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EFFECT OF TILLAGE, STRAW MULCHES AND GRASS UPON SOIL-MOISTURE LOSSES AND SOIL TEMPERATURES IN THE LOWER RIO GRANDE VALLEY

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Summary

Tests were conducted at Substation No. 15, Weslaco, Texas for 4 years on evaporation from soil and straw-mulch surfaces and evapotranspiration from grass-covered surfaces.

Evaporation from straw and soil-mulched surfaces was not significantly different. Grass covers required 30 to 35 percent more moisture than soil and straw-mulched surfaces.

Fertilization of grass caused a 7 to 8 percent increase in moisture requirement.

Data indicate that the temperatures under soil-mulch covers generally were higher in spring, summer and fall than straw mulch and grass covers. However, soil under grass cover had higher average temperature during the winter. Straw-mulch surfaces were intermediate in effect on soil temperatures at the 3-inch depth but showed the lowest soil temperatures at the 9-inch depth.

Correlative analyses indicated that evapotranspiration from grass was influenced significantly by air and soil temperatures. Air and soil temperatures did not seem to influence evaporation from soil-mulched surfaces, but air temperatures appeared to have some influence on evaporation from straw-mulched surfaces. The factors which influence evaporation and evapotranspiration under various covers were investigated and the possible mechanisms in the moisture-loss processes are discussed in this report.

Definition of Terms

Transpiration refers to the sum of water removed by vegetation from a particular area during a specified time.

Evaporation refers to the amount of water lost from a free-water surface or a particular area of fallow or barren soil during a specified time. Usually it is expressed in inches per day or a total in inches or feet.

Evapotranspiration refers to the amount of water removed by vegetation and that lost by evaporation for a particular area during a specified time. Usually it is expressed in inches per day.

Mulch refers to a loose covering on the surface of the soil. Usually it consists of organic residues such as a loose straw covering (straw mulch), but it may be loose soil (soil mulch) produced by other inorganic materials or by cultivation.

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C. J. GERARD, M. E. BLOODWORTH and W. R. COWLEY *

In the spring of 1955, an experiment was initiated to study the influence of tillage, straw mulch and grass on soil-moisture losses and soil-temperature changes. The objectives of this experiment were: (1) to study the effects of climate on seasonal evaporation from areas with soil and straw mulches and evapotranspiration from a growing grass and (2) to study the effect of climate on soil temperatures and their related effects on evaporation and transpiration.

A better understanding of soil-moisture losses due to evaporation from soil and straw-mulched surfaces is important to farmers, particularly in the irrigated areas where water supplies are limited. It is equally important to know the factors which influence evapotranspiration from a growing grass. Farmers are especially concerned with the influence of the above covers on the water requirements of citrus orchards. Information on soil-moisture losses and/or utilization is essential if methods to reduce water losses are to be determined.

Literature Review

Fundamental studies on evaporation and evapotranspiration have received limited attention. Mathews and Cole (5)[1] stated that 20 to 25 percent of the rainfall in the Great Plains area is stored. Approximately 70 to 75 percent of the precipitation in the dryland areas is lost principally due to evaporation according to Hyde (2). The importance of evaporation in irrigated areas is magnified when shortages of water for supplemental irrigation exist. The mechanism of soil-moisture evaporation is still not fully understood.

Penman (6, 7, 8, 9), Hyde (2), Jones and Kohnke (3) and Taylor and Cavazza (11) have discussed the mechanisms of soil evaporation. Penman (6) found that the amount of water lost from a moist soil before the occurrence of surface drying is rapid because capillarity supplies liquid water to the soil surface. He indicated further that evaporation is rapidly retarded when a dry surface develops. Penman calls this the critical stage, a stage where evaporation is reduced 50 percent because capillarity is unable to keep the surface moist. Russell (10) also found that the evaporation rate falls rapidly after surface drying has occurred.

The second stage of evaporation is largely caused by vapor flow. Penman (6) found that the rate of water loss by evaporation following surface drying was not related to the amount lost previous to surface drying. The mechanism of moisture movement in this stage is considered to be due largely to evaporation and condensation within the pores of the material. Taylor and Cavazza (11) suggested that molecular hopping could account for large amounts of moisture vapor movement. As the process of evaporation becomes even slower, Lemon (4) has suggested that the loss was probably restricted to vapor diffusion.

