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INTRODUCTION

Land preparation, seed germination, root growth, availability of plant nutrients, activities of soil organisms and effectiveness of herbicides are affected by soil temperature. Numerous stations record air temperature. Soil temperature measurements are not commonly available.

Studies by Fitton and Brooks (1931), McCalla and Duley (1946), Carson and Moses (1963), and Baker (1965) show that differences in texture, moisture, organic matter, slope, aspect of slope and cover result in soil temperature differences. The physics of heat transfer in soil is discussed by Sellers (1965).

Soil temperature measurements between 1888–1904 at Lincoln, Nebraska, are among the earliest recorded in the United States. Monthly summaries of these data by Carter (1928) show air temperature and soil temperature at different depths, but soil temperature prediction from air temperature was not attemped.

As an aid in determining spring seeding dates for crops in far eastern U.S.S.R., Krasnianski (1961) developed linear equations using air temperature to predict soil temperature at 5 and 10 cm. depths. High correlations in this study showed close relationships between air and soil temperature but errors of estimate were not reported.

This study concerns the use of weekly average air temperature for predicting weekly average soil temperature under different conditions of surface cover during different times of year. Probabilities of weekly average air temperature for Lincoln as well as other Nebraska locations are available (Neild 1967). These probabilities and the soil temperature prediction equations may be used in determining expected soil temperatures.

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PROCEDURE

Data used in this study were air and soil temperatures reported from the University of Nebraska Agronomy Farm near Lincoln during 1960–65 (Nebraska Climatological Data, U.S. Weather Bureau). Air temperature was recorded in a standard U.S. Weather Bureau shelter. Temperatures under a bare soil and brome grass sod at various depths were recorded by a Palmer soil thermometer. The soil type was Sharpsburg silty clay loam on a nearly level site.

A computer was used to derive constants for the following soil temperature prediction model:

$Y = a + bX_1 + cX_2$

X_1 = weekly average air temperature.

X_2 = week number of the year begining March 1.

Y = weekly average soil temperature at different depths and under varying cover conditions.

For the 8 inch depth during the summer season a nonlinear model involving X_2^2 in addition to X_1 and X_2 was used.

Week number was used as a variable expressing lag in warming and cooling at different depths during different seasons.

Data for different periods of the year classified as spring, summer and fall were analyzed separately. Week numbers corresponding with calendar weeks during different seasons are given in Table 1.

Table 1. Week numbers and calendar weeks of different seasons.

Spring		Summer		Fall	
Week number	Calendar week	Week number	Calendar week	Week number	Calendar week
1	3/1 – 3/7	14	5/31 – 6/6	27	8/30 – 9/5
2	3/8 – 3/14	15	6/7 – 6/13	28	9/6 – 9/12
3	3/15 – 3/21	16	6/14 – 6/20	29	9/13 – 9/19
4	3/22 – 3/28	17	6/21 – 6/27	30	9/20 – 9/26
5	3/29 – 4/4	18	6/28 – 7/4	31	9/27 – 10/3
6	4/5 – 4/11	19	7/5 – 7/11	32	10/4 – 10/10
7	4/12 – 4/18	20	7/12 – 7/18	33	10/11 – 10/17
8	4/19 – 4/25	21	7/19 – 7/25	34	10/18 – 10/24
9	4/26 – 5/2	22	7/26 – 8/1	35	10/25 – 10/31
10	5/3 – 5/9	23	8/2 – 8/8	36	11/1 – 11/7
11	5/10 – 5/16	24	8/9 – 8/15	37	11/8 – 11/14
12	5/17 – 5/23	25	8/16 – 8/22	38	11/15 – 11/21
13	5/24 – 5/30	26	8/23 – 8/29	39	11/22 – 11/28
				40	11/29 – 12/5

RESULTS AND DISCUSSION

Regression equations for estimating soil temperature, coefficients of determination (R^2) measuring variation in soil temperature associted with regression (air temperature and week number) and standard errors (S.E.) in estimating soil temperature for different depths under bare soil and sod during spring, summer and fall are given in Table 2.

During spring and fall, R^2 X 100 shows temperature and week number to explain 85% or more of the variation in soil temperature. During the summer, at depths less than 8 inches and under sod in particular, coefficients of determination were lower. These lower values are quite probably associated with variations in shading and canopy height of the growing brome grass.

Regression coefficients measuring the relationship between week number and soil temperature show the soil at shallow depths to be warming up at an average rate ranging from 1.29 to 1.78° F. per week during the spring and to be cooling at an average rate between 1.75 to 2.22° F. per week during the fall.

Table 2. Regression equations, coefficients of determination and standard errors for estimating soil temperature.

Depth	Bare soil	Sod
Spring		
< 1″	$Y = 0.82X_1 + 1.35X_2 + 7.04$ $R^2 = .97$ S.E. = 3.07	$Y = 0.66X_1 + 1.30X_2 + 9.22$ $R^2 = .94$ S.E. = 3.59
2″	$Y = 0.67X_1 + 1.29X_2 + 9.23$ $R^2 = .96$ S.E. = 3.01	$Y = 0.46X_1 + 1.64X_2 + 13.46$ $R^2 = .95$ S.E. = 2.80
4″	$Y = 0.52X_1 + 1.57X_2 + 12.06$ $R^2 = .96$ S.E. = 2.82	$Y = 0.41X_1 + 1.50X_2 + 15.57$ $R^2 = .90$ S.E. = 3.77
8″	$Y = 0.47X_1 + 1.59X_2 + 12.49$ $R^2 = .93$ S.E. = 3.37	$Y = 0.31X_1 + 1.78X_2 + 19.15$ $R^2 = .92$ S.E. = 3.31
Summer		
< 1″	$Y = 0.91X_1 + 20.44$ $R^2 = .61$ S.E. = 3.59	$Y = 0.68X_1 + 29.71$ $R^2 = .41$ S.E. = 4.03
2″	$Y = 0.77X_1 + 23.67$ $R^2 = .62$ S.E. = 2.92	$Y = 0.66X_1 + 25.50$ $R^2 = .58$ S.E. = 2.76
4″	$Y = 0.71X_1 + 24.74$ $R^2 = .62$ S.E. = 2.72	$Y = 0.53X_1 + 0.39X_2 + 25.00$ $R^2 = .47$ S.E. = 3.47
8″	$Y = 0.28X_1 + 6.50X_2 - 0.15X_2^2 - 13.52$ $R^2 = .74$ S.E. = 2.19	$Y = 0.22X_1 + 6.05X_2 - 0.14X_2^2 - 8.40$ $R^2 = .77$ S.E. = 1.91
Fall		
< 1″	$Y = 0.49X_1 - 2.22X_2 + 108.84$ $R^2 = .90$ S.E. = 4.42	$Y = 0.50X_1 - 1.81X_2 + 89.68$ $R^2 = .92$ S.E. = 3.41
2″	$Y = 0.38X_1 - 2.20X_2 + 110.48$ $R^2 = .92$ S.E. = 3.63	$Y = 0.38X_1 - 1.77X_2 + 93.87$ $R^2 = .93$ S.E. = 2.79
4″	$Y = 0.36X_1 - 1.95X_2 + 102.46$ $R^2 = .92$ S.E. = 3.29	$Y = 0.33X_1 - 1.75X_2 + 96.54$ $R^2 = .88$ S.E. = 3.20
8″	$Y = 0.32X_1 - 2.00X_2 + 107.96$ $R^2 = .85$ S.E. = 4.67	$Y = 0.18X_1 - 2.00X_2 + 114.96$ $R^2 = .94$ S.E. = 2.51

