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CONTENTS

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COMPARISONS OF DAYTIME AND NIGHTTIME SOIL AND AIR TEMPERATURES

ALFRED SMITH[1]

INTRODUCTION

The importance of minimum, optimum, and maximum temperatures as well as of average temperatures for plant and animal life has been stressed by many writers. The time and rate of germination of seeds is without question largely dependent on soil temperature conditions. With most cultivated plants growth does not begin until a temperature of 40° to 50° Fahrenheit is reached by the soil.

Mosier and Gustafson[6] state that growth is most vigorous at from 80° to 90° F, and that the soil nitrifying bacteria are most active at temperatures between 60° and 85° F. Other investigators give higher or lower ranges, as King[4] who in referring to Ebermayer's investigations states that growth takes place most vigorously after the soil has reached 68° to 70° F, and that the maximum activity of the nitrifying bacteria occurs after a soil temperature of 98° has been reached; but if the soil reaches a temperature of 113° F their activity is nearly stopped, it being as weak as at 54°.

The effect of temperature on plant diseases and insect damage has received considerable attention. Smith[9] shows that the effect of the temperature on parasites or fungous diseases of insects may be different from that on the insects themselves. He refers to the oat aphis which multiplies at a temperature of 40° or above, while the common parasite of this and of many other aphids is not active at a

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temperature below 56°. At a temperature of about 70°, however, the parasite will multiply approximately ten times as rapidly as its host. Jones, Johnson and Dickson[2] point out that the general curve of plant disease development rises rather gradually to its optimum, then makes a sharp drop as temperature rises above this. The optimum they found was about 82° F for most of the diseases they investigated.

That temperature has an important effect on certain physical processes in soils has long been recognized. Bouyoucos[1] demonstrated that the rate of percolation of water increases with rise of temperature to about 86° F, and then decreases with further rise in temperature. This was true with a sandy loam, silt loam, clay loam, clay and muck soils while with a sandy soil the rate of flow increases with a constantly rising temperature. In the former soils he explains the results on the basis of the swelling of the colloidal material. The rate of flow of air through soils he found decreased with rise in temperature. King[4] shows that soil ventilation due to diurnal changes in soil temperature will range from 0 up to possibly 20 cubic inches per square foot.

The importance of daytime and nighttime atmospheric or soil changes has received little consideration. Kincer[3] has pointed out that in sections where the summer rainfall is not abundant, greater benefit to vegetation results if the rains come largely during the nighttime. There is not as great an evaporation from the soil and the cultivated soil is not so likely to be crusted as when the rains are of the daytime type where the effect of the hot sunshine often produces harmful results. Photosynthesis or the assimilation of carbon dioxide and a greater rate of transpiration by plants is a normal activity during the periods of sunlight according to the general principles of plant physiology. Mason[5] reports that from records of the leaf elongation of palms in darkness it appears that such effects are diametrically opposed to the daylight activities. He has shown that the "inhibiting of the date-palm leaf growth in intense sunlight of the desert regions is due chiefly to the action of rays of light of definite wave length, that photosynthesis is most active in longer wave lengths and thus growth is inhibited by light that has but little potency in photosynthesis and conversely carbon assimilation is favored by light that has but little ability in inhibiting growth."

There seems to be a justification when considering the changes that are regularly taking place in the soil and air temperatures to consider the daytime hours and nighttime hours separately and not simply a certain daily (24 hours) maximum or minimum temperature.

METHOD OF OBTAINING TEMPERATURE DATA

Air temperatures were obtained by means of a thermograph placed in a U. S. Weather Bureau shelter at a height of 4½ feet above the soil surface. Soil temperatures were automatically recorded every 15 minutes by means of a Leeds and Northrup temperature recorder with electrical resistance thermometers placed at several depths in an area that was kept free of growing vegetation. Details concerning the area at Davis, California, where the observations were made have been described in a previous publication.[8] The daily period of 24 hours was divided into two periods, the daytime or daylight hours and nighttime or the period between sunset and sunrise.

Portions of two years have been selected for this discussion, namely: February 20 to October 1, 1925, and January 1 to June 21, 1927. All of the temperature data obtained during these two years has been shown elsewhere[8] by hour intervals, together with information on the character of the sky, general wind direction and periods of rainfall. The data herein reported were obtained by using all of the 15-minute records for each thermometer. In the 1925 period the shortest day was on September 30 when sunrise occurred at 6:01 and sunset at 5:51. The longest days were between June 16 and June 22 inclusive, when sunrise occurred at 4:39 or 4:40 and sunset at 7:34 or 7:35. The number of daylight hours therefore ranged from approximately 11 hours to 15 hours. During the 1927 period the shortest day was on January 1 when sunrise occurred at 7:26 and sunset at 4:54. The longest days were from June 16 to the end of the period. The number of daylight hours ranged from slightly over 9 hours to approximately 15 hours. The maximum air temperature for the day usually occurred several hours before sunset and for the night just after sunset. The minimum day and night air temperatures in general occurred around sunrise. The lag in the occurrence of the soil maximum and minimum temperatures at various depths with respect to the time of occurrence of the air maximum and minimums is approximately as follows: 3-inch depth—2 hours; 6-inch—4 hours; 12-inch—8 hours; 24-inch—70 hours; and 36-inch—80 hours.

It is clear from the preceding that daily soil temperature changes occur to a depth of 12 inches. At the 6-inch and 12-inch depths due to the lag as shown previously, the maximum soil temperatures will occur near or after sunset and therefore the night temperatures for these depths should average higher than the day temperatures. During

the warmer periods of the year the maximum soil temperature at a depth of 6 inches may occur approximately two hours before sunset.[7] At this depth, therefore, the day and night maximum temperatures should be, in general, in close agreement.

TEMPERATURES IN 1925

The maximum, minimum and average soil and air temperatures obtained during the daytime and nighttime for each day of the period of February 20 to September 30 inclusive, 1925, are shown in figures 1–7 inclusive.

In order to fully understand the seasonal changes, tables 1–6 inclusive have been prepared. In these tables the highest and lowest maximums, minimums, and averages for the daytime and nighttime as well as the date of their occurrence, the usual maximums, minimums and averages between certain dates and the greatest spread which is the largest range in temperature between the maximum and minimum on one day are all shown for the period of February 20 to September 30 inclusive, 1925. In these tables special emphasis has been placed on the number of times when the air or soil temperatures were below 40° as most investigators usually mention some temperature around 40° as being the point where biological processes in the soil become active and that with air temperatures around 40° plant growth commences.

