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CONTENTS

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DAILY AND SEASONAL AIR AND SOIL TEMPERATURES AT DAVIS, CALIFORNIA*

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INTRODUCTION

Since 1924 certain phases of soil temperature have been studied at Davis, California, in order to ascertain the influence of various soil conditions, of moisture, and of the shading effect of crops upon soil temperatures.

The data herein reported will show that the ranges in thermal environment of various parts of a growing plant-top, stems, and roots are apparently very great. For example, the leaves and branches on July 17, 1925, were in atmosphere heated to 116° Fahrenheit; the stem (unshaded) just below the ground surface was in soil having a temperature of 143°; while the roots would be in a medium at 107° for the 3-inch depth, and 84° for the 24-inch depth.

Bacteria and fungi of many varieties may live at low temperatures in the soil. The limit below which most cultivated plants are practically inactive lies in general between 40 and 45° F. Bacterial activity which increases the supply of available nitrogen is stimulated by relatively high temperatures while at extremely high temperatures this activity is reduced to a degree as unimportant as when too low temperatures prevail. Thus a knowledge of the range of

* The cooperation of several individuals is hereby acknowledged: Mrs. J. B. Simmons, Messrs. J. W. Tidmore and Fred Flint for their assistance in collecting the data; and Mr. J. L. Lynde for preparing the final copy of the figures.

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temperature at various depths in the soil, will be helpful in the interpretation of bacterial activity.

The effect of soil temperatures on the chemical reactions taking place in soils is shown by the varying character of the soil solution throughout the year. The diffusion of the dissolved material away from the soil and through the roots and other tissues of the plant are probably hastened with a rise of temperature.

The sharp contrast between the highly decomposed soils of wet tropical regions and the moderately decomposed soils of the polar regions is due to the greater rainfall in the tropics and the influence of high temperatures in promoting rapid chemical action in the soil.

LOCATION OF EXPERIMENTAL SITE

The site under study lies on a recent alluvial fan, the apex of which is approximately 14 miles west of the site and the base is about 7 miles east. The slope in the immediate vicinity ranges from 5 to 10 feet per mile in a general southeast direction. The nearest hills are those at the apex of the fan. The soil which is a member of the Yolo series is derived mainly from sedimentary rocks and is brown in color when moist.

The texture of the surface soil is loam and at a depth of 3 feet it changes to a fine sandy loam of a light brown color. From well borings made in the immediate vicinity it is found that no hardpan or bedrock is encountered within 150 feet of the surface. The surface water table is normally at a depth of about 20 feet while the depth of the irrigation wells are approximately 120 feet. The source of the soil moisture in the upper six feet of soil was from rainfall alone as it has been determined[10] that with the Yolo loam "water tables at ten feet or more below the surface would be below the maximum height of capillary rise and would result in no movement of water to the surface."

As the rains occur during the winter only and the air temperatures are lower during the rainy season the moisture content in the surface soil is naturally higher from September to May than during the rest of the year. During the dry season the moisture content of the surface soil was decreased by direct evaporation from the bare plots, as the land was not cropped, and all weeds and other vegetation was kept down by regular cultivation. No crops or vegetation have been allowed to grow on this plot after 1923.

SOIL AND ATMOSPHERIC CLIMATE

The "soil climate" is to a large extent dependent on the "atmospheric climate," as many investigators have shown that the changes in barometric pressure, temperature, humidity, and other climatic factors influence the soil climate. Some of the recent contributors to this phase of research have been Bouyoucos and McCool,[1] Taylor,[14] Walker,[16] Harrington,[3] Shaw,[9] and Smith.[11] Certain elements of soil climate, as for instance temperature, have pronounced effects on plant growth, diseases, bacterial activity, etc. These problems have received widespread attention during the past few years as by Jones, Johnson and Dickson,[4] Camp and Walker,[2] Valleau, Kenny and Kinney,[15] Mason,[7] and many others. Russell[8] has made an areal analysis of California climates and suggested a classification of the various types based on the classification scheme of Vladimir Köppen.[5] Russell characterizes the climate of the Sacramento Valley where this soil temperature work has been carried on as "Hot Summer Mediterranean, olive climate, with its warmest month averaging above 71° F. The type of Mesothermal climate characterized by at least three times as much rainfall in its wettest winter month as received during its driest month is commonly known as Mediterranean."

In the latest annual summary of the United States Department of Agriculture Weather Bureau[6] the average annual precipitation for Davis is given as 17.03 inches with the month of January having an average of 3.87 inches and the driest months, June and July having an average of 0.01 inch. The warmest month, July, at Davis averages 74.6° F.

SOIL MOISTURE VARIATIONS

Determinations of the moisture content of the area where these soil temperature studies were carried on were made at frequent intervals. The samples were obtained by means of a soil tube, at the following depths, in inches: 0–4, 4–8, 8–12, 12–24, 24–36, 36–48, 48–60, and 60–72 in four locations in the area. The samples were dried to constant weight at 212° F and the percentage calculated on oven dry basis.

With subsoil drainage unrestricted, which condition existed in this area, during the winter season the soil retained moisture up to its normal moisture capacity or to its field moisture capacity of 20–22 per cent in the loam surface soil (0–36 inches) and 16 to 18 per cent in the fine sandy loam subsoil (36–72 inches). This condition was reached after the seasonal rainfall totaled about 3 inches which appeared sufficient to replenish the moisture lost during the previous dry season. Many moisture equivalent determinations made on part of the soil samples from which the soil moisture tests were made show that the moisture equivalent of the surface loam soil is around 20 per cent and of the fine sandy loam subsoil is 16, or approximately the amount of moisture normally present in the soil during the rainy season.

During the dry season of the year, on account of the fact that this area was not irrigated, the moisture content of the soil decreased. The surface 4 inches naturally dried out to the greatest extent so that by September, when the rains usually start, it contained approximately 5.00 per cent. The moisture content of the next layer (4–8 inches), dropped to about 12 per cent and for the section, 8–12 inches, to about 15 per cent. In the sections, 12–24 inches, and 24–36 inches, the lowest moisture content was about 18 per cent. In the various sections of 36–72 inch depth the soil was a fine sandy loam and the lowest moisture content was around 15 per cent. With no crop growing, and cultivating the surface 4 inches once a month, there was a changing moisture content extending to a depth of 72 inches. The loss of moisture from the soil was brought about mainly by vapor movement, possibly aided by some capillary movement. In another portion of this area, experiments were conducted with various types of paper mulches which will be reported in the future. Certain phases of this study have been reported[12] but mention is made here in order to offer evidence about soil moisture movements. By covering the soil with an unperforated black paper at the beginning of the dry season it was found that the surface 4-inch section contained approximately 20 per cent of moisture at the end of the dry season. The 4–8 inch section was drier and its moisture content at the end of the dry season was generally about 12 per cent. Beads of moisture collected on the underside of the paper and as only the 0–4 inch area maintained its moisture content and the area immediately below it was much drier it is clear that moisture movement in the vapor phase is an important consideration.

INSTALLATION OF RESISTANCE THERMOMETERS

Electrical resistance thermometers were standardized and placed at the depths of ½, 3, 6, 12, 24, and 36 inches in the bare cultivated area. They were put in place by digging a small hole, carefully preserving the soil from the various depths. The thermometer bulbs were then inserted in the undisturbed soil horizontally so that they were at least 8 inches from the wall of the excavation. The soil was then replaced, care being exercised to attain the same structure as originally existed at the various depths.‡ The resistance thermometers were connected to an overhead cable which extends for a distance of 150 feet to a small frame structure wherein an automatic Leeds and Northrup temperature recorder was installed. The temperature from each individual resistance thermometer was recorded every 15 minutes, day and night, in degrees Farhenheit. Air temperatures herein recorded were obtained at a height of four and one-half feet above the soil at the Davis Station of the United States Weather Bureau located approximately 1400 feet northwest of the soil temperature plots. A shelter house similar to the United States Weather Bureau type is located on the area where the soil temperature studies were made, and tests made at different seasons were found to be in close agreement with those occurring at the Davis Weather Bureau Station. Therefore, the data for the curves were taken from the records of the latter. Temperatures of the immediate soil surface are not reported herein although occasional records were obtained by use of the copper bulb thermometer.[11] The soil temperature ranges, occurrence of maximums and minimums with respect to sunrise and sunset, and the diurnal range for the various depths during the warmest week in 1925 have been previously reported.[12] From the data given in the accompanying figures similar information can be obtained for any part of the periods shown. In preparing the figures it was necessary to record the data by hourly intervals but care was always exercised that the actual maximums and minimums were accurately shown.

‡ Temperatures are now being obtained in another phase of the project, at depths of 48, 60, and 72 inches also. The results will be reported in a later publication.

INTERPRETATION OF FIGURES

The prevailing sky condition for each particular day is given, being indicated as cloudy if the sky was overcast the greater part of the 24-hour period although there may have been a few hours with a clear sky as allowed in the Weather Bureau classification. The same is shown relative to direction of the wind and in case it was variable it is so indicated. During the winter months the north winds are cold while during the dry summer months they are hot. The southwest wind is cool in the summer and warm in the winter as it comes through the Golden Gate over the San Francisco Bay and then swings northward over land areas for a distance of about 30 miles before it reaches this area.

The rainfall occurring on any particular date is also shown so that the effect of this climatic element can also be noted.

The data herein reported is for two continuous periods, February to October, 1925, and December, 1926 to July, 1927. Occasionally the instrument was stopped because of making adjustments, failure of current, or for repairs; such periods are indicated by breaks in the curves. After installing a direct current motor, trickle charger and 24-volt battery having 50 ampere hours capacity, there have been relatively few interruptions in operation. Since this change was made the recorder has been operating on almost perfect schedule and in a period of 24 hours the usual time error is not over 2 minutes. Corrections are made when necessary and this error is not cumulative. When operating on the alternating current the line load varied and the current would be cut off for short periods making the time error greater. The temperatures shown on the graphs are within one degree of accuracy and the time error is less than 5 minutes.

TEMPERATURE RECORDS FOR 1925 PERIOD

The first set of figures (1–31 inclusive) covers the interval from February 23, 1925 to September 28, 1925 and shows the temperature ranges that crops would be subjected to when planted early in the spring and harvested before the heavy rains commenced in the fall. In this period of 31 weeks (217 days) a large number of crops are sown and harvested in California. For emphasis, it is again stated that the area where these studies were made was not irrigated.

Air Temperature Ranges During 1925 Period.—The minimum air temperature of 30° was reached at 6 A.M. on March 10, 1925 (fig. 3) while the sky was clear and at the beginning of a six-day period without rain and with a prevailing wind direction from the north. The maximum air temperature of 116° was reached at 1 P.M. on July 17 (fig. 21) on a clear day with north wind. In the autumn the minimum air temperature before September 28 was nearly 45° in the week of September 21 (fig. 31). The range in air temperature during the 1925 period was 86°.

Soil Temperatures at One-half Inch Depth for 1925 Period.—The minimum soil temperature for soil thermometer No. 1 (one half inch depth) occurred at practically the same time as the minimum air temperature on March 10 (fig. 3) and was 29° F. The maximum soil temperature at one-half inch depth which was of sufficient duration to affect the deeper soil amounted to 143° and occurred on July 17 (fig. 21) at 2 P.M., one hour after the maximum air temperature. A higher maximum of 146° (fig. 23) was reached at this depth but this was not reflected in the temperatures of the deeper soil layers because the soil was drier and the duration was not as long on July 17. The minimum temperature in the autumn before September 28 for the one-half inch depth was 55° and occurred at practically the same time as the minimum air temperature (fig. 31). There was a range in temperature during the 1925 period at a depth of one-half inch in the soil of 114° or *28 degrees greater than in the range in the air temperatures* during the same period.