Regression coefficients measuring average change in soil temperature per 1° F. change in air temperature show the effect of air temperature on soil temperature to decrease with depth in all seasons. For example, a 1° F. change in air temperature resulted in changing soil temperature 0.82, 0.67, 0.52, and 0.47° F. respectively at depths of < 1, 2, 4 and 8 inches during the spring and 0.91, 0.77, 0.71 and 0.28° F. respectively during the summer on bare soil.

Average rate of soil temperature change per 1° change in air temperature was less under sod than in bare soil. This was particularly true at shallow depths. During the spring for example, a 1° F. change in air temperature resulted in a change of 0.82 and 0.66° F. at < 1 inch depths respectively under bare soil and sod compared to 0.47 and 0.31° F. at 8 inches. Standard errors in estimating weekly average soil temperature ranged from 2.80 – 3.77° F. in the spring, 1.91 – 4.03° F. in the summer and 2.79 – 4.67° F. in the fall.

Prediction equations in Table 2 were tested using independent data from different years and for different locations in Nebraska. Estimated and actual bare soil temperatures at different depths in 1966 are compared in Figure 1 (a-d). With exception of early July, actual and estimated soil temperatures were in close agreement.

Figure 2(a-c) compares estimated and actual temperatures for different locations and soil types. Figure 2a is data from 2″ under a bare Sharpsburg silty clay loam at the Mead Field Laboratory about 30 miles north of Lincoln. Figure 2b is data from a 2″ depth under a brome grass sod covering a Moody silty clay loam at the Northeast Experiment Station about 140 miles north of Lincoln. Data in Figure 2c are from a 2 inch depth under a bare Bridgeport fine sandy loam at the Box Butte Experiment Station about 370 miles west of Lincoln. With exception of early August at the Northeast Station and early March at the Box Butte Station, the data are in relative agreement.

Nomographs in Figure 3 (a-u) may be used to rapidly estimate soil temperature. For example, if the average temperature for the week beginning April 26 (Week 9) is 55° F. (Fig. 3c) reading up to line 9 then left shows the estimated soil temperature at 2″ under bare soil is 58° F. Nomographs except those in Figure 3i and 3j represent prediction equations for any week during the summer period for the depths shown.

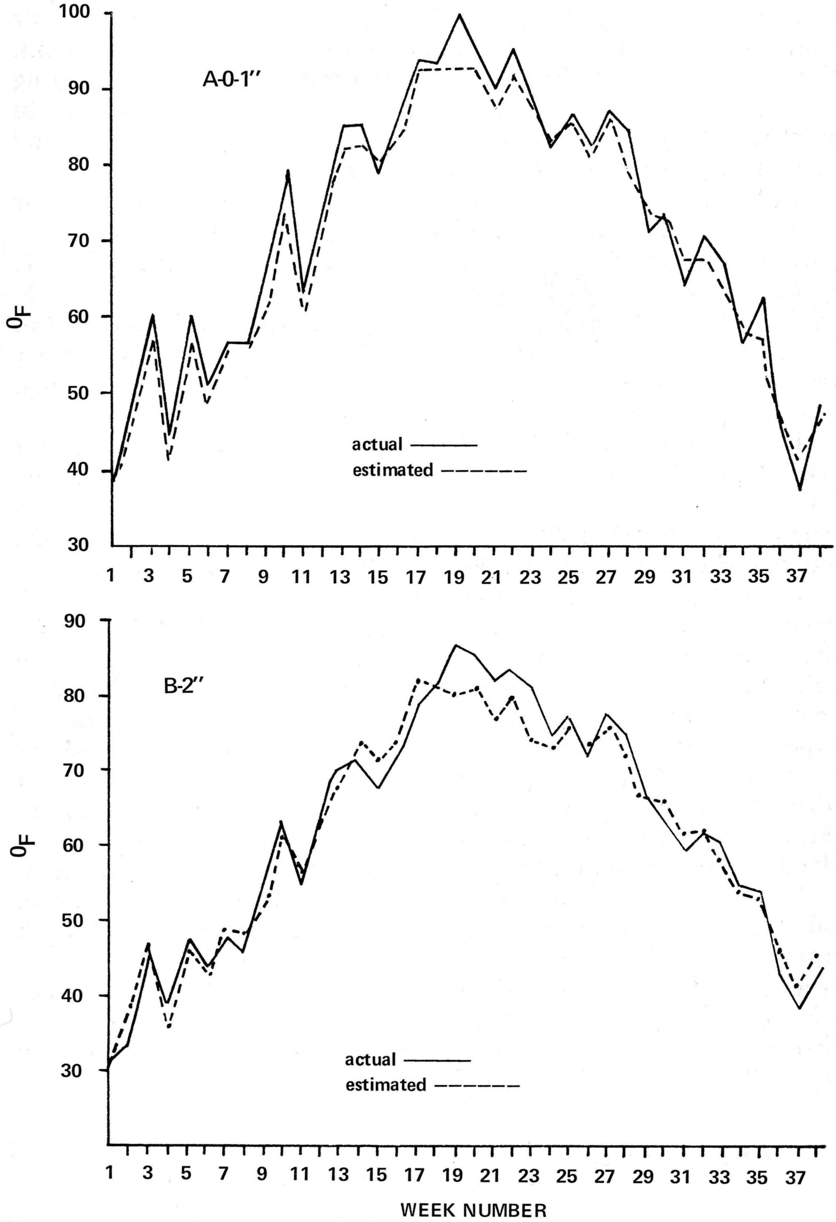


Figure 1. Estimated and actual soil temperature, Lincoln, Nebraska, 1966.

