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SOIL TEMPERATURES IN THE UNITED STATES [1]

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By writing to all the agricultural experiment stations and examining the available literature on the subject, soil temperatures for 32 stations in the United States have been obtained. Only the very cordial cooperation of the agricultural experiment stations, the library of the United States Weather Bureau, and certain individuals has made possible the collection of the data. The stations, though few in number, are fairly representative of the country as a whole.

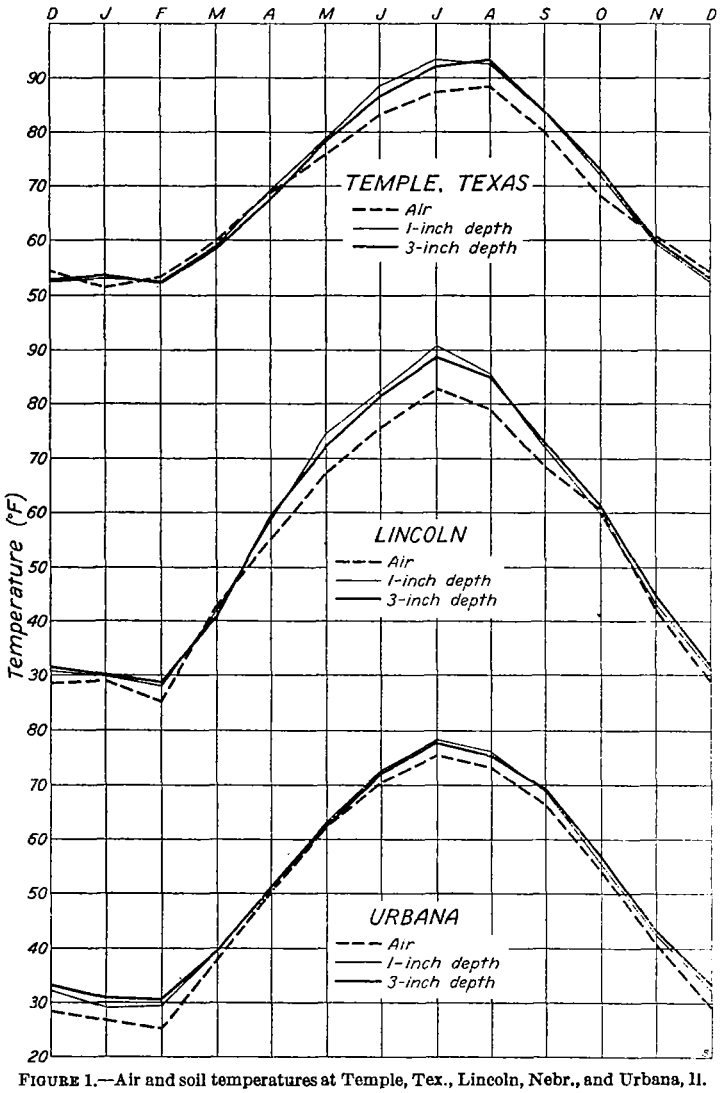

FIGURE 1.—Air and soil temperatures at Temple, Tex., Lincoln, Nebr., and Urbana, Ill.

Many variations in the conditions under which the soil temperatures were taken occur. In general, the experiment stations obtained soil temperatures not because of interest primarily in the temperatures themselves, but to determine the extent to which the temperatures were favorable or unfavorable for an important local crop or for bacteria harmful or helpful to that crop. Thus the thermometers were often placed at the depth at which the seed would be planted, so the depths for the different stations vary considerably. Also, because the interest was chiefly in connection with crops, records were often taken only during the growing season instead of throughout the year. Soils such as clay, loam, sand, peat, etc., are indicated; soil covers are various—bare, cultivated, sod, orchard, tobacco, cotton, mulches, etc.; exposures noted at different stations indicate variations between hillsides and bottom lands, dry soil and wet soil, shade and sun, etc. The accompanying table of soil temperatures indicates these variations where possible; it will be noted that some stations make no specification whatever as to the soil, soil cover, or exposure at the place where the soil thermometers were placed. In cases where temperatures of several kinds of soil or soil cover or exposure were recorded at one station, all of the data are included in the table for purposes of comparison at the station itself.

The material was sent to the authors in many different forms—some of it had already been published; some was in the form of graphs from which the desired temperatures could be read; in many instances the original thermograph records were sent and readings and tabulations were made from them; often a letter from an official of the station indicated all the soil temperatures that the station had available. Where possible, the temperatures in the tables were obtained by averaging the mean daily maximum and mean daily minimum temperatures for each month.

It is very apparent that the soil temperatures obtained for the 32 stations are by no means uniform—variations occur in the years, months, or days of record, the method

[1] Based on a paper presented before the Association of American Geographers at Worcester, Mass., December 29, 1930, by Edith M. Fitton.

of taking the record and of compiling tables from it, the kind of soil, depth, soil cover, and exposure. Hence the records at different stations are not strictly comparable with one another; however, the data are valuable for the individual stations, especially when temperatures for different depths, soils, and exposures are recorded at a single station. The scantiness of the material now available emphasizes the need for many additional observations of soil temperatures, which should be made under conditions as uniform as possible.

A study of the tabulated records now at hand and the graphs which illustrate them suggests a number of conclusions.

(*a*) Air and soil temperatures near the surface vary in a fairly parallel manner.

Since the temperature of the air is chiefly dependent on radiation and conduction from and to the ground, it follows that the diurnal and annual courses of the air temperatures and the ground temperatures should be quite similar. A number of stations provided air temperatures as well as soil temperatures. (See fig. 1 and the accompanying tables.)

(*b*) The soil temperatures at slight depths are generally higher than the air temperatures throughout the year. (Fig. 1.)

By day and especially in summer the ground is warmed to a much higher temperature than the air above it, so much so that, though it is cooled to a lower temperature at night, the mean temperature of the ground remains higher than that of the air. At Urbana, Ill., "the average monthly temperature of the soil to a depth of 1 to 3 inches is always higher than that of the air above it" (**14**, p. 42), but at Lincoln Nebr., (**21**) and at Temple, Tex., this statement does not hold true in the spring and fall. In the spring the reason is perhaps that it takes longer for the soil, continually cooled by conduction from below to warm up; in the fall, with shorter days and a longer period of nocturnal radiation, the soil cools more rapidly, though, as the winter months show, not to as great a degree as the air. Because of intense surface heating, the summer months show the widest variation between the air and soil temperatures, the soil at the 1-inch depth being considerably warmer than at 3 inches, with the interesting exception of August at Temple, Tex. The explanation for the exception probably lies in the fact that the deeper soil has become thoroughly warmed during the long summer of this southern station, and, since it retains its warmth at night better than the surface soil, its temperature shows a higher monthly average.

