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MANAGEMENT OF SOILS
IN **SOUTHWESTERN** MINNESOTA

A Correspondence Course

Unit 9: Climatology

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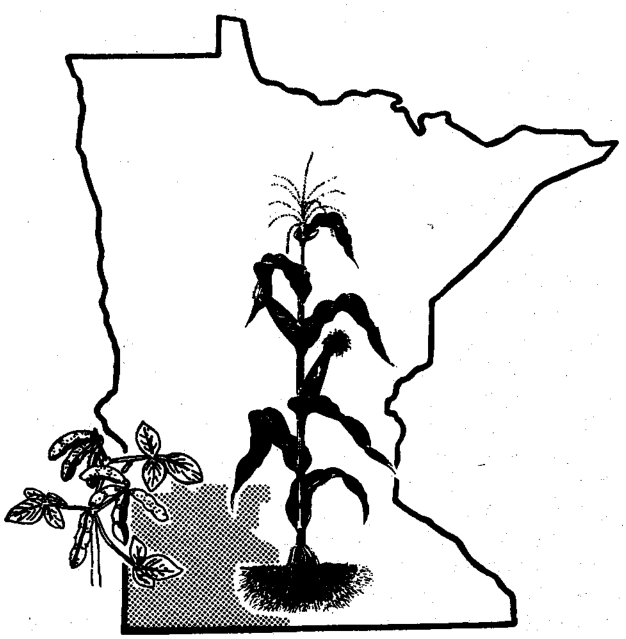
Objectives

- Recognize climate as a natural resource important to management.
- Understand some of the causes of local climate variability.
- Become familiar with some applications of climate to agricultural planning and decisionmaking.



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CLIMATE AS A NATURAL RESOURCE

Though often highly variable and unreliable, climate is a natural resource exploited by agricultural managers. In conjunction with other natural resources (primarily soil and water), climate determines the composition and distribution of agricultural enterprises. Southwestern Minnesota is blessed with a longer growing season than most other areas of the state. However, large variations in growing season precipitation greatly influence the agricultural productivity of this area of the state.

CLIMATE VARIABILITY

Interannual Variability

Unlike soils and water, climate can be quite unstable from year to year. Still, its dominant characteristics are used to make many decisions such as crop variety selection, planting and harvesting schedules, irrigation need, crop-drying facilities, and scouting and spraying schedules for crop pests (weeds, diseases, and insects).

Table 1 shows average dates for corn and soybean development in southwestern Minnesota. Since environmental conditions govern both soil preparation (tillage) and crop development, the difference between the earliest and latest dates (three weeks or more in some cases) illustrates the impact of year-to-year climatic differences. These differences, called interannual variability, are a dominant feature of mid-latitude continental climates like Minnesota's.

Despite this type of variability, growers will still generally make long-range plans and schedules based on historic climate "normals" (averages from at least 30 years or more). For example, in southwestern Minnesota the frost usually leaves the ground by the first week of April. So with dry weather, the second half of April provides an opportunity for spring tillage and seeding of small grains. By May 1, soil temperatures (seedbed depth) are usually above 50° F and row crops can be planted with the assurance that temperatures will not inhibit germination. Seed variety selection is often based on these "normal" conditions and the probability that frost usually ends the crop season during the first week of October.

This knowledge is sometimes biased by recent experiences, so a late planting season or early frost might cause a grower to choose a shorter-season variety to compensate the next year. However, all things considered, it is best to use climatic "normals" in anticipating crop production needs and schedules. Though climate may be one of the most unreliable of our natural resources, it can be very unforgiving of those who disregard it.

Local Climate Variability

A second kind of climatic variability is that associated with the interaction of common weather systems and the topography of the landscapes over which they pass. This leads to spatial variance in environmental conditions that can sometimes affect agricultural operations differently even within the same county or group of counties.

Some of the more common climatic elements will be discussed using long-term records from several locations within the southwestern district (Figure 1). Due to the scarcity of data over the most recent 30-year period (1951-1980), some perimeter locations just outside of this district were used to help describe the general climate.