Figure 1 continued

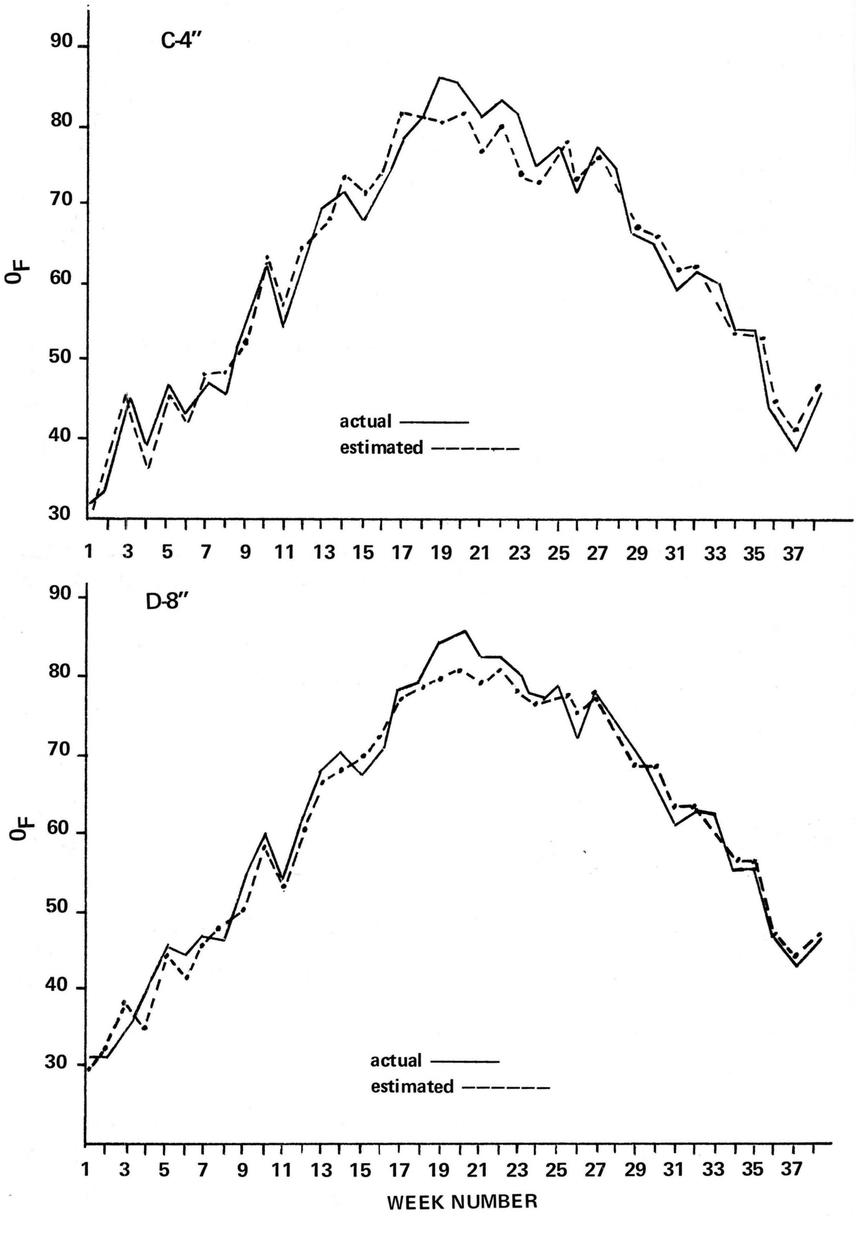


Figure 1 (continued).

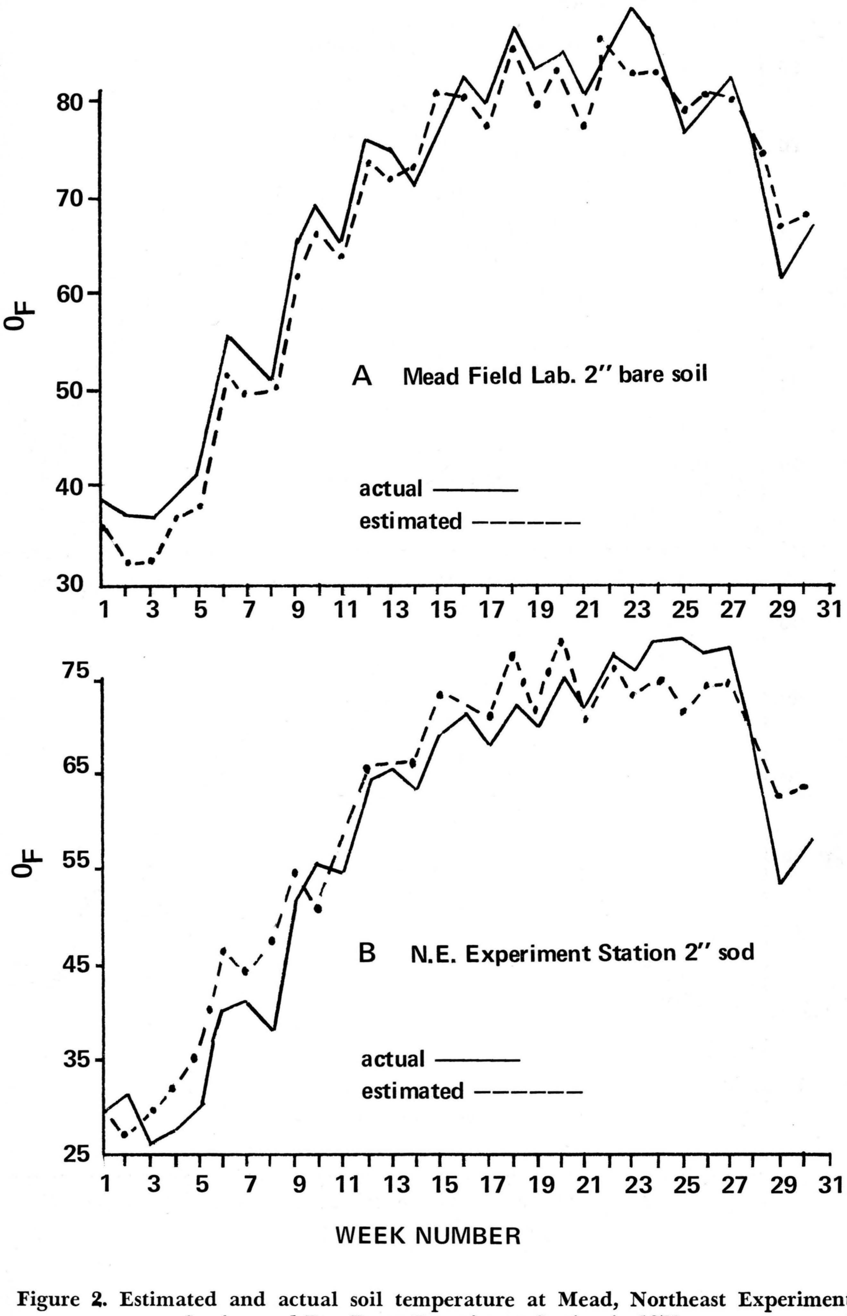


Figure 2. Estimated and actual soil temperature at Mead, Northeast Experiment Station and Box Butte Experiment Station in 1970.