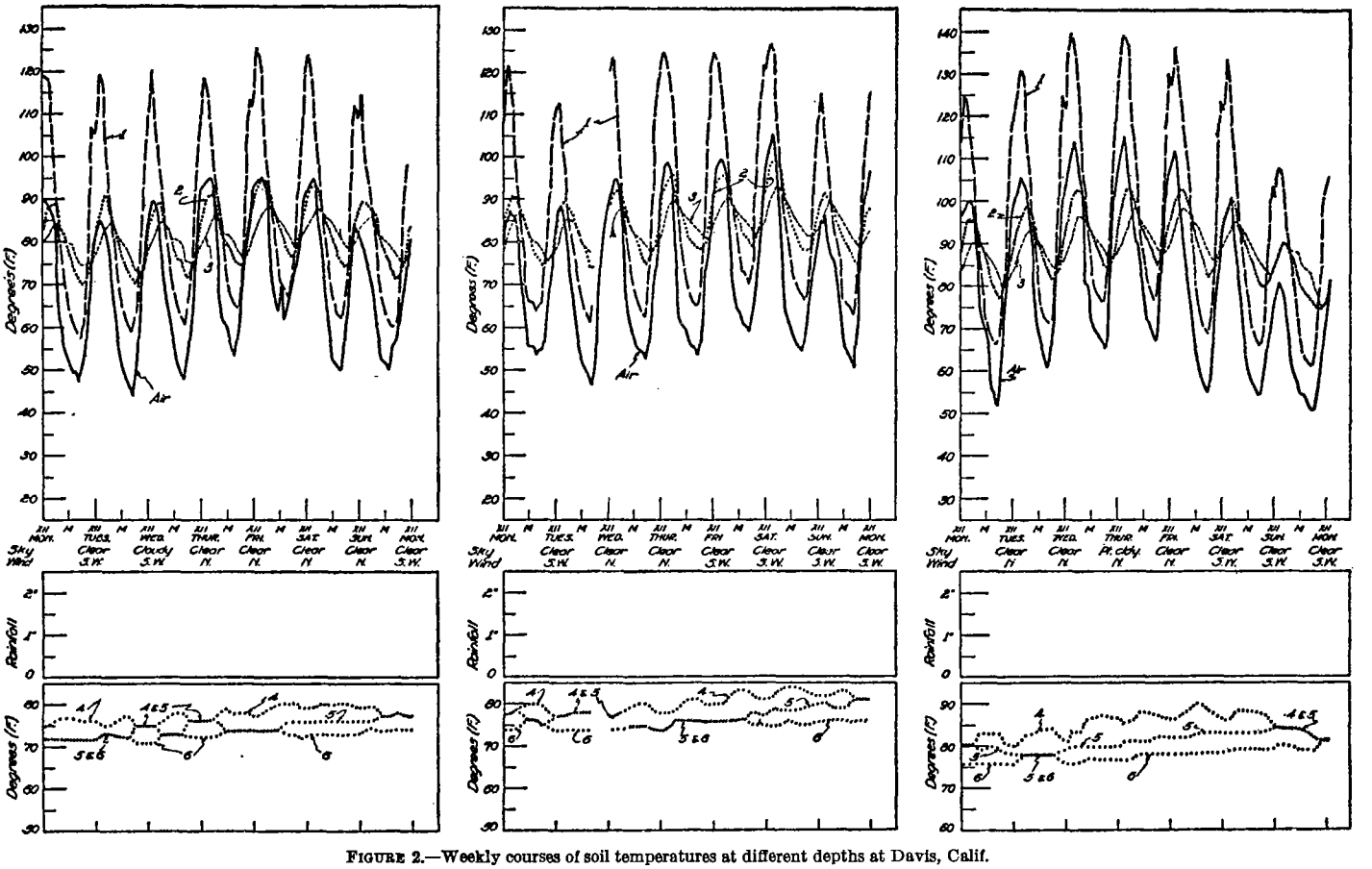

FIGURE 2.—Weekly courses of soil temperatures at different depths at Davis, Calif.

(*c*) The diurnal range in soil temperatures extends to a depth of about 3 feet (**60**, p. 79).

A study of the original thermograms which were sent by a number of stations showed this to be a fact, as does also Figure 2, from a soil paper by Alfred Smith published in Hilgardia (**32, a**, p. 91). The 36-inch-depth line is seen to have the least fluctuation during the weeks shown.

(*d*) The annual range in soil temperature is quite apparent at a depth of 10 feet, the greatest depth for which a record is obtainable in the United States.

Bozeman, Mont. (fig. 3) furnished soil temperatures to a depth of 10 feet. Here the annual range is still reasonably apparent and it probably extends to a depth of 30 or 40 feet (**60**, p. 80). Where the temperature line for the 10-foot depth is superimposed on the 1-foot temperature line, the greatly decreased annual range with

depth is at once apparent. The increase in uniformity of temperature with increase in depth, progressively indicated from top to bottom of Figure 3, is due to the fact that in the summer time with increasing depth the soil becomes colder; in the wintertime, with increasing depth, the soil becomes warmer.

(*e*) The lag of maximum and minimum soil temperatures increases with depth.

According to Alfred Smith's experiments at Davis, Calif., the lag "varies from less than 1 hour at the ½-inch

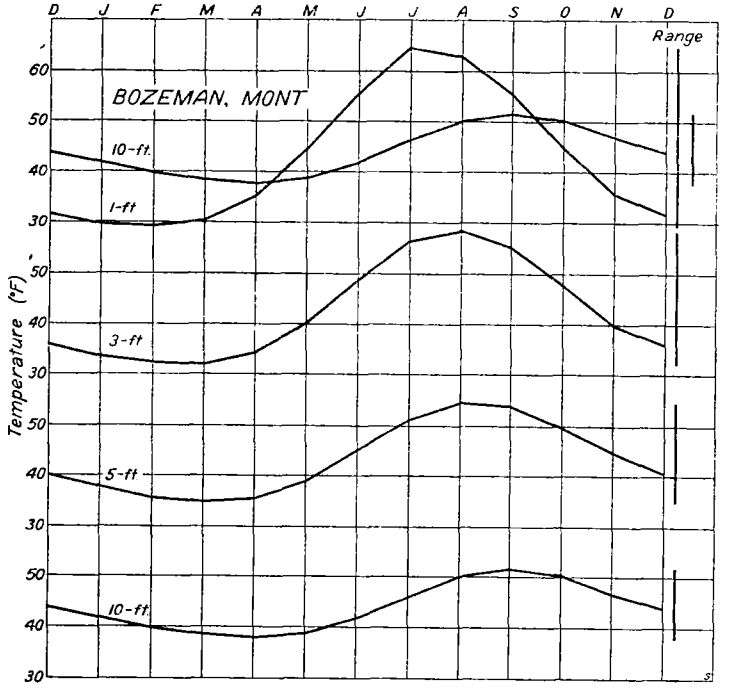

FIGURE 3.—Soil temperatures at Bozeman, Mont.

depth to approximately 80 hours at the 36-inch depth (**32b,** p. 111). Figure 3 shows that at the 10-foot depth the lag in annual maximum and minimum is as much as four or five months, September and April being the months of the extreme temperatures.

(*f*) A cover crop lessens the diurnal and annual temperature ranges.

The tables show only three stations that supplied soil temperatures specifying several different soil covers;

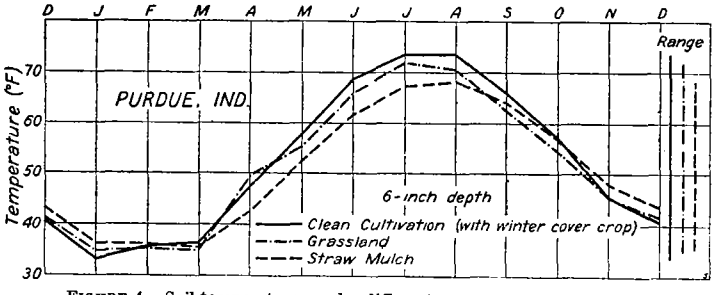

FIGURE 4.—Soil temperatures under different cover crops at Purdue, Ind.

the data for Purdue, Ind., are shown in Figure 4. The mean annual range under straw mulch is least; under clean clutivation it is greatest. The spring and summer months show the greatest differences in temperature between the soil under clean cultivation and that under straw mulch, because the bare ground warms up so much more rapidly as well as to a greater degree than the ground under straw.

(*g*) In the winter time, northerly stations where the snow cover is more or less permanent show higher mean monthly soil temperatures than stations somewhat farther south or west but lacking a good snow cover.