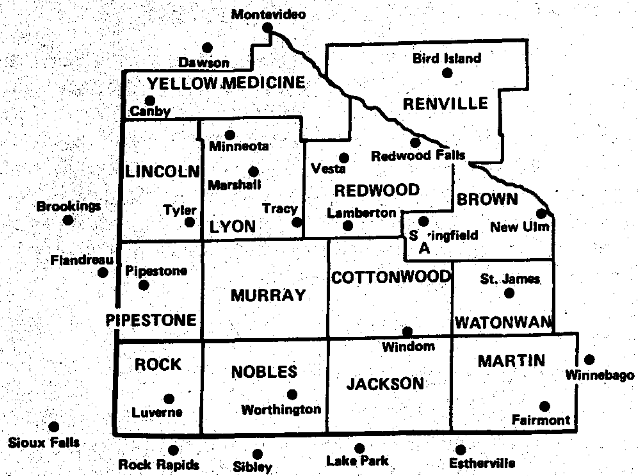

Figure 1. Locations of climate-recording stations in and near southwestern Minnesota.

Precipitation

Table 2 shows the average monthly and annual precipitation for 27 locations. Winnebago on the eastern edge of the southwestern district shows the greatest annual average (31.29 inches), while Tyler in Lincoln County on the western side of the district has the lowest (23.57 inches). Note that both Brookings and Flandreau in South Dakota receive less precipitation (less than 22 inches), illustrating the east-to-west moisture gradient. Using values from all of the locations, the annual mean for the southwestern district is 25.92 inches, with a range of nearly 8 inches.

Between 60 and 70 percent of the total annual precipitation comes during the crop season months of May to September. With very few exceptions, January is the driest month and June is the wettest. Average values for November, December, January, February, and March represent liquid equivalent of all forms of precipitation, including snow. Though snowfall can be substantial in some of these months, the ratio of snow depth to liquid equivalent is generally in the range from 10:1 to 15:1. Thus, even though total snowfall in some winters may be several feet, actual precipitation during the winter is quite low.

Figure 2 shows the typical pattern in the soil moisture profile over the year. Note the four distinct stages. Since

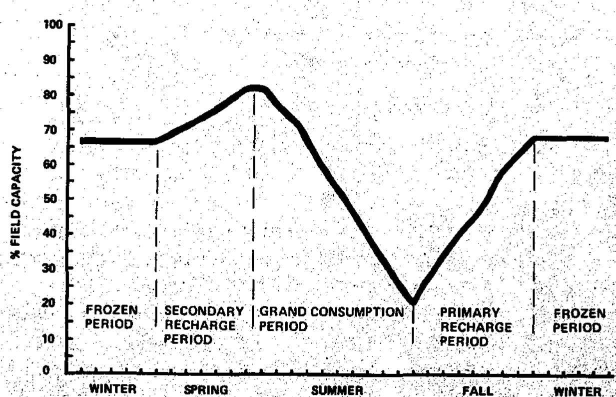

Figure 2. Annual soil moisture profile stages.

soils are generally frozen from December through February, little precipitation goes into recharging soil moisture and the profile is usually quite stable. The greatest recharge period is September through November, after crops have matured and are no longer using soil moisture reserves for transpiration. Most of the precipitation during these months is retained by the soil.

A secondary recharge period occurs during March and April, when soils are thawing and before crops have germinated. Following dry fall periods when soil moisture deficits are substantial just prior to the winter freeze-up, the recharge during March and April can be important and larger than that depicted in Figure 2. May through August is referred to as the "grand consumption" period, when crop water use exceeds moisture supplied by precipitation and the soil moisture profile is depleted. In southwestern Minnesota, this reserve is rarely depleted to the wilting point level (a soil moisture quantity too low for roots to effectively use), except perhaps on the sandy soils with low water-holding capacities.

Table 3 shows the average monthly and annual snowfall at the recording stations. Montevideo and Bird Island along the northern edge of the district and Winnebago in the southeast receive the greatest annual snowfall with averages of over 45 inches. Areas along the western border receive the least amount of snowfall with the two eastern South Dakota sites showing totals of about 30 inches. Total winter snowfall has been highly variable in the southwestern district and has ranged from a low of approximately 9 inches to a high of 90 inches, a tenfold difference. Winters without the usual amount of snow are generally warmer than normal, while winters with excessive snow tend to be colder than normal. This effect is largely the result of the high reflectance of solar radiation from a snow surface. Fresh snow reflects 90 percent or more of the solar radiation, and even aged or dirty snow still reflects 40 to 50 percent. Most other surfaces such as soil or vegetation reflect less than 25 percent.

