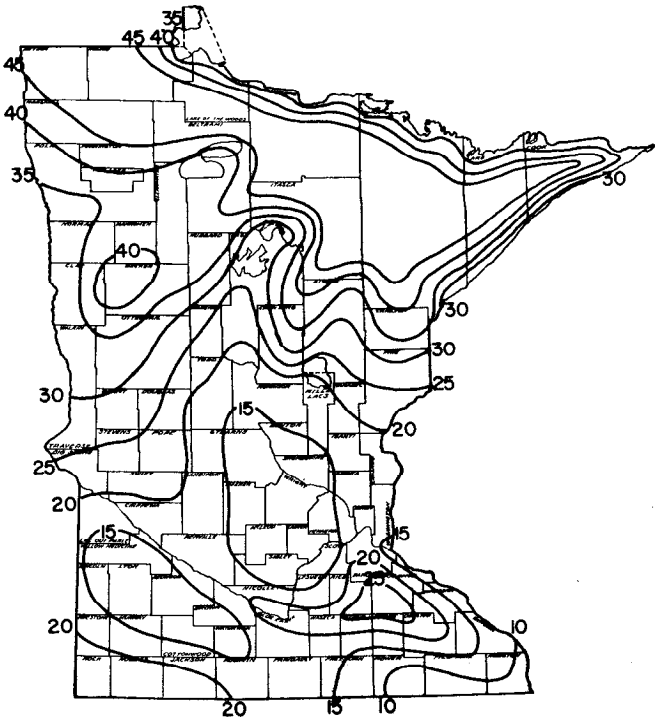

Figure 11. Average duration in days of early fall — more than 20 percent of the minimum temperatures are 40° F. or lower. In early fall cool season crops, such as winter grains, are planted, and warm season crops, such as dent corn and soybeans, mature rapidly.

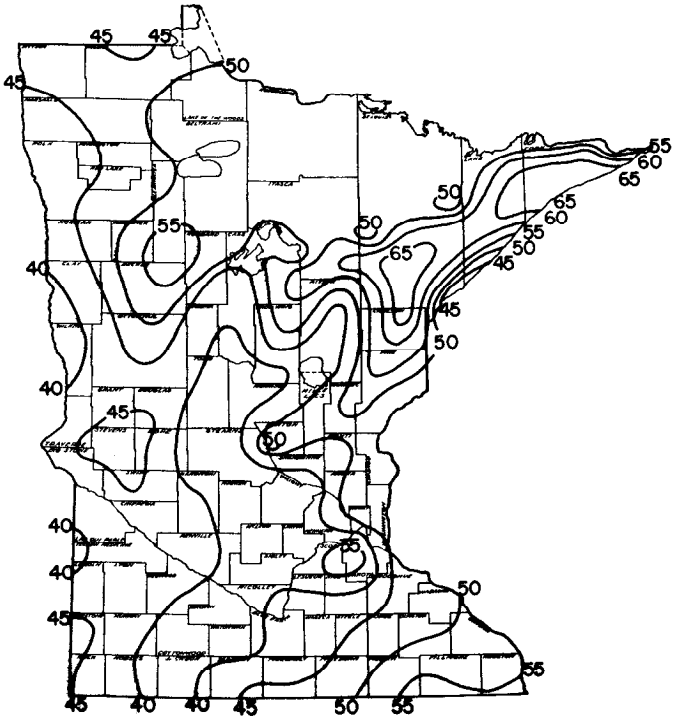

Figure 12. Average duration in days of late fall — more than 10 percent of the minimum temperatures are 32° F. or lower. In late fall warm season annuals, such as dent corn and soybeans, are harvested, and cool season crops, such as winter grains, grow rapidly.

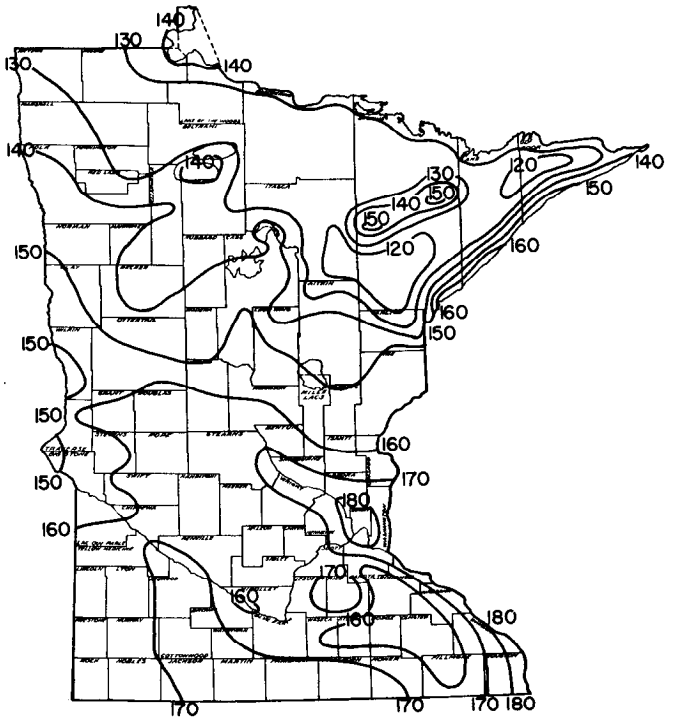

Figure 13. Average duration in days of the warm season crop period — late spring through late fall.