The minimum air temperatures and soil temperatures at a depth of one-half inch were at times below 40° during this 1925 period, but at a depth of 3 inches the minimum soil temperatures were never lower than 42°. For the soil depths beyond 3 inches the minimums were as follows: 6-inch depth—44°, 12-inch depth—48°, 24-inch depth —50°, and 36-inch depth—50°.

The average night temperatures at the 6-inch soil depth were usually higher than the average day temperatures, while at the ½ and 3-inch depths the reverse was true. The average day and night temperatures at the 6-inch depth were usually within 2° of each other and the same was true for the 12-inch soil depth.

A study of the figures and tables will show that there is no daily rise and fall in temperatures at the 24- and 36-inch depths in the soil. At these depths the temperature changes are slow and do not vary from day to day, as a general rule, more than 2°. On account of these facts only one curve is used to show the temperature changes at these depths and it is designated as "daily averages."

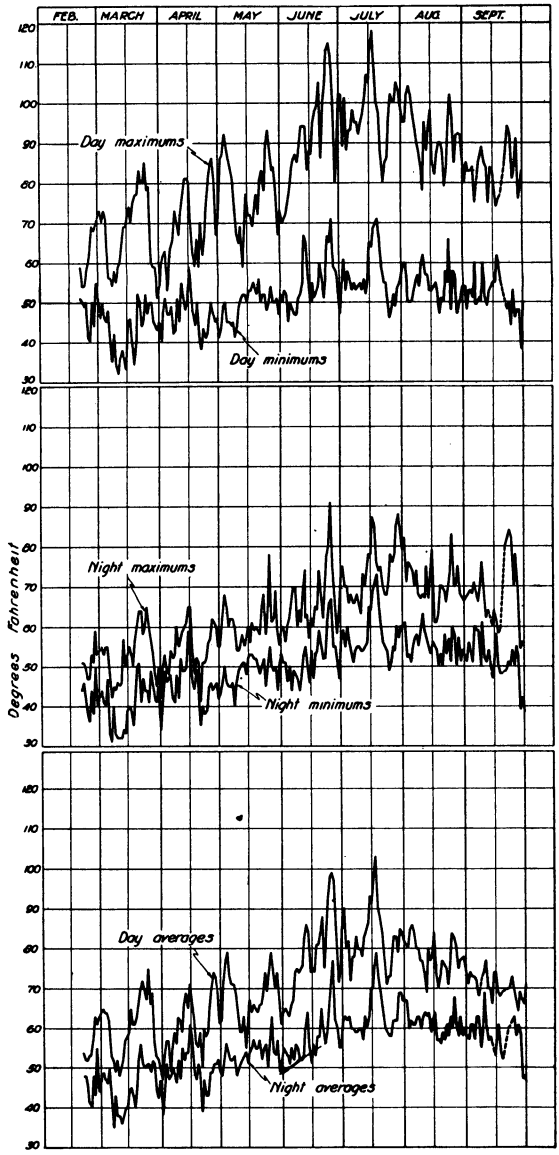

Fig. 1. Air temperatures for 1925 period.

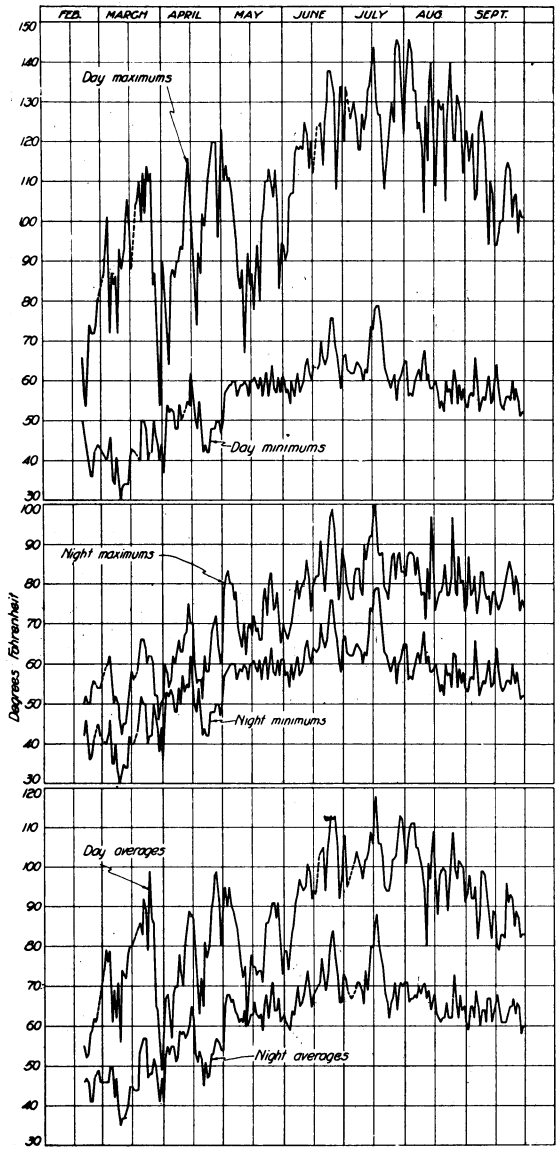

Fig. 2. Soil temperatures at ½-inch depth for 1925 period.