Soil Temperatures at 3-inch Depth for 1925 Period.—The minimum soil temperature for the 3-inch depth (thermometer No. 2) was 42° and occurred at 7 A.M. on March 10 (fig. 3) one hour after the minimum air temperature had been reached. The maximum temperature at this depth amounting to 107° was reached on July 17 (fig. 21), two hours after the maximum air temperature. The lowest temperature for the 3-inch depth after the summer months and before September 28 was 68° and occurred during the last week. The range in temperature for the 3-inch depth was 65° or 21° less than that of the air and 49° less or only 57 per cent of the range for the one-half inch depth.

Soil Temperatures at 6-inch Depth for 1925 Period.—The soil temperatures obtained at a depth of 6 inches are indicated by curve No. 3 on the figures. The minimum temperature at this depth was 44° and occurred at 8 A.M. on March 10 (fig. 3) two hours after the minimum air temperature. The maximum temperature of 101° was reached on

July 17 (fig. 21) which gives a range of temperature at the 6-inch depth of 57° during this period. This range was 88 per cent of the range which had occurred at the 3-inch depth or 50 per cent of the range for the one-half inch depth. After the summer period the minimum temperature reached at the 6-inch depth was 73° which occurred during the week of September 21 (fig. 31). At the depth of 6 inches during this period of 31 weeks the soil temperature did not fall below 44° F.

Soil Temperatures at 12-inch Depth for 1925 Period.—Daily changes in soil temperatures are clearly evident at the 12-inch depth shown in figures 1–31 inclusive and as has been previously reported.[8] The temperatures obtained for this depth are indicated on the figures by curve 4. The minimum temperature was 48° at 12 noon on March 10 (fig. 3) or six hours after the minimum air temperature. The maximum temperature of 93° was reached at 1 A.M. on July 18 (fig. 21) which was twelve hours after the maximum air temperature. A range in temperature of 45° is shown for the 12-inch depth or 79 per cent as great as occurred at the 6-inch depth, or 40 per cent of the range for the one-half inch depth. The minimum temperature at the end of the period was 73°, the same as for the 6-inch depth.

Soil Temperatures at 24-inch Depth for 1925 Period.—The temperatures for the 24-inch depth are shown as curve 5 on the figures. The minimum was 52° and occurred on March 12 (fig. 3) at midnight or sixty-six hours after the minimum soil temperature. The maximum of 87° was reached at 12 noon on July 19 which was twenty-three hours after the maximum air temperature. The range of 35° for this depth was 78 per cent as great as had occurred at the 12-inch depth or nearly 31 per cent of the range for the one-half inch depth. The temperatures during the last week (fig. 31) at this depth were fairly constant, dropping to 77° during the last two days. In general there are no regular increases accompanied by decreases in temperature during a twenty-four hour period at this depth, there being either a gradual warming or a gradual cooling.

Soil Temperatures at 36-inch Depth for 1925 Period.—The minimum temperature for the 36-inch depth (curve 6) was 53° which occurred at midnight on March 12 (fig. 3) at the same time as the minimum for the 24-inch depth. The maximum of 84° occurred at 11 A.M. (fig. 22) on July 22 which was 118 hours after the maximum air temperature. The range in temperature for this depth was 31° and was 90 per cent of that at the 24-inch depth or 27 per cent as great as had occurred in the one-half-inch section. Throughout the entire last week (fig. 31) the temperature for this depth was uniform. It will be noted that curve 6 which indicates the temperature changes for this depth is smoother than the others.

Effect of Character of Sky, Rain, and Wind During 1925 Period.—It is difficult to show the effect of the rain, wind, or cloudiness by the scale used in the accompanying figures. Average conditions for each twenty-four hour period only are shown. The velocity of the wind naturally varies considerably in a twenty-four hour period. It was regularly noticed that sudden changes in wind direction, velocity or cloudiness were reflected in the soil temperatures to a depth of at least 3 inches when these conditions endured for as short a period as ten minutes. Preceding the middle of May in general the north wind has a cooling effect on the soil temperatures while later the opposite is true. The south winds are opposite in effect to the north winds. Many times during the summer months the wind is from the north during the daylight hours and at night there is a slight southerly cooling wind. This could be clearly shown only by using such a scale for the figures whereby the velocity and direction of the winds could be indicated at least by fifteen-minute intervals. The effect of "day breezes" during the summer months is therefore warming as the air moves a long distance over land areas while the "night breezes" are cooling because they come from over water surfaces and only a short distance over land areas.

Clear weather before the middle of May is accompanied by increasing soil temperatures but when combined with north winds a decreasing effect is noted. Cloudy weather without rain culminated by southerly winds aids in reducing the daily range in soil temperature for the surface 24 inches of soil. Particular periods can be observed when the effect of cloudiness or wind direction are more noticeable than at other times. The effect of rainfall on soil temperatures is most effectively shown in figures 5 and 6 where during the period of March 29–31, inclusive, there was a total rainfall of about 3 inches. This rain came after a period of five dry weeks.

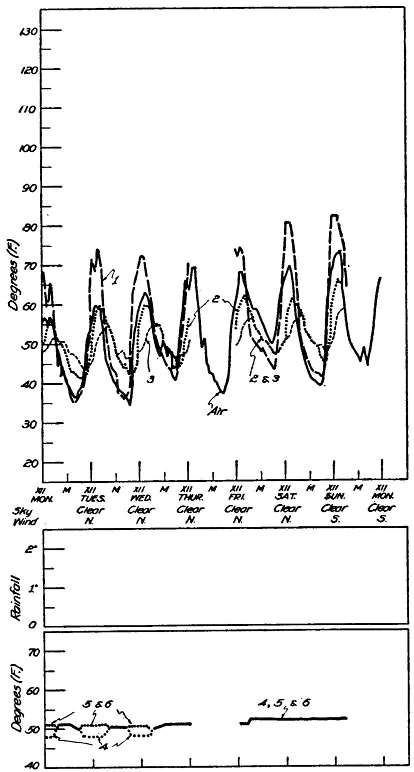

Fig. 1.—Week of February 23, 1925.

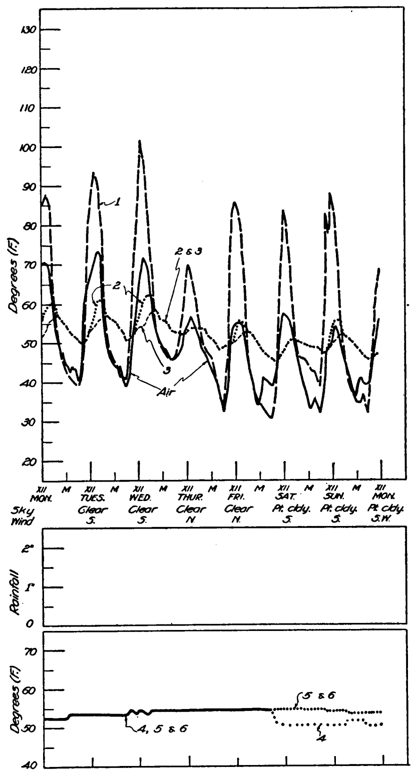

Fig. 2.—Week of March 2, 1925.

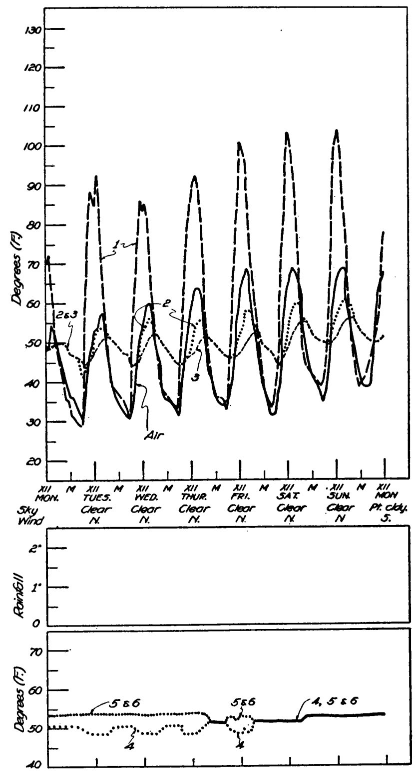

Fig. 3.—Week of March 9, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

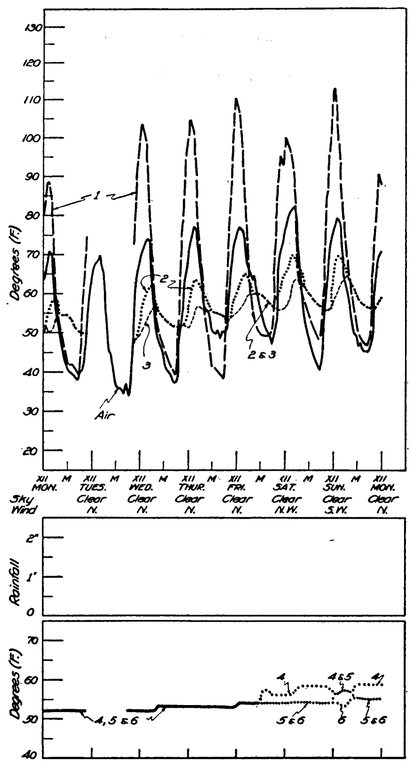

Fig. 4.—Week of March 16, 1925.

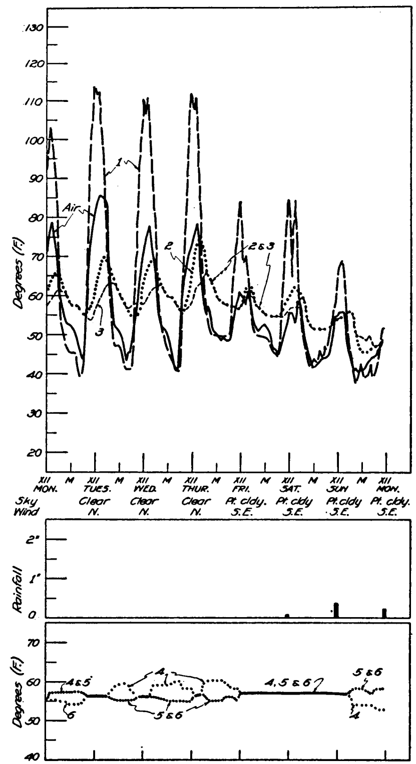

Fig. 5.—Week of March 23, 1925.

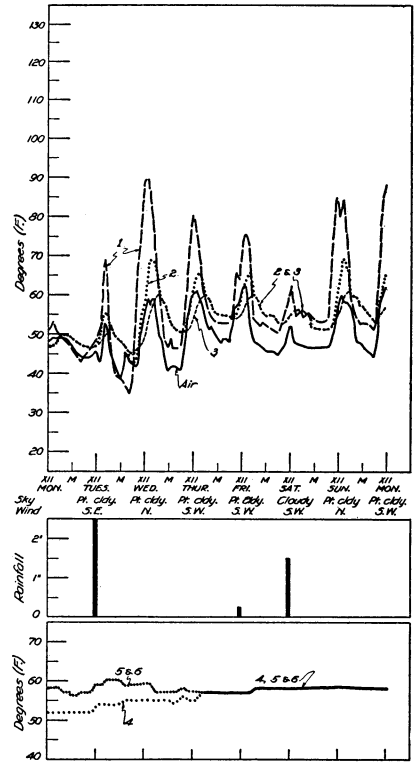

Fig. 6.—Week of March 30, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

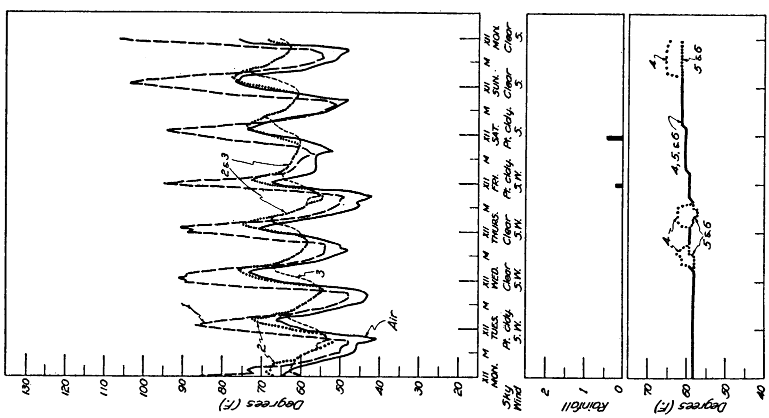

Fig. 7.—Week of April 6, 1925.