By means of Figure 5, the winter air and soil temperatures at East Lansing and Lincoln (**21**) may be compared. While the air temperatures at East Lansing average 5° F. or more below those at Lincoln, the soil temperatures are several degrees higher than those at Lincoln. The explanation seems to lie in the fact that a snow cover of fairly permanent duration maintains the soil temperatures at about 32° regardless of the air temperature, whereas

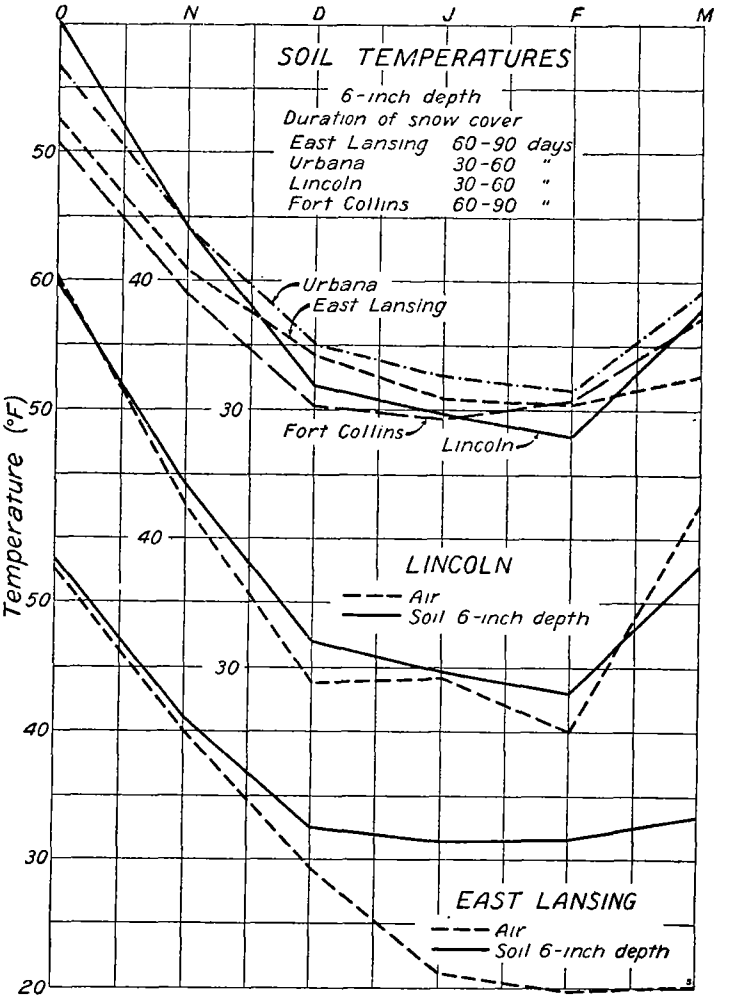

FIGURE 5.—Winter-time soil temperatures at East Lansing, Mich., Urbana, Ill., Lincoln, Nebr., and Fort Collins, Colo.; air and soil temperatures at East Lansing and Lincoln

lack of snow cover allows the soil temperature to average lower than the freezing point under winter conditions that in general favor surface temperatures below freezing. The winter time soil temperatures at Fort Collins are of interest. (Fig. 5.) Early in the winter this station has low soil temperatures, probably due to early cooling because of altitude and lack of early snow cover. Later in the winter, however, the deeper snow cover prevents the soil temperatures from falling any lower and even insulates the soil sufficiently to allow warmth from below to cause a slight rise in soil temperature.

A uniformity of temperature throughout the winter months which is probably maintained by the snow cover is apparent in most of the illustrations.

(*h*) The presence of moisture in the soil tends to give a low and uniform temperature.

Auburn, Ala., Columbia, Mo., and Corvallis, Oreg., have furnished soil temperatures specifying whether the soil is wet or dry. At Auburn the wet bottom-land soil seems to be warmer than the dry hilltop soil, but this may be merely the result of the method of obtaining the means by averaging the maximum and minimum temperatures, for the minimum temperatures on the wet ground are several degrees higher than on the dry sandy ground. At Columbia the "seepy spot" on the slope is generally cooler by about 1° than the other two exposures, both at the 12-inch and 36-inch depths. In 3 instances out of a possible 24 comparisons the seepy spot was found to be warmer than the other exposures.

At Corvallis the difference is between irrigated and unirrigated soils. The conclusion is that "the presence of irrigation water and the resulting evaporation tends to give a low uniform temperature, but the difference due to irrigation would decrease with depth" (**31**, p. 30). At East

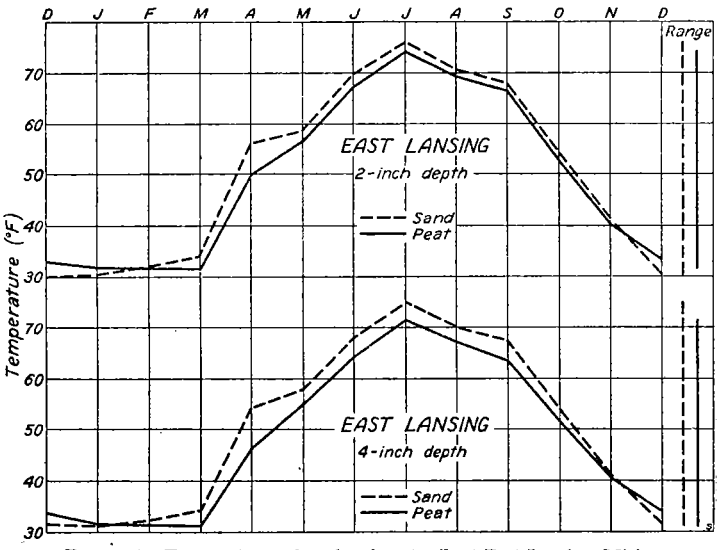

FIGURE 6.—Temperatures of sand and peat soils at East Lansing, Mich.

Lansing, Mich. (fig. 6), a comparison between the dry sand and the moist peat soils shows that peat tends to maintain a more uniform temperature than sand, being warmer in winter and cooler in summer.

(*i*) Loam, clay, and peat soils never become as warm in summer as the drier gravel and sand soils.

Figure 6 and the data in the table for East Lansing, Mich., show that at all depth highest summer temperatures are found in the sandy and gravel soils, lowest temperatures in the peat and clay soils. In the winter time all of the soils tend to be at a temperature of about 32° F. when under a snow cover.

(*j*) Soil temperature and its annual range decreases with altitude.

The upper portion of Figure 7 shows the decrease of temperature with increasing altitude for both north and south slopes. The lower portion of the figure shows the lessening range with increase in altitude.

(*k*) South exposures at any altitude have higher temperatures and a greater range than north exposures.

The lower portion of Figure 7 shows this graphically. It is of interest to note how much less rapidly the maximum temperatures on the south slope decrease with altitude than the maximum temperatures on the north slope. The mean temperatures for the south exposures averages 12° F. or more above those for the north exposures at the same levels, and even at 9,000 feet the mean for the south exposure is still almost 5° higher than the mean for the north exposure at only 7,000 feet.