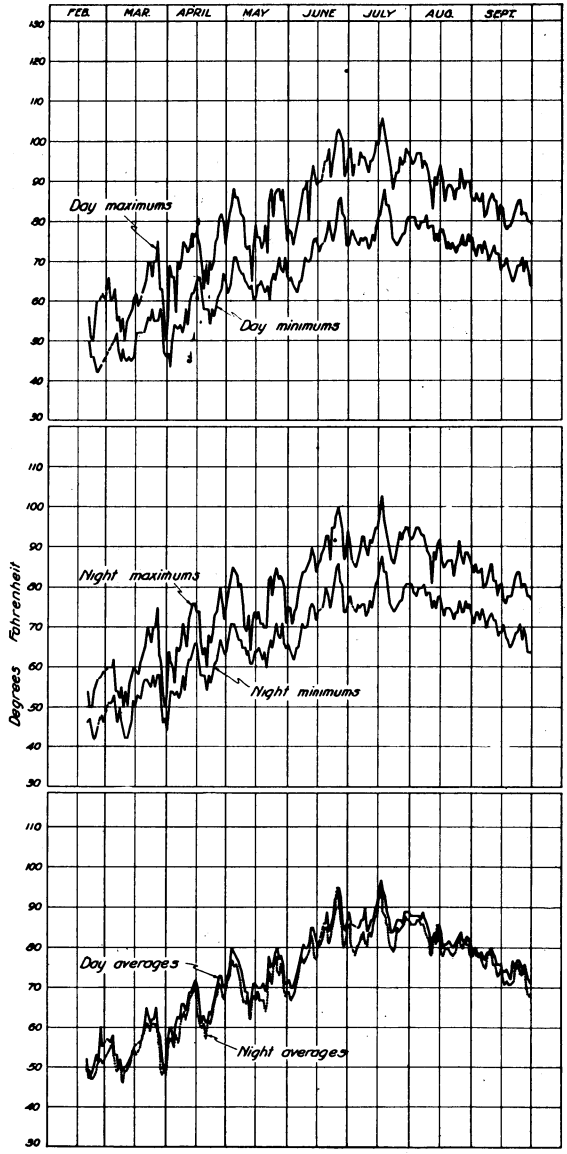

Fig. 3. Soil temperatures at 3-inch depth for 1925 period.

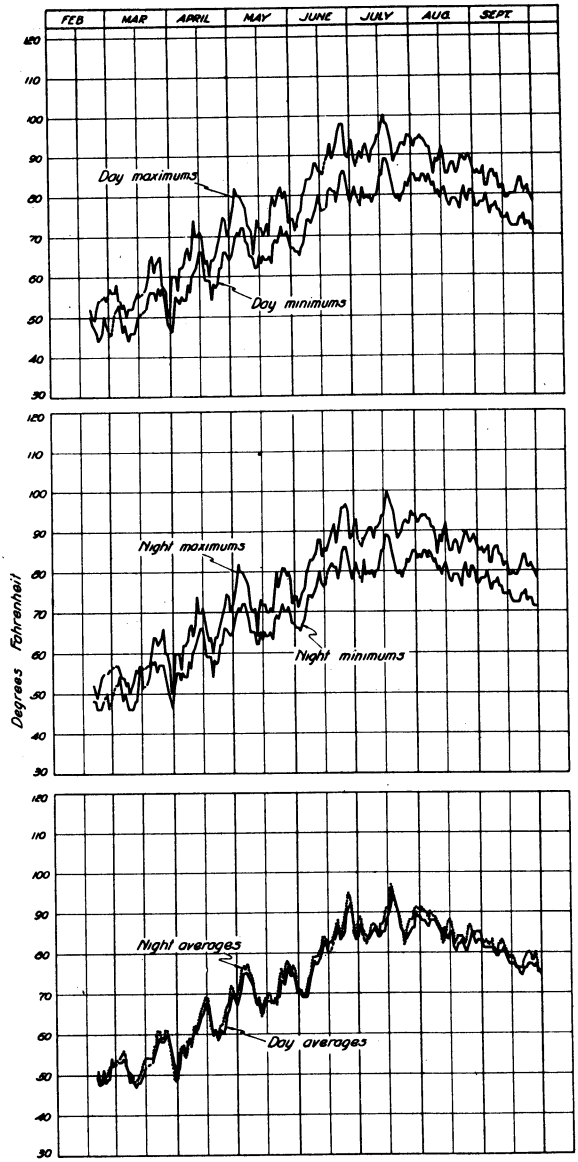

Fig. 4. Soil temperatures at 6-inch depth for 1925 period.

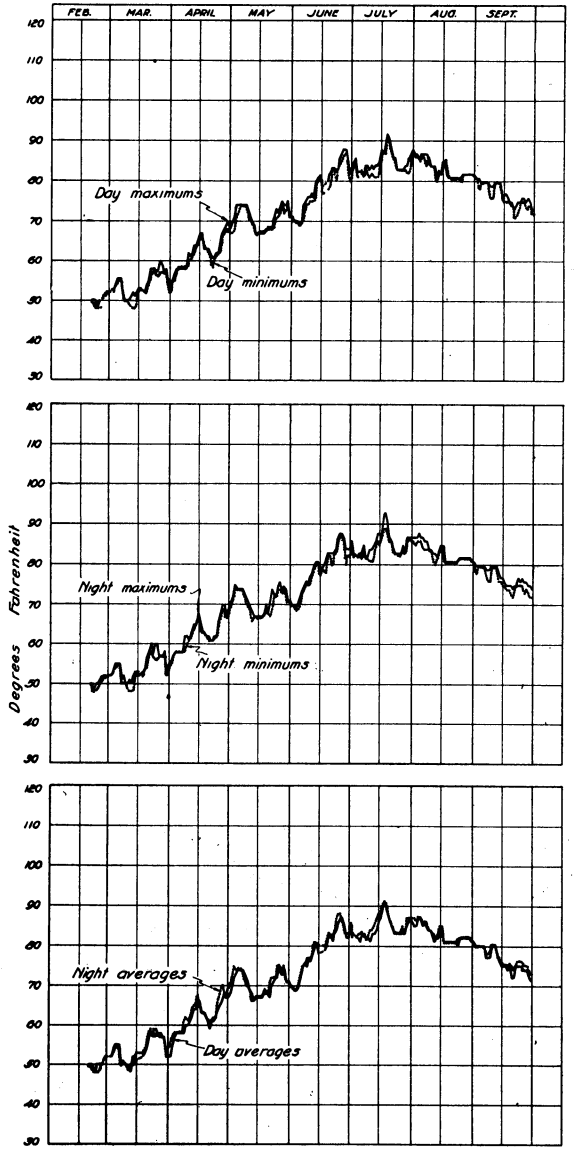

Fig. 5. Soil temperatures at 12-inch depth for 1925 period.