In irrigated soils the processes of rapid, intermediate and slow-evaporation rates are repeated many times during each growing season. This process is initiated not only after each soil-wetting rain, as in the dryland areas, but also after each application of supplemental irrigation. In the production of citrus, grapes, strawberries and vegetable crops, it is sometimes possible to maintain or to establish different types of soil covers with little difficulty. The individual's desire to establish such covers is dependent on the availability of water as well as on the influence of such covers on crop requirements and production.

Hyde (1) has postulated that soil temperature is probably the most variable property of surface soils. Russell (10) has given an excellent review of the influence of soil covers on soil temperatures.

[1]Numbers in parentheses refer to literature cited.

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Figure 1. Grass plots being sprig sodded initially with Medio bluestem grass. Tensiometers were set at depths of 9, 18, 30 and 42 inches in each treatment for measuring soil moisture tension changes within the soil profile.

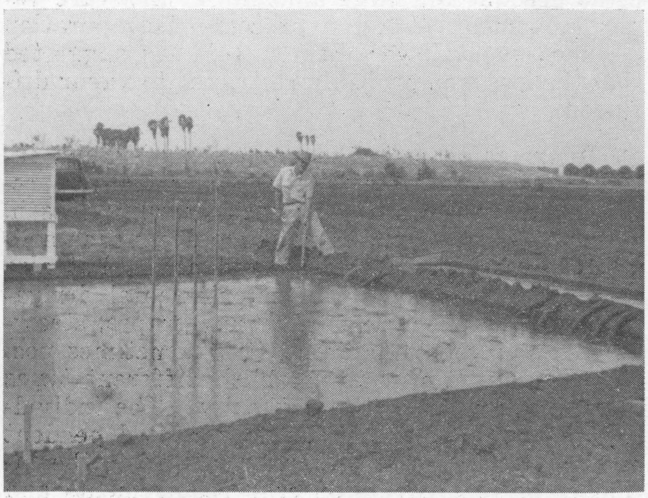


Figure 2. All plots were watered individually by flooding.

Figure 3. Overall layout of plots, instrument shelters and method of applying irrigation water. All soil-moisture samples were taken within the center area of each plot.

Procedure

This experiment was conducted on Willacy fine sandy loam soil at the Weslaco station. A randomized block design consisting of three replications was used. Plots were 25 by 25 feet with a 4-foot alleyway between plots. The initiation and layout of the plots are indicated in Figures 1, 2 and 3.

Soil-mulched plots were maintained by hand to a depth of 3 inches. Under this procedure the plots were re-established 4 to 5 days after each irrigation or following a high intensity rain which usually packed the soil surface. Soil-mulched plots were kept clean of vegetation by hand and chemical methods. The soil-mulched plots were split in the fall of 1957 to include mulched and nonmulched-soil surfaces. A straw cover or mulch was maintained on plots in this treatment to a depth of approximately 3 inches.

Sprigs of Medio bluestem (*Andropogon nodosus*) were planted on March 17, 1955. However, Common Bermudagrass (*Cynadon dactylon*) eventually crowded out the Medio bluestem and is now the predominant grass. Grass plots were split to include a nonfertilized and fertilized treatment in the fall of 1957. Half of each plot was fertilized with 90 pounds of nitrogen per acre four times a year. Grass yields were obtained four times in 1958.

All plots were sampled to a depth of 5 feet before and after each irrigation (approximately once a month) in order to determine soil-moisture losses under the various soil covers.

Recording thermographs[2] were installed to determine the effect of the various surface covers on soil temperatures at depths of 3 and 9 inches. Air temperatures were determined at the site with a recording thermograph. A soil thermograph[3] also was installed at the 1-inch depth in the soil-mulched plots. All thermographs were housed 3 feet above the ground in instrument shelters, Figures 1, 2 and 3.

Evaporation from an open Class A standard weather bureau pan was determined daily at the experimental site. An anemometer also was installed at the same location. Rainfall, relative humidity and wind velocity data were obtained.

Results and Discussion

Soil-moisture losses under various covers are indicated in Figures 4 and 5. Results in Figure 4 represent average moisture losses in inches per day for each month of the year. These averages are by months for the period of March 1955

[2]The recording thermographs were manufactured by the Dickson Company, Chicago 19, Illinois.

