AG-FO-3114
1987

MANAGEMENT OF SOILS
IN SOUTHEASTERN MINNESOTA
A Correspondence Course

Unit 9: Climatology

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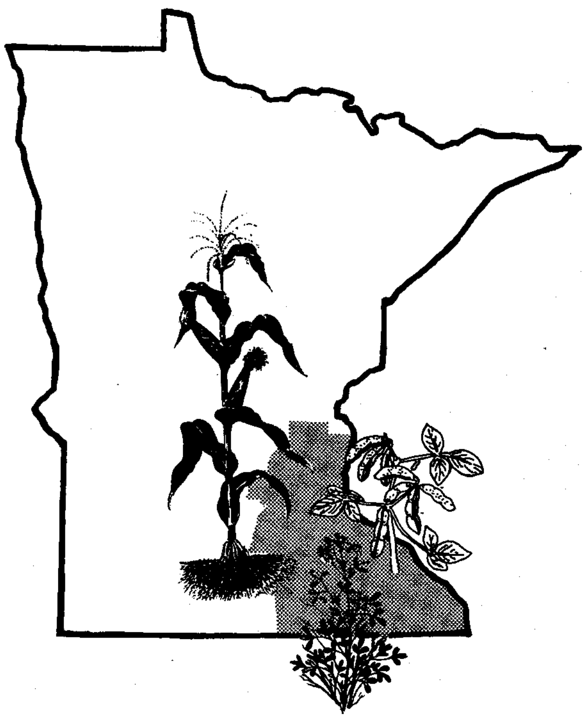
Objectives

- 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. Southeastern Minnesota is often looked upon with envy by the rest of the state, since it represents the best combination of temperature and moisture that the state has to offer for growing crops.

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 southeastern 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). For example, in southeastern 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 degrees 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 by October 1.

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 southeastern district (Figure 1). Due to the scarcity of data over the most recent 30-year period (1951-1980), several perimeter locations, including some just across the Mississippi River in Wisconsin, were used.

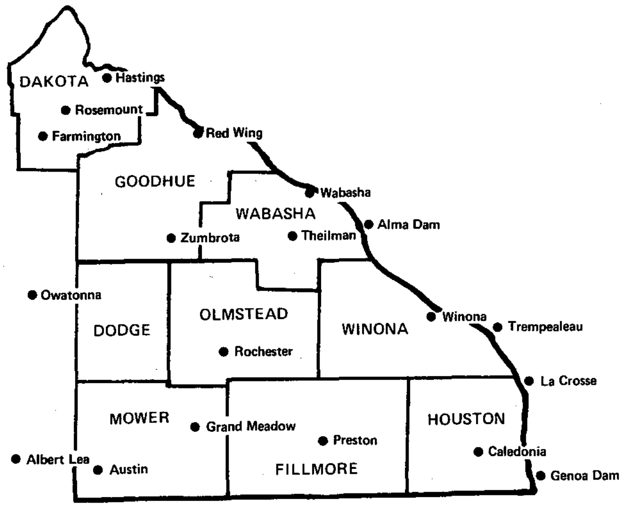

Figure 1. Locations of climate-recording stations in southeastern Minnesota.

Precipitation

Table 2 shows the average monthly and annual precipitation for nineteen locations. Caledonia in Houston County shows the greatest annual average (34.25 inches), while Hastings in Dakota County has the lowest (27.48 inches). Using the values from all 19 locations, the annual mean for the southeastern district is 30.71 inches, with a range of 6.77 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, February 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 20:1. 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 soils are generally frozen from December through February, little precipitation goes into recharging soil moisture

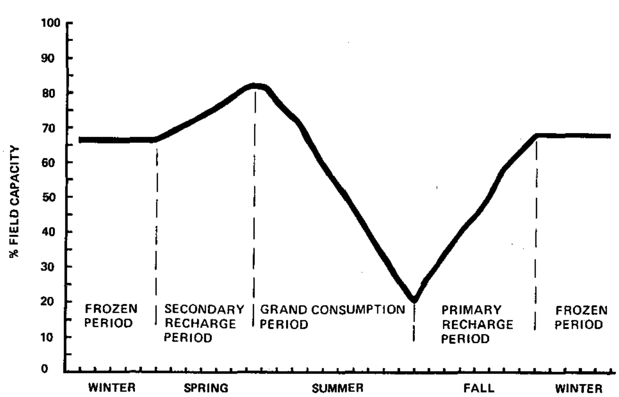

Figure 2. Annual soil moisture profile stages.