Snowfall plays an important role in southwestern Minnesota in protecting alfalfa and pasture lands against winterkill. Research has shown that snow cover of six inches or more provides adequate insulation for alfalfa stands to survive winter temperatures from −20° F to −30° F.

Temperature

Table 4 shows the average monthly and annual temperatures for 21 locations. In some cases, temperatures were recorded at different times of the day. Fortu·nately, techniques have been developed to take out this type of bias in the temperature records using various cor ection factors. These were applied to the locations shown in Table 4, so the variability can be attributed to geographic differences and not to the manner by which the data were recorded.

The range in annual temperatures is about 3° F. Warmest locations are generally in the southern part of the district and the coolest in the western and northern areas. Differences in temperature during the winter are probably attributable to geography and amount and persistence of snow cover.

Table 5 shows the dates associated with various probabilities for the last spring frost and first fall frost. Frost dates vary considerably from year to year; there have been years when the first fall frost has not occurred until the third week of October, while as recently as 1974 it came as early as September 3 to some counties of the southwestern district. The range in the average freeze-free season within the district is from 140 days in the north to about 160 days near the Iowa border. Pipestone has a relatively short growing season for its position in the landscape due to the higher elevation (1705 ft).

Spring frost is rarely a threat to row crops since their growing points usually remain under the soil surface until June. However, fall frost can be of concern, particularly in those years when planting was delayed or cool summer temperatures did not permit normal crop development. Matching crop maturity (hybrid or variety selection) to length of the freeze-free season is an important management decision. A mismatch can lead to an immature crop vulnerable to fall frost damage, or a mature crop of high moisture content that requires substantial artificial drying before storage.

Growing Degree Days (GDD)

Table 6 shows the average monthly and seasonal Growing Degree Days (GDD) for field corn at the various locations. GDD is a mathematical transformation of temperature, usually representing the difference between the daily mean ([max + min]/2) and some base value required for biological activity (crop or insect, for example). The base value for field corn is 50° F. Upper and lower thresholds which define the temperature range for biological activity are also often used. These thresholds are 86° F and 50° F, respectively, for field corn. If the maximum temperature exceeds 86° F, the 86° upper threshold is considered the maximum for computing the daily mean. Likewise, when the daily minimum temperature is below 50° F, the 50° lower threshold is used as a minimum temperature for computing the daily mean. Cumulative GDD are recorded on a seasonal basis.

Table 6 shows that there is a range of over 400 seasonal GDD in southwestern Minnesota. GDD relate closely to the development rate of field corn hybrids. For example, a hybrid rated as 115-day relative maturity (RM) requires about 2455 GDD from planting to maturity, while a hybrid rated 105-day RM requires about 2254 GDD. Since about 10 percent of the seasonal GDD cannot be used by the crop because they occur before planting or after fall frost, locations that average 2700 or more GDD are probably most compatible for growing 115-day RM hybrids. Locations with the lowest average seasonal GDD totals are better candidates for producing 110- or 105-day RM hybrids. Elevation plays a key role in this variability; higher locations in southwestern Minnesota tend to have lower GDD totals.

The average maturity date for field corn in southwestern Minnesota is September 14 (Table 1). When corn has matured by this date, there are, on the average, about 300 or more GDD left in the crop season for field drying. This is an important benefit, considering the increasing costs of artificial drying. Late September and October temperatures can reduce kernel moisture by 2 to 3 percent per week if the crop has matured. Late-planted, late-maturing, or poorly selected hybrids can miss out on this inherent field-drying opportunity provided by the "normal" late September and early October GDD.

SOME APPLICATIONS OF CLIMATOLOGICAL DATA

The discussion above focused on some of the basic climatic elements and how they vary geographically within southwestern Minnesota. Quite often climatic data can be used to help schedule or anticipate certain field operations.

When Should I Cut Alfalfa?

A recent Minnesota Agricultural Experiment Station study showed that alfalfa development can be estimated using a form of GDD. This relationship was applied using the historic climatic data from in and near southwestern Minnesota. Estimates were made for the occurrence of the 1/10 bloom stage in alfalfa, considered optimum for forage quality and yield. The estimates for three cutting dates (Table 7) reflect local climate variability. Some producers may be geared to harvesting the first cutting the last week of May, while others are more likely to make the same cutting the first week of June. In most years, the climate will permit three cuttings by mid-August at all locations.

However, scheduling alfalfa harvests is greatly complicated by rain, particularly during the first cutting. Historical precipitation data can be used to estimate the probability of receiving two or more dry days during each cutting period (Figure 3).