[3]This recording thermograph is a product of the Foxboro Company, Foxboro, Massachusetts.

through December 1958. Results in Figure 5 represent average moisture losses from November 1957 through December 1958. Evaporation from straw and soil-mulched surfaces was not significantly different. However, evaporation from straw and soil-mulched plots did vary, but the trends were not consistent from year to year. Moisture utilization and/or loss by grass were significantly greater than from soil and straw-mulched surfaces. Grass required 30 to 35 percent more moisture than was lost through evaporation from the soil and straw-mulched plots. The results give some indication of the moisture requirements of grass versus mulch-type farming operations in fruit orchards. This would have particular significance with reference to the overall water requirement. Evapotranspiration from the grass plots usually was low in the winter because frost often killed the Bermudagrass cover. Moisture loss from the grass was about 75 percent of the moisture loss from a free-water surface as predicted by Penman (7).

Comparisons between mulched and unmulched soil surfaces were obtained. The limited data indicate that soil mulching was effective in reducing evaporation during this period. Fertilization caused a 7 to 8 percent increase in the moisture requirement of the grass cover.

Soil and air temperature data were obtained and are reported in Table 1 and Figures 6 through 17. Average temperatures by 3-hour increments during the day and by months are reported in Table 1. Figures 6 through 17 show the soil-temperature changes at a depth of 3 inches during an average day for each month under the different covers. Trends for each month by years were similar to the averages obtained over a 2 or 4-year period. For this reason it is believed that the results reported in Table 1 and Figures 6 through 17 represent a true indication of the trends in temperature changes under the various covers even though different periods of time are sometimes reflected by the averages.

Soil temperatures at the 3-inch depth indicated that the greatest daily fluctuations occurred under a soil-mulch cover with the smallest fluctuations occurring under grass. Typical soil and air temperature fluctuations for winter are indicated in Figure 18. A soil mulch tended to cause higher average soil temperatures at the 3-inch depth during the spring, summer and fall. Higher average soil temperatures occurred under grass cover during the winter. Soil temperatures under grass at 3 inches, as shown in Figures 6 through 17, do not respond quickly to changes in air temperatures. Weekly temperature charts obtained from a grass cover almost invariably showed a circular pattern with no definite minimum and maximum as indicated in Figure 18. In contrast, soil temperatures under a soil mulch at 3 inches reflected the maximum and minimum of air temperature changes. The straw-mulched plots were intermediate with respect to

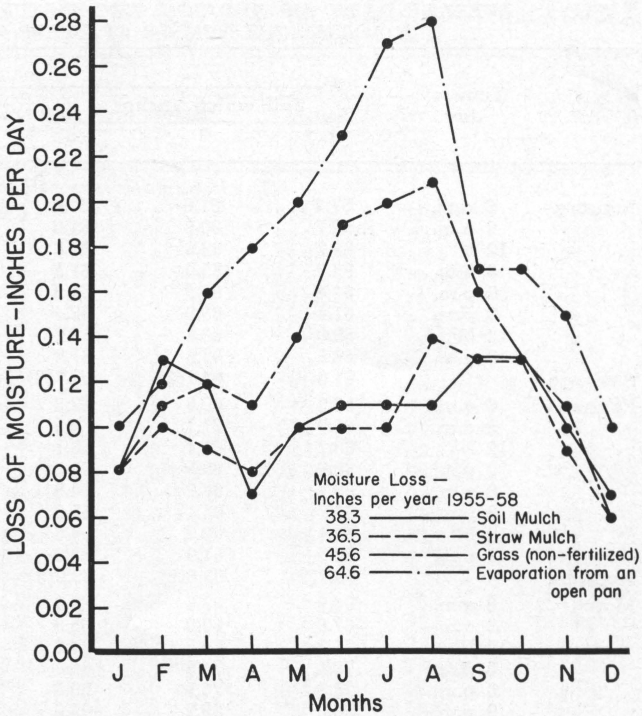


Figure 4. The average soil moisture losses expressed in inches per day during different months of the year as influenced by different covers for March 1955 through December 1958.

high temperatures and temperature fluctuations during the day at a soil depth of 3 inches. Because of these conditions, close-clipped grass cover in an orchard in the winter may be beneficial by keeping soil temperatures above freezing. This could be of greater benefit in young orchards where the amount of shading by the trees would be small.