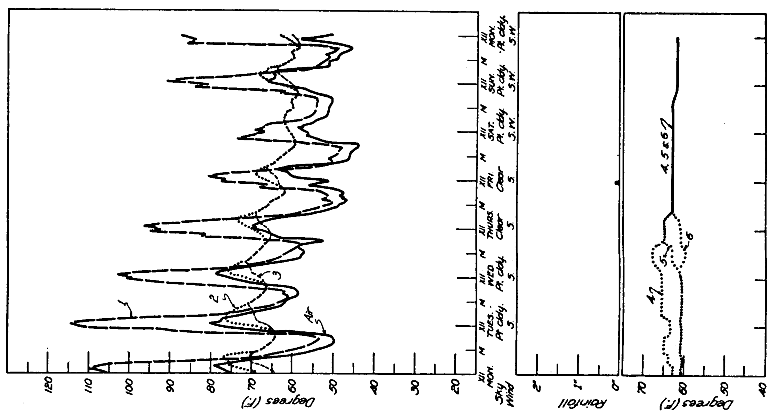

Fig. 8. Week of April 13, 1925.

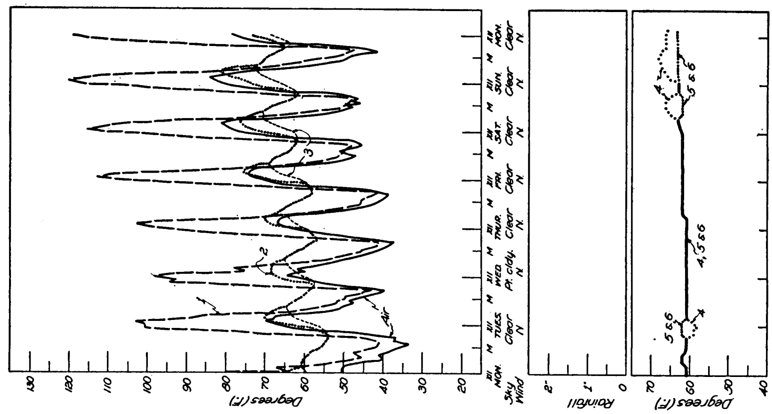

Fig. 9.—Week of April 20, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

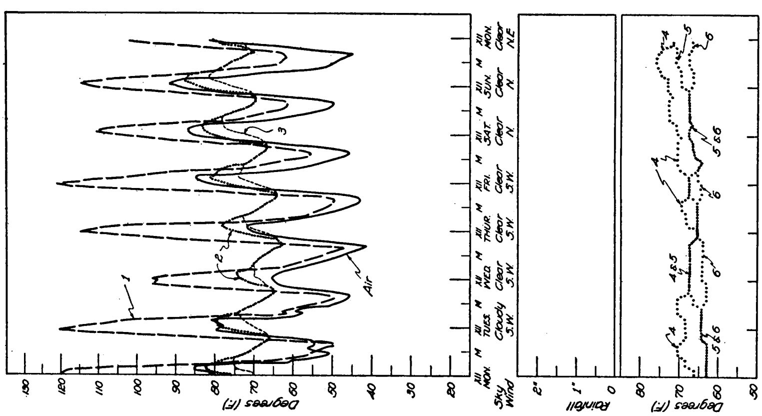

Fig. 10. Week of April 27, 1925

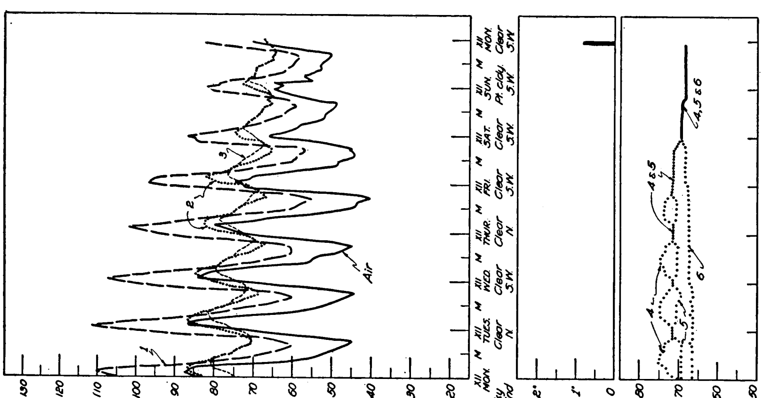

Fig. 11. Week of May 4, 1925

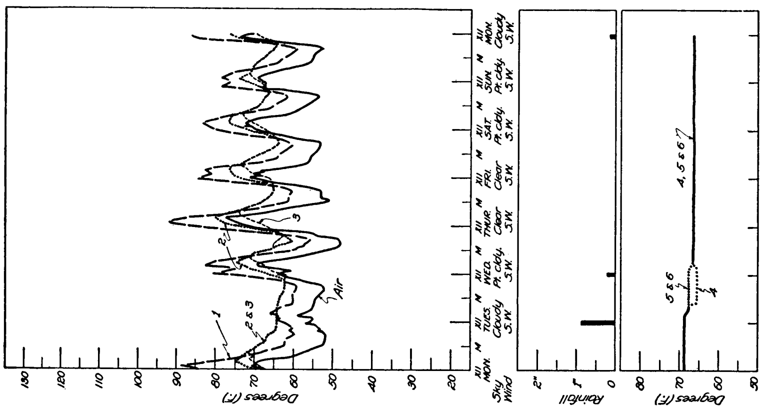

Fig. 12.—Week of May 11, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

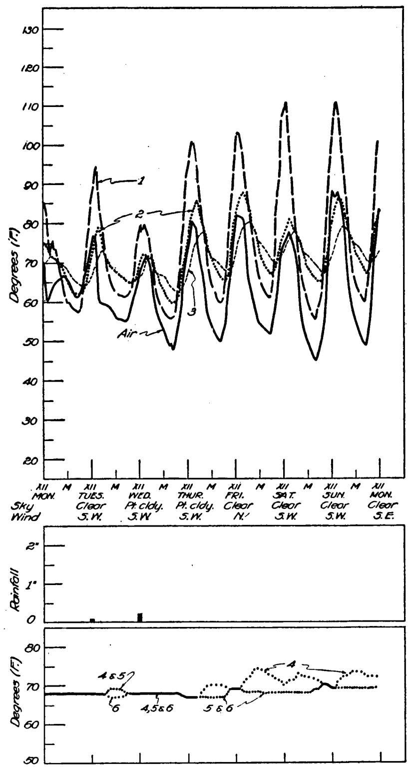

Fig. 13. Week of May 18, 1925

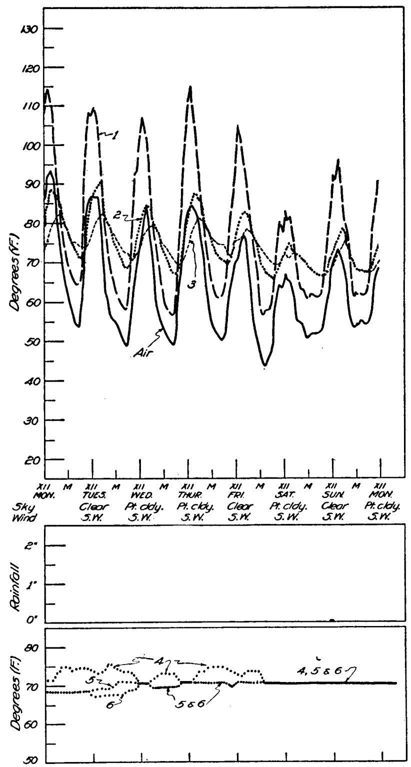

Fig. 14. Week of May 25, 1925

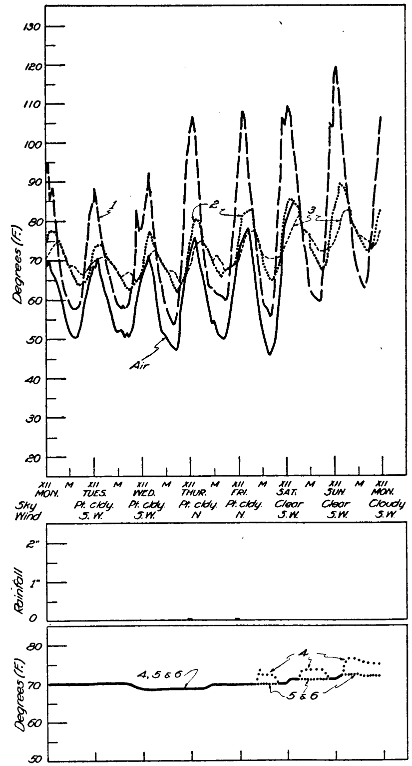

Fig. 15.—Week of June 1, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

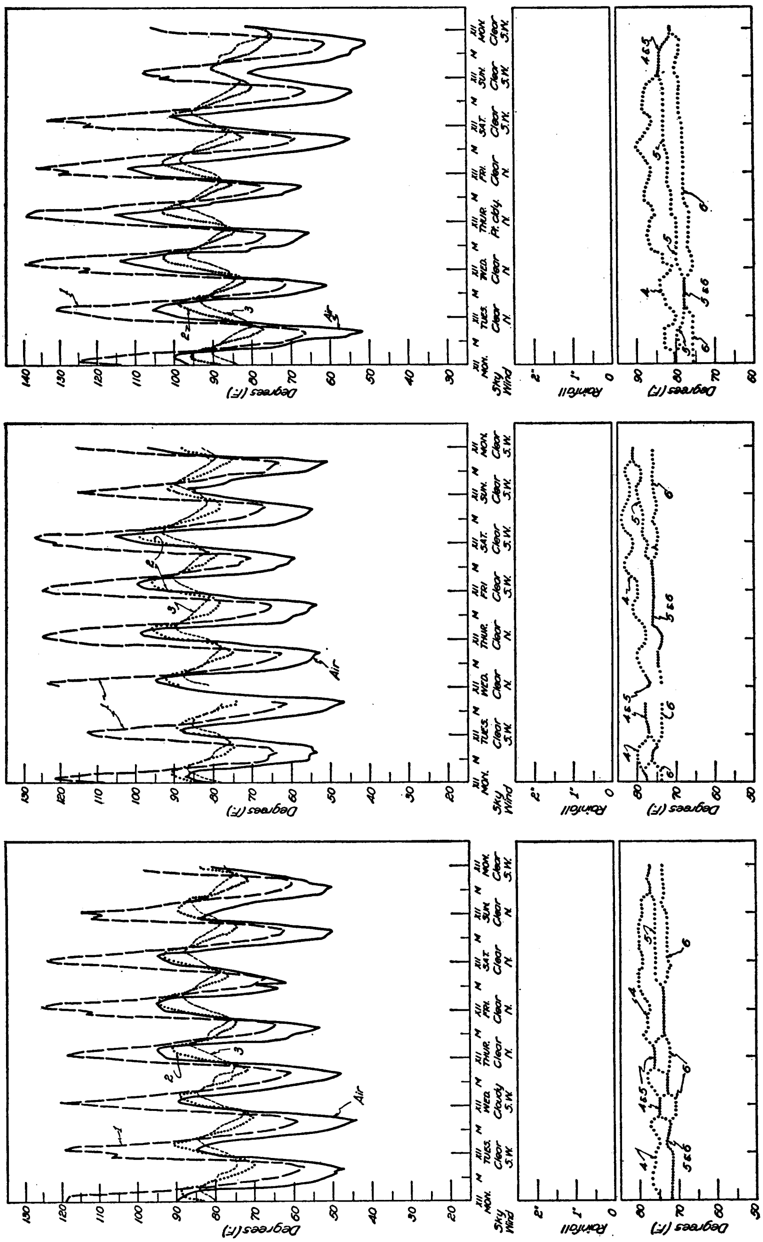

Fig. 16. Week of June 8, 1925 Fig. 17. Week of June 15, 1925 Fig. 18.—Week of June 22, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