These probabilities show that there is a 10 to 15 percent better chance of having two consecutive dry days for the third cutting than for the first. The probability for three, four, and five consecutive dry days during harvest is about 20 percent better for the last cutting than for the first. Using the 50 percent probability level as a criterion, it is reasonable to expect only about two dry days for the first cutting, three dry days for the second cutting, and four dry days for the third cutting. A further examination of the rainfall frequency distributions shows that alfalfa producers generally will find cutting the first harvest in mid to late May less of a risk than cutting in early June.

Foiling the Corn Borer

In recent years, one of the most important crop pests in southwestern Minnesota has been the European corn borer. The annual economic impact of this pest due to yield

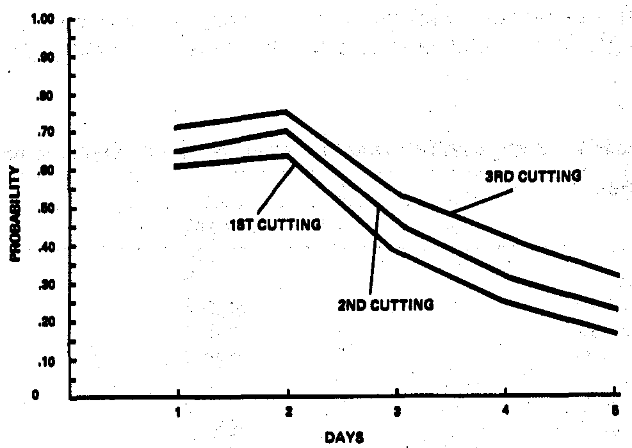

Figure 3. Probability of successive dry days for alfalfa harvesting.

loss and control costs can be millions of dollars.

Like most other crop pests, the corn borer's activity is governed by the weather. A degree-day method similar to that used for field corn can be used to estimate the first appearance of this insect and to track its life cycle. Table 8 shows the relationship between degree-day temperature accumulation (base 50° F) and the life cycle of European corn borer in Minnesota. The first moths usually appear in the southwestern district between June 10 and June 20. Once the egg masses from these moths are detected on corn leaves, the life cycle of the insect can be tracked using daily degree-day summations. This is a valuable tool in establishing schedules for scouting fields, determining if action thresholds (severe enough populations) have been reached, and deciding whether to treat with an insecticide.

Insecticide treatment is advised when 50 percent of the plants show shotholing of the leaves (from feeding) and first generation larvae are still feeding in the leaf whorls. This may occur from about 800 to 1300 degree days. Second generation moths are vulnerable to a high mortality caused by severe weather (thunderstorms with high winds and intense rainfall) from about 1700 to 1800 degree days. Treatment of second generation larvae, though rare, can occur up to six weeks after the 1900 degree-day level is reached.

The development of several other insect species can be tracked using degree-day methods. Some growers and crop consultants keep their own local daily temperature records just for such uses.

Planning Nitrogen and Herbicide Applications

Fall application of nitrogen fertilizer is common throughout the southwestern district. Some forms of nitrogen fertilizer, however, are quite susceptible to denitrification losses when soils are too wet and warm. When soil temperature drops below 50° F, losses due to denitrification are minimal. Thus, soil temperature is sometimes used as a criterion in determining when to apply fall nitrogen.

Table 9 shows estimates of the average date for the last occurrence of 50° F at a soil depth of two inches. These estimates were based on average air temperatures and their relationship to bare soil temperatures. The dates shown in Table 9 reflect climatic differences due to latitudinal position, elevation, proximity to the Minnesota River valley, slope of the surrounding landscape, and other surface features. They can be used as a rule of thumb in determining a timetable for fall nitrogen fertilizer applications.

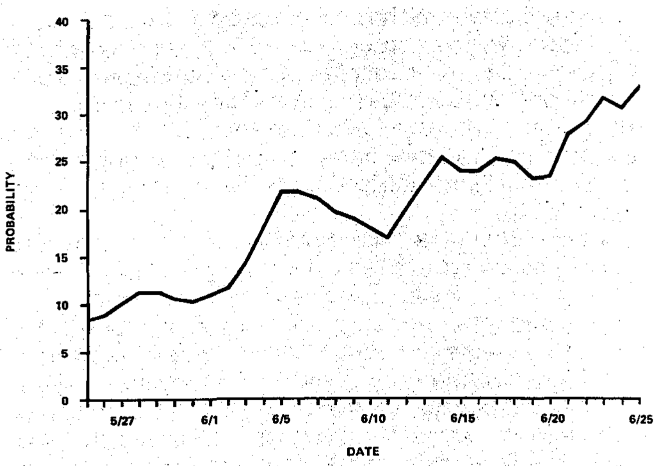

Figure 4. Probability for a temperature of 85° F or greater during the normal postemergence weed control period in southwestern Minnesota. Data are three-day running means for Worthington, covering the period 1894-1987.