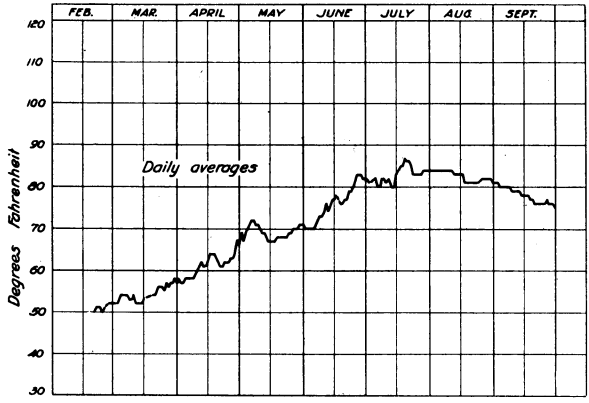

Fig. 6. Soil temperatures at 24-inch depth for 1925 period.

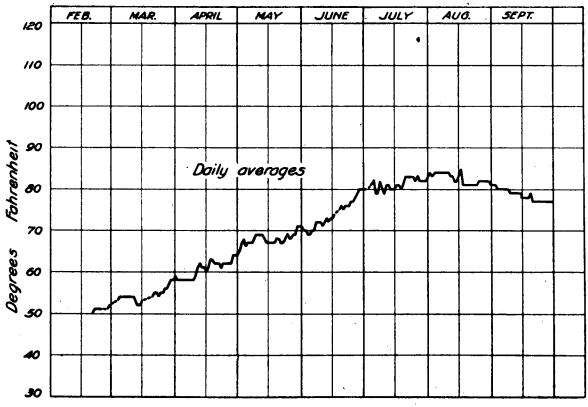

Fig. 7. Soil temperatures at 36-inch depth for 1925 period.

TABLE 1

DAYTIME AND NIGHTTIME AIR TEMPERATURES, FEBRUARY 20 TO SEPTEMBER 30, 1925

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
July 17	117°	March 30	51°	February 20 to June 5	60°–80°	June 26, July 19	71°	March 10	32°	March 7 to 19 April 21, September 29	Less than 40°	July 26	54°
				June 5 to September 30	80°–100°					February 20 to June 9	40°–50°		
										June 9 to September 30	50°–60°		
Nighttime maximums						Nighttime minimums							
June 25	91°	April 20	41°	February 20 to June 1	50°–60°	July 18	73°	March 6	31°	March 5 to 17 March 31, April 20 to 23 September 28 to 30	Less than 40°	July 29	31°
				June 1 to September 30	60°–80°					February 20 to June 10	40°–50°		
										June 10 to September 30	50°–60°		
Daytime averages						Nighttime averages							
July 27	103°	April 1	47°	February 20 to June 5	50°–70°	July 17	79°	March 6	35°	March and April	Less than 40°	July 1	27°
				June 5 to September 30	70°–90°					February 20 to May 1	40°–50°		
										May 1 to July 1	50°–60°		
										July 1 to September 1	60°–70°		
										September 1 to 30	50°–60°		

TABLE 2

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, ½-INCH DEPTH, FEBRUARY 20 TO SEPTEMBER 30, 1925

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
July 28, August 5	146°	February 22, March 30	54°	February 20 to June 6	70°–110°	July 18, 19	79°	March 10	30°	11 times between February 24 and April 2	Less than 40°	July 28	86°
				June 6 to September 15	110°–140°					February 20 to May 1	40°–50°		
										May 1 to September 30	50°–70°		
Nighttime maximums						Nighttime minimums							
July 17	100°	March 10	42°	February 20 to June 1	50°–70°	July 17, 18	79°	March 9	30°	12 times between February 23 and April 1	Less than 40°	August 14	29°
				June 1 to September 30	70°–90°					February 20 to June 10	40°–60°		
										June 10 to August 10	60°–70°		
										August 10 to September 30	50°–60°		
Daytime averages						Nighttime averages							
July 17	118°	March 30	49°	February 20 to June 5	60°–90°	July 17	88°	March 9	35°	5 times around March 10	Less than 40°	March 24	51°
				June 5 to September 5	90°–110°					February 20 to May 1	40°–60°		
				September 5 to September 30	80°–90°					May 1 to September 30	60°–70°		

TABLE 3

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 3-INCH DEPTH, FEBRUARY 20 TO SEPTEMBER 30, 1925

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
July 17	107°	March 9, 30	50°	February 20 to June 5	50°–80°	July 18	88°	February 24	42°	Several times between February 20 and April 2	Less than 50°	June 24	21°
				June 5 to September 30	80°–100°					February 20 to June 10	50°–70°		
										June 10 to September 30	70°–80°		
Nighttime maximums						Nighttime minimums							
July 17	103°	5 times between February 21 and March 30	50°	February 20 to June 5	50°–80°	July 17	88°	March 10	42°	Several times between February 20 and April 2	Less than 50°	March 26, June 7, 8	17°
				June 5 to September 30	80°–95°					February 20 and June 10	50°–70°		
										June 10 to September 30	70°–80°		
Daytime averages						Nighttime averages							
July 17	97°	February 21	47°	February 20 to June 10	50°–80°	June 25, July 17	95°	March 14	46°	Several times between February 20 and April 1	Less than 50°	July 9	8°
				June 10 to September 1	80°–90°					February 20 to June 10	50°–80°		
				September 1 to September 30	70°–80°					June 10 to September 1	80°–90°		
										September 1 to September 30	70°–80°		

TABLE 4

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 6-INCH DEPTH, FEBRUARY 20 TO SEPTEMBER 30, 1925

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
July 17	101°	February 22	49°	February 20 June 6	50°–80°	July 17, 18	89°	February 24, March 10	44°	February 20 to June 6	45°–70°	June 23	15°
				June 6 to September 30	80°–95°					June 6 to September 30	70°–85°		
Nighttime maximums						Nighttime minimums							
July 17	100°	February 22	49°	February 20 to June 6	50°–80°	July 16, 17	89°	Several times between February 20 and March 21	46°	February 20 to June 6	50°–70°	July 8	12°
				June 6 to September 30	80°–95°					June 6 to September 30	70°–85°		
Daytime averages						Nighttime averages							
July 17, 18	94°	March 10	47°	February 20 to June 6	50°–75°	July 17	97°	February 21, 22	48°	February 20 to June 6	50°–75°	June 25, July 17	30°
				June 6 to September 5	80°–90°					June 6 to September 5	80°–90°		
				September 5 to September 30	70°–80°					September 5 to September 30	70°–80°		

TABLE 5

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 12-INCH DEPTH, FEBRUARY 20 TO TO SEPTEMBER 30, 1925