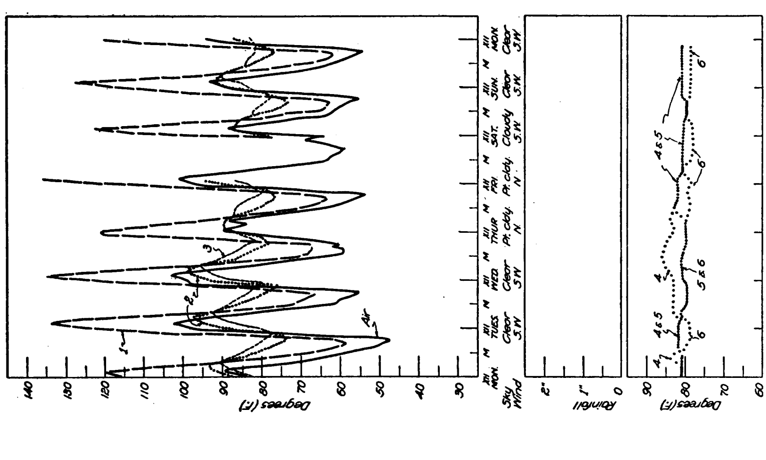

Fig. 19. Week of June 29, 1925

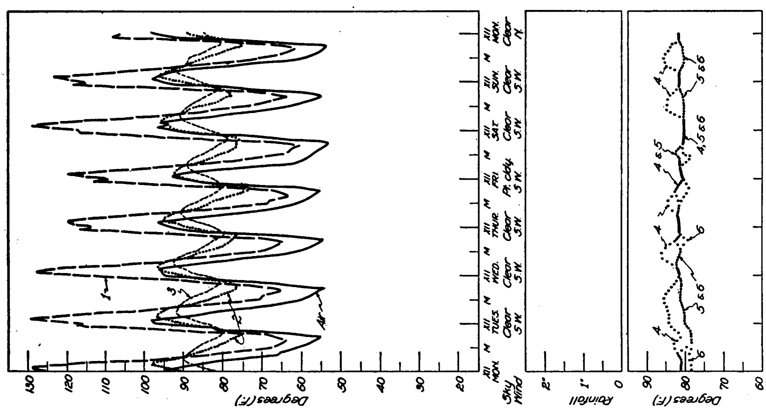

Fig. 20. Week of July 6, 1925

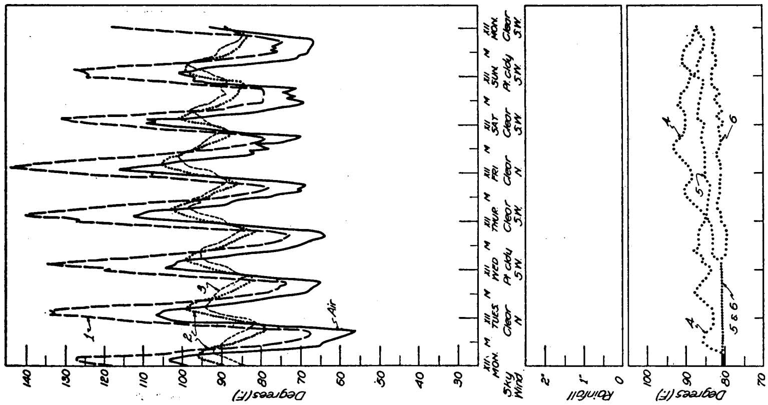

Fig. 21.—Week of July 13, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

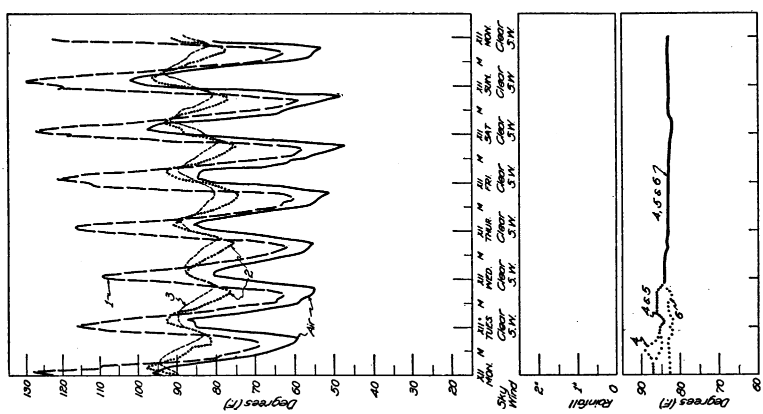

Fig. 22. Week of July 20, 1925

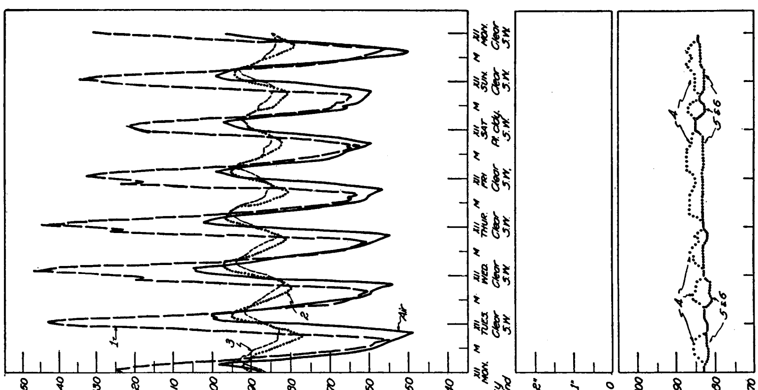

Fig. 23. Week of July 27, 1925

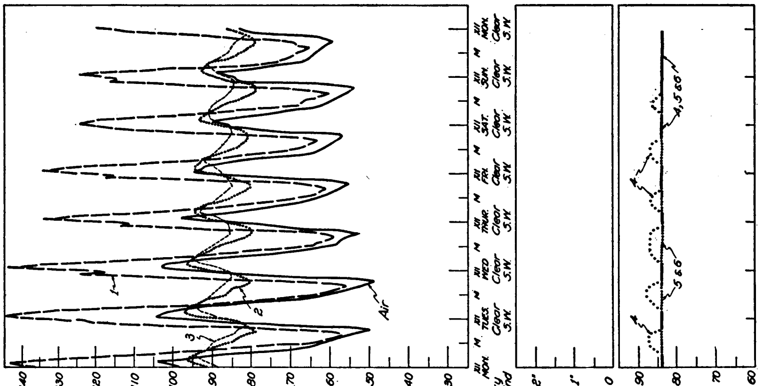

Fig. 24.—Week of August 3, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

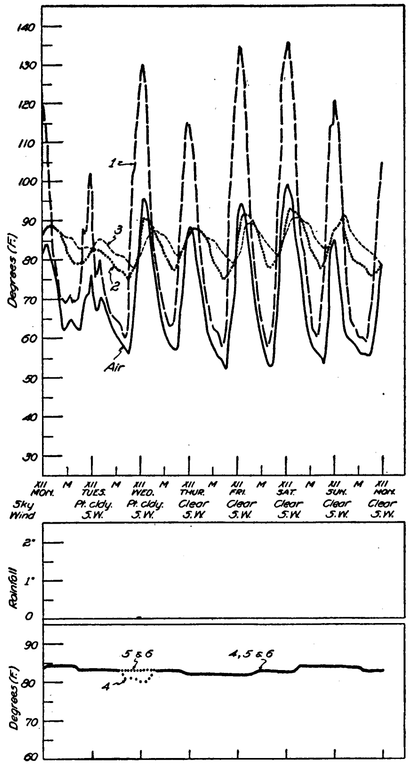

Fig. 25. Week of August 10, 1925

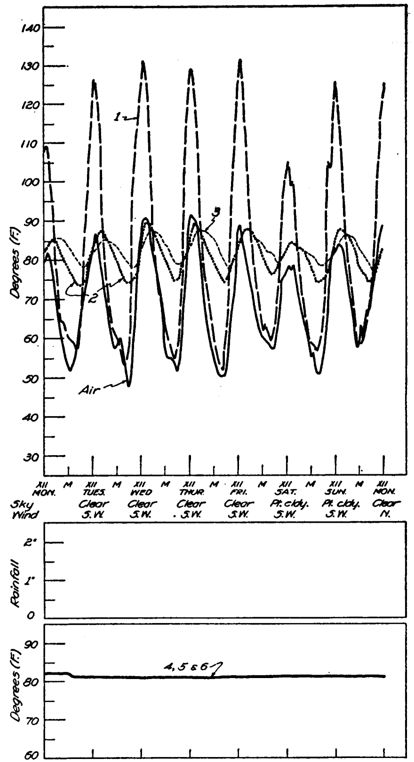

Fig. 26. Week of August 17, 1925

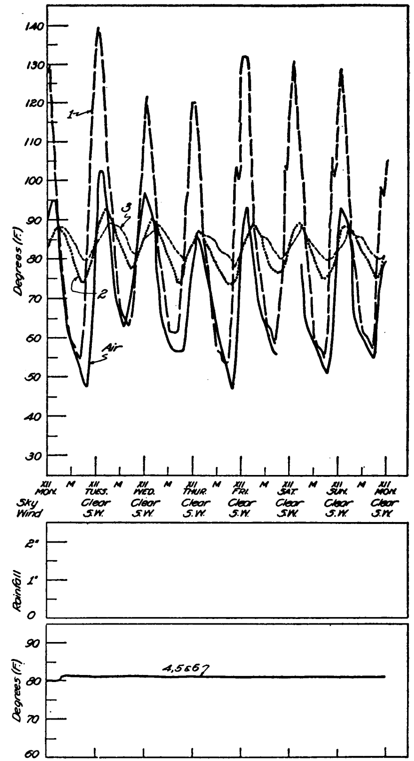

Fig. 27.—Week of August 24, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

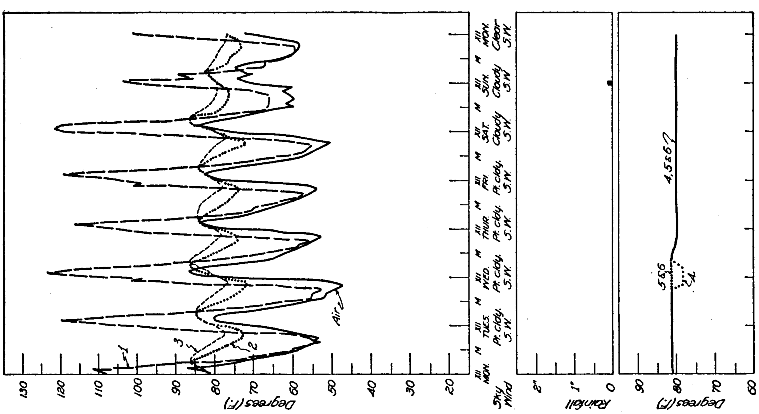

Fig. 28. Week of August 31, 1925

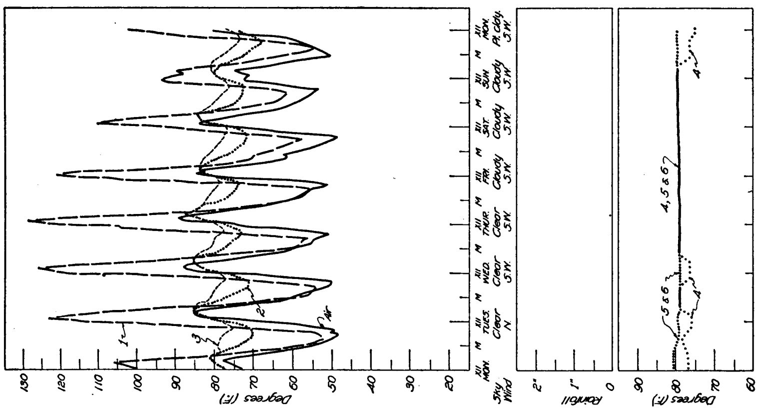

Fig. 29. Week of September 7, 1925

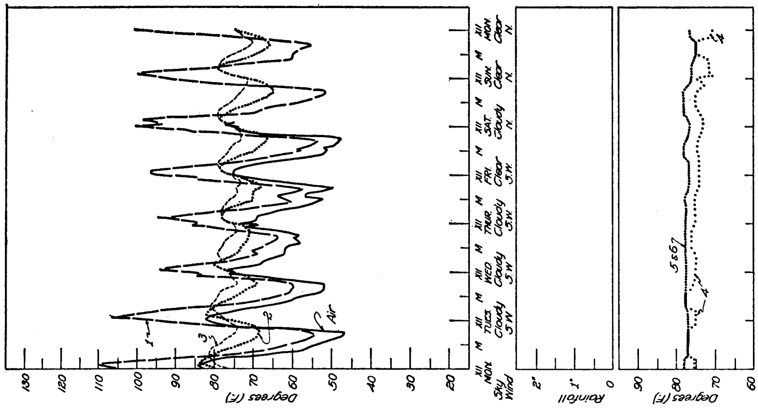

Fig. 30.—Week of September 14, 1925.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

TEMPERATURE RECORDS FOR 1927 PERIOD

The next set of figures (32–57) inclusive takes into consideration the temperature conditions that fall sown crops would be subjected to. This period extends from December 20, 1926 to June 20, 1927 and is also of aid in comparing certain similar dates with the first set (figures 1–31). The lowest air temperatures at Davis usually occur during December or January and frequently the highest occur about the middle of June so this set of data might prove of value from that viewpoint as well as for fall sown crops and short season spring crops.

Air Temperature Ranges During 1927 Period.—The lowest air temperature was 24° and occurred at 5 A.M. on December 27 (fig. 32) while the sky was clear and the air calm. This was preceded by a period of four days when the prevailing wind direction was from the north. For the five days from December 27 (fig. 32) to December 31 (fig. 33), inclusive, the minimum ranged from 24° to 26° F. The maximum air temperature of 105° occurred at 2 P.M. on June 15 (fig. 57) during a period of clear weather when the prevailing wind was from the north. During the periods when the maximum and minimum air temperatures were reached, the north wind had either a cooling or warming effect depending on whether the land area over which it passed was cold as in winter or warm as in summer. The range in the air temperatures during the 1927 period of observation was 81°.

Soil Temperatures at One-half Inch Depth for 1927 Period.—The minimum soil temperature at the one-half inch depth (curve 1) was 32° and occurred at 5 A.M. on December 27 (fig. 32) at practically the same time when the minimum air temperature occurred. The surface soil at this time was moist. The maximum temperature of 108° was reached at 3 P.M. on June 15 (fig. 57), one hour after the maximum air temperature had occurred and when the surface soil was dry. A range of 76° is indicated in the temperatures at the one-half inch depth which is about 94 per cent as great as that of the air temperatures. It is particularly of interest to note that although the temperature of the air four and one-half feet above the soil reached a minimum of 24° the lowest temperature of the soil at a depth of one-half inch was 32°—or 8° higher.

Soil Temperatures at 3-inch Depth for 1927 Period.—The temperatures at the 3-inch depth are shown in the graphs as curve 2. A minimum of 37° occurred at 7 A.M. on December 27 (fig. 32) two hours after the minimum air temperature, although a slightly lower temperature is shown on December 24 with a higher air minimum. The maximum of 96° was reached at 4 P.M. on June 15 (fig. 57) two hours after the air maximum. A range of 59° occurred at this depth from December 20 to June 20. This was slightly over 77 per cent as great as had occurred at the one-half inch depth during the same period. The lag in the soil temperatures as compared to the air temperatures is clearly shown at the time of the occurrence of the maximum and minimum for this soil depth.

Soil Temperatures at 6-inch Depth for 1927 Period.—The minimum temperature of 41° was reached at the 6-inch depth (curve 3) at 10 A.M. on December 27 (fig. 32) five hours after the minimum air temperature, while the maximum of 91° occurred at 4 P.M. on June 15 (fig. 57) or two hours after the maximum air temperature. The range in temperature during this period, December 20 to June 20, at the 6-inch depth was 50° or about 85 per cent as great as had occurred at the 3-inch depth in the same interval or 66 per cent of the range for the one-half inch depth.

Soil Temperature Changes at 12-inch Depth for 1927 Period.—The temperatures obtained at the 12-inch depth are indicated by curve 4 which shows a minimum of 42° on December 26 (fig. 32). The same temperature was also reached on December 27 (fig. 33). The maximum temperature for this depth was 84° at 10 P.M. on June 15 (fig. 57), eight hours after the maximum air temperature was reached. The range in temperature for this depth was 42° or approximately 55 per cent as great as had occurred at the one-half inch depth during the same interval. The figures, 32–57, clearly show as do the preceding ones that there is in general a distinct rise and fall in the soil temperatures at the 12-inch depth.

Soil Temperature Changes at 24-inch Depth for 1927 Period.—The minimum temperature recorded for the 24-inch depth (curve 5) was 48° and occurred at 11 A.M. on December 31 (fig. 33). This time was 102 hours after the minimum air temperature of 24° had been reached. The maximum of 79° at 10 A.M. on June 17 (fig. 57) was forty-four hours after the maximum air temperature of 105°. The range in temperature for this depth was 31° between the winter and June 20, or mid-summer. This range was only 41 per cent as great as had occurred at the one-half inch depth during the same period. In general, as previously shown, there is no marked rise and fall in the daily soil temperatures in this area at a depth of 24 inches, this characteristic being confined to the surface 12 inches.