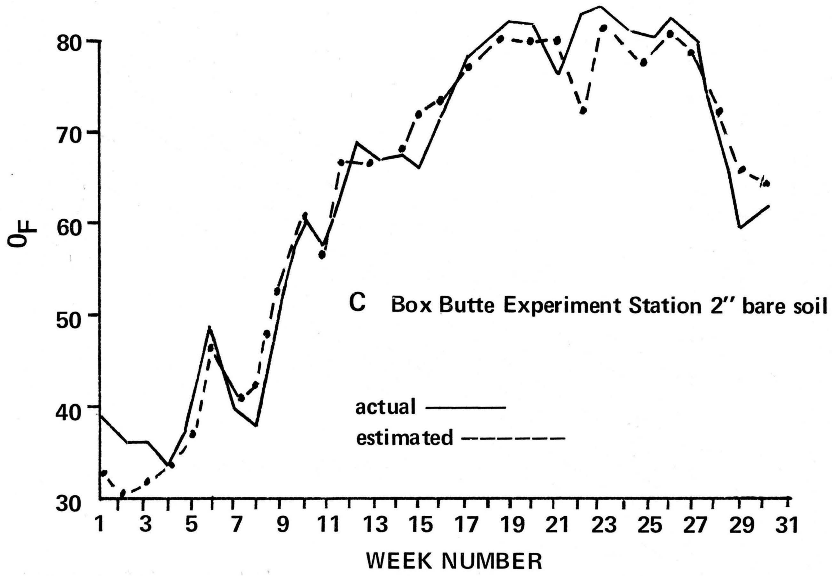


Figure 2 (continued).

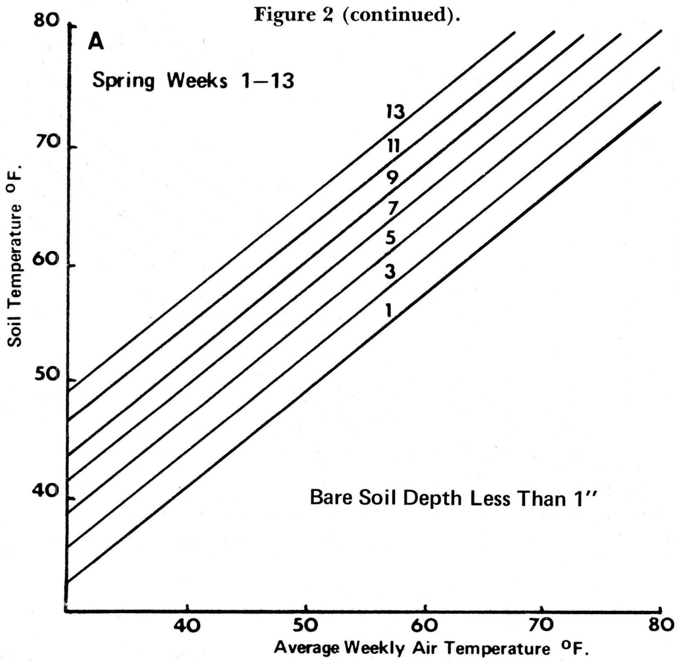


Figure 3. Nomographs for estimating *soil temperature.*

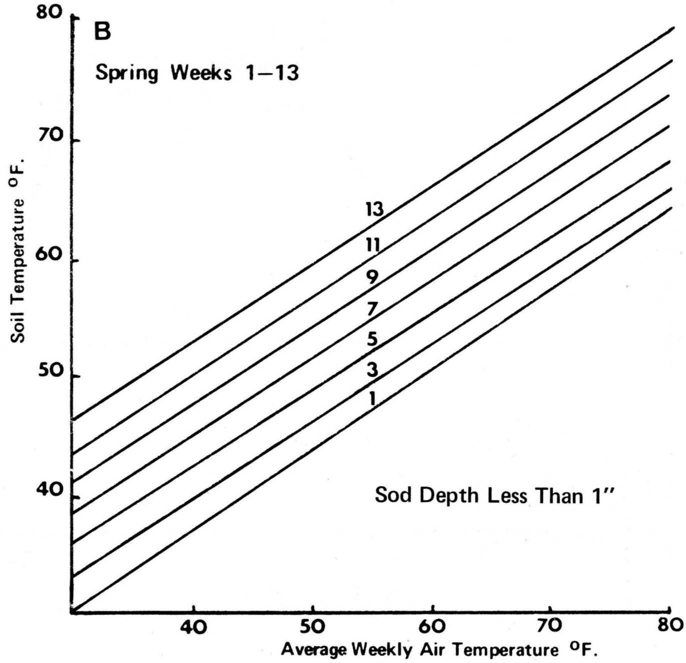


Figure 3 (continued).

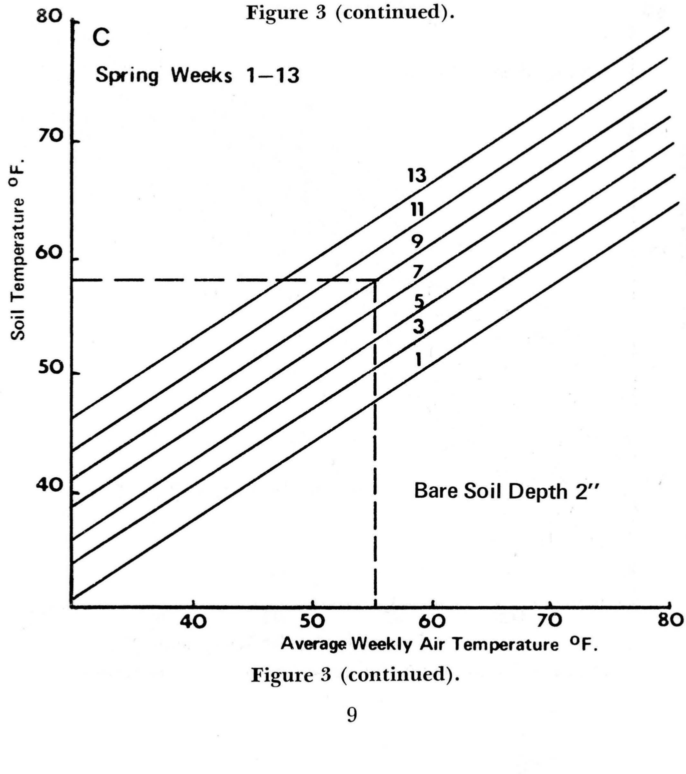
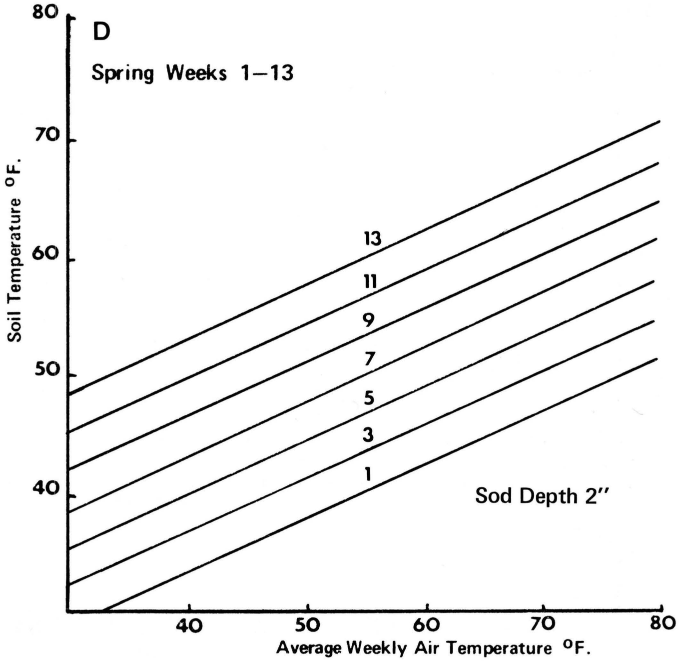


Figure 3 (continued).