Daily and monthly ranges, shown in Tables 2 and 3 for certain stations, provide further quantitative comparisons of soil temperature characteristics at different depths at the several seasons and in various climates. Daily ranges are greatest nearest the surface. The 1922–1925 series at Fargo, N. Dak. (**18**), described as an unusually warm period, had a daily range at 1-inch depth in excess of the range of air temperature a few feet above the ground. The other Fargo series (**19**), however, at ½-inch depth showed a range only one-fourth to one-third as great as that at 1

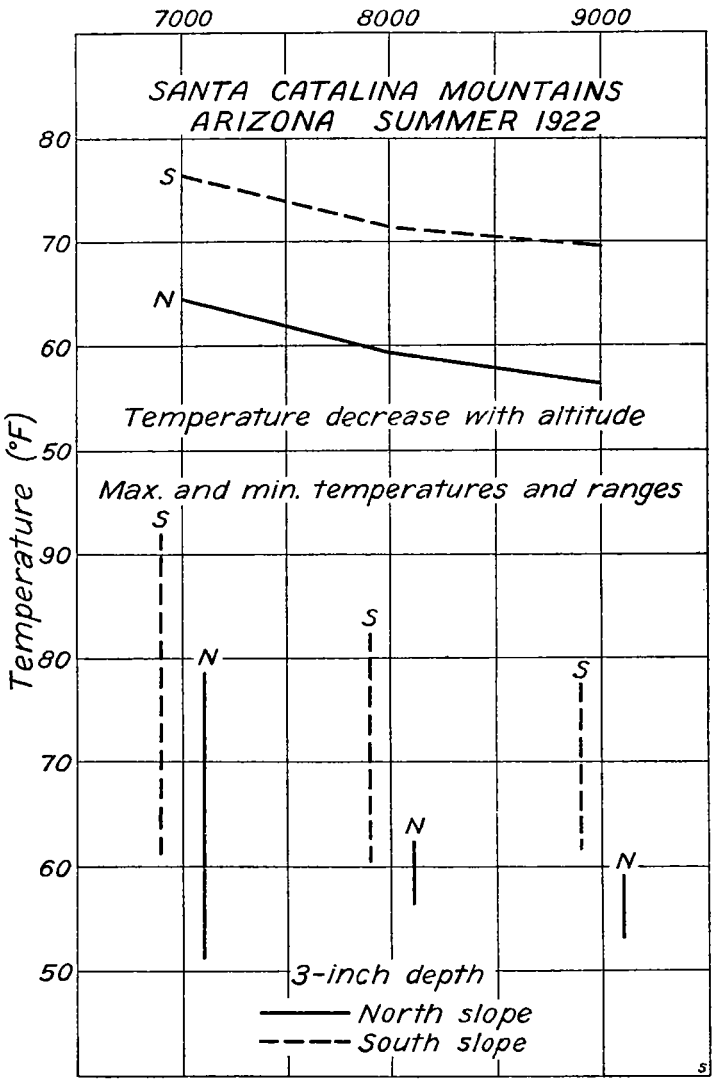

FIGURE 7.—Mean, maximum, and minimum temperatures at different altitudes on the north and south sides of the Santa Catalina Mountains, Ariz.

inch in the first series. In general (Table 2), the range of soil temperature at the 3-inch depth was about three-fourths the range of air temperature in the warmer half year and less than two-thirds of the reduced air temperature range in the colder half year.

From this general surface layer downward the daily range decreases geometrically. In the most complete New Haven series (**4**) the daily range decreases by about half for each 3-inch increase in depth, becoming at 12 inches only one-fifth to one-tenth that at 3 inches. In the other New Haven series (**5**), the range at 6 inches is about the same as in the first, but that at 12 inches is still nearly as large, and the range at 18 inches is much like

that at half the depth in the first series. As these observations were made in borings, a more rapid exchange of heat than usually occurs in the ground may have taken place in these holes. In the New York Botanical Gardens daily ranges at a depth of 1 foot in clay soil mixed with loam were about the same as at the same depth in the first New Haven series, namely 1° to 2(+)° F.

Any covering on the soil reduces the daily range markedly. In the Purdue experiment (**13**) ranges at 6 inches under straw were only 2.5° to 5° F., while those under clean cultivation were 8° to 12° F. in the warmer half year. Ranges under grassland were nearly as large as those under clean cultivation, however. Ranges under straw, cover crop, or grass were all about the same in winter, generally 3° to 5° except in January, when reduced to 1.4° (cover crop) to 2.1° (grassland) probably by the snow cover.

The effect probably of snow cover is also seen in the ranges at Wooster and Columbus, Ohio (**11**), where the range at 6 inches is smaller in proportion to that at 1 inch in winter than in summer. In the colder half year the range at 6 inches is only one-fourth of the 5° range at 1 inch, while in the warmer half year the range at 6 inches is one-third of the 20+° range at 1 inch. In general there are much smaller daily ranges at slight depths in winter than in summer, though the range of air temperature is not changed so much. The air temperature range decreases by a third, while that of the soil decreases by a half to three-quarters or more. At a depth of 18 inches, for which depth we have ranges through the year only at Lexington, Ky. (**12**), the diurnal range becomes about the same small value, 1° F., in all months.

The drier climates, so far as these samples go, have the larger daily ranges of soil temperature. Also the drier months in the warm season have the larger ranges. The ranges at Fargo, N. Dak. (**18** and **19**), increased markedly toward late summer as the normal convectional rainfall decreased.

Monthly ranges (Table 3) are considerable to depths of 12 inches in the north and 24 inches in the south. They decrease fairly rapidly with increase of depth, but proportionally not nearly so fast as the daily ranges. At Temple, Tex., the temperature even at a depth of 4 feet has a mean annual monthly range of more than 5° F.

TABLE 1.—*Soil temperatures (°F.)*

Figures for every day of each month or for every month over a period of years are not always available. Where the record covers only one year, the acutal number of days of record is given as an exponent of the temperature figure in those months in which there is not a record for every day; when data are available over a period of several years, those averages in which several days of one or more months are missing or in which a whole month or more is missing are indicated thus (*)

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

AMHERST, MASS.—TOBACCO FIELD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(1)	1927-28	5 inches						*65.5	*71.8	69.4	*67.6				
(2)	1929	2 feet	^{1}36.0	^{1}34.0		^{1}43.0	^{1}57.0		^{3}69.0						
(2)	1929	3 feet							^{3}60.0						
(2)	1929	4 feet	^{1}37.0	^{1}38.0		^{1}41.0	^{1}50.0								
(2)	1929	8 feet	^{1}45.0	^{1}42.0		^{1}41.0	^{1}46.0		^{3}55.0						

STORRS, CONN.

(3)	1922	Air							^{18}68.8	^{27}66.9	^{12}65.0				
		6 inches							^{18}73.0	^{30}70.6	^{12}66.2				

NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN

(4)	1926	Air					^{21}65.2	70.0	77.0	75.8	67.4	56.0	^{24}47.3		
		3 inches					^{8}60.7	^{29}68.4	81.2	^{30}74.9	^{28}67.0	54.4	^{18}46.1		
		6 inches					^{5}66.3	^{29}65.7	74.8	^{30}73.1	^{27}65.9	54.5	^{17}47.0		
		9 inches					^{8}58.6	65.0	72.4	^{30}72.4	^{28}66.1	54.8	^{19}46.8		
		12 inches					^{8}56.1	^{29}63.4	71.2	^{30}71.2	^{28}65.2	^{30}55.2	^{18}48.2		

NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL

(5)	1924	Air				45.0	53.2								
		6 inches				44.2	54.2								
		12 inches				43.5	52.6								
		18 inches				43.2	51.6								

NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM

(6)	1902	Air						^{22}63.9	70.2	68.2	61.9	^{28}53.4	^{23}46.6	^{14}31.3	
		12 inches						^{21}48.2	51.6	^{29}48.2	43.5	35.8	29.5	^{21}29.7	

BLACKSBURG, VA.—HAGERSTOWN SILT LOAM IN AN ORCHARD

(7)	1915	Air							70.2	68.2	
		3 inches							76.4	74.3	Sod.
		24 inches							70.0	71.2	Do.
		3 inches							75.8	75.0	Partially cultivated.
		24 inches							69.3	69.9	Do.
		3 inches							76.1	76.0	Intensely cultivated.
		24 inches							69.4	70.5	Do.

ATHENS, GA.—LAND BEDDED UP FOR COTTON

(8)	1926	Air					68.3	Average from Apr. 22 to May 20.			
		1.5 inches					68.4	Do.			