Soil Temperature Changes at 36-inch Depth for 1927 Period.—The temperatures recorded for the 36-inch depth are shown as curve 6 in the figures. The minimum for this depth was 52°, occurring at 12 noon on December 31 (fig. 33) or 103 hours after the minimum air temperature of 24° had occurred. The maximum of 76° was reached on June 17 (fig. 57) or six hours after the maximum for the 24-inch depth. The range in temperature was 24° or slightly over 31 per cent as great as had occurred in the one-half inch section during the same period, December 20 to June 20.

The lag in temperatures between the 24-inch depth and the 36-inch depth are clearly indicated in the accompanying figures.

Effect of Character of Sky, Rain, and Wind During 1927 Period.—From December 20 to April 18 there was some rainfall every week with the exception of the week beginning March 21 (fig. 45). During this moist period the air temperature curves and the soil temperature curves 1, 2, and 3 which represented the one-half inch, 3-inch, and 6-inch depths and all of which are in the upper portion of the figures (figs. 32–57), are very close together. There was no great rise and fall in temperatures such as was shown during the same part of the 1925 period. The fact that the surface soil was moist for this length of time (December–April) combined with the large amount of cloudiness reduced the temperature ranges in the surface soil. Later in the summer of 1927 there was little rain, and the surface soil being drier, there was a noted change in the degree of spread of curves 1, 2, 3, and the air temperature curve. The week of February 14 (fig. 40) is outstanding for the similarity of the curves in the upper portion of the figure. Maximum temperatures for that week occurred on Friday when the sky was clear with a southwest wind. The week of May 23 (fig. 54) was clear except on Friday when a cloudy sky combined with rain occurred. On this day, the soil and air temperature curves in the upper portion of the figure drop considerably but rise again the next day with clear weather.

Clear days during the summer portion of the 1927 period with the atmosphere calm or with north winds result in increasing the soil temperatures in the surface soil. On the other hand, the opposite effect can be seen on clear days with southerly winds.

As in the previous set of charts, during the winter months the north winds have a cooling effect while the southerly winds have a warming effect on the soil temperatures. Cloudy days in winter have a warming effect on soil temperatures while in summer the opposite is true.

The time of occurrence of the maximum and minimum soil temperatures as compared to the air maximum and minimum varies with the season, character of the sky, etc. As a general rule, the maximum and minimum temperatures at the one-half inch depth occur within one hour after the air maximum or minimum. The lag for the other depths is approximately as follows: 3-inch, 2 hours; 6-inch, 4 hours; 12-inch, 8 hours; 24-inch, 70 hours; and 36-inch, 80 hours.

The distribution of the rainfall during the 1925 and 1927 periods is here shown so that the climatic characteristics of the two periods may be indicated. These data were compiled from the United States Department of Agriculture, Weather Bureau climatological data for those years.

TABLE 1

MONTHLY PRECIPITATION FOR 1925 PERIOD WITH DEPARTURES FROM THE NORMAL, DAVIS, CALIFORNIA

February		March		April		May		June		July		August		September	
Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
4.28	+1.47	3.10	+0.69	2.15	+1.06	1.63	+1.00	0.02	−0.12	0	−0.01	0.03	+0.02	0.10	−0.23

During the 1925 (February to September inclusive) period as shown in table 1 the total precipitation was 11.31 inches which was 3.88 inches above normal. This is likely to create an erroneous application to the soil temperatures unless one notes the character of the rainfall. The first figure for the 1925 season is for the week of February 23 (fig. 1). There was no rainfall from February 23 until March 28, as shown in figure 5. On March 31 (fig. 6) there was

TABLE 2

MONTHLY PRECIPITATION FOR 1927 PERIOD WITH DEPARTURES FROM THE NORMAL, DAVIS, CALIFORNIA

December		January		February		March		April		May		June	
Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
0.58	−2.82	2.18	-1.69	4.66	+1.85	1.07	−1.34	2.48	+1.39	0.31	−0.32	0.47	+0.33

a recorded rainfall of 2.50 inches which brought the rainfall for March to 0.69 above normal. As the period of February 23 to March 28 was without rain, the soil temperature curves have distinct peaks and depressions.

In like manner the precipitation data is shown for the second period starting with December 1926.

During the 1927 period as shown in table 2 there was a total precipitation of 11.75 inches which was 2.60 inches below normal for the months of December–June inclusive. A study of the daily or weekly distribution of the rainfall of the figures for the 1927 period will show that up to the week of April 18 (fig. 49) the rainfall, although below normal except for February, was well distributed—frequent light rains. After April 15 in this period, to May 20 (fig. 53) there was no recorded rainfall. It is clearly evident from the above that one must consider the daily or hourly distribution of the rain instead of the monthly amounts only, in order to note the effect of this climatic element on the soil temperatures.