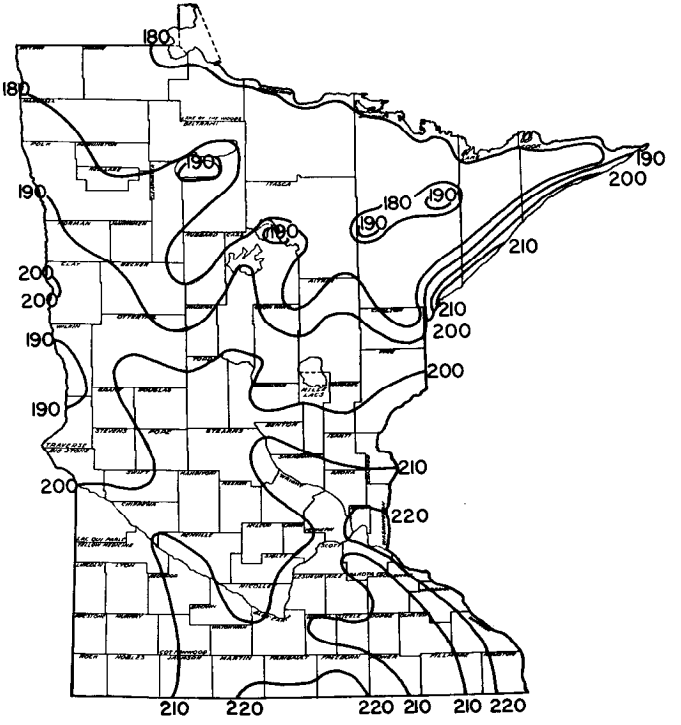

Figure 14. Average duration in days of the total crop season — early spring through late fall.

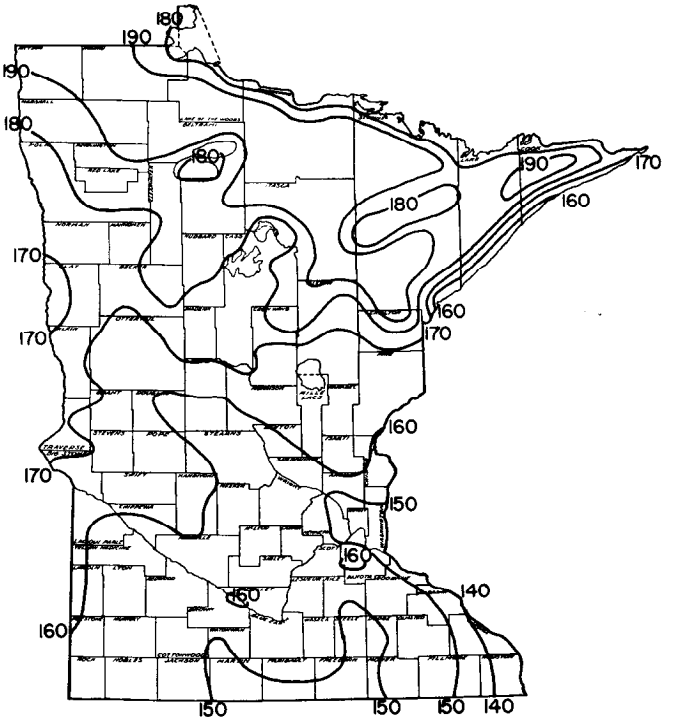

Figure 15. Average duration in days of winter — more than 20 percent of the minimum temperatures are 16° F. or lower; crop plants are dormant.

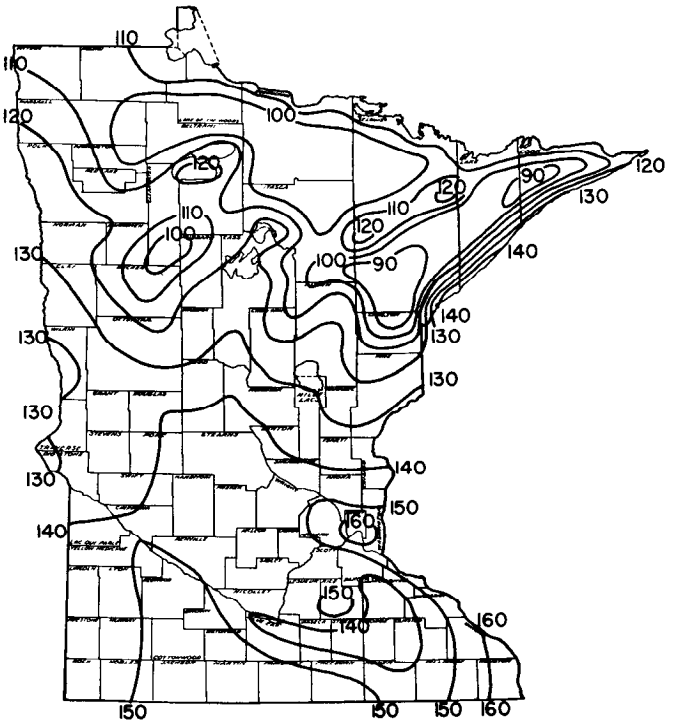

Figure 16. Average duration (50-percent probability) in days of the period free of 32° F. or lower temperatures.