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
July 18	93°	February 23	48°	February 20 to June 6	50°–70°	July 18	92°	Around February 23 and March 12	48°	February 20 to June 6	50°–70°	March 12	4°
				June 6 to September 30	70°–86°					June 6 to September 30	70°–86°		
Nighttime maximums						Nighttime minimums							
July 18	93°	February 22	48°	February 20 to June 6	50°–73°	July 17, 18	89°	February 22, March 11 to 13	48°	February 20 to June 6	50°–73°	July 18	4°
				June 6 to September 30	73°–88°					June 6 to September 30	73°–88°		
Daytime averages						Nighttime averages							
July 18	91°	February 23, March 12	48°	February 20 to June 6	50°–75°	July 18	91°	February 23	48°	February 20 to June 6	50°–75°	May 3, July 11	3°
				June 6 to September 15	75°–91°					June 6 to September 15	75°–91°		
				September 15 to September 30	70°–75°					September 15 to September 30	70°–75°		

TABLE 6

DAILY AVERAGE SOIL TEMPERATURES, 24-INCH AND 36-INCH DEPTHS, FEBRUARY 20 SEPTEMBER 30, 1925

24-inch depth						36-inch depth					
Highest		Lowest		Usual		Highest		Lowest		Usual	
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.
July 19	87°	Several times between February 20 and March 14	50°–52°	February 20 to June 6	50°–70°	August 16	85°	Several times between February 20 and March 14	50°–52°	February 20 to June 6	50°–70°
				June 6, September 30	75°–85°					June 6, September 30	75°–82°

DAYTIME AND NIGHTTIME SOIL AND AIR TEMPERATURES IN 1927

The maximum, minimum and average soil and air temperatures obtained during the daytime and nighttime for each day of the period of January 1 to June 21, 1927, are shown in figures 8–14 inclusive.

The seasonal changes are more clearly shown in tables 7–12 inclusive. In these the highest and lowest maximums, minimums and averages for the daytime and nighttime as well as the date of their occurrence, the usual maximums, minimums and averages between certain dates and the greatest spread which is the largest range in temperature between maximum and minimum on one day are all shown for the period of January 1 to June 21, 1927.

The minimum air temperatures and the soil temperatures at the ½-inch depth were below 40° several times during this 1927 period, but at a depth of 3 inches the minimum soil temperatures were below 40° only 3 times. For the soil depths beyond 3 inches the minimums, day or night were as follows: 6-inch depth—41°; 12-inch depth—44°; 24-inch depth—48°; and 36-inch depth—52°.

The average day and night temperatures at the 6-inch depth were usually within 1° of each other, the night averages at this depth in general being higher than the day averages, while at the ½ and 3-inch depths the reverse was usually the case. The average night temperatures at the 12-inch depth were usually 2° or less higher than the average day temperatures.

As previously stated a study of the figures will show that there is no daily rise and fall in temperature at the 24-inch and 36-inch depths and for this reason only one curve is used to show the temperature changes at these depths and it is designated as "daily averages."

DISCUSSION OF DATA

The occasional gaps in the data as shown by figures 1–14 are due to brief failures of the temperature recorder or thermograph. These are indicated on the graphs by an appropriate symbol (- - -). These missing data do not affect the conclusions which are drawn because there were relatively few times when they were of any duration.

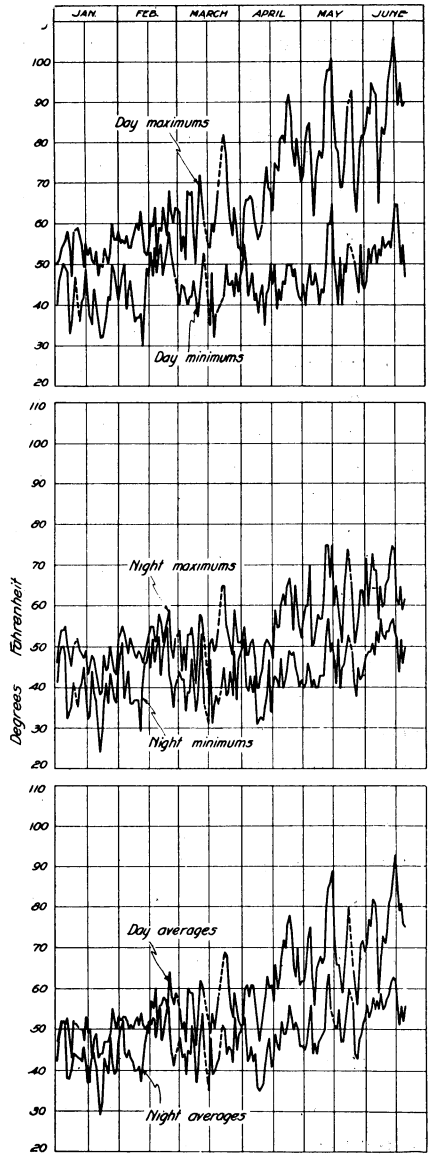

Fig. 8. Air temperatures for 1927 period.

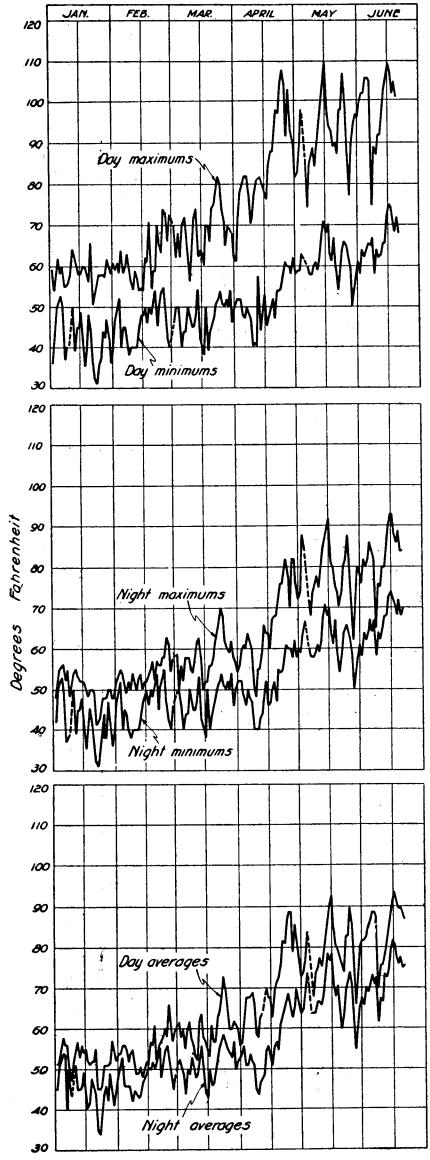

Fig. 9. Soil temperatures at ½-inch depth for 1927 period.