A critical period during the crop season follows immediately after crop emergence. During this time, growers assess whether or not they will need a herbicide for postemergence weed control. Most herbicides have specific label instructions governing their use. Some have particular environmental conditions which limit their effectiveness and/or lead to crop injury.

Banvel herbicide, for example, is used for postemergence weed control in field corn. Typically, it is applied between late May and mid June. The label cautions about volatilization and drift problems associated with this compound when temperatures exceed 85° F. Historical climatic records can be used to construct probabilities for this temperature threshold during the period that most postemergence weed control takes place. Figure 4 illustrates these probabilities at Worthington using a three-day running mean basis. The data were derived from the 1894 to 1987 records. It is evident from these data that the risk of volatilization and drift from Banvel application is about four times as great in late June as it is in late May. Such data can be used in determining postemergence weed control measures based on the time of season.

Table 1. Average and extreme dates for corn and soybean development in southwestern Minnesota, 1966-1985.[a]

Stage	Time of Occurrence		
	earliest	average	latest
Corn			
Planting	4/30	5/9	5/20
Tasseling	7/4	7/19	7/29
Maturity	9/3	9/14	9/30
Soybean			
Planting	5/9	5/19	5/28
Blooming	7/3	7/13	7/22
Maturity	9/9	9/20	9/28

[a]Dates represent when 50 percent of the reported acreage reached the designated stage.

Table 2. Average monthly and annual precipitation for southwestern Minnesota and vicinity climate stations, 1951-1980.

Station	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
	(inches)												
Bird Island[a]	0.83	0.90	1.48	2.36	3.17	4.38	3.77	3.89	2.28	1.94	1.24	0.77	27.01
Brookings	0.34	0.50	0.97	2.02	3.06	4.41	2.85	3.15	1.95	1.33	0.66	0.45	21.69
Canby	0.70	0.92	1.54	2.49	3.03	3.94	3.50	3.03	2.09	1.58	1.15	0.89	24.86
Dawson	0.76	0.95	1.51	2.38	3.08	4.01	2.84	3.41	1.99	1.60	1.10	0.82	24.45
Estherville	0.79	1.02	1.82	2.68	3.69	4.34	3.37	3.81	3.19	1.79	1.26	0.83	28.59
Fairmont	0.72	0.93	1.75	2.71	3.71	4.27	3.88	4.20	2.98	1.91	1.24	0.89	29.19
Flandreau	0.37	0.64	1.12	2.04	2.97	3.97	2.73	2.93	2.35	1.58	0.70	0.52	21.92
Lake Park	0.60	0.86	1.60	2.22	3.30	4.53	3.75	3.69	2.98	1.73	1.14	0.86	27.26
Lamberton[a]	0.65	0.61	1.48	2.80	3.26	3.69	3.76	2.68	2.87	2.36	1.16	0.72	26.04
Luverne[a]	0.59	0.84	1.80	2.51	3.44	4.03	3.51	3.55	3.12	2.47	1.29	0.88	28.03
Marshall	0.54	0.86	1.47	2.48	3.03	4.09	3.76	2.96	2.44	1.75	1.14	0.81	25.33
Minneota	0.57	0.70	1.43	2.45	2.99	3.91	3.50	3.17	2.20	1.67	0.98	0.74	24.31
Montevideo	0.86	1.05	1.49	2.40	3.29	4.53	3.14	3.80	2.44	1.69	1.21	0.88	26.78
New Ulm	0.76	0.94	1.72	2.30	3.62	4.37	3.87	3.65	2.61	1.96	1.35	0.87	28.02
Pipestone	0.46	0.77	1.30	2.22	3.45	4.13	2.97	3.39	2.85	1.80	0.87	0.69	24.90
Redwood Fls.	0.60	0.70	1.24	2.30	3.11	3.79	3.84	3.39	2.25	1.84	1.18	0.67	24.91
Rock Rapids	0.51	0.91	1.50	2.30	3.21	4.02	3.19	3.74	2.73	1.65	1.02	0.75	25.53
St. James	0.50	0.61	1.45	2.48	3.45	4.12	3.78	3.63	2.97	1.69	1.18	0.67	26.53
Sibley	0.59	0.98	1.72	2.42	3.52	4.45	3.70	4.36	2.92	1.85	1.05	0.83	28.39
Sioux Falls	0.50	0.93	1.58	2.36	3.21	3.70	2.71	3.13	2.79	1.57	0.92	0.72	24.12
Springfield	0.57	0.82	1.50	2.32	3.24	3.53	3.49	3.54	2.54	1.93	1.18	0.72	25.38
Tracy	0.58	0.80	1.56	2.44	3.25	3.72	3.24	2.92	2.69	1.86	1.21	0.76	25.03
Tyler	0.42	0.58	1.24	2.19	2.98	4.22	3.14	3.05	2.54	1.64	0.91	0.66	23.57
Vesta	0.64	0.84	1.32	2.48	3.25	4.04	3.37	3.39	2.18	1.95	1.09	0.74	25.29
Windom	0.55	0.72	1.51	2.49	3.54	3.97	3.56	3.58	3.11	1.83	1.21	0.73	26.80
Winnebago	0.89	1.01	1.82	2.47	3.92	4.95	4.23	3.74	3.08	1.91	1.24	1.03	30.29
Worthington[a]	0.52	0.82	1.44	2.08	3.47	4.22	3.47	3.23	2.87	1.72	0.97	0.69	25.50