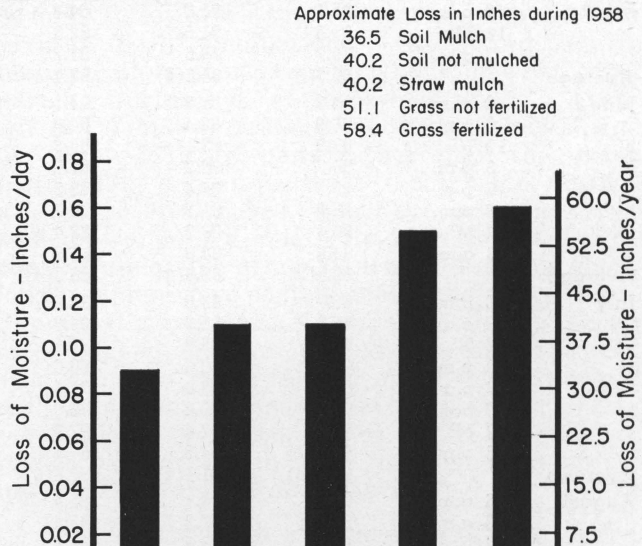


Figure 5. The average soil-moisture losses expressed in inches per day and inches per year as influenced by different soil covers in 1958 at Weslaco, Texas.

TABLE 1. AVERAGE DAILY AIR AND SOIL TEMPERATURES DURING THE YEAR, BY MONTHS. NUMBER IN PARENTHESES INDICATES THE NUMBER OF YEARS DATA COLLECTED TO ARRIVE AT AVERAGE