Table 4. Average commencement date of the agricultural seasons*

Station number and name	Early spring	Late spring	Summer**	Early autumn**	Late autumn	Winter
1 Ada	4/17	6/3	-	-	9/8	10/23
2 Albert Lea	3/31	5/14	-	-	9/21	11/8
3 Alexandria	4/10	5/22	-	-	9/19	11/2
4 Argyle	4/17	6/4	-	-	9/5	10/17
5 Artichoke Lake	4/12	5/23	-	-	9/14	10/28
6 Babbitt	4/20	5/29	-	-	9/12	10/28
7 Baudette	4/20	6/6	-	-	9/1	10/23
8 Beardsley	4/11	5/28	-	-	9/9	10/23
9 Bemidji	4/25	6/9	-	-	8/27	10/19
10 Big Falls	4/24	6/14	-	-	8/24	10/14
11 Bird Island	4/5	5/20	6/15	9/2	9/19	10/29
12 Brainerd	4/13	5/26	-	-	9/14	10/28
13 Cambridge	4/11	5/21	6/18	8/27	9/13	10/28
14 Campbell	4/19	5/29	-	-	9/13	10/23
15 Canby	4/7	5/18	6/14	9/4	9/19	10/29
16 Cloquet	4/26	6/17	6/30	7/4	8/11	10/18
17 Crookston	4/18	5/29	6/29	8/5	9/10	10/21
18 Detroit Lakes	4/13	6/4	6/26	7/27	9/5	10/23
19 Duluth (airport)	4/13	5/31	-	-	9/12	11/3
20 Duluth (city)	4/9	5/23	-	-	9/20	11/1
21 Fairmont	4/3	5/15	-	-	9/24	11/7
22 Faribault	4/2	5/16	-	-	9/23	11/4
23 Farmington	4/4	5/18	-	-	9/21	10/26
24 Fergus Falls	4/9	5/25	-	-	9/14	10/26
25 Fosston	4/20	6/3	-	-	8/31	10/21
26 Grand Marais	4/13	6/4	-	-	8/26	11/2
27 Grand Meadow	4/7	5/19	6/17	8/29	9/7	10/31
28 Grand Rapids	4/24	6/9	6/30	7/7	8/24	10/12
29 Gull Lake Dam	4/15	5/26	-	-	9/17	10/27
30 Hallock	4/25	6/8	6/29	7/15	8/31	10/17
31 Hinckley	4/10	5/28	-	-	9/9	10/29
32 International Falls	-	6/4	6/29	7/23	8/26	-
33 Itasca State Park	4/25	6/13	6/30	7/17	8/21	10/19
34 Leech Lake Dam	4/17	6/7	-	-	9/1	10/20
35 Little Falls	4/13	5/20	-	-	9/16	10/27
36 Mahoning Mine	4/17	5/27	-	-	9/13	10/29
37 Maple Plain	4/5	5/18	-	-	9/23	11/2
38 Meadowlands	4/22	6/17	-	-	8/8	10/10
39 Milaca	4/9	5/22	-	-	9/12	10/28
40 Milan	4/7	5/25	-	-	9/13	10/27

Table 4. Average commencement date of the agricultural seasons* (continued)

Station number and name	Early spring	Late spring	Summer**	Early autumn**	Late autumn	Winter
41 Minneapolis	3/31	5/9	5/31	9/13	9/29	11/9
42 Montevideo	4/5	5/17	-	-	9/18	10/31
43 Moorhead	4/9	5/21	-	-	9/18	10/26
44 Moose Lake	4/17	6/1	-	-	8/26	10/30
45 Mora	4/10	5/24	6/23	8/17	9/6	10/27
46 Morris	4/13	5/23	6/18	8/19	9/12	10/27
47 New London	4/9	5/18	6/4	9/2	9/20	10/28
48 New Ulm	4/6	5/22	6/17	8/25	9/17	10/26
49 Park Rapids	4/19	6/1	-	-	9/9	10/24
50 Pine River Dam	4/22	6/4	6/26	7/27	8/31	10/21
51 Pipestone	4/7	5/20	6/14	8/26	9/15	10/31
52 Pokegama Dam	4/20	6/11	-	-	8/29	10/18
53 Red Lake Falls	4/20	6/7	-	-	9/2	10/17
54 Red Lake Indian Agency	4/20	6/5	-	-	9/6	10/27
55 Redwood Falls	4/4	5/13	-	-	9/19	11/2
56 Roseau	4/23	6/6	-	-	8/31	10/15
57 St. Cloud	4/7	5/17	6/16	8/31	9/13	11/3
58 St. Paul	3/31	5/9	-	-	9/24	11/10
59 St. Peter	4/2	5/19	-	-	9/19	11/1
60 Sandy Lake Dam Libby	4/18	6/7	-	-	9/7	10/23
61 Springfield	4/5	5/16	-	-	9/25	11/2
62 Tracy	4/6	5/17	6/11	9/8	9/20	11/1
63 Two Harbors	4/8	5/24	-	-	9/21	11/6
64 Virginia	4/22	6/4	6/27	7/18	9/4	10/25
65 Wadena	4/13	5/28	6/21	8/14	9/7	10/21
66 Walker	4/17	5/26	-	-	9/16	10/30
67 Warroad	4/21	6/5	-	-	9/7	10/23
68 Waseca	4/5	5/22	6/14	8/26	9/16	10/29
69 Wheaton	4/13	5/19	-	-	9/13	10/25
70 Willmar	4/8	5/18	-	-	9/18	10/30
71 Winnebago	4/4	5/15	6/7	9/6	9/23	11/3
72 Winnibigoshish Dam	4/17	5/30	-	-	9/17	10/27
73 Winona	3/28	5/11	6/6	9/9	9/21	11/11
74 Worthington	4/6	5/17	6/11	8/31	9/22	10/31
75 Zumbrota	4/3	5/23	6/23	8/18	9/12	10/28