TABLE 1.—*Soil temperatures* (°F.)—Continued

AUBURN, ALA.—SANDY SOIL ON A HILL, FREQUENTLY CULTIVATED DURING CROPS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(9)	1889	Air	46.9	46.3	54.7	62.5	70.1	76.1	80.7	77.6	74.8	62.3	53.1	57.8	63.6
		3 inches	48.5	50.5	55.2	65.5	72.2	74.0	86.5	82.2	75.5	64.8	52.2	52.0	64.9
		6 inches	48.2	55.5	53.8	64.8	72.0	73.5	85.8	81.5	75.0	65.2	52.8	51.2	64.9
		24 inches	49.5	50.5	53.8	62.5	70.5	74.2	81.5	80.0	80.8	68.2	58.8	55.0	65.4
		48 inches	52.5	50.5	53.5	59.8	67.2	72.2	77.0	78.0	79.8	70.8	63.5	58.5	65.3
		96 inches	58.0	55.5	55.2	57.2	61.2	67.2	71.0	73.2	75.0	72.5	77.0	63.5	65.5

AUBURN, ALA.—BOTTOM LAND ON THE BANK OF A SMALL STREAM

(9)	1889	3 inches	48.0	51.0	55.2	64.0	73.8	75.0	87.5	83.2	76.2	64.8	52.8	51.8	65.3
		6 inches	48.8	51.5	55.2	65.8	73.5	74.5	86.8	83.0	76.0	65.5	53.0	50.5	65.3
		24 inches	51.2	51.8	54.5	63.0	70.5	74.8	81.2	80.2	77.5	68.8	59.2	55.0	65.6
		48 inches	53.5	52.2	54.2	60.5	67.2	72.2	77.0	78.0	77.0	71.2	63.5	59.0	65.5

EAST LANSING, MICH.—LOAM

(10)	December, 1914, to November, 1915	2 inches	31.3	31.5	33.3	55.2	57.0	67.9	73.4	68.5	67.2	53.4	41.0	32.5	51.0
		4 inches	32.0	32.1	33.9	53.0	56.4	66.4	72.8	68.1	65.9	52.8	41.4	33.6	50.7
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	32.6	45.4	57.0	68.9	74.0	70.6	64.8	52.6	40.7	34.2	50.2
		12 inches	32.7	31.7	32.5	42.0	55.5	67.6	73.0	70.9	65.1	54.1	42.4	36.7	50.4
(10)	December, 1911, to November, 1914	18 inches	34.5	33.1	33.1	40.8	53.1	64.3	70.2	69.3	64.5	55.1	44.0	38.6	50.0
(10)	December, 1911, to November, 1915	Air	21.2	19.8	30.1	48.1	57.1	66.3	71.4	68.5	63.4	52.6	40.1	29.4	47.3

EAST LANSING, MICH.—GRAVEL

(10)	December, 1914, to November, 1915	2 inches	31.8	32.2	34.3	56.2	58.5	69.8	75.7	70.5	67.7	53.7	41.4	32.3	52.0
		4 inches	32.3	32.7	34.4	54.8	57.8	67.9	74.2	69.4	66.7	53.6	41.7	33.0	51.5
(10)	December, 1911, to November, 1915	6 inches	31.2	31.0	33.6	47.6	58.4	70.4	75.0	71.5	65.4	53.2	40.9	34.2	51.0
		12 inches	32.1	31.4	33.5	44.0	56.6	68.7	73.6	71.0	64.7	53.6	41.6	35.8	50.6
(10)	December, 1911, to November, 1914	18 inches	33.7	32.8	33.7	42.8	55.0	66.8	72.2	70.4	64.9	54.6	43.1	37.6	50.6

EAST LANSING, MICH.—SAND

(10)	December, 1914, to November, 1915	2 inches	30.6	32.2	34.3	56.2	58.7	70.0	76.2	70.8	68.2	54.1	41.1	30.2	51.9
		4 inches	31.3	32.7	34.5	54.4	58.1	68.6	75.0	70.0	67.4	54.0	41.5	31.8	51.6
(10)	December, 1911, to November, 1915	6 inches	30.5	30.5	33.6	47.7	58.5	69.9	74.5	71.4	65.3	53.0	40.5	33.8	50.8
		12 inches	32.2	31.4	33.4	42.9	56.3	67.8	72.8	70.7	64.5	53.6	41.9	36.0	50.3
(10)	December, 1911, to November, 1914	18 inches	34.3	33.0	33.9	42.5	54.4	65.5	71.1	69.9	64.8	55.0	43.8	38.3	50.5

EAST LANSING, MICH.—CLAY

(10)	December, 1914, to November, 1915	2 inches	31.9	32.1	33.9	54.4	57.4	67.8	74.4	69.4	66.7	52.9	41.1	32.3	51.2
		4 inches	32.0	32.3	33.7	52.0	55.3	65.5	71.6	68.2	65.5	52.3	41.2	33.0	50.2
(10)	December, 1911, to November, 1915	6 inches	31.3	30.9	33.2	45.7	57.2	68.8	73.8	70.5	64.8	52.8	41.2	34.4	50.4
		12 inches	32.7	31.7	32.9	42.3	55.5	67.0	72.2	70.2	64.6	53.5	42.2	36.6	50.1
(10)	December, 1911, to November, 1914	18 inches	34.2	32.8	33.3	41.5	54.2	65.3	70.9	69.8	64.9	55.1	43.9	38.2	50.3

EAST LANSING, MICH.—PEAT

(10)	December, 1914, to November, 1915	2 inches	32.0	31.9	31.9	49.9	56.7	67.5	74.2	69.4	66.9	52.9	40.5	33.3	50.6
		4 inches	31.9	31.7	31.6	46.6	55.0	64.6	71.5	67.5	64.7	51.5	40.7	34.0	49.3
(10)	December, 1911, to November, 1915	6 inches	30.8	30.4	31.4	41.1	56.8	68.5	73.9	71.0	65.1	52.9	40.9	34.7	49.8
		12 inches	32.6	31.6	31.9	38.6	54.7	66.9	72.1	71.3	65.6	54.8	42.8	36.6	50.0
(10)	December, 1911, to November, 1914	18 inches	35.2	33.7	33.4	37.8	53.2	64.5	70.8	70.3	65.6	56.4	45.2	39.2	50.4

WOOSTER, OHIO

(11)	1924 to April, 1925	1 inch	*30.3	32.5	*35.2	*47.3	50.8	62.6	63.0	[18] 62.3	------	50.4	37.4	32.0	------
		6 inches	*35.0	37.2	*41.0	*44.8	51.8	65.3	68.8	[24] 69.6	------	50.6	40.6	34.4	------

COLUMBUS, OHIO

(11)	1923	1 inch	------	------	------	------	------	------	------	------	------	------	[4] 43.0	43.4	------
		6 inches	------	------	------	------	------	------	------	------	------	------	[4] 48.4	[30] 49.2	------

LEXINGTON, KY.

(12)	1922–1927	3 inches	*32.7	*35.5	*42.1	*56.0	*62.8	*74.6	*77.1	*76.7	*73.1	*58.3	*45.6	39.2	56.1
(12)	June, 1928 to June, 1929	4 inches	[24] 20.4	17.3	35.4	[19] 49.8	[24] 55.6	*69.4	75.4	[30] 74.6	63.3	55.8	37.6	[30] 24.4	48.2
(12)	1922–1929	18 inches	*36.3	*35.9	*41.5	*52.0	*57.5	*67.8	*70.6	*73.4	*70.2	*59.8	*49.1	41.1	54.6
(12)	1922–1923	36 inches	*41.8	*40.5	*44.0	*50.3	*56.2	*65.8	*70.5	*73.4	*68.8	*62.0	*53.9	47.5	56.2

PURDUE, IND.—CLEAN CULTIVATION WITH WINTER COVER CROP

(13)	May, 1913, to May, 1915	6 inches	33.3	35.9	36.4	47.8	57.6	68.8	73.5	73.9	66.0	57.4	45.6	40.6	53.0

PURDUE, IND.—STRAW MULCH

(13)	May, 1913, to May, 1915	6 inches	36.3	36.2	35.4	42.6	52.4	61.6	67.3	68.2	64.1	57.3	48.0	43.3	51.1

TABLE 1.—*Soil temperatures (°F.)*—Continued

PURDUE, IND.—GRASS LAND

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(13)	May, 1913, to May, 1915	6 inches	35.0	35.6	35.1	49.7	55.5	66.0	71.9	70.6	62.7	54.9	45.6	41.4	52.0

URBANA, ILL.