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 southeastern 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. Caledonia receives the greatest annual snowfall with an average of 48.5 inches. In part, this is due to its relatively high elevation (1175 ft mean sea level) in the landscape. Alma Dam in Wisconsin receives the least annual snowfall with an average of only 35.1 inches. The moderating influence of the Mississippi often keeps the near-surface air temperatures high enough to prevent snowfall along its banks during transitional months such as April and October. Thus, during these months most of the precipitation comes as rain rather than snow. However, during midwinter the river can provide a moisture source, resulting in heavier snowfalls nearby.

Snowfall plays an important role in southeastern 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 degrees to −30 degrees F.

Temperature

Table 4 shows the average monthly and annual temperatures for sixteen locations. In some cases, temperatures were recorded at different times of the day. Fortunately, techniques have been developed to take out this type of bias in the temperature records using various correction 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.

Locations along the Mississippi River show the highest annual temperatures. Alma Dam, Genoa Dam, La Crosse, Trempealeau, and Winona are all between 600 and 700 feet in elevation as well as being close to the river. Subsidence (downward movement of air) off the surrounding bluffs can produce significant warming and in conjunction with the moderating effects of the river may help explain why the winter temperatures at these sites are uniformly higher than others in the district. Caledonia, Rosemount, and Zumbrota have the lowest annual temperatures in the district.

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 areas of the southeastern district. The range in the average freeze-free season within the district is from about 160 days along the Mississippi River banks to approximately 135 days at Zumbrota.

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 degrees F. Upper and lower thresholds that define the temperature range for biological activity are also often used. These thresholds are 86 degrees F and 50 degrees F, respectively, for field corn. If the maximum temperature exceeds 86 degrees F, the 86 degree upper threshold is considered the maximum for computing the daily mean. Likewise, when the daily minimum temperature is below 50 degrees F, the 50 degree 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 500 seasonal GDD in southeastern Minnesota. Elevation plays a key role in this variability; higher locations tend to have lower GDD totals. 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.

The average maturity date for field corn in southeastern Minnesota is September 18 (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 southeastern 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 southeastern 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 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 will generally 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 southeastern Minnesota has been the European corn borer. The annual economic impact of this pest due to yield

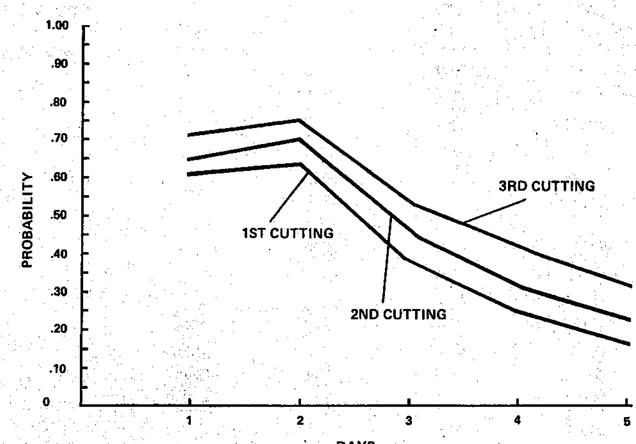

Figure 3. Probability of successive dry days for alfalfa harvesting.

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 degrees F) and the life cycle of European corn borer in Minnesota. The first moths usually appear in the southeastern 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.

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 Application

Fall application of nitrogen fertilizer is common throughout the southeastern 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 degrees 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 degrees 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 Mississippi River, 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.

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

Stage	Time of Occurrence		
	earliest	average	latest
Corn			
Planting	5/2	5/15	5/23
Tasseling	7/6	7/21	8/1
Maturity	9/8	9/18	10/2
Soybean			
Planting	5/17	5/25	6/3
Blooming	7/12	7/20	7/27
Maturity	9/16	9/24	10/2