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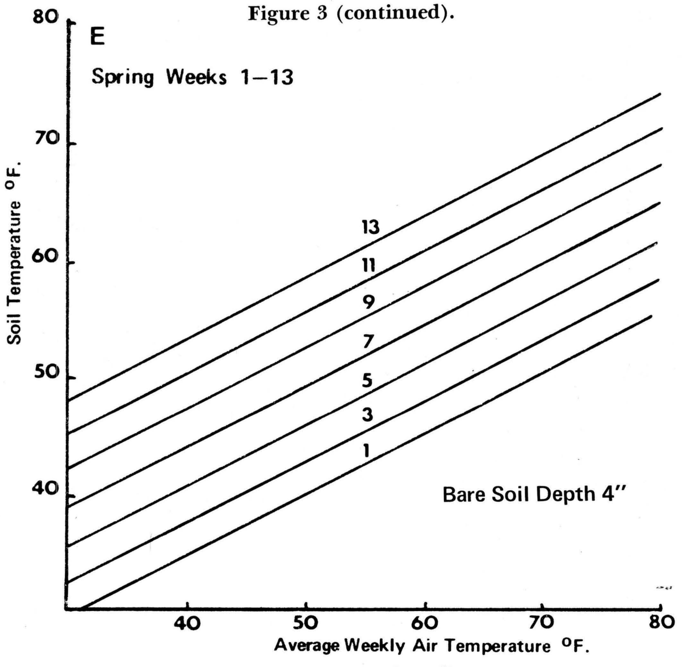

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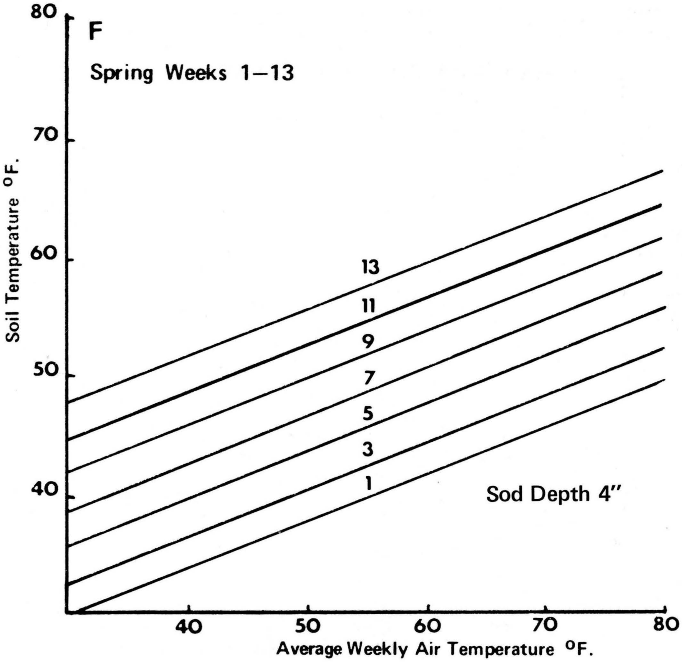

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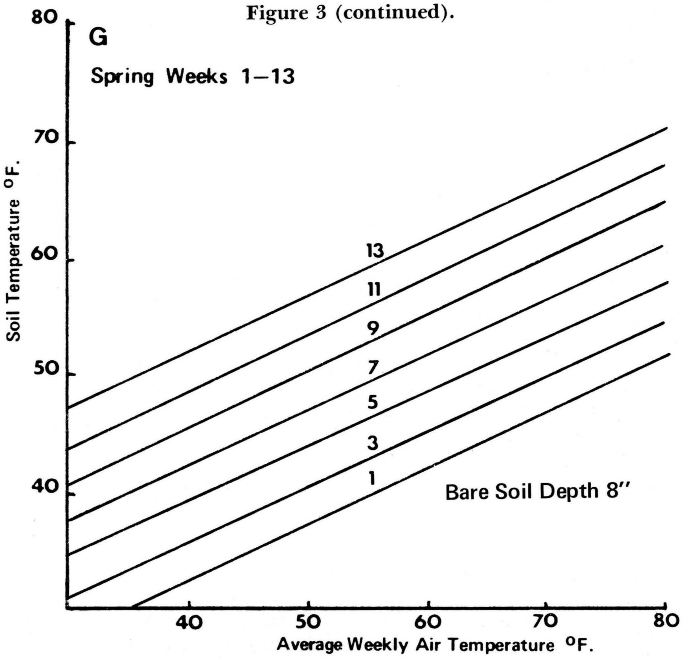

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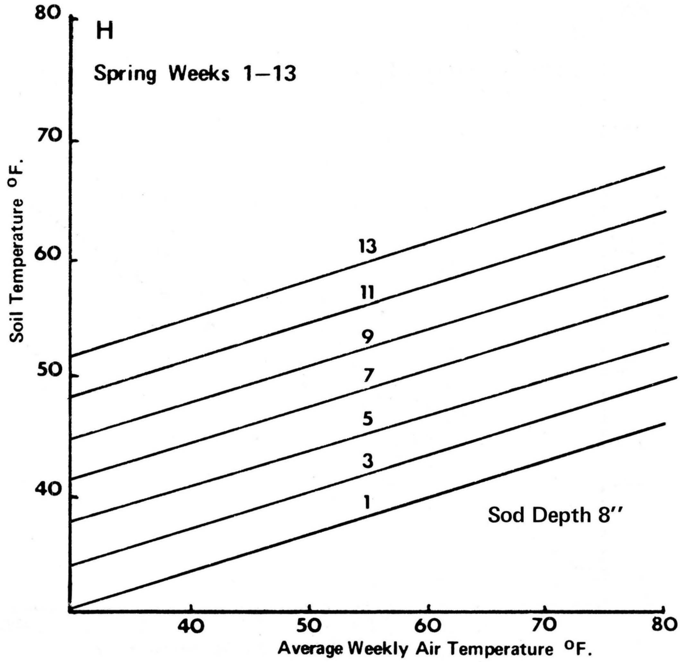