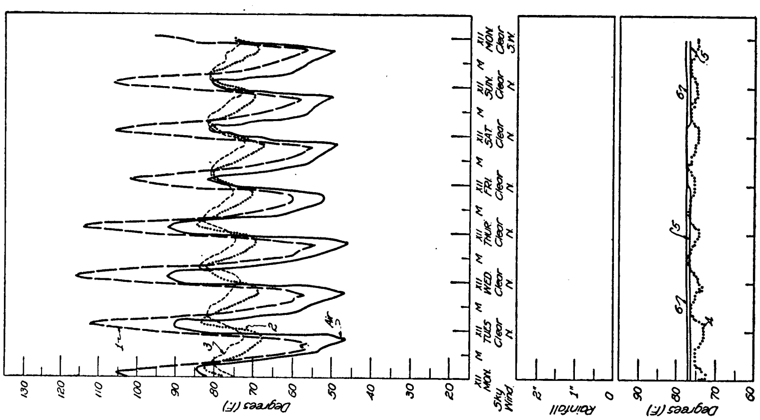

Fig. 31. Week of September 21, 1925

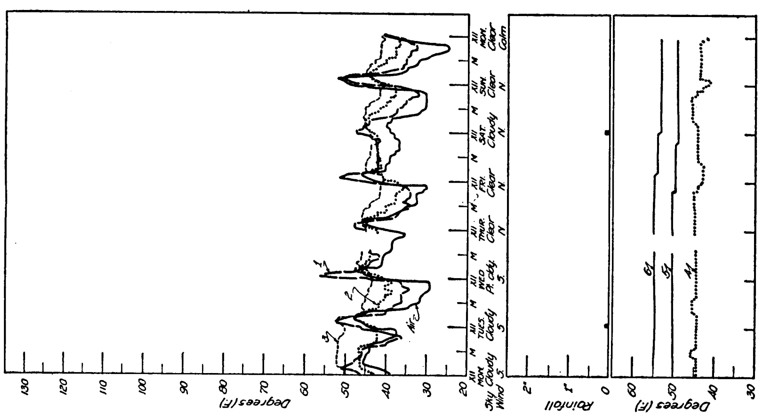

Fig. 32. Week of December 20, 1926

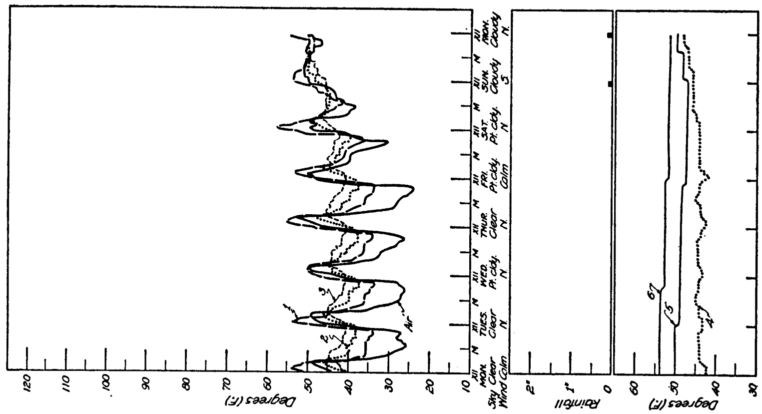

Fig. 33.—Week of December 27, 1926.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

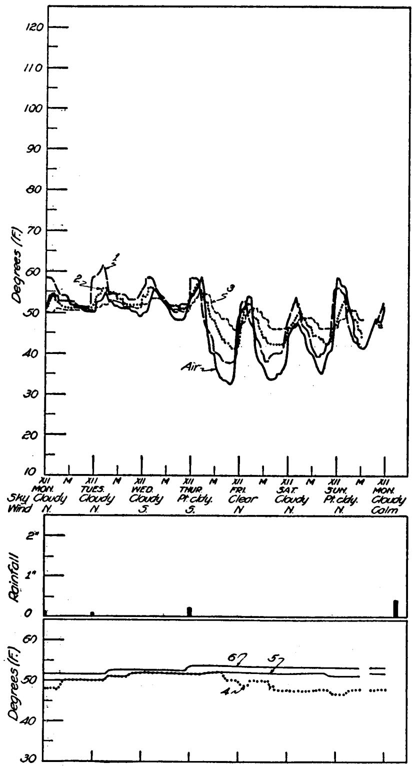

Fig. 34. Week of January 3, 1927

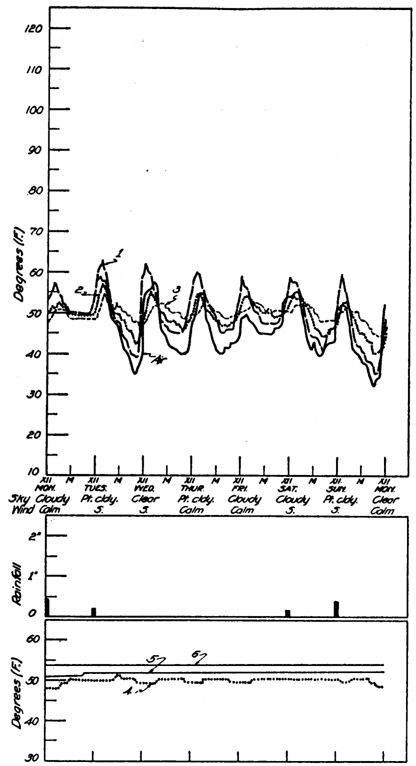

Fig. 35. Week of January 10, 1927

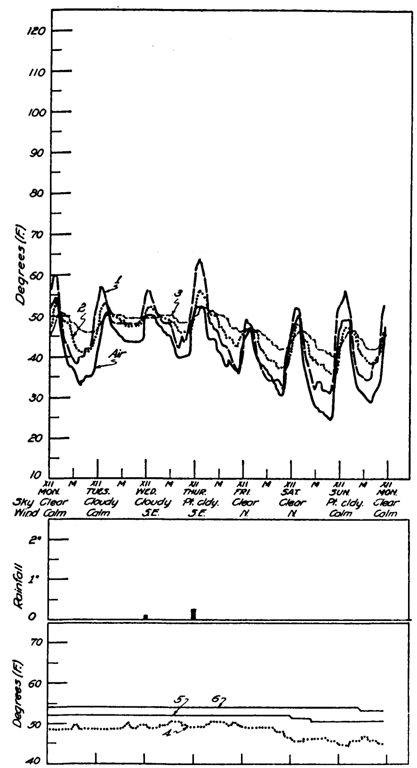

Fig. 36.—Week of January 17, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

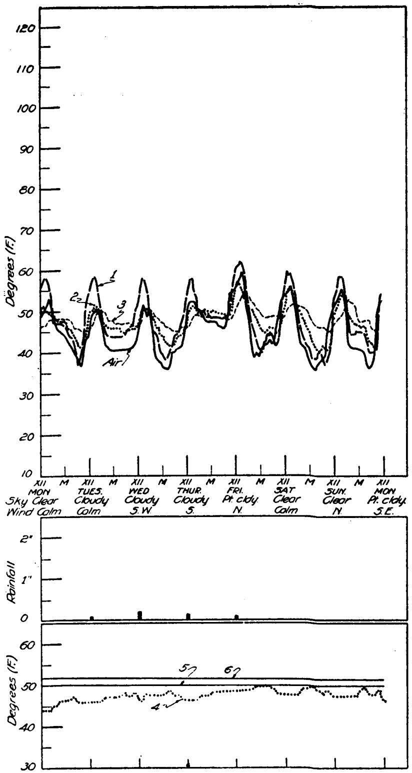

Fig. 37. Week of January 24, 1927

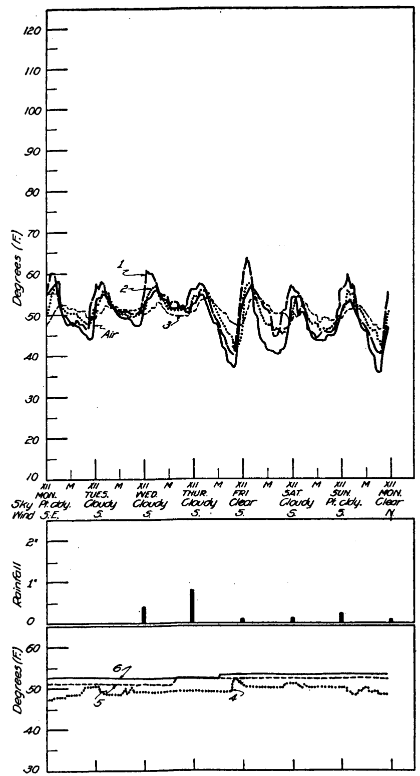

Fig. 38. Week of January 31, 1927

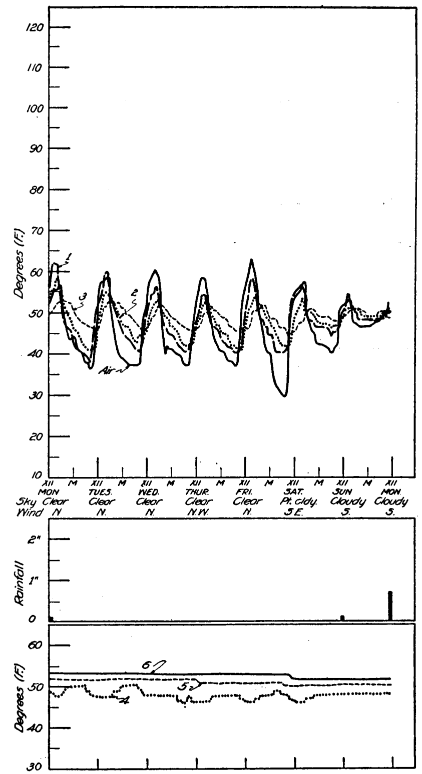

Fig. 39.—Week of February 7, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

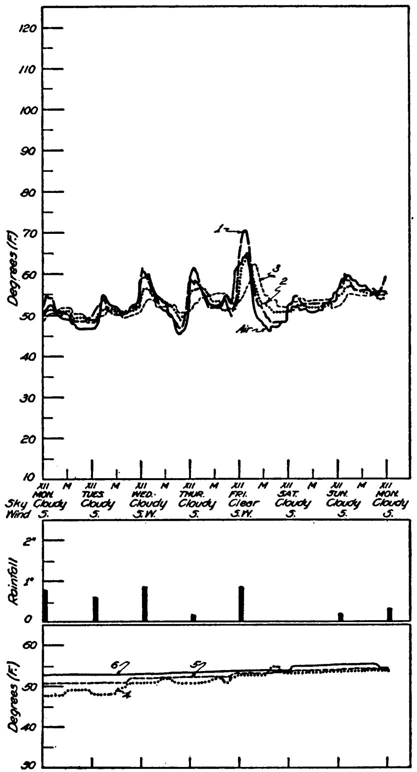

Fig. 40. Week of February 14, 1927

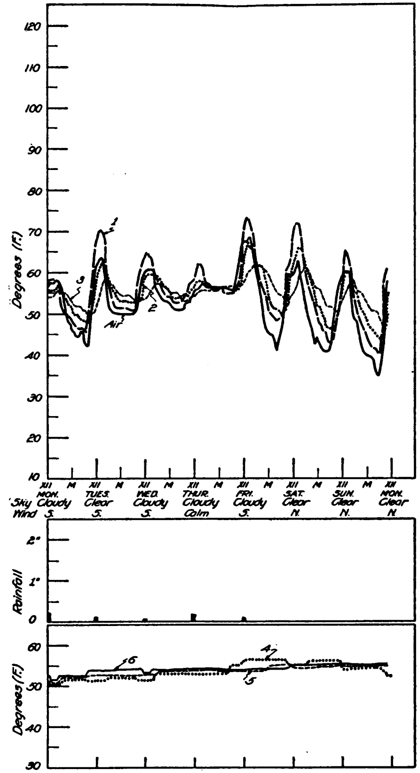

Fig. 41. Week of February 21, 1927

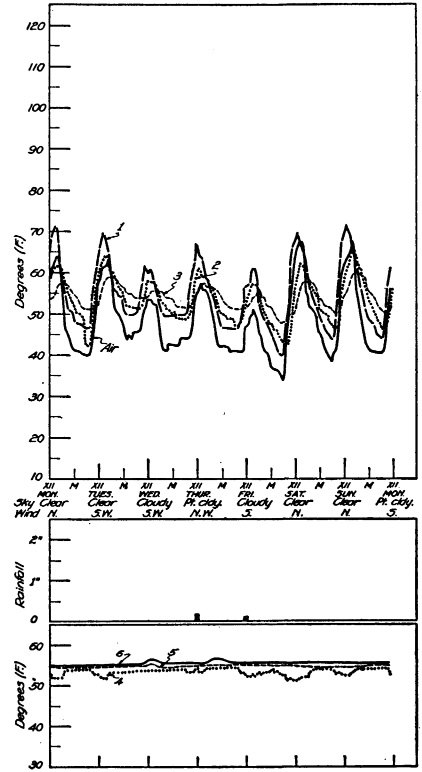

Fig. 42.—Week of February 28, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