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

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

Station	Month												
	J	F	M	A	M	J	J	A	S	O	N	D	Annual
	(inches)												
Albert Lea	0.80	0.84	1.78	2.81	3.97	4.79	4.22	3.81	3.04	2.14	1.47	0.90	30.57
Alma Dam	0.84	0.64	1.85	2.76	3.65	4.47	4.44	3.89	3.36	2.42	1.57	0.92	30.81
Austin	1.17	0.98	1.98	2.78	3.90	4.43	3.95	3.92	3.09	2.13	1.59	1.20	31.12
Caledonia	1.03	1.02	2.41	3.25	4.14	4.63	4.65	3.95	3.69	2.36	1.84	1.28	34.25
Farmington	0.78	0.91	1.83	2.35	3.52	4.69	4.01	4.20	2.96	2.07	1.41	1.01	29.74
Genoa Dam	0.75	0.85	1.85	3.22	3.68	4.48	4.31	3.88	3.49	2.18	1.61	0.99	31.29
Gr. Meadow	0.95	0.91	2.08	2.77	4.14	4.61	4.10	4.07	3.27	2.24	1.51	0.99	31.64
Hastings	0.63	0.60	1.49	2.17	3.30	4.61	4.15	3.71	2.91	1.92	1.23	0.76	27.48
La Crosse	0.94	0.89	1.96	3.05	3.61	4.15	3.83	3.70	3.47	2.08	1.50	1.07	30.25
Owatonna[a]	0.91	0.72	1.60	2.61	3.86	4.07	4.12	3.79	3.37	2.23	1.43	1.02	29.73
Preston	0.86	0.80	1.99	2.82	3.80	4.67	4.13	4.05	3.26	2.26	1.42	1.04	31.10
Redwing	0.82	0.71	1.67	2.46	3.73	4.81	4.49	3.97	3.39	2.17	1.44	1.02	30.68
Rochester	0.74	0.69	1.73	2.50	3.42	4.12	3.82	3.85	3.07	2.08	1.39	0.84	28.26
Rosemount	0.92	0.83	1.81	2.46	3.69	4.77	3.99	4.29	3.17	2.22	1.48	1.03	30.66
Theilman	0.84	0.70	1.82	2.72	3.52	4.51	4.42	4.03	3.43	2.46	1.58	0.89	30.92
Trempealeau	0.85	0.82	2.14	2.83	4.09	4.39	4.08	4.05	3.69	2.14	1.56	1.04	31.68
Wabasha	0.87	0.68	1.80	2.80	3.88	4.45	4.21	3.94	3.33	2.47	1.61	1.06	31.10
Winona	1.14	0.93	2.07	2.89	4.17	4.62	4.25	4.25	3.44	2.15	1.63	1.17	32.72
Zumbrota	0.82	0.63	1.55	2.52	3.61	4.58	4.07	3.63	3.48	2.30	1.34	0.96	29.49

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

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

Station	Month								
	J	F	M	A	snow-free	O	N	D	Annual
	(inches)								
Albert Lea	8.9	7.6	9.5	2.6		0.3	4.5	8.5	44.4
Alma Dam	10.7	7.3	8.7	1.8		T[b]	2.5	8.9	35.1
Austin	8.6	7.7	8.6	2.3		0.2	3.7	9.0	40.6
Caledonia	9.2	8.5	10.6	3.1		0.2	4.2	8.4	48.5
Farmington	9.1	8.8	10.0	2.6		0.3	5.6	8.7	44.6
Genoa Dam	8.5	7.1	7.6	1.4		T[b]	2.8	7.8	38.0
Grand Meadow	11.5	8.8	11.0	2.6		0.2	4.6	9.5	47.2
Hastings	9.0	7.2	6.7	1.6		0.1	2.5	7.6	35.9
La Crosse	9.9	8.4	8.9	1.9		0.1	3.3	8.6	41.0
Owatonna[a]	10.1	8.0	7.9	3.3		0.5	3.4	10.1	42.3
Preston	7.6	6.4	8.5	1.7		0.1	3.3	8.4	40.1
Redwing	9.8	8.7	9.8	2.6		0.2	3.9	9.9	40.5
Rochester	9.0	7.7	9.9	3.4		0.5	4.7	9.9	44.8
Rosemount	9.3	7.2	9.8	2.8		0.3	4.7	8.8	42.0
Theilman	9.5	6.9	8.4	0.8		0.1	1.7	6.6	37.7
Trempealeau	7.9	7.4	9.5	2.0		0.1	3.0	8.2	42.2
Wabasha[a]	11.0	6.6	7.3	1.8		0.1	3.7	9.4	37.2
Winona	10.9	9.2	10.1	2.1		0.1	4.0	8.6	45.2
Zumbrota	7.7	6.5	8.5	1.8		0.3	3.7	7.9	39.1

[a]The 1951 - 1980 record was incomplete.
[b]T = trace (too small to measure).