* As defined in the text.

** Critical temperature occurrence probabilities necessary for calculation of summer and early autumn dates were determined for only certain stations.

Table 5. Average duration in days of the agricultural seasons

Station number and name	Early spring	Late spring	Summer	Early autumn	Late autumn	Warm-season crop period*	Total crop season**	Winter
1 Ada	47	-	-	-	45	142	189	176
2 Albert Lea	44	-	-	-	48	178	222	143
3 Alexandria	42	-	-	-	44	164	206	159
4 Argyle	48	-	-	-	42	135	183	182
5 Artichoke Lake	41	-	-	-	44	158	199	166
6 Babbitt	39	-	-	-	47	152	191	174
7 Baudette	47	-	-	-	52	139	186	179
8 Beardsley	47	-	-	-	44	148	195	170
9 Bemidji	45	-	-	-	53	132	177	188
10 Big Falls	51	-	-	-	51	122	173	192
11 Bird Island	45	26	79	17	40	162	207	158
12 Brainerd	43	-	-	-	44	155	198	167
13 Cambridge	40	28	70	17	45	160	200	165
14 Campbell	40	-	-	-	40	147	187	178
15 Canby	41	27	82	15	40	164	205	160
16 Cloquet	52	13	4	38	68	123	175	190
17 Crookston	41	31	37	36	41	145	186	179
18 Detroit Lakes	52	22	31	40	48	141	193	172
19 Duluth (airport)	48	-	-	-	52	156	204	161
20 Duluth (city)	44	-	-	-	42	162	206	159
21 Fairmont	42	-	-	-	44	176	218	147
22 Faribault	44	-	-	-	42	172	216	149
23 Farmington	44	-	-	-	35	161	205	160
24 Fergus Falls	46	-	-	-	42	154	200	165
25 Fosston	44	-	-	-	50	140	184	181
26 Grand Marais	52	-	-	-	68	151	203	162
27 Grand Meadow	42	29	73	9	54	165	207	158
28 Grand Rapids	46	21	7	48	49	125	171	194
29 Gull Lake Dam	41	-	-	-	40	154	195	170
30 Hallock	44	21	16	47	47	131	175	190
31 Hinckley	48	-	-	-	50	154	202	163
32 International Falls	-	25	24	34	-	-	-	-
33 Itasca State Park	49	17	17	35	59	128	177	188
34 Leech Lake Dam	51	-	-	-	49	135	186	179
35 Little Falls	37	-	-	-	41	160	197	168
36 Mahoning Mine	40	-	-	-	46	155	195	170
37 Maple Plain	43	-	-	-	40	168	211	154
38 Meadowlands	56	-	-	-	63	115	171	194

Table 5. Average duration in days of the agricultural seasons (continued)

Station number and name	Early spring	Late spring	Summer	Early autumn	Late autumn	Warm-season crop period*	Total crop season**	Winter
39 Milaca	43	-	-	-	46	159	202	163
40 Milan	48	-	-	-	44	155	203	162
41 Minneapolis	39	22	105	16	41	184	223	142
42 Montevideo	42	-	-	-	43	167	209	156
43 Moorhead	42	-	-	-	38	158	200	165
44 Moose Lake	45	-	-	-	65	151	196	169
45 Mora	44	30	55	20	51	156	200	165
46 Morris	40	26	62	24	45	157	197	168
47 New London	39	17	90	18	38	163	202	163
48 New Ulm	46	26	69	23	39	157	203	162
49 Park Rapids	43	-	-	-	45	145	188	177
50 Pine River Dam	43	22	31	35	51	139	182	183
51 Pipestone	43	25	73	20	46	164	207	158
52 Pokegama Dam	52	-	-	-	50	129	181	184
53 Red Lake Falls	48	-	-	-	45	132	180	185
54 Red Lake Indian Agency	46	-	-	-	51	144	190	175
55 Redwood Falls	39	-	-	-	44	173	212	153
56 Roseau	44	-	-	-	45	131	175	190
57 St. Cloud	40	30	76	13	51	170	210	155
58 St. Paul	39	-	-	-	47	185	224	141
59 St. Peter	47	-	-	-	43	166	213	152
60 Sandy Lake Dam Libby	50	-	-	-	46	138	188	177
61 Springfield	41	-	-	-	38	170	211	154
62 Tracy	41	25	89	12	42	168	209	156
63 Two Harbors	46	-	-	-	46	166	212	153
64 Virginia	43	23	21	48	51	143	186	179
65 Wadena	45	24	54	24	44	146	191	174
66 Walker	39	-	-	-	44	157	196	169
67 Warroad	45	-	-	-	46	140	185	180
68 Waseca	47	23	73	21	43	160	207	158
69 Wheaton	36	-	-	-	42	159	195	170
70 Willmar	40	-	-	-	42	165	205	160
71 Winnebago	41	23	91	17	41	172	213	152
72 Winnibigoshish Dam	43	-	-	-	40	150	193	172
73 Winona	44	26	95	12	51	184	228	137
74 Worthington	41	25	81	22	39	167	208	157
75 Zumbrota	50	31	56	25	46	158	208	157

* The period between commencement dates of late spring and winter
** The period between commencement dates of early spring and winter.