(14)	1897–1916*	Air	26.9	25.4	38.3	50.2	62.4	70.6	75.5	73.3	66.1	54.4	40.9	28.6	51.0
		1 inch	29.2	29.5	39.8	51.0	63.0	72.6	78.2	76.2	69.0	55.5	42.2	32.1	53.2
		3 inches	31.0	30.6	39.5	50.6	62.2	72.2	77.8	75.8	69.0	56.8	43.0	33.4	53.5
		6 inches	32.6	31.5	39.3	49.2	60.5	70.5	75.8	74.8	68.8	57.0	44.0	35.0	53.2
		9 inches	33.2	33.0	39.2	48.7	59.8	69.4	74.7	74.0	68.6	57.4	45.2	36.0	53.3
		12 inches	34.0	33.2	38.6	48.4	58.8	68.0	73.8	73.2	68.2	58.0	46.2	37.4	53.2
		24 inches	37.6	37.1	38.6	47.1	55.4	62.6	68.5	69.7	66.7	59.5	50.6	42.7	53.0
		36 inches	41.0	38.8	40.1	46.0	53.6	60.3	66.0	67.8	66.1	60.7	53.0	45.8	53.3

CHICAGO, ILL.—ST. IGNATIUS' COLLEGE

(15)	1897–1900	Air	27.7	25.2	36.4	48.8	60.3	62.9	73.6	70.5	65.5	56.7	41.2	29.8	49.7
		4 feet	43.9	41.0	42.2	46.4	53.4	60.8	67.1	68.5	67.4	60.5	55.2	47.0	54.4

COLUMBIA, MO.

(16)	1928	Air			[25] 39.3	[29] 44.3	[30] 57.9	62.5	[30] 71.4	[30] 69.6	[1] Near top of gentle slope.
		12 inches			[22] 45.0	[27] 49.5	[28] 57.9	[26] 64.0	[28] 71.4	[26] 72.3	
		36 inches			44.8	50.5	61.9	66.9	75.7	74.2	
		12 inches			44.2	49.3	57.4	63.7	70.9	71.6	[2] About 200 feet from [1], a seepy spot on slope.
		36 inches			45.0	50.2	62.1	66.9	75.4	74.8	
		12 inches			44.4	49.5	59.7	65.3	73.4	73.8	[3] About 400 feet from [1], at lower part of slope.
		36 inches			45.1	50.7	63.5	68.0	77.2	76.6	

FAYETTEVILLE, ARK.

(17)	May, 1928, to May, 1929	Air	35.8	[20] 33.3	50.9	58.3	*64.6	68.7	77.2	[30] 77.9	68.2	64.6	46.9	[30] 40.1	57.2
		5 inches	40.5	[28] 38.3	51.3	60.6	*65.5	70.7	83.3	[30] 84.9	73.9	69.6	[26] 55.9	[30] 43.9	61.5

FARGO, N. DAK.—SCIENCE GARDEN

(18)	1922–1925*	1 inch					62.3	69.7	77.0	76.4	61.2	49.8			

FARGO, N. DAK.

(19)	1929–30	Air			*42.9	*54.8	64.4	72.6	70.2						
		½ inch			*44.8	*59.8	68.9	73.7	72.2						

BROOKINGS, S. DAK.

(20)	1888	Air (maximum)						84.0	78.2						
		2 inches						81.6	76.4						
		12 inches						69.5	69.7						

LINCOLN, NEBR.—BARE SOIL

(21)	1900–1904	Air	29.2	25.1	42.8	56.5	67.8	75.6	82.7	79.1	68.4	60.7	42.5	28.8	54.9
		1 inch	30.0	28.2	42.4	58.6	74.5	82.3	90.8	85.6	72.0	60.0	43.5	31.0	58.2
		3 inches	30.0	28.7	41.1	59.3	72.1	81.2	88.6	85.3	72.9	61.4	44.3	31.6	58.0
		6 inches	29.6	28.0	37.9	54.5	68.7	77.5	83.6	82.0	71.0	60.2	44.1	31.9	55.8
		9 inches	30.0	28.4	35.7	50.8	64.4	73.0	79.4	77.9	70.5	59.0	44.3	33.4	53.9
		12 inches	31.4	29.3	35.0	48.2	60.8	69.5	75.8	75.0	66.6	58.4	45.1	34.8	52.5
		24 inches	35.1	32.9	34.7	44.8	56.5	64.2	70.8	71.6	66.9	59.7	49.5	39.5	52.2
		36 inches	38.1	35.3	35.7	43.0	53.2	61.1	67.5	69.4	66.7	60.7	52.1	43.2	52.2

LINCOLN, NEBR.

22	1894–1904*	1 inch	28.2	28.0	40.1	58.7	70.9	79.2	86.9	85.1	73.7	58.1	40.6	31.2	56.7
	1894–1904*	3 inches	38.5	27.8	38.8	57.6	69.7	78.1	85.1	84.0	73.5	59.4	42.7	31.4	56.4
	1894–1904*	6 inches	29.0	28.1	37.4	53.6	66.7	76.1	82.1	80.9	72.0	58.3	42.6	31.7	54.9
	1894, 1898–1904*	9 inches	29.8	28.0	36.0	50.8	64.2	73.7	79.7	78.9	71.0	58.5	38.9	28.8	53.2
	1894–1904*	12 inches	30.2	29.9	35.6	49.1	61.2	69.7	75.8	75.6	69.2	57.9	44.5	34.6	52.8
	1894–1904*	24 inches	35.1	33.1	35.3	45.4	56.9	64.6	70.5	72.0	68.2	60.0	49.2	39.5	52.5
	1894–1904*	36 inches	38.1	35.1	36.0	43.6	53.8	61.5	67.7	69.8	67.9	61.3	51.9	43.0	52.5

MANHATTAN, KANS.—FURROWS

23	1914–1919	Surface			28.4	Average for 5 winters from December to February or March.
		2-inch furrow			28.8	
		4-inch furrow			30.0	
		6-inch furrow			30.2	

TEMPLE, TEX.

24	1921–1924	Air	51.5	53.2	59.8	68.0	75.6	83.4	87.1	88.6	79.9	68.7	61.0	54.4	69.3
	1918–1924	1 inch	53.1	52.6	59.4	69.1	78.8	88.6	93.7	93.2	83.8	72.6	59.8	52.6	71.4
	1918–1924	3 inches	53.2	52.3	58.6	67.9	78.3	86.5	92.2	93.3	83.9	73.1	60.2	52.8	71.0
	1918–1924	6 inches	53.3	52.7	58.7	67.5	77.3	85.6	91.7	92.3	83.8	73.3	60.9	53.4	70.9
	1918–1924*	12 inches	54.6	53.5	58.1	65.9	74.9	83.4	87.8	88.9	83.8	74.8	62.9	55.4	70.3
	1918–1924	24 inches	56.9	55.2	58.2	64.8	72.1	78.9	84.2	86.9	83.6	76.3	67.0	59.5	70.3
	1918–1924	36 inches	59.6	57.4	59.0	64.2	70.2	76.4	81.7	84.4	83.3	78.7	71.0	62.9	70.7
	1918–1924	48 inches	61.1	58.9	59.0	63.6	68.7	74.0	79.2	82.2	82.1	79.2	73.2	65.0	70.5