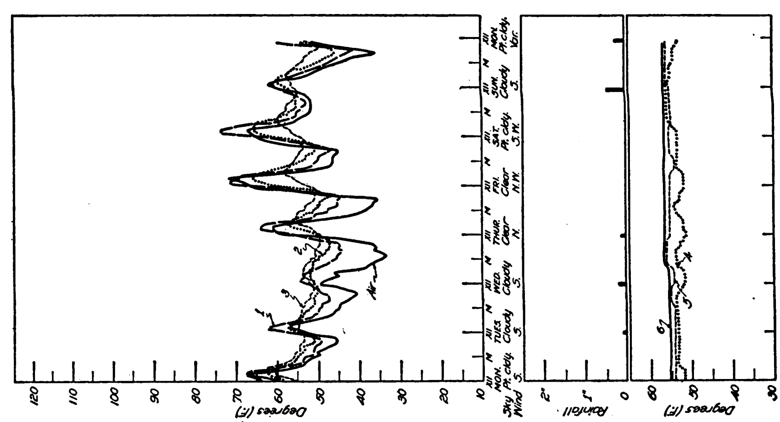

Fig. 43. Week of March 7, 1927

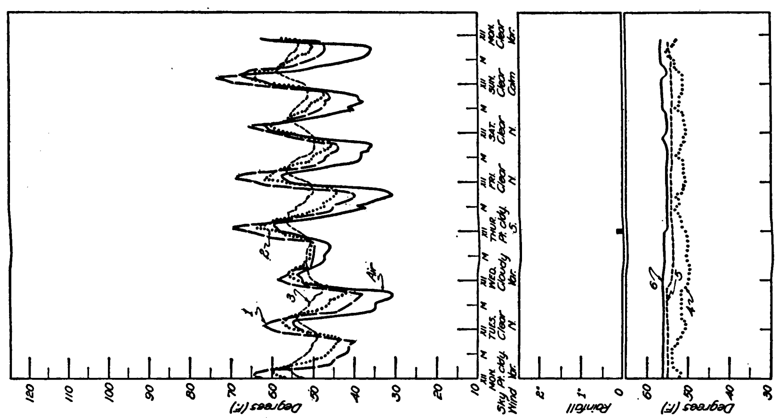

Fig. 44. Week of March 14, 1927

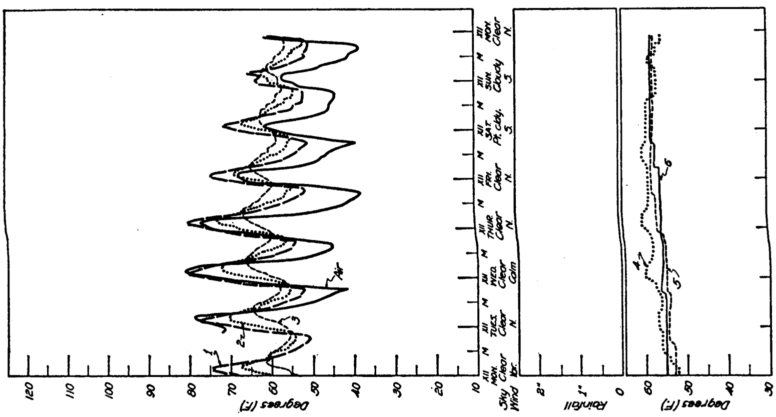

Fig. 45.—Week of March 21, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

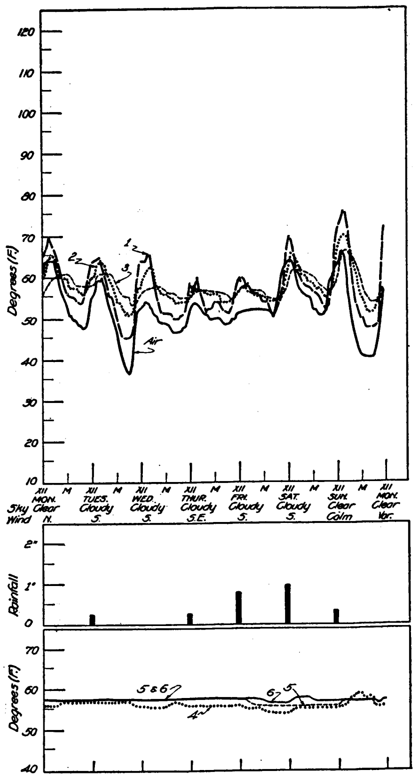

Fig. 46. Week of March 28, 1927

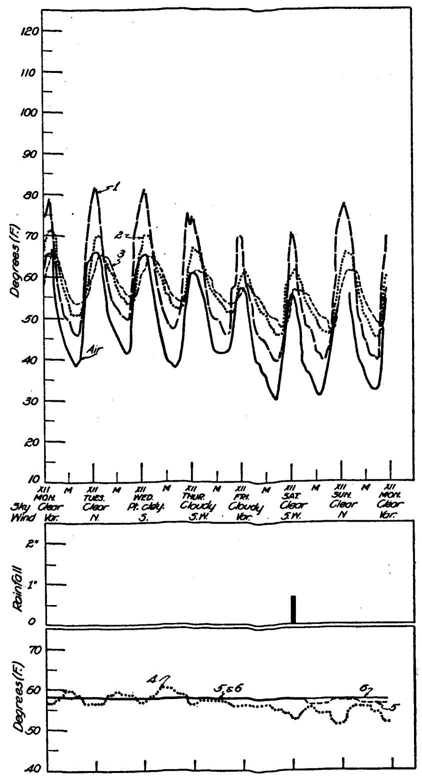

Fig. 47. Week of April 4, 1927

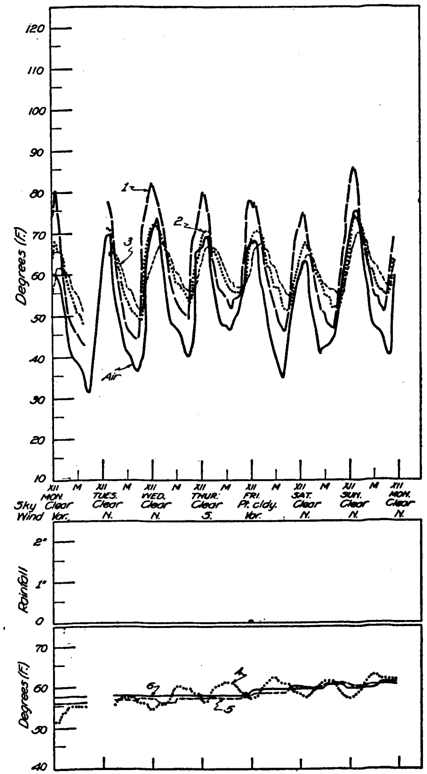

Fig. 48.—Week of April 11, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

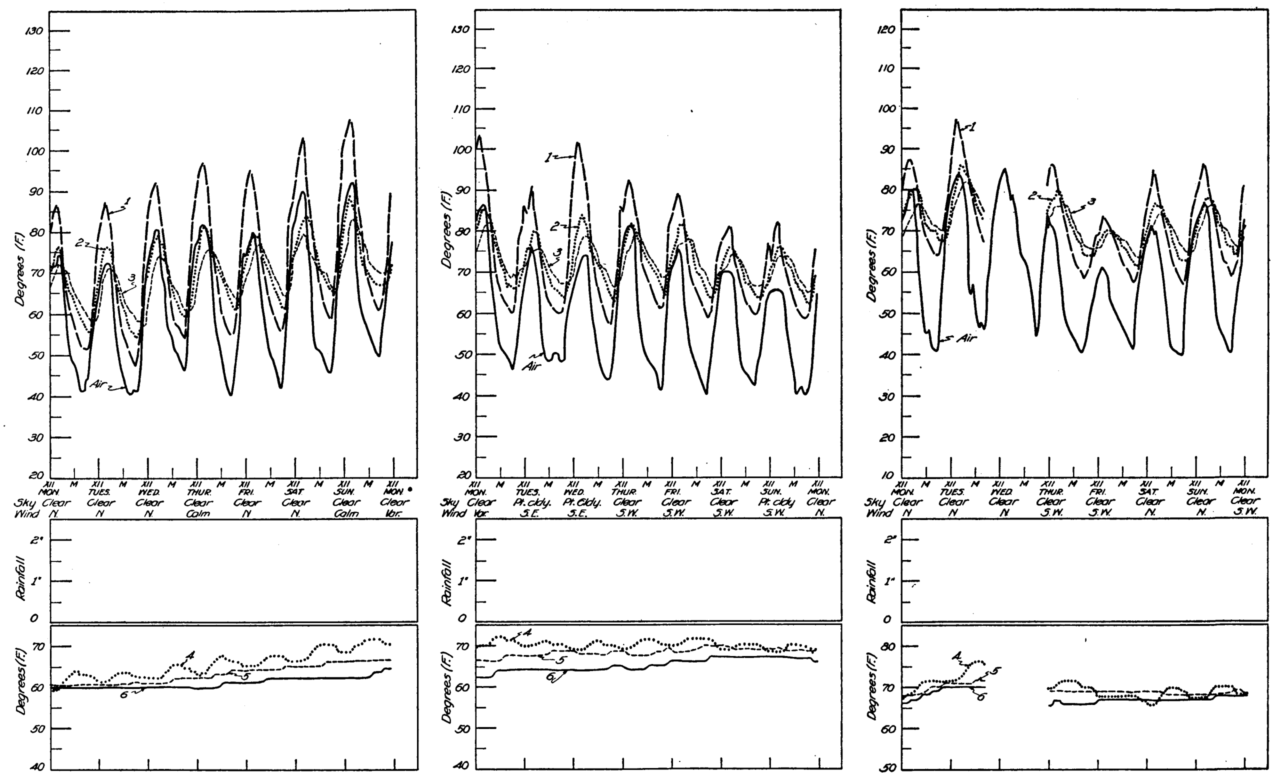

Fig. 49. Week of April 18, 1927 Fig. 50. Week of April 25, 1927 Fig. 51.—Week of May 2, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