[a]Data from the 1951-1980 period were incomplete so data from other years were substituted.

Table 3. Average monthly and annual snowfall for southwestern Minnesota and vicinity climate stations, 1951-1980.

Station	Month								
	J	F	M	A	snow-free	O	N	D	Annual
	(inches)								
Bird Island[a]	9.3	9.3	10.8	2.8		0.4	5.4	7.9	45.9
Brookings	4.9	6.3	8.0	1.5		0.5	3.0	6.0	30.2
Canby	6.4	7.9	9.7	3.0		0.9	4.2	6.7	38.8
Dawson	8.2	8.9	8.1	2.5		0.3	4.2	7.7	39.9
Estherville[a]	7.7	7.8	7.8	1.6		0.4	4.4	7.5	37.2
Fairmont	8.6	8.7	11.3	1.9		0.4	3.3	8.0	41.7
Flandreau	4.1	7.0	8.2	1.4		0.7	2.7	6.3	30.4
Lake Park	6.1	7.7	9.3	1.7		0.4	3.4	8.0	36.6
Lamberton[a]	8.4	8.0	7.9	2.3		0.5	4.0	9.0	40.1
Luverne[a]	8.6	7.8	10.3	1.1		0.8	4.7	9.4	42.7
Marshall	7.0	9.5	10.2	2.7		0.7	4.3	8.5	42.9
Minneota	6.3	6.5	8.9	3.6		0.5	3.8	6.0	35.6
Montevideo	8.1	9.8	11.2	2.5		0.5	4.9	8.1	45.1
New Ulm	9.0	9.2	10.4	2.0		0.3	4.0	8.4	43.3
Pipestone[a]	4.9	7.1	8.6	2.7		0.7	3.6	6.2	33.8
Redwood Falls	6.2	6.6	8.0	2.1		0.5	4.8	6.2	34.4
Rock Rapids	5.7	8.7	9.4	1.2		0.4	3.1	6.6	35.1
St. James	6.8	7.1	10.9	2.2		0.5	3.4	7.0	37.9
Sibley	6.2	7.2	10.2	1.6		0.4	3.2	6.8	35.6
Sioux Falls	6.2	9.5	10.2	1.4		0.5	3.8	7.9	39.5
Springfield	7.8	8.9	10.2	2.1		0.6	4.3	7.6	41.5
Tracy	6.8	6.9	11.0	2.2		0.8	4.5	6.9	39.1
Vesta	6.8	7.3	9.1	1.6		0.5	4.4	6.7	36.4
Windom	6.7	6.4	9.7	2.4		0.6	3.7	7.2	36.7
Winnebago	9.6	9.5	11.8	2.1		0.4	4.1	9.4	46.9
Worthington[a]	6.3	7.8	11.3	2.1		0.5	4.7	7.2	39.9

[a]The 1951-1980 record was incomplete.