Table 6. Probability of duration of the season free of minimum temperatures of 16°F. or lower and the season free of minimum temperatures of 20°F. or lower

Station number and name	Percent probability									
	16°F. or less					20°F. or less				
	90	70	50	30	10	90	70	50	30	10
1 Ada	186	199	208	217	231	163	177	187	197	211
2 Albert Lea	219	231	239	247	259	203	215	222	230	241
3 Alexandria	204	215	223	230	241	184	197	206	215	229
4 Argyle	180	195	205	215	229	161	174	183	193	206
5 Artichoke Lake	196	210	220	229	243	175	191	201	212	227
6 Babbitt	188	199	206	214	225	168	179	188	196	208
7 Baudette	183	196	205	214	227	161	174	184	193	207
8 Beardsley	192	207	216	226	241	161	178	190	202	219
9 Bemidji	174	187	196	205	218	151	164	173	181	195
10 Big Falls	170	184	194	204	219	150	164	174	183	197
11 Bird Island	204	217	226	235	248	191	203	212	221	234
12 Brainerd	195	208	217	225	238	169	181	189	197	209
13 Cambridge	198	212	222	232	247	178	193	204	214	229
14 Campbell	184	199	209	219	233	159	175	185	196	211
15 Canby	203	215	224	232	244	181	197	207	217	233
16 Cloquet	172	186	196	206	220	147	160	169	179	192
17 Crookston	186	199	208	217	230	164	178	187	197	211
18 Detroit Lakes	191	204	213	223	236	166	181	191	201	216
19 Duluth (airport)	201	214	223	233	246	174	186	194	202	214
20 Duluth (city)	204	216	224	232	244	185	198	207	216	229
21 Fairmont	215	227	236	244	257	198	211	219	228	240
22 Faribault	214	227	237	247	261	196	210	219	228	241
23 Farmington	202	217	228	238	253	183	197	207	216	230
24 Fergus Falls	197	210	219	228	241	177	191	201	211	225
25 Fosston	181	195	204	213	226	164	178	188	197	211
26 Grand Marais	201	213	222	230	242	187	201	210	219	232
27 Grand Meadow	205	217	226	235	248	187	200	209	218	231
28 Grand Rapids	167	184	195	206	222	145	157	169	179	193
29 Gull Lake Dam	193	205	214	223	236	178	190	198	207	219
30 Hallock	172	185	194	203	217	143	159	170	181	197
31 Hinckley	199	211	220	229	242	170	184	194	204	218
32 International Falls	-	-	-	-	-	-	-	-	-	-
33 Itasca State Park	174	186	195	203	215	150	163	173	181	195
34 Leech Lake Dam	183	197	206	215	229	163	177	186	195	209
35 Little Falls	195	209	219	228	243	178	191	200	210	223
36 Mahoning Mine	193	205	213	221	232	174	185	193	201	212
37 Maple Plain	208	221	229	237	250	191	204	213	221	234
38 Meadowlands	167	184	196	207	225	142	155	164	173	187

Table 6. Probability of duration of the season free of minimum temperatures of 16°F. or lower and the season free of minimum temperatures of 20°F. or lower (continued)

Station number and name	Percent probability									
	16°F. or less					20°F. or less				
	90	70	50	30	10	90	70	50	30	10
39 Milaca	198	212	222	231	245	180	191	199	207	218
40 Milan	201	214	223	232	245	174	189	198	208	222
41 Minneapolis	220	233	241	249	262	206	218	226	235	246
42 Montevideo	207	219	228	236	248	191	205	214	223	237
43 Moorhead	197	211	220	229	242	180	194	204	214	228
44 Moose Lake	193	207	216	226	240	157	175	187	199	217
45 Mora	197	211	221	231	246	175	189	198	208	221
46 Morris	194	208	217	227	241	175	190	200	210	224
47 New London	199	212	221	230	243	183	197	206	215	229
48 New Ulm	201	214	224	233	247	183	196	205	214	227
49 Park Rapids	185	197	206	214	226	163	176	185	195	208
50 Pine River Dam	179	193	202	211	225	156	170	180	190	204
51 Pipestone	205	217	225	234	246	184	196	204	212	224
52 Pokegama Dam	178	192	202	212	227	152	166	176	185	199
53 Red Lake Falls	177	191	200	210	223	159	173	183	192	206
54 Red Lake Indian Agency	187	200	208	217	229	167	181	190	199	212
55 Redwood Falls	209	222	231	241	254	196	208	217	225	237
56 Roseau	172	186	196	206	220	152	166	175	185	199
57 St. Cloud	208	220	227	235	247	186	200	209	218	231
58 St. Paul	221	233	241	250	262	206	219	228	236	249
59 St. Peter	211	225	234	244	258	193	207	217	226	240
60 Sandy Lake Dam Libby	185	199	209	218	232	166	180	189	199	213
61 Springfield	208	223	233	244	259	197	211	221	231	245
62 Tracy	207	218	226	234	245	192	204	212	221	233
63 Two Harbors	209	220	228	236	247	192	205	214	223	236
64 Virginia	183	196	205	213	227	163	175	184	193	206
65 Wadena	189	202	211	220	233	162	178	188	199	214
66 Walker	193	205	213	222	234	177	188	196	204	216
67 Warroad	183	197	206	216	234	157	172	182	192	207
68 Waseca	205	218	227	236	249	189	203	213	223	237
69 Wheaton	192	206	216	225	240	173	189	200	211	227
70 Willmar	203	215	224	232	245	186	201	211	221	235
71 Winnebago	210	223	232	241	254	197	209	217	226	238
72 Winnibigoshish Dam	190	202	211	219	231	175	187	195	203	214
73 Winona	225	237	245	253	264	207	221	230	240	253
74 Worthington	206	219	227	236	249	192	204	211	219	231
75 Zumbrota	205	220	230	239	254	182	197	207	217	232