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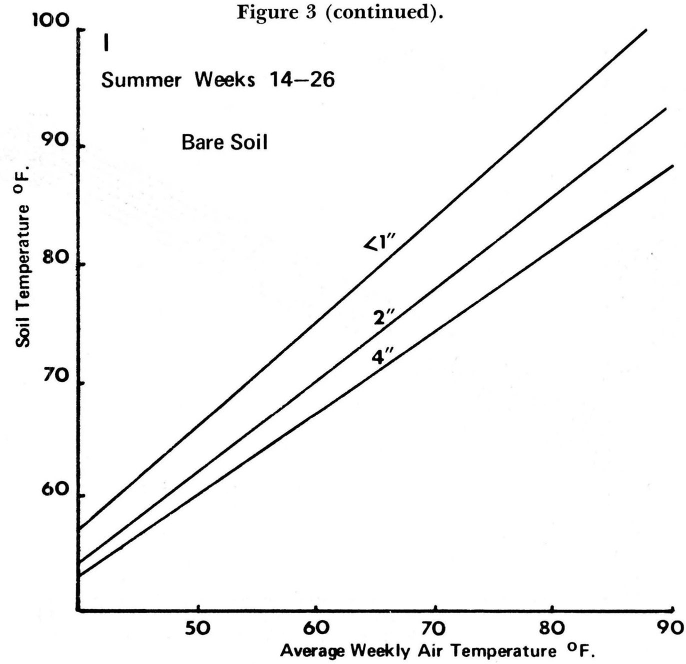

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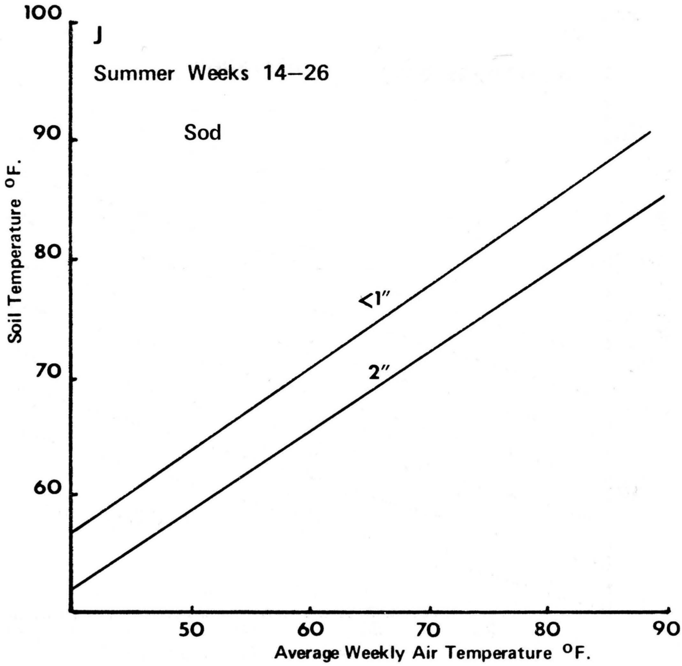
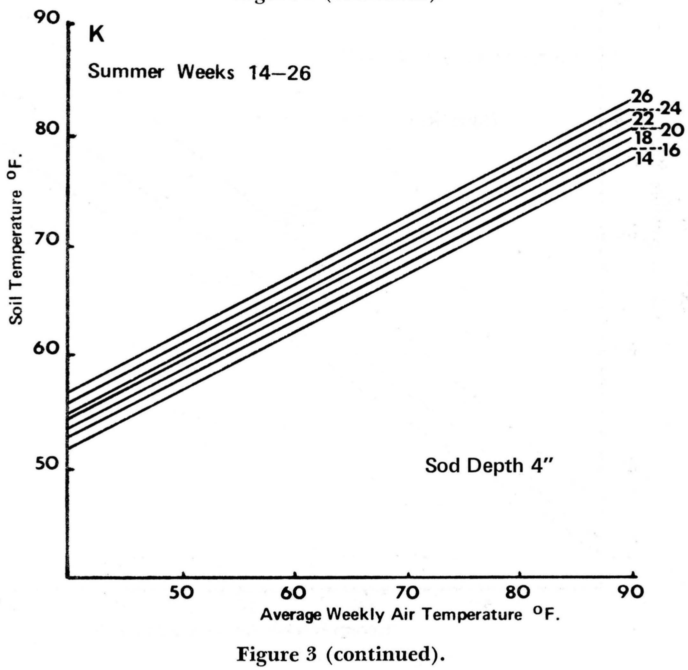


Figure 3 (continued).



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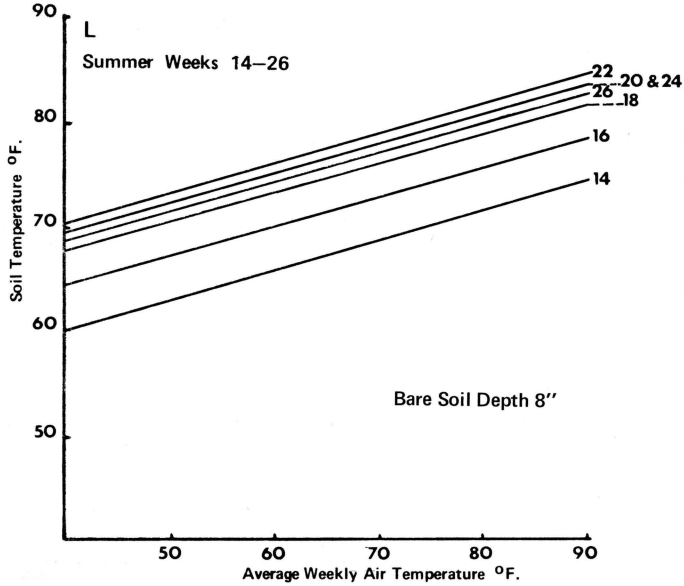

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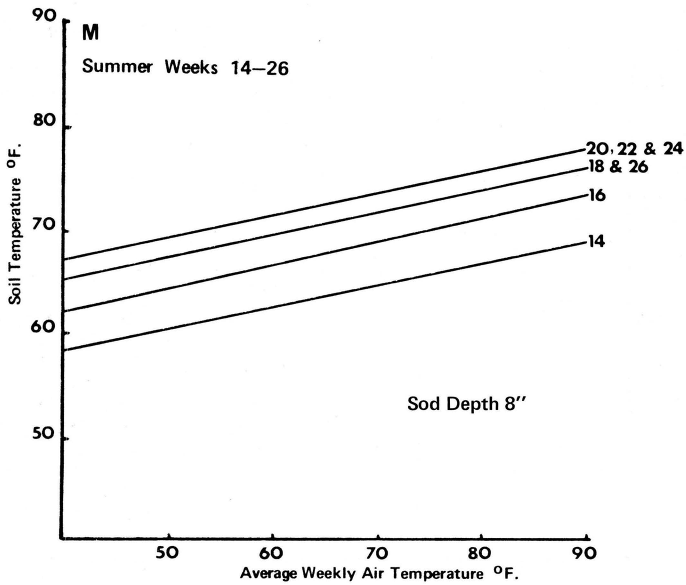