Month	Time of day	Soil cover							Air[3]
		Soil mulch, inches			Straw mulch, inches		Grass, inches		
		1	3	9	3	9	3	9	
		Average temperature readings in °F							
January	6 a.m.	57.4	61.0	61.4	60.3	60.1	61.5	61.7	54.1
	9 a.m.	58.7	60.8	61.0	60.3	60.1	61.3	61.7	59.1
	12 N[1]	63.2	62.5	61.2	60.7	60.3	61.8	61.8	68.1
	3 p.m.	65.7	65.0	61.5	60.6	60.3	62.9	62.0	70.7
	6 p.m.	64.4	65.5	61.9	60.6	60.3	62.6	61.9	64.5
	9 p.m.	61.4	65.0	62.4	59.9	60.3	62.1	61.9	59.5
	12 M[2]	59.8	63.6	62.2	58.8	60.3	61.9	61.9	57.0
	3 a.m.	58.6	62.6	61.9	58.8	60.1	61.6	61.8	55.7
Average		61.0(2)	63.1(3)	61.7(3)	60.1(3)	60.2(2)	62.0(2)	61.9(2)	61.1(3)
February	6 a.m.	59.3	60.5	62.8	60.9	60.1	64.3	64.3	58.0
	9 a.m.	61.7	61.1	62.5	60.3	60.1	63.9	64.2	63.5
	12 N[1]	68.7	65.4	63.1	61.5	60.4	64.2	64.5	70.4
	3 p.m.	69.6	68.5	64.2	63.1	60.5	64.5	64.8	72.5
	6 p.m.	65.7	66.9	64.9	63.0	60.6	64.7	64.8	67.9
	9 p.m.	62.7	64.1	65.0	63.0	60.5	64.6	64.7	62.4
	12 M[2]	61.1	62.2	64.5	61.6	60.5	64.6	64.5	60.3
	3 a.m.	60.5	61.3	63.8	60.8	60.4	64.5	64.5	59.0
Average		63.7(2)	63.8(3)	63.0(3)	61.7(3)	60.4(2)	64.4(2)	64.5(2)	64.3(3)
March	6 a.m.	64.9	63.6	65.6	62.4	62.4	64.9	65.4	59.1
	9 a.m.	67.8	63.3	65.3	62.4	62.4	64.9	65.4	66.6
	12 N[1]	71.3	71.5	64.9	63.9	63.0	65.4	65.5	73.9
	3 p.m.	78.4	74.9	68.4	65.8	63.4	66.3	65.8	76.0
	6 p.m.	73.9	73.1	69.8	65.6	63.5	66.1	66.0	71.0
	9 p.m.	69.3	69.2	69.2	64.8	63.2	66.0	66.0	64.5
	12 M[2]	67.3	66.2	68.0	63.8	63.1	65.6	65.9	61.8
	3 a.m.	66.0	64.6	67.1	63.1	62.6	65.3	65.8	60.4
Average		69.9(3)	68.3(3)	67.3(3)	63.8(2)	63.0(2)	65.6(2)	65.7(2)	66.7(3)
April	6 a.m.	72.5	73.0	74.6	73.0	69.7	70.7	70.6	67.1
	9 a.m.	76.9	72.6	74.3	73.3	69.7	71.0	70.6	75.1
	12 N[1]	83.6	77.6	75.6	76.2	69.8	72.0	70.9	82.0
	3 p.m.	88.0	83.1	78.1	77.8	70.1	72.7	71.0	83.3
	6 p.m.	84.1	81.9	78.9	77.2	70.2	72.4	71.2	77.4
	9 p.m.	79.3	78.9	78.8	75.6	70.2	72.1	71.2	71.3
	12 M[2]	76.0	77.0	77.1	74.9	70.1	71.5	71.2	69.1
	3 a.m.	74.5	75.4	76.1	74.1	69.2	71.1	71.2	67.8
Average		79.8(3)	77.5(4)	76.8(4)	75.2(4)	69.9(3)	71.7(3)	71.0(3)	74.1(4)
May	6 a.m.	77.9	78.0	80.3	76.8	72.5	76.6	76.6	72.1
	9 a.m.	85.5	79.2	79.9	77.1	72.5	76.6	76.6	80.7
	12 N[1]	96.7	88.7	81.1	79.4	72.8	77.8	76.9	86.6
	3 p.m.	99.9	92.9	83.7	81.0	72.9	78.9	77.1	87.8
	6 p.m.	92.1	91.1	85.1	80.1	73.1	78.8	77.3	82.3
	9 p.m.	84.1	85.6	84.4	79.1	73.0	78.2	77.3	76.1
	12 M[2]	81.5	81.5	82.8	78.4	73.0	77.7	77.2	73.8
	3 a.m.	79.7	79.6	81.7	77.6	72.9	77.1	77.0	72.0
Average		87.3(3)	84.6(4)	82.4(4)	78.7(4)	72.8(3)	77.7(3)	77.0(3)	78.9(4)
June	6 a.m.	84.8	81.8	84.1	81.9	76.9	79.0	78.6	73.7
	9 a.m.	86.9	82.4	84.0	82.3	76.8	79.3	78.4	82.7
	12 N[1]	93.9	93.1	85.8	83.8	77.0	79.8	78.7	88.4
	3 p.m.	96.7	100.2	88.0	84.8	77.2	80.6	78.8	88.5
	6 p.m.	93.5	99.4	89.3	84.7	77.6	80.6	78.8	84.0
	9 p.m.	88.8	91.7	88.7	83.9	77.7	80.4	78.8	76.7
	12 M[2]	86.4	86.3	87.4	83.1	77.4	79.9	78.8	74.4
	3 a.m.	84.8	83.8	85.9	82.4	77.4	79.5	78.7	72.7
Average		89.5(3)	89.9(4)	86.3(4)	82.9(3)	75.6(3)	79.7(3)	78.7(3)	80.1(4)
July	6 a.m.	86.7	83.8	84.6	83.0	78.3	80.8	80.9	74.6
	9 a.m.	85.9	85.9	84.8	83.6	78.9	80.9	80.9	84.5
	12 N[1]	91.6	95.2	87.6	85.4	80.8	81.5	80.9	90.8
	3 p.m.	99.6	100.6	90.6	86.8	80.9	82.0	81.1	91.7
	6 p.m.	94.2	98.6	91.4	86.5	79.3	81.9	81.1	87.7
	9 p.m.	91.3	92.6	89.9	85.1	78.9	81.6	81.1	80.4
	12 M[2]	88.7	87.4	87.6	84.3	78.8	81.4	81.1	77.4
	3 a.m.	87.0	84.8	86.1	83.7	78.6	81.1	81.1	75.4
Average		90.2(3)	91.1(4)	87.8(4)	84.8(3)	79.3(3)	81.4(3)	81.0(3)	82.8(4)
August	6 a.m.	88.7	84.1	85.4	84.0	78.9	80.3	80.6	74.8
	9 a.m.	90.5	87.9	85.4	84.5	78.9	80.9	80.6	84.9
	12 N[1]	96.3	96.8	88.5	86.0	78.9	81.8	81.0	92.8
	3 p.m.	99.2	99.4	91.2	86.9	79.1	82.4	81.1	94.1
	6 p.m.	98.4	97.2	91.5	86.2	79.3	82.1	81.0	89.4

[1]N = Noon.