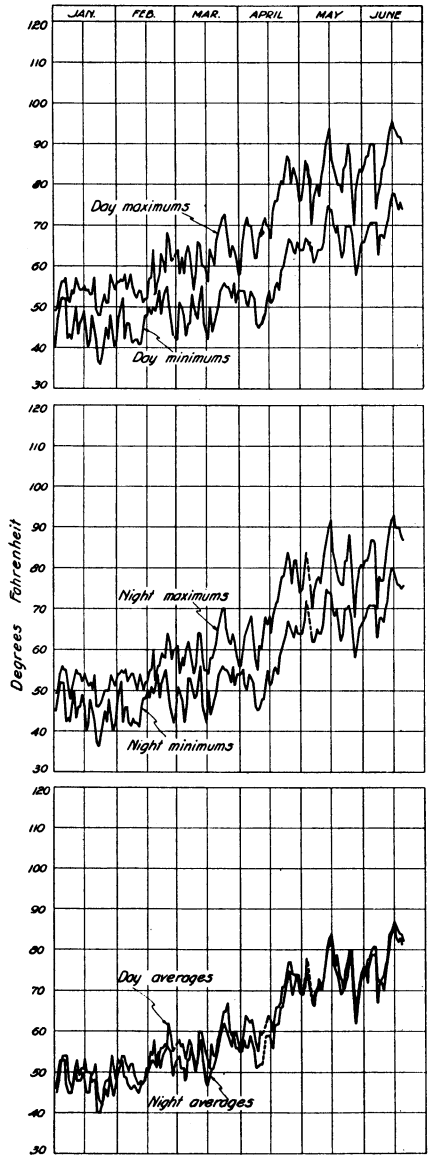

Fig. 10. Soil temperatures at 3-inch depth for 1927 period.

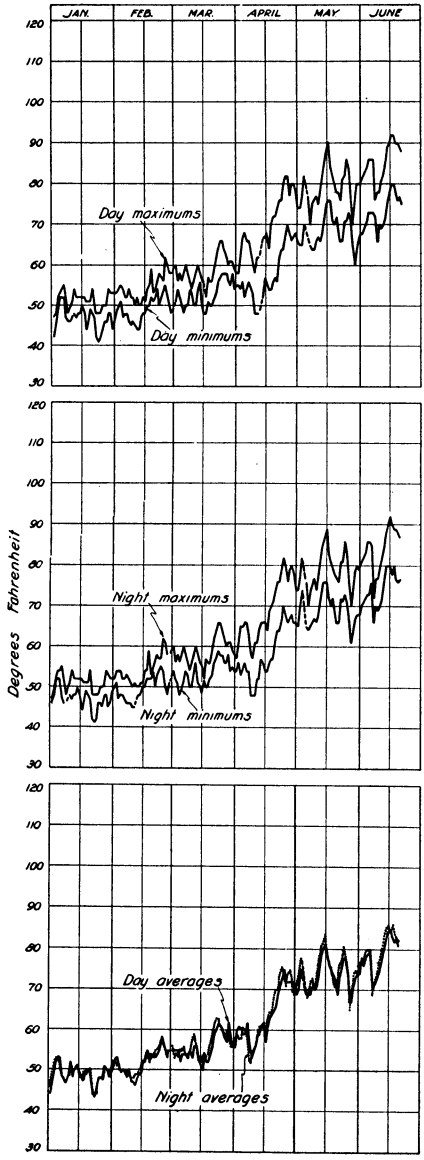

Fig. 11. Soil temperatures at 6-inch depth for 1927 period.

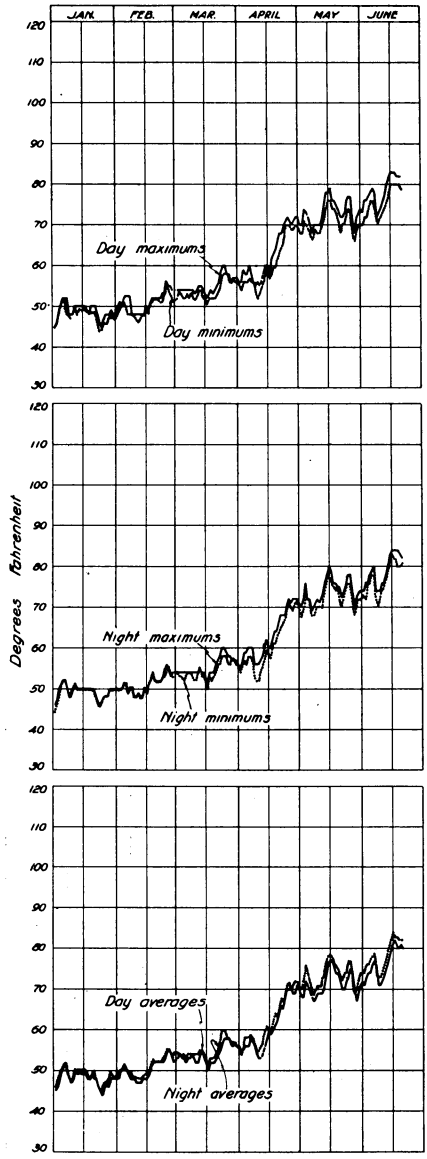

Fig. 12. Soil temperatures at 12-inch depth for 1927 period.

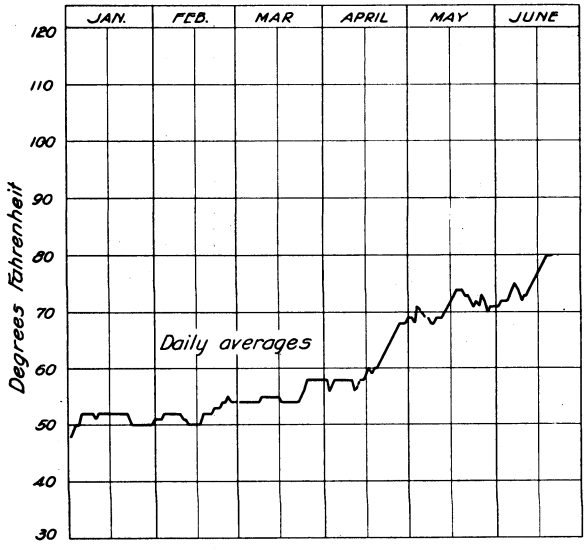

Fig. 13. Soil temperatures at 24-inch depth for 1927 period.