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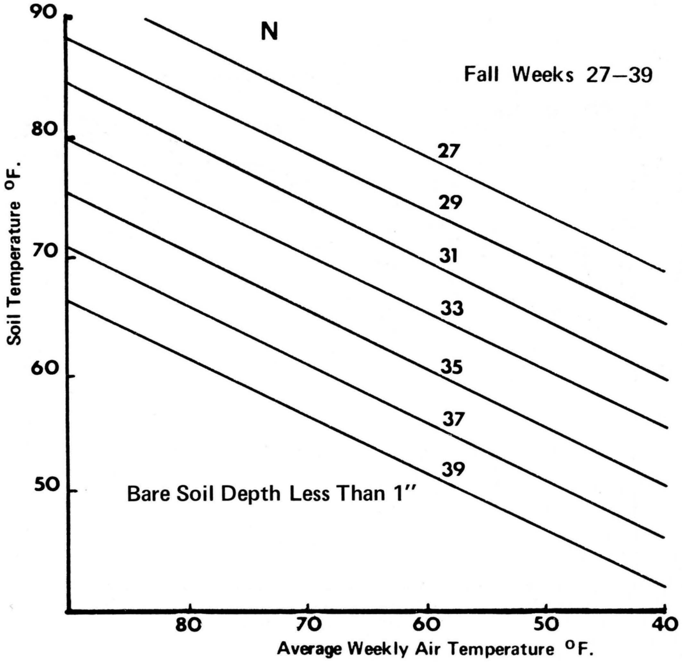

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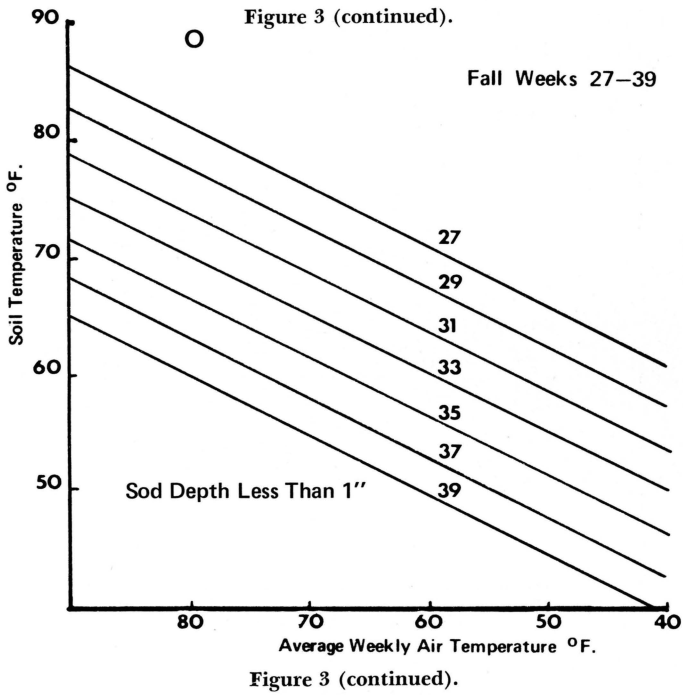

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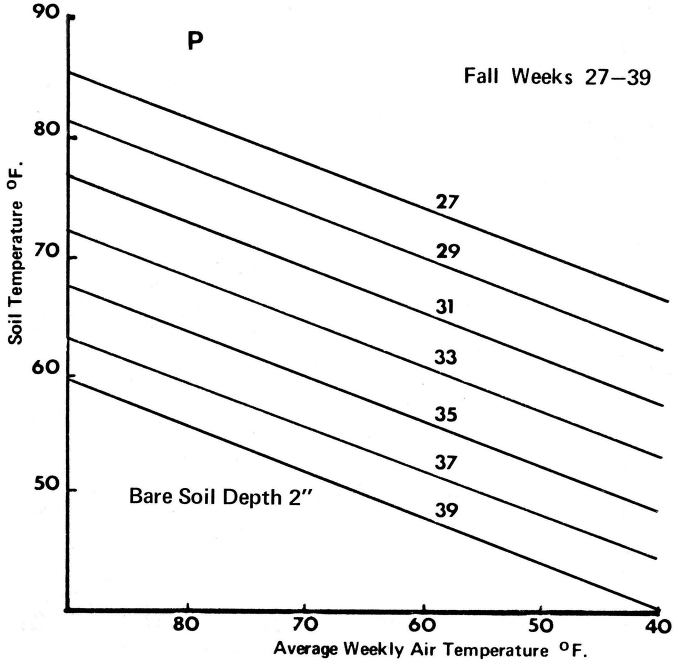

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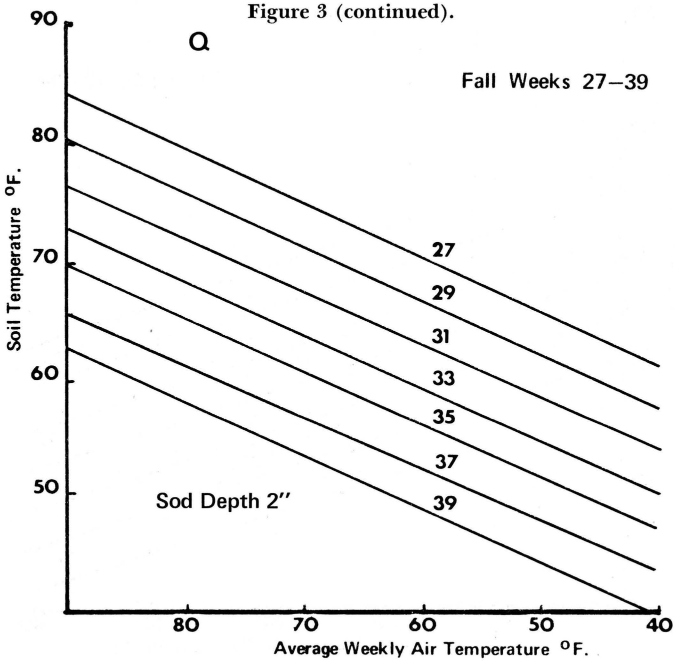