Table 4. Average monthly and annual temperatures for southwestern Minnesota and vicinity climate stations, 1951-1980.[a]

Station	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Annual
	(°F)												
Bird Island[b]	8.1	14.5	26.3	43.9	57.5	67.5	72.1	69.5	60.1	49.1	31.6	17.2	43.1
Brookings	8.1	14.5	26.5	43.2	55.5	65.2	70.5	68.4	58.3	47.1	30.6	16.7	42.1
Canby	9.4	15.8	27.1	43.9	57.3	67.7	73.3	71.2	61.0	49.6	32.1	18.2	43.9
Estherville	11.5	17.8	28.4	45.3	58.4	68.0	72.4	70.0	60.7	49.5	33.5	19.5	44.6
Fairmont	10.9	17.4	28.2	45.6	59.2	69.0	73.3	70.9	62.0	50.6	33.5	19.3	45.0
Flandreau	9.3	15.7	27.2	44.3	56.6	66.6	72.1	69.8	59.5	47.9	31.5	17.9	43.2
Lake Park	10.7	17.1	27.9	44.9	57.7	67.5	72.4	70.0	60.6	49.4	33.0	18.9	44.2
Lamberton[b]	10.0	15.5	27.9	44.6	57.6	67.5	71.8	69.0	59.7	49.0	32.6	18.0	43.6
Marshall	10.3	16.4	27.6	44.7	57.9	67.9	72.8	70.6	60.7	49.4	32.5	18.7	44.1
Montevideo	7.7	14.4	26.7	44.2	57.4	66.9	71.8	69.6	59.8	49.1	31.5	17.2	43.0
New Ulm	9.9	16.0	28.0	45.4	58.1	68.0	72.7	70.1	61.0	50.0	33.1	19.1	44.3
Pipestone	8.4	14.9	26.7	43.4	55.9	66.0	71.2	69.1	59.0	47.5	30.7	16.9	42.5
Redwood Fls.	10.2	16.6	28.8	45.4	58.5	68.0	72.6	71.0	60.7	49.5	32.5	18.2	44.3
Rock Rapids	11.7	18.3	29.5	46.4	58.8	68.7	73.7	71.3	61.3	49.8	33.5	20.1	45.3
Sibley	10.6	17.0	28.2	44.8	57.0	66.9	71.7	69.1	60.0	49.0	32.8	19.4	43.9
Sioux Falls	11.3	18.1	29.3	45.8	58.2	68.4	74.4	72.1	61.7	49.7	32.9	19.6	45.1
Springfield	9.7	16.0	27.7	44.9	58.1	68.1	72.1	69.4	60.5	49.6	32.7	18.4	43.9
Tracy	10.1	16.1	27.3	44.2	57.5	67.7	72.7	70.4	60.5	49.3	32.4	18.3	43.9
Windom	9.9	16.2	27.5	44.2	57.3	67.7	72.4	69.8	60.4	49.4	33.1	19.7	44.0
Winnebago	10.5	16.9	28.0	45.0	57.8	67.7	72.0	69.7	60.6	49.6	33.1	18.4	44.1
Worthington[b]	10.6	16.9	27.6	44.5	57.3	67.1	71.8	69.3	59.7	48.7	32.4	18.3	43.7

[a]In order to compensate for differences in daily observation times, all values were corrected to 0800 local standard time.
[b]Certain records from the 1951-1980 period were missing and data from other years were substituted.

Table 5. Spring and fall dates associated with 50 percent and 10 percent frost probabilities for selected climate stations.[a]

Station	Last Spring Frost		First Fall Frost	
	P=.50	P=.10	P=.50	P=.10
Bird Island	5/9	5/25	9/30	9/18
Canby	5/8	5/22	9/30	9/18
Fairmont	5/5	5/19	10/8	9/23
Lamberton	5/8	5/23	10/1	9/17
Montevideo	5/7	5/21	10/1	9/17
New Ulm	5/10	5/26	9/29	9/16
Pipestone	5/10	5/23	9/30	9/14
Redwood Falls	5/3	5/16	10/3	9/18
Springfield	5/6	5/20	10/7	9/24
Tracy	5/7	5/21	10/4	9/19
Winnebago	5/5	5/19	10/5	9/22
Worthington	5/7	5/21	10/5	9/21

[a]Based on the occurrence of a minimum temperature of 32° F or lower.