Table 7. Probability of duration of the season free of minimum temperatures of 24°F. or lower and the season free of minimum temperatures of 28°F. or lower

Station number and name	Percent probability									
	24°F. or less					28°F. or less				
	90	70	50	30	10	90	70	50	30	10
1 Ada	136	151	162	172	187	124	136	143	151	163
2 Albert Lea	185	197	205	213	225	165	177	185	193	205
3 Alexandria	167	180	189	197	210	141	153	161	169	180
4 Argyle	135	149	158	167	180	123	133	140	147	157
5 Artichoke Lake	154	168	178	187	201	135	149	159	168	182
6 Babbitt	147	159	168	176	188	129	141	149	158	170
7 Baudette	137	149	158	167	179	118	130	138	145	157
8 Beardsley	145	160	169	179	194	129	141	149	157	169
9 Bemidji	136	148	155	163	174	115	126	134	142	153
10 Big Falls	135	145	153	160	170	104	116	124	132	144
11 Bird Island	170	182	190	198	210	146	158	167	176	188
12 Brainerd	150	163	173	182	196	130	141	149	156	167
13 Cambridge	163	175	183	191	203	143	155	163	171	183
14 Campbell	138	152	162	171	186	127	139	148	157	170
15 Canby	169	180	188	196	207	143	157	167	177	191
16 Cloquet	127	141	150	159	173	104	116	125	134	146
17 Crookston	143	156	165	174	187	126	138	146	154	166
18 Detroit Lakes	138	153	164	175	190	121	135	144	153	167
19 Duluth (airport)	145	158	167	175	188	131	143	152	160	172
20 Duluth (city)	168	181	190	199	211	142	155	164	173	186
21 Fairmont	175	189	199	208	222	152	166	176	185	199
22 Faribault	166	181	191	201	215	149	163	173	183	197
23 Farmington	168	181	190	199	212	144	158	168	178	192
24 Fergus Falls	153	169	179	189	204	136	149	158	167	180
25 Fosston	138	151	161	170	183	121	134	143	152	165
26 Grand Marais	160	174	184	194	208	120	141	155	170	191
27 Grand Meadow	170	183	191	199	212	141	155	164	173	187
28 Grand Rapids	122	139	150	161	178	107	120	129	138	151
29 Gull Lake Dam	152	166	176	186	200	137	147	153	160	171
30 Hallock	122	137	147	157	172	111	124	133	142	155
31 Hinckley	152	166	176	185	200	127	142	152	162	176
32 International Falls	141	155	165	174	188	117	131	140	150	163
33 Itasca State Park	127	141	150	159	173	101	114	123	132	145
34 Leech Lake Dam	139	152	161	169	182	115	128	137	146	159
35 Little Falls	158	170	179	187	200	138	151	160	169	182
36 Mahoning Mine	156	168	177	185	197	129	141	150	158	170
37 Maple Plain	171	184	192	201	213	147	162	171	181	195
38 Meadowlands	121	134	143	152	165	93	108	119	130	145

Table 7. Probability of duration of the season free of minimum temperatures of 24°F. or lower and the season free of minimum temperatures of 28°F. or lower (continued)