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

Station (elevation in feet)	J	F	M	A	M	J	J	A	S	O	N	D	Annual
	(degrees F)												
Albert Lea (1220)	9.5	15.2	26.7	43.7	56.6	67.0	71.7	69.1	59.6	48.5	32.2	18.2	43.2
Alma Dam[b] (670)	12.5	17.2	29.0	45.0	57.9	67.8	72.7	70.9	61.6	50.9	34.7	20.9	45.1
Austin (1215)	9.2	15.5	27.2	44.3	56.8	66.3	70.7	68.3	59.8	48.9	32.5	18.5	43.2
Caledonia[b] (1175)	10.9	14.2	28.1	43.8	55.8	65.1	70.2	67.6	59.0	47.7	32.6	18.8	42.8
Farmington (980)	8.3	14.7	26.8	44.5	57.6	66.9	71.5	69.1	59.9	48.9	32.2	17.7	43.2
Genoa Dam (639)	13.4	18.8	30.2	46.3	58.8	67.9	72.8	70.6	62.0	51.1	35.7	22.3	45.8
Gr. Meadow (1350)	10.6	16.2	27.1	43.9	56.6	66.1	70.4	68.0	59.1	48.4	32.6	18.5	43.1
La Crosse (651)	12.9	18.7	29.8	46.7	59.4	68.5	73.4	71.2	62.3	51.2	35.2	21.4	45.9
Owatonna (1150)	8.0	14.4	28.0	44.2	56.9	67.1	71.9	68.9	59.9	48.8	32.8	17.8	43.2
Preston (930)	10.7	16.5	28.0	44.0	56.0	65.2	70.2	67.8	59.0	48.2	32.8	19.7	43.2
Rochester (1297)	9.7	16.0	26.9	44.1	56.9	66.6	71.1	68.7	59.9	49.0	32.5	18.4	43.3
Rosemount (950)	7.5	13.6	26.3	43.1	55.9	65.8	70.7	68.1	58.8	48.0	31.4	17.1	42.2
Theilman[b] (737)	9.3	14.7	28.7	44.5	56.3	65.7	70.7	67.1	58.8	48.6	33.5	19.3	43.2
Trempealeau (660)	11.6	17.3	28.9	45.6	58.4	67.5	72.4	70.1	61.2	50.3	34.5	20.8	44.9
Winona (652)	12.7	18.3	29.6	45.9	58.5	67.9	72.8	70.2	61.0	50.3	34.9	20.6	45.2
Zumbrota (985)	9.1	14.8	26.6	43.8	56.1	66.0	71.0	68.5	59.3	48.6	32.3	18.4	42.9

[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
Albert Lea	5/3	5/18	10/6	9/20
Farmington	5/9	5/22	10/1	9/20
Grand Meadow	5/10	5/22	9/29	9/6
La Crosse	5/1	5/16	10/8	9/21
Winona	4/29	5/15	10/8	9/20
Zumbrota	5/12	5/28	9/26	9/11

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

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

Station (elevation in ft)	A	M	J	J	A	S	O	Annual
Albert Lea (1220)	104	308	536	685	615	354	179	2781
Alma Dam[b] (670)	119	341	556	687	642	390	200	2935
Austin (1215)	100	287	491	627	559	328	159	2551
Caledonia[b] (1175)	117	291	487	631	567	337	160	2590
Farmington (980)	107	311	509	658	590	337	171	2683
Genoa Dam (639)	144	365	565	704	646	406	225	3055
Grand Meadow (1350)	100	298	496	630	564	331	167	2586
La Crosse (651)	127	351	552	707	647	394	202	2980
Owatonna[b] (1150)	114	299	521	679	594	345	169	2721
Preston (930)	93	277	471	614	547	310	146	2458
Rochester (1297)	100	298	502	644	577	335	169	2625
Rosemount (950)	91	279	480	633	561	315	155	2514
Theilman[b] (737)	129	326	514	648	579	352	181	2729
Trempealeau (660)	114	330	529	685	621	369	191	2839
Winona (652)	127	342	544	693	627	376	200	2909
Zumbrota (985)	95	280	486	642	573	325	165	2566

[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 southeastern Minnesota based on the Growing Degree Days required to reach flowering.[a]

Station	First Cutting	Second Cutting	Third Cutting
Albert Lea	5/31	7/3	8/6
Alma Dam	5/28	6/29	8/1
Austin	6/1	7/6	8/12
Caledonia	5/29	7/4	8/10
Farmington	5/31	7/4	8/8
Genoa Dam	5/26	6/28	7/31
Grand Meadow	6/1	7/6	8/12
La Crosse	5/27	6/29	8/1
Owatonna	5/30	7/3	8/6
Preston	6/2	7/8	8/15
Rochester	6/1	7/6	8/11
Rosemount	6/1	7/6	8/11
Theilman	5/27	7/2	8/6
Trempealeau	5/29	7/2	8/5
Winona	5/27	6/30	8/2
Zumbrota	6/2	7/7	8/12

[a]First cutting is based on the average accumulation of 1035 GDD above a base temperature of 36 degrees F. Subsequent cuttings are based on base 50 degrees 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 degrees 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 degrees F under bare soil (depth = 2 inches) in the fall.[a]

Station	Date
Albert Lea	10/20
Alma Dam	10/30
Austin	10/22
Caledonia	10/15
Farmington	10/22
Genoa Dam	10/30
Grand Meadow	10/19
La Crosse	10/30
Owatonna	10/22
Preston	10/18
Rochester	10/22
Rosemount	10/17
Theilman	10/20
Trempealeau	10/28
Winona	10/28
Zumbrota	10/20

[a]Estimates based on the relationship between air temperature and bare soil temperature.

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