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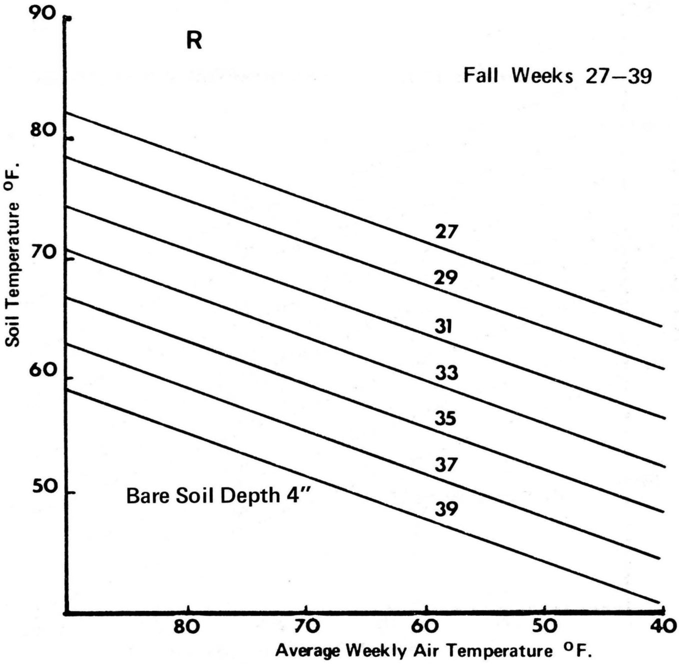

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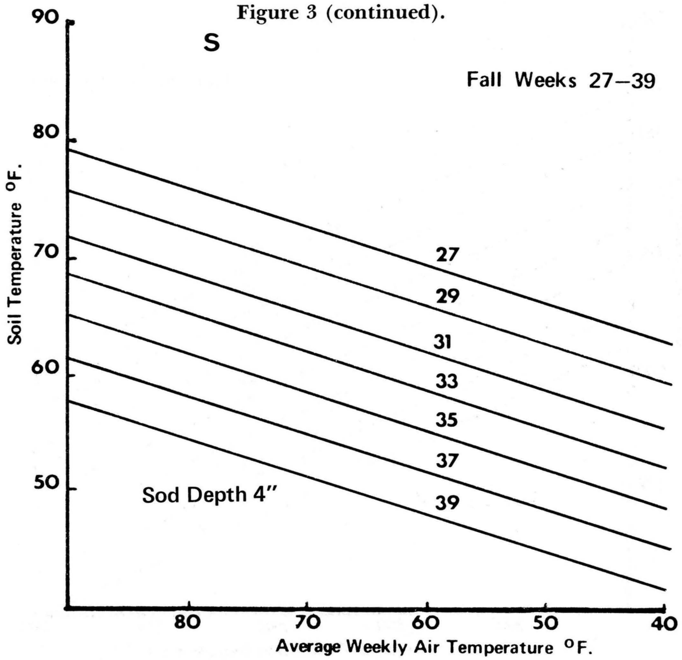

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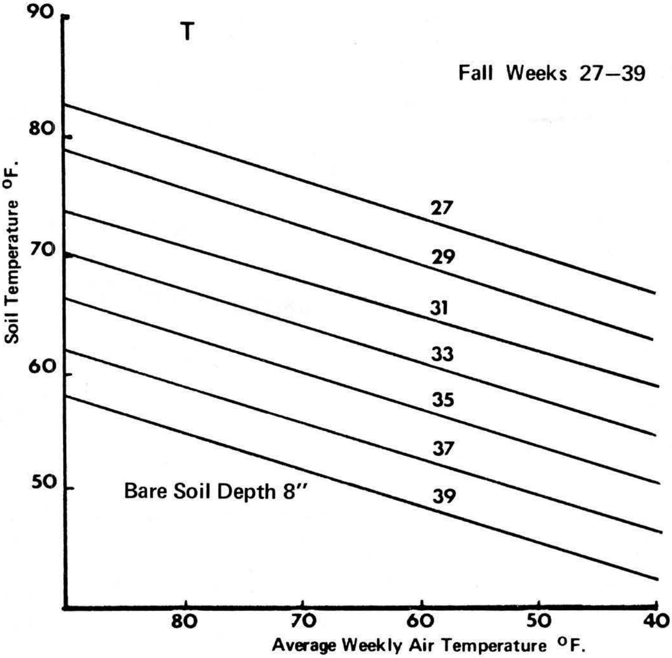

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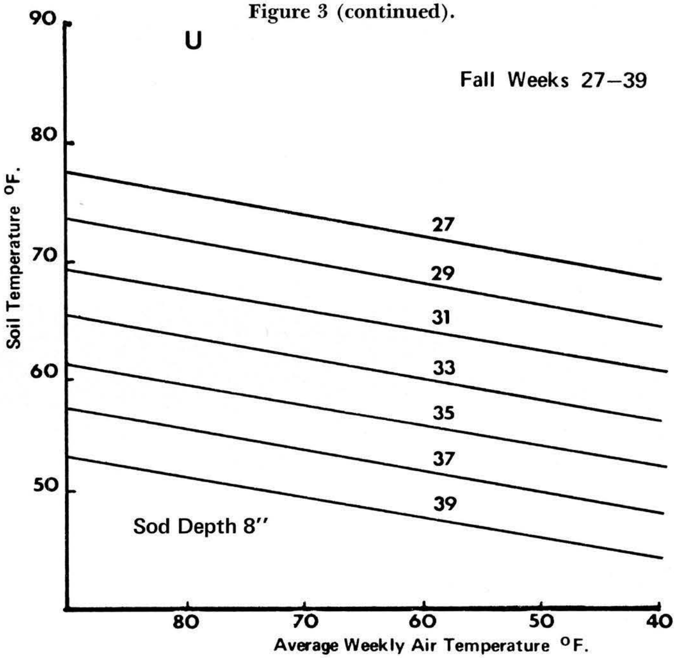

Figure 3 (continued).

LITERATURE CITED

Baker, D. G.
1965. Factors affecting soil temperature. Minn. Farm and Home Sci. 22(4):11–13.

Carson, J. E. and H. Moses
1963. The annual and dirurnal heat exchange in upper layers of soil. Jour. Appl. Meteor. 2(3): 397–406.

Carter, H. G.
1928. A comparison of air temperature and soil temperature. Mo. Wea. Rev. 56 (4):138–139.

Fitton, E. M. and C. F. Brooks
1931. Soil and temperature in the United States. Mo. Wea. Rev. 59:6–16.

Krasnianskaia, V. P.
1961. Relationship between the temperature of the air and the temperature at a depth of 5 and 10 cm. and its practical application. Dal'nevostochnyi Nauchno-issledovatel'skii Gidrometeorologicheskii Institut, Trudy, vyp. 12, Leningrad, pp. 106–110. English translation from Russian. WB/T–91. U.S.D.C.

McCalla, T. M. and F. T. Duley
1946. Effect of crop residue on soil temperature. J. Am. Soc. Agron. 38:75–88.

Neild, R. E.
1967. Probabilities of weekly average temperatures in Nebraska. Neb. Agr. Exp. Sta. Misc. Pub. 15.

Sellers, W. D.
1965. Physical climatology. The University of Chicago Press, Chicago and London.