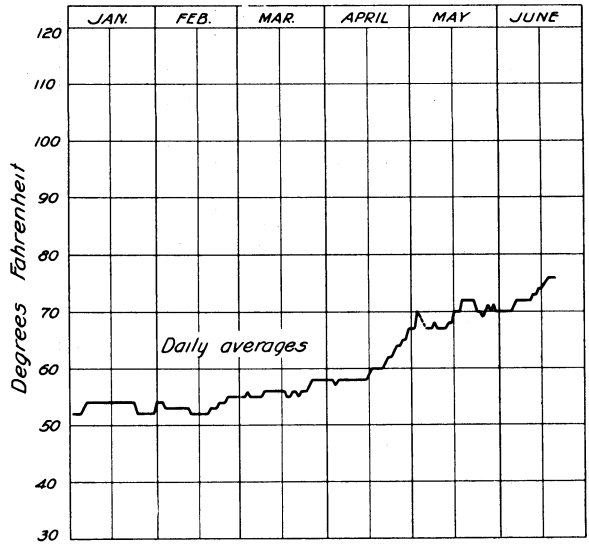

Fig. 14. Soil temperatures at 36-inch depth for 1927 period.

TABLE 7

DAYTIME AND NIGHTTIME AIR TEMPERATURES, JANUARY 1 TO JUNE 21, 1927

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
June 15	105°	January 8, 21	47°	January 1 to April 15	50°–70°	May 15, June 16, 17	65°	February 12	30°	25 times between January 7 and April 12	Less than 40°	April 24	42°
				April 15 to June 21	70°–95°					January 1 to May 12	40°–50°		
										May 12 to June 21	45°–55°		
Nighttime maximums						**Nighttime minimums**							
May 12, 13, 15 and June 14	75°	January 22	38°	January 1 to April 15	40°–55°	May 13, June 8, 14	57°	January 22	24°	48 times between January 6 and April 15	Less than 40°	May 4	26°
				April 15 to June 21	55°–65°					January 1 to April 15	35°–50°		
										April 15 to June 21	40°–55°		
Daytime averages						**Nighttime averages**							
June 15	93°	January 8, 18, 21	43°	January 1 to April 15	45°–60°	June 14	63°	January 22	29°	18 times between January 6 and April 11	Less than 40°	June 15	30°
				April 15 to June 21	60°–80°					January 1 to April 15	38°–52°		
										April 15 to June 21	45°–60°		

TABLE 8

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, ½-INCH DEPTH, JANUARY 1 TO JUNE 21, 1927

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
May 15, June 15	110°	January 21	50°	January 1 to April 15	55°–75°	June 15, 16	75°	January 23	32°	13 times between January 1 and March 18	Less than 40°	April 24	50°
				April 15 to June 21	80°–100°					January 1 to April 15	35°–55°		
										April 15 to June 21	55°–70°		
Nighttime maximums						Nighttime minimums							
June 14, 15	93°	January 21	42°	January 1 to April 15	45°–65°	June 14	74°	January 22	32°	15 times between January 6 and March 15	Less than 40°	May 14, 15	22°
				April 15 to June 21	65°–90°					January 1 to April 15	40°–50°		
										April 15 to June 21	50°–70°		
Daytime averages						Nighttime averages							
June 15	94°	January 21, 22	45°	January 1 to April 15	50°–65°	June 14	82°	January 22	34°	January 21, 22, 23	Less than 40°	April 20	33°
				April 15 to June 21	70°–90°					January 1 to April 15	40°–55°		
										April 15 to June 21	60°–80°		

TABLE 9

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 3-INCH DEPTH, JANUARY 1 TO JUNE 21, 1927

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
June 15	96°	January 22, 23	49°	January 1 to April 15	50°–70°	June 15, 16	78°	January 23	37°	January 22, 23, 24	Less than 40°	March 1	20°
				April 15 to June 21	70°–90°					January 1 to April 15	40°–55°		
										April 15 to June 21	55°–75°		
Nighttime maximums						Nighttime minimums							
June 15	93°	January 21, 22	46°	January 1 to April 15	50°–65°	June 14, 15	80°	January 22	37°	January 21, 22, 23	Less than 40°	May 15	18°
				April 15 to June 21	70°–90°					January 1 to April 15	40°–55°		
										April 15 to June 21	55°–75°		
Daytime averages						Nighttime averages							
June 15	87°	January 23	42°	January 1 to April 15	45°–63°	June 15	86°	January 21, 22	40°	January 1 to April 15	45°–60°	March 25, April 10	18°
				April 15 to June 21	67°–85°					April 15 to June 21	65°–83°		

TABLE 10

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 6-INCH DEPTH, JANUARY 1 TO JUNE 21, 1927

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
June 15, 16	91°	January 1	47°	January 1 to April 15	50°–65°	June 15, 16	80°	January 23	41°	January 1 to April 15	45°–55°	May 15	14°
				April 15 to June 21	70°–90°					April 15 to June 21	60°–75°		
Nighttime maximums						**Nighttime minimums**							
June 15	91°	January 1	47°	January 1 to April 15	50°–65°	June 13, 14, 15, 17	80°	January 22	41°	January 1 to April 15	45°–55°	May 15	13°
				April 15 to June 21	70°–85°					April 15 to June 21	60°–75°		
Daytime averages						**Nighttime averages**							
June 15, 16	85°	January 23	43°	January 1 to April 15	45°–62°	June 15, 17	86°	January 23, 24	44°	January 1 to April 15	45°–62°	March 23, April 24	3°
				April 15 to June 21	65°–85°					April 15 to June 21	65°–85°		