TABLE I.—*Soil temperatures (°F.)*—Continued

BOZEMAN, MONT.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
25	1916–1920	1 foot	29.7	29.1	30.2	35.0	44.2	55.4	64.4	62.9	55.4	44.6	35.4	31.5	43.2
		2 feet	31.8	30.7	31.4	34.8	42.8	52.3	60.0	61.4	56.2	47.0	38.6	34.1	43.4
		3 feet	33.5	32.2	32.0	34.1	40.0	48.7	56.1	58.1	55.1	47.6	39.9	35.6	42.7
		4 feet	36.0	34.4	33.6	34.6	38.8	46.1	53.8	57.3	55.2	49.2	42.8	38.3	43.3
		5 feet	37.7	35.7	34.7	35.3	38.8	44.8	51.0	54.2	53.7	49.8	44.4	40.2	43.4
		7.5 feet	41.2	39.3	37.9	37.4	38.7	42.0	46.6	50.8	51.9	50.0	46.4	43.4	43.8
		10 feet	41.8	39.8	38.5	37.9	38.7	41.7	46.1	50.0	51.4	50.1	46.9	43.9	43.9

MOSCOW, IDAHO

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
26	1898, 1899, and 1901 (1901 only in January, February, March, October, November, and December)	1 inch				40.7	49.4	57.1	63.8	63.4	52.7	47.0	38.2	32.2	
		3 inches	30.8	28.8	34.4	41.2	51.2	58.0	64.1	67.5	54.6	47.8	40.8	33.8	46.1
		6 inches	31.8	30.2	34.6	42.9	48.6	56.0	63.6	65.4	56.8	50.5	41.6	34.6	46.4
		9 inches	32.8	31.0	35.0	45.9	48.9	54.8	62.9	64.9	57.5	51.8	42.8	36.4	47.1
		12 inches	33.2	32.8	35.4	44.7	48.4	54.8	62.2	64.3	58.1	52.2	43.6	37.4	47.7
		24 inches	35.8	34.5	36.2	44.5	47.5	52.9	59.2	62.5	58.2	53.2	45.8	39.2	47.5
		36 inches	37.8	36.2	37.0	40.5	46.2	50.1	55.9	60.0	57.8	53.8	48.0	41.6	47.1
		4 feet	39.8	38.0	38.0	40.5	45.4	48.8	53.7	58.1	57.1	53.8	48.8	43.4	47.1
		5 feet	40.8	39.5	38.8	40.6	44.6	47.5	51.8	56.3	56.5	54.0	49.6	44.6	47.0
		6 feet	42.8	40.8	39.6	41.5	44.6	47.1	50.6	54.7	55.5	54.0	51.6	46.2	47.4

FORT COLLINS, COLO.

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(27)	1889–1927	3 inches	27.7	29.6	36.5	46.6	56.5	66.7	71.4	69.3	61.1	48.3	36.7	29.7	48.3
		6 inches	29.3	30.6	37.1	47.4	56.6	67.0	71.9	70.4	62.8	50.8	39.0	30.2	49.4
		1 foot	32.8	31.1	36.6	45.5	55.8	65.5	70.9	70.1	63.7	52.3	40.7	33.2	49.8
		2 feet	32.9	32.7	36.8	45.3	53.3	62.5	68.5	68.8	64.0	54.4	43.7	36.5	50.0
		3 feet	35.4	32.6	37.1	43.6	51.1	59.1	65.2	66.6	63.4	55.5	46.0	38.9	49.5
		6 feet	42.5	40.5	40.8	44.2	48.8	54.2	59.2	61.8	62.0	58.0	52.1	46.5	50.9

SANTA CATALINA MOUNTAINS, ARIZ.

Reference No.	Year	Depth	Elevation	Slope	Maximum	Minimum	Range	Mean
			Feet					
(28)	Averages of 18 weekly readings of soil temperatures, summer of 1922	3 inches	9,000	North	59.3	53.1	6.2	56.2
			9,000	South	77.7	61.6	16.1	69.6
			8,000	North	62.4	56.5	5.9	59.4
			8,000	South	82.6	60.9	21.7	71.8
			7,000	North	78.9	50.6	28.3	64.7
			7,000	South	91.9	61.3	30.6	76.6

PULLMAN, WASH.—BLUEGRASS SOD

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(29)	April, 1912, to January, 1913	1 inch	31.7			46.5	60.2	62.7	66.0	75.4	60.2	42.0	40.0	33.2	
		2 inches	31.9			45.4	57.8	63.2	65.9	73.2	58.9	42.0	39.9	33.7	
		6 inches	32.3			44.7	54.9	62.3	64.8	70.2	57.2	42.4	40.4	34.5	
		1 foot	32.7			44.8	52.8	62.2	64.9	67.7	56.7	45.0	42.2	36.0	
		2 feet	35.6			44.3	50.6	59.0	62.8	66.5	58.5	48.5	45.0	39.2	
		3 feet	37.5			44.1	48.9	56.3	60.9	64.8	58.9	50.9	47.4	41.9	

PENDLETON, OREG.—DRY, LIGHT SOIL, THIN GRASS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(30)	1890	Air	21.0	30.1	42.0	52.2	60.1	63.0	68.8	68.8	60.0	49.6	40.4		
		4 inches	26.7	37.3	44.9	62.2	72.3	74.2	84.6	83.3	73.2	57.4	45.8		
		8 inches	27.8	36.6	40.9	55.3	66.3	68.4	77.6	75.8	66.5	53.7	43.2		
		12 inches	30.4	37.1	39.8	52.2	63.1	65.8	73.7	73.3	65.7	54.7	45.2		
		24 inches	34.6	38.1	40.1	50.1	60.9	63.7	71.0	71.7	66.7	57.3	48.5		

CORVALLIS, OREG.—WET AND DRY SOILS UNDER ALFALFA AND CLOVER COVERS

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(31)	1910	Air							[3] 81.8	[4] 71.9	[2] 71.8				
		3 inches, dry							[3] 80.7	[4] 77.8	[2] 70.5				Average, under alfalfa and clover.
		3 inches, wet							[3] 76.2	[4] 71.6	[2] 64.5				
		3 inches, dry							[3] 82.0	[4] 77.5	[2] 71.0				Under alfalfa.
		3 inches, wet							[3] 77.0	[4] 71.8	[2] 64.0				
		3 inches, dry							[3] 79.3	[4] 78.0	[2] 70.0				Under clover.
		3 inches, wet							[3] 75.5	[4] 71.5	[2] 65.0				

DAVIS, CALIF.—DEEP, RECENT ALLUVIAL SOIL, UNCROPPED

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(32)	February to September, 1925, and January to June, 1927.	Air	44.8	49.9	51.6	54.2	60.3	69.1	75.6	70.8	63.6				
		½ inch	48.0	51.1	58.4	63.2	74.8	82.0	90.6	86.0	77.4				
		3 inches	48.2	49.9	55.2	61.9	72.9	78.9	86.6	83.2	76.4				
		6 inches	48.8	50.2	54.5	60.9	72.0	78.0	87.2	84.5	79.4				
		12 inches	48.5	50.2	53.7	60.2	70.8	76.4	84.4	83.0	77.2				
		24 inches	53.2	51.9	54.6	59.7	68.4	72.9	82.8	82.8	78.2				
		36 inches	51.2	51.4	54.3	60.1	68.8	72.9	80.8	82.5	78.6				

TABLE 2.—*Mean daily ranges—Soil and air temperatures (° F.)*

[Superior figures in figure columns are additional references under "Literature Cited" at end of article]