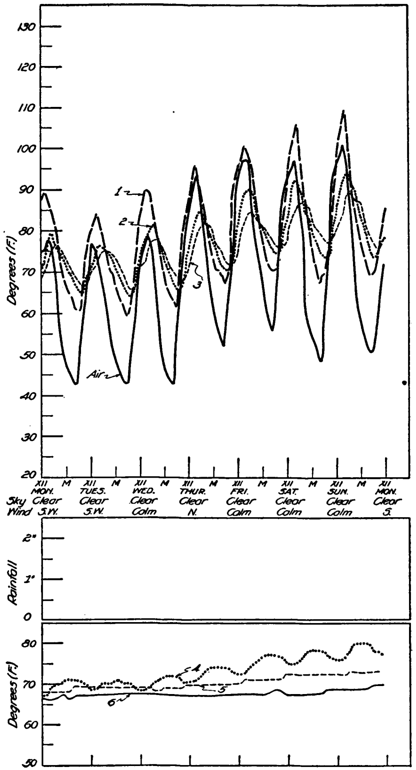

Fig. 52. Week of May 9, 1927

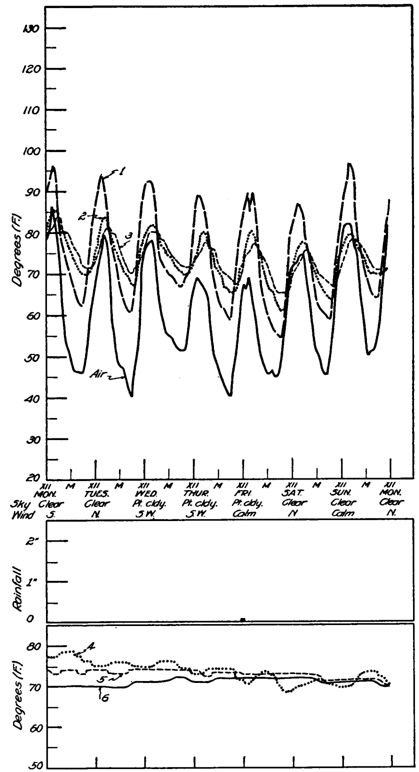

Fig. 53. Week of May 16, 1927

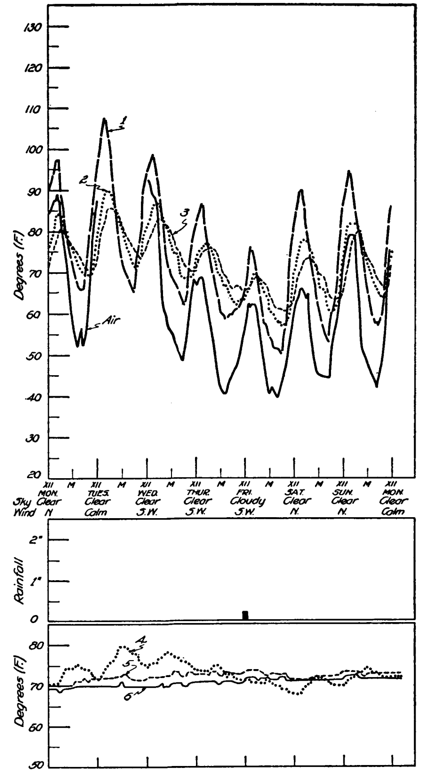

Fig. 54.—Week of May 23, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

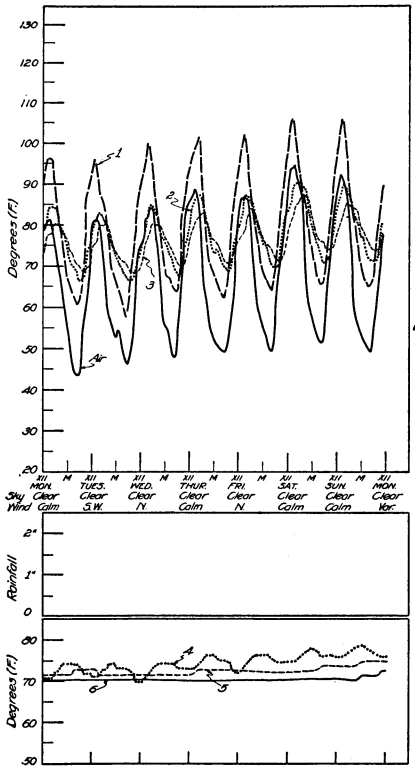

Fig. 55. Week of May 30, 1927

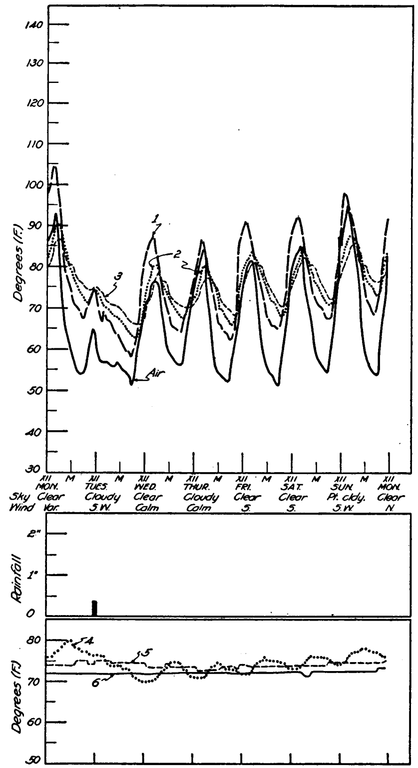

Fig. 56. Week of June 6, 1927

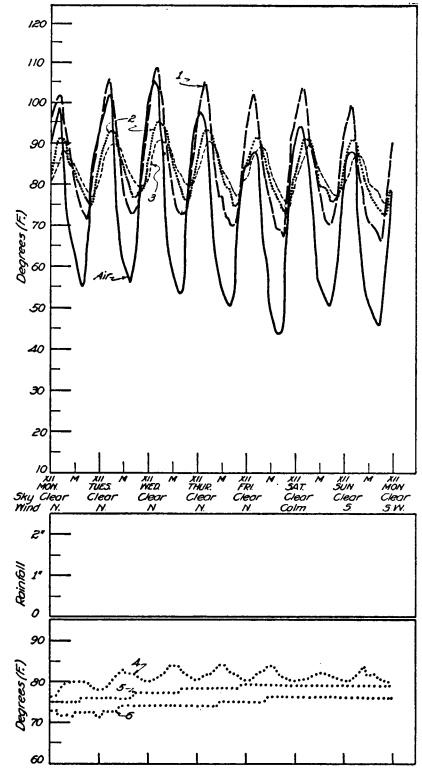

Fig. 57.—Week of June 13, 1927.

Soil and air temperatures and atmospheric conditions. Curve *1* shows soil temperature at one-half inch depth; *2* at 3; *3* at 6; *4* at 12; *5* at 24; and *6* at 36-inch depths.

SUMMARY

The moisture content of the surface 3 feet of loam was 20–22 per cent, while the subsoil, of fine sandy loam, was 16–18 per cent, after a seasonal rainfall totaling about 3 inches which replenished the moisture lost by evaporation during the preceding season. The moisture equivalent of the loam is around 20, and for the fine sandy loam, it is 16. No crops were grown on this area after 1923 and the weeds were kept down by cultivating once a month. During the dry season, the moisture content of the surface 4 inches was reduced to approximately 5 per cent. The next depth, 4–8 inches, contained about 12 per cent, and the deeper layers of the loam contained less. In the last foot of soil, 66–72 inches, the moisture content was about 15 per cent. The changing moisture content was due almost entirely to vapor movement. Where an unperforated black paper mulch had been placed on the soil surface, the moisture content in the surface 4 inches was about 20 per cent, while in the other depths below the surface 4-inch layer, the moisture content during the dry season was practically the same as in the cultivated area not covered with paper mulch.

The temperature changes occurring at the one-half inch, 3, 6, 12, 24 and 36-inch depths as well as the air temperature are shown for the period of February 23, 1925 to September 28, 1925 by hourly intervals. During these months many California crops are seeded and harvested and would be subjected to somewhat similar conditions of ''soil climate.''

The range in the air temperatures during the 1925 period was 86° while at a depth of one-half inch the soil temperature range was 114°. The range for the deeper soil areas was progressively smaller so that at the 36-inch depth, it was the least, or 31°.

The effect of the character of the sky, rainfall, and wind during the 1925 period are indicated in certain graphs more clearly than in others. The diurnal range is influenced by these climatic elements and during this period it was less than 2° at the 36-inch depth and up to 66° at the one-half inch depth.

The temperature changes occurring at the one-half inch 3, 6, 12, 24, and 36-inch depths as well as the air temperatures are shown for a second period, December 20, 1926 to June 20, 1927 by hourly intervals. These conditions would be met in general by the winter-growing California crops seeded and harvested during this period.

The range in air temperatures during the 1927 period was 81° while at a depth of one-half inch it was 76°. The lowest air temperature recorded was 24° while the lowest soil temperature at the one-half inch depth was 32°—or 8 degrees higher. The range for the deeper soil layers was progressively smaller so that at the 36-inch depth it was only 24° during this period.

The effect of the character of the sky, rainfall, and wind during the 1927 period are well shown in the graphs. From December 20 to April 18, there was some rainfall each week with one exception. During this moist period the air temperature curve and soil temperature curves for the one-half inch, 3-inch, and 6-inch depths coincide very closely. Cloudiness prevailed during most of this period so that the diurnal temperature range was very small for these depths.

The time of the occurrence of the maximum and minimum soil temperatures as compared to the maximum and minimum air temperatures, or the lag, varies from less than one hour at the one-half inch depth to approximately eighty hours at the 36-inch depth.

The effect of the daily distribution of the rainfall on the soil temperatures is very marked and during years when the monthly rainfall is recorded as being above normal, the soil temperatures during that month may show a very distinct rise and fall on account of the fact that the rainfall may have been confined to a very short period.

The various parts of plants growing in the field, such as the leaves, stems, and roots, are subjected to widely different temperature conditions. On July 17, 1925, the leaves and branches were in air heated to 116°; the stem (unshaded) just below the ground surface was in soil having a temperature of 143°; while the roots were in a medium with a temperature of 107° at the 3-inch depth to 84° at the 24-inch depth.

The possible influence of soil temperatures on the activity of bacteria, fungi, available nitrogen, chemical reactions taking place in soils, diffusion of the dissolved material through the roots and plant tissues and the rate of decomposition in soils is indicated by the seasonal temperature changes occurring at various depths in soils.

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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.
6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.
7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.
8. Effect of Salts on the Intake of Inorganic Elements and on the Buffer System of the Plant, by D. R. Hoagland and J. C. Martin. July, 1923.
9. Experiments on the Reclamation of Alkali Soils by Leaching with Water and Gypsum, by P. L. Hibbard. August, 1923.
10. The Seasonal Variation of the Soil Moisture in a Walnut Grove in Relation to Hygroscopic Coefficient, by L. D. Batchelor and H. S. Reed. September, 1923.
11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.
12. The Effect of the Plant on the Reaction of the Culture Solution, by D. R. Hoagland. November, 1923.
13. Some Mutual Effects on Soil and Plant Induced by Added Solutes, by John S. Burd and J. C. Martin. December, 1923.
14. The Respiration of Potato Tubers in Relation to the Occurrence of Blackheart, by J. P. Bennett and E. T. Bartholomew. January, 1924.
15. Replaceable Bases in Soils, by Walter P. Kelley and S. Melvin Brown. February, 1924.
16. The Moisture Equivalent as Influenced by the Amount of Soil Used in its Determination, by F. J. Veihmeyer, O. W. Israelsen and J. P. Conrad. September, 1924.
17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.
18. Factors Influencing the Rate of Germination of Seed of Asparagus officinalis, by H. A. Borthwick. March, 1925.
19. The Relation of the Subcutaneous Administration of Living Bacterium abortum to the Immunity and Carrier Problem of Bovine Infectious Abortion, by George H. Hart and Jacob Traum. April, 1925.
20. A Study of the Conductive Tissues in Shoots of the Bartlett Pear and the Relationship of Food Movement to Dominance of the Apical Buds, by Frank E. Gardner. April, 1925.