TABLE 11

DAYTIME AND NIGHTTIME SOIL TEMPERATURES, 12-INCH DEPTH, JANUARY 1 TO JUNE 21, 1927

Daytime maximums						Daytime minimums						Greatest spread	
Highest		Lowest		Usual		Highest		Lowest		Usual			
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Deg. Fahr.
June 15, 16, 17	83°	January 1, 24	45°	January 1 to April 15	45°–60°	June 15 to 19	80°	January 23, 24	44°	January 1 to April 15	44°–60°	June 15, 16, 17	3°
				April 15 to June 21	65°–80°					April 15 to June 21	65°–80°		
Nighttime maximums						**Nighttime minimums**							
June 15, 18	84°	January 1, 23	46°	January 1 to April 15	45°–60°	June 15	83°	January 1	44°	January 1 to April 15	45°–60°	June 18	4°
				April 15 to June 21	65°–80°					April 15 to June 21	65°–80°		
Daytime averages						**Nighttime averages**							
June 16	82°	January 24	44°	January 1 to April 15	45°–60°	June 15	84°	January 23	45°	January 1 to April 15	45°–60°	March 23, June 4	3°
				April 15 to June 21	65°–80°					April 15 to June 21	65°–80°		

TABLE 12

DAILY AVERAGE SOIL TEMPERATURES, 24-INCH AND 36-INCH DEPTHS, JANUARY 1 TO JUNE 21, 1927

24-inch depth						36-inch depth					
Highest		Lowest		Usual		Highest		Lowest		Usual	
Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.	Date	Tem.
June 18, 20	80°	January 1	48°	January 1 to April 15	50°–60°	June 17 to 20	76°	January 1 to 4	52°	January 1 to April 15	52°–58°

The 1925 period under consideration extended from February 20 to September 30 inclusive. Where the ranges in temperature are given, as between two dates, it is to be understood that they indicate the general trend. By a close study of the figures one will find that there were a few days when these ranges or spreads were below or above those mentioned. The ranges during this 1925 period in the air day maximums were of about the same magnitude as those of the soil at the 3-inch depth, while the air day minimums were more comparable with those of the soil at the ½-inch depth. The night maximums and minimums for the air were of practically the same range as were the ½-inch soil temperatures. The average day air temperatures were of about the same magnitude as those of the soil at the 3-inch depth, while the average night air temperatures were more comparable with those of the soil at the ½-inch depth. At the 6-inch depth the average night temperatures were as much as 3° higher and at the 12-inch depth less than 2° higher than the average day temperatures. At the ½ and 3-inch depths the average day temperatures were higher than the average night temperatures.

After about the first part of June, 1925, there was a distinct rise in the air and soil temperatures and after September 5 a noticeable drop.

The 1927 period extended from January 1 to June 20 inclusive and furnishes another period for comparisons of daytime and nighttime temperatures. This period, however, extends just up to the beginning of the warm summer and not through the summer as was the case with the 1925 period. The soil temperatures shown at the ½-inch depth are more comparable with the air temperatures than any of the other soil depths. This includes the maximums, minimums, and average temperatures during the daytime and nighttime. After about April 20, 1927, there was a distinct rise in the air and soil temperatures.

The daytime and nighttime maximums and minimums were lower in 1927, as a general rule, than in 1925. This is due to two factors: first, the 1925 period included more of the warmer months, and second, during the early part of the 1925 period there was different distribution of the rain and consequently different soil temperature conditions than in the corresponding portion of the 1927 period. In 1925 the number of days when it rained were few but on those days the rainfall was heavy, while in 1927 there were more days when it rained but the rainfall was light for any particular day. This has been previously shown, both by tables and figures.[8]

SUMMARY

This paper presents a comparison of air and soil temperatures at depths of ½, 3, 6, 12, 24, and 36 inches in an area that was kept free of vegetation and not irrigated. Two periods were selected, one in 1925 from February 20 to September 30; and the second in 1927 from January 1 to June 20. The data presented are the maximum, minimum and average temperatures which were found between sunrise and sunset and which are called the daytime or day temperatures and from sunset to sunrise, the nighttime or night temperatures. It is the belief of the writer that a consideration of such temperature fluctuations is of importance as they may relate to plant and animal life.

In the 1925 period the number of daylight hours ranged from approximately 11 hours to 15 hours, while in the 1927 period which did not include as many of the warmer months they ranged from slightly over 9 hours to approximately 15 hours. The maximum air temperature for the daytime usually occurred several hours before sunset and for the night, just after sunset. The minimum day and night air temperatures in general occurred around sunrise. The maximum day soil temperatures at the ½- and 3-inch soil depths occurred before sunset while at the 6- and 12-inch depths due to the lag they usually occurred near or after sunset. The night temperatures for the 6- and 12-inch depths, therefore, averaged higher than the day temperatures.

In the 1925 period a day minimum air temperature of less than 40° occurred only a few times and at the ½-inch depth there were 11 times when it was below 40°. At depths of 3, 6, 12, 24, and 36 inches at no time was the day minimum below 42°. A night minimum air temperature of less than 40° occurred only a few times while at the ½-inch depth it occurred 12 times. At depths of 3, 6, 12, 24, and 36 inches the lowest night minimum was 42° for the 3-inch depth. The maximum day and night temperatures for the air and various soil depths varied considerably during the period.

The day average temperatures for the air, ½-inch, and 3-inch soil depths were higher than the night temperatures, while at the 6- and 12-inch depths the reverse was true in the 1925 period. At depths of 24 and 36 inches there was no regular rise and fall in the temperatures during a 24-hour period, simply either a gradual cooling or warming depending on the season of the year.

During the 1927 period a day minimum air temperature of less than 40° occurred 25 times, while at the ½-inch soil depth it occurred 13 times and at the 3-inch depth only three times. At depths of 6, 12, 24, and 36 inches at no time was the day minumum below 41°. A minimum night air temperature of less than 40° occurred 48 times, at the ½-inch depth 15 times, and only 3 times at the 3-inch depth. At depths of 6, 12, 24, and 36 inches the lowest night minimum was 41° at the 6-inch depth. The maximum day and night temperatures for the air and various soil depths were of less magnitude in the 1927 period than in the 1925 period.

The same fact was established by the 1927 data as was by the 1925 data relative to the relationship between the day and night average temperatures.

The general ranges in the day and night maximums, minimums and averages for the air and various soil depths are fully discussed for each of the two periods as well as the exact ranges for certain days when the largest or smallest ranges occurred.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.
4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
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