Station number and name	Percent probability									
	24°F. or less					28°F. or less				
	90	70	50	30	10	90	70	50	30	10
39 Milaca	156	169	179	188	201	135	149	158	167	181
40 Milan	154	168	178	188	202	130	143	151	160	173
41 Minneapolis	191	203	211	219	231	169	181	189	197	209
42 Montevideo	168	182	191	201	215	145	159	168	177	190
43 Moorhead	153	167	176	186	200	133	148	158	168	183
44 Moose Lake	144	157	166	175	188	113	126	135	144	157
45 Mora	147	163	173	183	199	127	141	150	159	173
46 Morris	155	169	179	189	203	130	144	153	162	176
47 New London	170	182	190	198	210	147	159	167	175	187
48 New Ulm	169	182	190	198	211	139	154	164	174	189
49 Park Rapids	137	151	161	171	185	124	136	145	153	166
50 Pine River Dam	136	151	162	173	188	115	128	138	148	161
51 Pipestone	157	171	181	191	205	138	150	159	168	180
52 Pokegama Dam	134	147	155	164	177	110	122	131	140	152
53 Red Lake Falls	133	147	157	167	181	119	129	137	144	154
54 Red Lake Indian Agency	145	158	166	175	187	118	131	140	149	162
55 Redwood Falls	175	188	197	205	218	147	162	172	182	197
56 Roseau	130	144	154	163	177	108	121	130	139	153
57 St. Cloud	163	177	187	197	211	149	161	170	179	191
58 St. Paul	194	206	214	223	235	173	184	192	200	211
59 St. Peter	171	185	195	205	220	144	158	167	176	189
60 Sandy Lake Dam Libby	141	155	164	174	187	118	134	145	155	171
61 Springfield	172	187	196	206	221	151	166	176	187	202
62 Tracy	173	184	192	200	211	147	160	169	178	191
63 Two Harbors	173	185	193	201	213	145	158	167	175	189
64 Virginia	138	153	163	173	188	124	135	143	151	162
65 Wadena	151	164	173	182	195	130	141	149	157	168
66 Walker	159	172	180	189	201	133	147	157	166	180
67 Warroad	136	149	159	169	183	122	133	141	149	160
68 Waseca	172	181	188	195	204	140	155	165	175	190
69 Wheaton	151	165	174	183	197	131	144	152	161	173
70 Willmar	165	178	187	196	209	138	152	162	172	186
71 Winnebago	177	189	197	205	217	151	165	174	183	197
72 Winnibigoshish Dam	157	170	179	188	202	134	144	151	157	167
73 Winona	188	201	210	219	232	165	177	186	195	207
74 Worthington	167	182	192	202	218	148	161	169	177	190
75 Zumbrota	163	176	186	196	209	133	147	157	167	181

Table 8. Probability of duration of the season free of minimum temperatures of 32°F. or lower

Station number and name	Percent probability				
	90	70	50	30	10
1 Ada	100	112	121	129	141
2 Albert Lea	134	147	156	165	177
3 Alexandria	123	134	141	149	160
4 Argyle	96	108	116	124	135
5 Artichoke Lake	118	129	137	145	157
6 Babbitt	109	120	127	134	144
7 Baudette	90	103	112	121	133
8 Beardsley	108	121	129	138	150
9 Bemidji	84	98	107	116	129
10 Big Falls	74	86	95	103	115
11 Bird Island	123	135	144	153	165
12 Brainerd	113	124	131	138	149
13 Cambridge	114	128	138	148	162
14 Campbell	109	120	127	134	145
15 Canby	126	137	145	153	164
16 Cloquet	60	78	90	102	120
17 Crookston	104	116	125	134	146
18 Detroit Lakes	93	109	120	131	147
19 Duluth (airport)	108	118	125	131	141
20 Duluth (city)	123	135	143	151	163
21 Fairmont	135	147	156	164	176
22 Faribault	133	145	152	160	171
23 Farmington	128	138	145	153	163
24 Fergus Falls	115	127	135	143	154
25 Fosston	93	106	115	124	138
26 Grand Marais	90	113	129	145	168
27 Grand Meadow	127	136	142	148	157
28 Grand Rapids	80	93	102	111	124
29 Gull Lake Dam	115	126	133	139	149
30 Hallock	85	99	109	119	133
31 Hinckley	108	120	128	136	147
32 International Falls	88	105	117	129	146
33 Itasca State Park	72	86	96	106	120
34 Leech Lake Dam	90	103	113	122	135
35 Little Falls	122	132	138	145	155
36 Mahoning Mine	112	122	129	135	145
37 Maple Plain	131	143	150	158	170
38 Meadowlands	58	76	88	100	118

Table 8. Probability of duration of the season free of minimum temperatures of 32°F or lower (continued)

Station number and name	Percent probability				
	90	70	50	30	10
39 Milaca	116	128	136	144	155
40 Milan	114	125	133	141	153
41 Minneapolis	147	159	167	175	187
42 Montevideo	127	139	147	155	167
43 Moorhead	123	132	138	144	153
44 Moose Lake	90	103	111	120	133
45 Mora	106	120	130	140	154
46 Morris	114	127	136	145	158
47 New London	126	138	146	154	166
48 New Ulm	118	132	142	152	166
49 Park Rapids	103	115	122	130	141
50 Pine River Dam	90	105	115	125	140
51 Pipestone	121	134	143	152	165
52 Pokegama Dam	82	95	104	113	125
53 Red Lake Falls	90	103	111	120	132
54 Red Lake Indian Agency	98	111	121	130	143
55 Redwood Falls	133	145	153	161	173
56 Reseau	89	102	110	118	131
57 St. Cloud	123	135	143	151	163
58 St. Paul	141	154	163	171	184
59 St. Peter	125	136	144	152	163
60 Sandy Lake Dam Libby	94	107	115	124	137
61 Springfield	135	147	155	163	175
62 Tracy	131	142	150	158	169
63 Two Harbors	124	135	143	152	163
64 Virginia	94	107	116	125	138
65 Wadena	104	116	126	136	148
66 Walker	116	127	134	142	153
67 Warroad	97	110	119	127	140
68 Waseca	117	131	140	149	163
69 Wheaton	120	131	138	145	156
70 Willmar	125	136	144	151	162
71 Winnebago	133	145	153	161	173
72 Winnibigoshish Dam	112	122	129	135	145
73 Winona	135	151	162	173	189
74 Worthington	132	143	151	159	170
75 Zumbrota	114	127	137	147	160