NEW HAVEN, CONN.—SANDY LOAM, LEVEL, EXPOSED TO SUN

Reference No.	Year	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(4)	1926	Air					[31] 14.2	11.1	11.2	10.6	10.7	8.3	[24] 9.6		
		3 inches					[8] 11.6	[29] 13.1	6.4	[30] 11.0	[28] 10.9	6.1	[18] 5.6		
		6 inches					[8] 6.2	[29] 7.4	8.7	[30] 5.8	[27] 6.6	4.4	[17] 3.0		
		9 inches					[8] 3.5	3.5	2.5	[30] 1.9	[28] 2.6	1.4	[19] 1.6		
		12 inches					[8] 1.6	[29] 1.7	1.2	[30] 1.0	[28] 1.3	[30] 1.1	[18] 0.9		

NEW HAVEN (YALE UNIVERSITY)—TEMPERATURES TAKEN IN BORINGS IN THE SOIL

(5)	1924	Air				20.1	17.5								
		6 inches				6.3	6.8								
		12 inches				5.7	6.6								
		18 inches				3.3	2.9								

NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM

(6)	1902	Air						[23] 18.9	17.7	20.0	16.9	[25] 16.9	[23] 15.8	[14] 11.2	
		12 inches						[21] 2.6	2.5	[29] 1.4	1.4	1.2	0.9	[21] 1.1	

ATHENS, GA.—LAND BEDDED UP FOR COTTON

(8)	1926	Air			26.7	Average from Apr. 22. to May 20.									
		1.5 inches			18.9										

WOOSTER, OHIO

(11)	1924 to April, 1925	1 inch	*3.6	5.3	*11.6	*21.8	22.2	23.2	22.9	[18] 17.0		16.9	8.5	4.9	
		6 inches	*1.0	1.2	*3.3	*7.3	7.8	9.0	8.3	[24] 8.4		3.3	2.7	1.5	

COLUMBUS, OHIO

(11)	1923	1 inch											[4] 6.9	9.8	
		6 inches											[4] 1.1	[30] 2.5	

LEXINGTON, KY.

(12)	1924–1927*	3 inches	1.2	3.2	5.8	7.5	6.2	7.7	8.7	7.1	8.4	6.9	5.1	4.3	6.0
	June, 1928, to June, 1929	4 inches	[24] 2.9	1.0	8.1	[29] 7.6	[24] 6.5	5.7	10.2	[30] 8.2	7.4	6.5	5.5	[30] 3.7	6.1
	1924–1927*	18 inches	0.8	1.6	0.9	1.0	1.0	0.8	0.9	0.8	0.8	1.1	1.0	1.4	1.0

PURDUE, IND.—CLEAN CULTIVATION WITH WINTER-COVER CROP

(13)	May, 1913 to May, 1915	6 inches	1.4	5.4	6.7	11.9	10.8	9.2	9.4	8.2	11.7	7.6	10.3	5.2	8.2

PURDUE, IND.—STRAW MULCH

(13)	May, 1913, to May, 1915	6 inches	1.8	2.7	1.6	5.3	3.5	3.7	2.6	3.2	4.2	3.8	4.4	3.5	3.4

PURDUE, IND.—GRASS LAND

(13)	May, 1913, to May, 1915	6 inches	2.1	4.1	3.8	9.0	9.8	8.7	8.4	6.8	7.4	5.0	7.7	4.7	6.5

FARGO, N. DAK.—SCIENCE GARDEN

(18)	1922–1925*	1 inch					27.9	30.2	36.3	43.8	32.9	22.3			

FARGO, N. DAK.

(19)	1929–30	Air				*21.8	*24.9	26.6	28.5	25.4					
		½ inch				*8.0	*7.0	9.0	15.9	13.6					

TABLE 3.—*Mean monthly ranges—Soil and air temperatures (° F.)*

NEW HAVEN, CONN.—SANDY LAOM, LEVEL, EXPOSED TO SUN

[Superior figures in figure columns are additional references under "Literature cited" at end of article]

Reference No.	Years	Depth	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual monthly range
(4)	1926	Air					[2] 33.0	37.0	41.0	39.0	35.0	34.0	[14] 37.0		
		3 inches					[2] 27.0	[29] 38.0	38.0	[30] 33.0	[28] 26.0	34.0	[18] 27.0		
		6 inches					[2] 18.0	[29] 26.0	26.0	[30] 21.0	[27] 21.0	27.0	[17] 19.0		
		9 inches					[9] 14.0	16.0	14.0	[30] 15.0	[28] 14.0	15.0	[19] 16.0		
		12 inches					[9] 10.0	[29] 11.0	11.0	[30] 12.0	[28] 12.0	[30] 18.0	[18] 14.0		
	NEW YORK BOTANICAL GARDENS—CLAY SOIL MIXED WITH LOAM														
(6)	1902	Air						[22] 40.5	37.4	37.4	44.8	[28] 43.6	[23] 40.5	[14] 36.9	
		12 inches						[21] 7.2	10.8	[29] 9.0	11.7	13.3	0.9	[21] 2.2	
	WOOSTER, OHIO														
(11)	1924 to April, 1925	1 inch	*17.4	26.7	*23.2	*44.4	42.5	42.0	34.5	[18] 30.5		34.5	30.0	28.0	
		6 inches	*6.8	11.6	*13.3	*27.5	23.0	27.5	18.5	[24] 19.0		18.5	19.5	12.5	
	COLUMBUS, OHIO														
(11)	1923	1 inch											[4] 10.0	20.0	
		6 inches											[4] 3.5	[30] 1.0	
	LEXINGTON, KY.														
(12)	1924–1928*	3 inches	14.5	13.0	26.3	31.7	19.3	18.3	17.2	17.8	16.2	25.5	[27] 28.0	28.5	21.4
	July, 1928, to June 1929	4 inches	[24] 20.5	13.5	37.5	21.0	[24] 16.5	[6] 5.5	[9] 7.0	[30] 20.0	25.5	29.0	29.5	18.5	20.3
	June, 1928 to May, 1929	8 inches	[24] 12.5	8.5	23.0	10.0	[24] 14.0	[19] 9.5	[9] 8.0	[30] 10.5	[29] 16.0	17.0	16.5	13.0	13.2
	1924*–1927*	18 inches	8.3	16.3	11.2	12.3	7.2	9.5	10.2	5.0	10.5	9.5	16.0	12.0	10.7
	FARGO, N. DAK.—SCIENCE GARDEN														
(18)	1922–1925*	1 inch					58.9	56.7	60.8	67.0	[3] 38.3	[17] 48.1			
	FARGO, N. DAK.														
(19)	1929–30	Air				*47.0	*66.2	60.2	62.0	59.0					
		½ inch				*27.0	*38.5	30.5	42.5	38.5					
	TEMPLE, TEX.														
(24)	1921–1924	Air	59.2	53.8	51.2	45.2	38.5	31.5	31.8	36.0	42.5	54.2	55.0	41.5	45.0
	1918–1924	1 inch	41.4	37.2	39.7	39.6	35.4	37.4	39.3	37.7	42.1	42.5	41.8	41.8	39.7
	1918–1924	3 inches	32.9	30.9	33.9	32.6	30.4	30.8	30.6	29.3	33.3	35.9	35.0	35.1	32.6
	1918–1924	6 inches	28.2	23.5	26.1	25.3	25.3	24.1	23.3	21.7	25.6	29.7	27.1	26.7	25.6
	1918–1924*	12 inches	19.0	16.8	13.8	14.0	15.8	8.9	10.5	7.7	12.6	17.8	15.8	20.7	14.4
	1918–1924	24 inches	11.9	10.5	9.7	8.1	11.5	8.4	5.4	5.5	6.6	10.0	10.5	12.3	9.2
	1918–1924	36 inches	10.1	6.6	4.9	5.8	7.9	6.1	4.1	4.4	4.4	6.6	9.4	10.1	6.7
	1918–1924	48 inches	7.1	6.5	2.8	4.7	6.2	7.0	3.8	3.2	2.6	5.3	7.0	10.8	5.6

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