Table 6. Average Growing Degree Days (base 50/86° F) by month during the crop season for southwestern Minnesota and vicinity climate stations, 1951-1980.[a]

Station	Month							
(elevation in ft)	A	M	J	J	A	S	O	Annual
Bird Island[b] (1089)	107	320	533	675	607	357	179	2778
Brookings (1642)	78	254	467	628	569	308	131	2435
Canby (1243)	104	306	532	702	646	369	180	2839
Estherville (1302)	112	329	541	679	614	363	182	2820
Fairmont (1187)	120	347	566	704	638	388	195	2958
Flandreau (1550)	98	286	502	671	609	333	151	2650
Lake Park (1465)	106	313	528	680	613	360	179	2779
Lamberton[b] (1144)	94	291	511	661	577	328	158	2620
Marshall (1152)	103	312	539	692	630	360	177	2813
Montevideo (985)	96	300	511	662	602	338	163	2672
New Ulm (860)	111	318	541	690	620	362	179	2821
Pipestone (1705)	81	269	485	649	592	319	139	2534
Redwood Falls (1025)	99	309	524	683	635	352	167	2769
Rock Rapids (1350)	122	336	558	712	648	378	183	2937
Sibley (1670)	110	299	513	660	588	348	170	2700
Sioux Falls (1418)	117	324	549	725	669	385	176	2945
Springfield (1066)	103	318	543	675	598	350	172	2759
Tracy (1403)	96	302	532	688	624	356	172	2770
Windom (1375)	105	303	533	681	609	351	173	2755
Winnebago (1110)	112	320	533	669	607	357	176	2774
Worthington[b] (1570)	103	305	517	665	595	336	164	2685

[a]In order to compensate for differences in daily observation time, all temperature values were corrected to 0800 standard time before computing Growing Degree Days (GDD).
[b]Certain records from the 1951-1980 period were missing, so data from other years were substituted.

Table 7. Estimated average cutting dates for alfalfa in southwestern Minnesota and vicinity based on the Growing Degree Days required to reach flowering.[a]

Station	First Cutting	Second Cutting	Third Cutting
Bird Island	5/31	7/7	8/10
Brookings	6/6	7/11	8/17
Canby	5/31	7/3	8/4
Estherville	5/29	7/1	8/4
Fairmont	5/27	6/29	8/1
Flandreau	6/2	7/6	8/9
Lake Park	5/30	7/3	8/6
Lamberton	6/1	7/5	8/7
Marshall	5/31	7/3	8/5
Montevideo	6/2	7/5	8/9
New Ulm	5/28	7/1	8/3
Pipestone	6/5	7/9	8/14
Redwood Falls	5/30	7/3	8/4
Rock Rapids	5/28	6/30	8/1
Sibley	5/30	7/3	8/7
Sioux Falls	5/28	6/30	7/31
Springfield	5/29	7/2	8/6
Tracy	6/1	7/4	8/6
Windom	5/29	7/2	8/5
Winnebago	5/28	7/2	8/6
Worthington	5/30	7/3	8/7

[a]First cutting is based on the average accumulation of 1035 GDD above a base temperature of 36° F. Subsequent cuttings are based on base 50° F GDD accumulations of 594 and 765, respectively.

Table 8. European corn borer development and degree-day accumulations.

Life Stage	Approximate Degree Days (base 50° F)
First Moth Flight	423
First Generation	
Egg Laying	605
Egg Hatch	700
Peak Larval Feeding	800-1300
Pupation	1440
Second Moth Flight	1710
Second Generation	
Egg Laying	1780
Egg Hatch	1900

Table 9. Estimated date of the last occurrence of 50° F under bare soil (depth = two inches) in the fall.*

Station	Date
Bird Island	10/21
Brookings	10/10
Canby	10/18
Estherville	10/23
Fairmont	10/28
Flandreau	10/14
Lake Park	10/22
Lamberton	10/18
Marshall	10/20
Montevideo	10/19
New Ulm	10/25
Pipestone	10/12
Redwood Falls	10/20
Rock Rapids	10/23
Sibley	10/22
Sioux Falls	10/23
Springfield	10/24
Tracy	10/21
Windom	10/24
Winnebago	10/23
Worthington	10/20

*Estimates are based on the relationship between air temperature and bare soil temperature.

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