Table 9. Probability of duration of the season free of minimum temperatures of 36°F. or lower and the season free of minimum temperatures of 40°F. or lower

Station number and name	Percent probability									
	36°F. or less					40°F. or less				
	90	70	50	30	10	90	70	50	30	10
11 Bird Island	104	116	125	134	146	82	95	104	113	126
13 Cambridge	95	108	116	124	137	67	84	95	106	123
15 Canby	103	115	124	133	145	84	95	103	111	122
16 Cloquet	22	43	57	71	92	1	17	28	39	55
17 Crookston	83	97	106	115	129	45	63	75	87	105
18 Detroit Lakes	68	87	99	111	130	29	51	67	83	105
27 Grand Meadow	99	113	122	131	145	74	89	100	111	126
28 Grand Rapids	40	61	75	89	110	4	23	36	49	68
30 Hallock	43	65	79	93	115	12	33	48	63	84
32 International Falls	57	77	91	104	125	20	41	56	70	91
33 Itasca State Park	30	53	68	83	106	0	19	33	47	66
41 Minneapolis	124	136	145	154	166	108	119	127	135	146
45 Mora	87	100	109	118	131	72	79	83	87	94
46 Morris	93	106	115	124	137	63	81	93	105	123
47 New London	103	117	127	137	151	81	95	104	113	127
48 New Ulm	96	112	123	134	150	68	86	98	110	128
50 Pine River Dam	61	78	90	102	119	27	48	63	78	99
51 Pipestone	100	112	120	128	140	73	90	101	112	129
57 St. Cloud	103	115	124	133	145	77	93	104	115	131
62 Tracy	112	123	131	139	150	91	103	112	121	133
64 Virginia	47	69	84	99	121	17	40	55	70	93
65 Wadena	81	94	104	114	127	52	70	83	96	114
68 Waseca	99	112	121	130	143	72	89	101	113	130
71 Winnebago	114	126	135	144	156	91	105	115	125	139
73 Winona	117	130	139	148	161	98	111	120	129	142
74 Worthington	109	121	129	137	149	81	97	109	121	137
75 Zumbrota	87	103	113	123	139	58	75	87	99	116

Table 10. Average duration of the season free of minimum temperatures of 50°F. or lower

Station number and name		Days	Station number and name		Days
11	Bird Island	30	47	New London	34
13	Cambridge	25	48	New Ulm	34
15	Canby	33	50	Pine River Dam	12
16	Cloquet	3	51	Pipestone	29
17	Crookston	16	57	St. Cloud	34
18	Detroit Lakes	12	62	Tracy	32
27	Grand Meadow	23	64	Virginia	8
28	Grand Rapids	7	65	Wadena	17
30	Hallock	9	68	Waseca	28
32	International Falls	7	71	Winnebago	43
33	Itasca State Park	6	73	Winona	51
41	Minneapolis	61	74	Worthington	32
45	Mora	20	75	Zumbrota	18
46	Morris	25			

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Summary

Using crop phenology dates at 9 stations as the basic data, the commencement date and duration of agricultural seasons at 75 Minnesota stations were determined using minimum temperature occurrence probabilities. Minnesota's agricultural seasons were then defined as follows:

1. Early spring begins when 20 percent or less of the minimum temperatures are 16° F. or lower. In early spring cool season perennial crops, such as bluegrass, begin to grow, and cool season annuals, such as spring oats, are planted.
2. Late spring begins when less than 20 percent of the minimum temperatures are 32° F. or lower. In late spring warm season crops, such as dent corn and soybeans, are planted, and cool season crops grow rapidly.
3. Summer begins when less than 10 percent of the minimum temperatures are 40° F. or lower. In summer warm season crops grow rapidly and cool season annuals, such as small grains, are harvested.
4. Early fall begins when more than 20 percent of the minimum temperatures are 40° F. or lower. In early fall cool season crops, such as winter grains, are planted, and warm season crops mature rapidly.
5. Late fall begins when more than 10 percent of the minimum temperatures are 32° F. or lower. In late fall cool season crops grow rapidly and warm season annuals, such as dent corn and soybeans, are harvested.
6. Winter begins when more than 20 percent of the minimum temperatures are 16° F. or lower. In winter crop plants are dormant.

This provides a realistic definition of agricultural seasons based upon crop growth and eliminates the usual calendar designation, which serves only as a crude guide in any case. These temperature-defined agricultural seasons may aid in establishing crop climatic boundaries and provide a guide for agricultural practices, especially planting and harvesting.

The probabilities of duration of selected minimum-temperature-free seasons also were calculated. The duration probabilities may be useful in the long-term planning of agricultural and industrial activities dependent upon the minimum temperatures considered: 16°, 20°, 24°, 28°, 32°, 36°, 40°, and 50° F.

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