[2]M = Midnight.

[3]Refers to air temperature in the weather instrument shelter at a height of approximately 3 feet.

TABLE 1. AVERAGE DAILY AIR AND SOIL TEMPERATURES DURING THE YEAR, BY MONTHS. NUMBER IN PARENTHESES INDICATES THE NUMBER OF YEARS DATA COLLECTED TO ARRIVE AT AVERAGE—Continued

Month	Time of day	Soil cover							Air[3]
		Soil mulch, inches			Straw mulch, inches		Grass, inches		
		1	3	9	3	9	3	9	
		Average temperature readings in °F							
	9 p.m.	92.7	92.8	90.5	85.3	79.4	81.6	80.8	81.8
	12 M[2]	90.1	88.8	89.4	84.8	79.2	81.3	80.7	78.6
	3 a.m.	88.1	85.8	86.0	84.1	79.1	80.9	80.6	76.0
Average		90.5(2)	91.7(4)	88.5(4)	83.9(3)	79.1(2)	81.5(3)	80.8(3)	84.1(4)
September	6 a.m.	81.6	78.4	80.1	81.2	76.8	79.0	78.6	72.9
	9 a.m.	83.0	79.1	79.9	81.8	76.8	79.1	78.6	81.9
	12 N[1]	87.5	87.4	81.3	84.5	76.9	79.6	78.9	86.6
	3 p.m.	90.3	90.9	83.4	85.2	76.9	80.0	78.9	87.8
	6 p.m.	88.4	89.2	84.2	84.4	77.0	79.8	79.2	83.5
	9 p.m.	85.3	84.5	83.6	83.2	77.2	79.8	79.2	77.8
	12 M[2]	83.1	81.6	82.6	82.4	77.0	79.5	79.1	75.1
	3 a.m.	81.4	79.3	81.1	81.7	77.0	79.5	78.8	73.5
Average		85.1(3)	83.8(4)	82.0(4)	82.2(3)	77.0(2)	79.6(3)	78.9(3)	79.9(4)
October	6 a.m.	76.3	72.0	73.8	73.2	69.5	73.3	73.2	66.3
	9 a.m.	76.2	72.2	73.7	73.6	71.0	73.2	73.2	76.3
	12 N[1]	79.9	78.6	74.7	76.6	71.0	73.6	73.3	82.3
	3 p.m.	81.6	81.3	77.0	78.0	71.0	74.2	73.4	82.9
	6 p.m.	81.0	79.7	77.4	77.0	70.8	74.2	73.4	76.8
	9 p.m.	79.6	78.0	77.0	75.3	70.7	74.0	73.4	71.4
	12 M[2]	78.6	75.8	76.1	74.2	70.6	73.8	73.5	68.6
	3 a.m.	77.3	73.4	74.9	73.3	70.5	73.6	73.2	67.0
Average		78.8(3)	76.4(4)	75.6(4)	75.2(3)	70.7(2)	73.7(3)	73.4(3)	74.3(4)
November	6 a.m.	67.0	63.9	67.0	66.6	61.0	68.6	68.5	59.3
	9 a.m.	66.7	63.5	66.9	65.2	61.5	68.6	68.6	66.7
	12 N[1]	69.1	69.1	67.8	67.9	61.5	69.0	68.6	73.5
	3 p.m.	69.5	72.6	69.0	69.4	61.6	69.6	68.7	74.2
	6 p.m.	71.0	71.5	69.7	69.6	62.8	69.6	68.7	68.3
	9 p.m.	70.1	68.4	69.2	68.6	62.8	69.6	68.7	63.8
	12 M[2]	69.5	66.8	68.6	68.0	62.7	69.0	68.6	61.7
	3 a.m.	67.7	65.2	67.9	67.3	62.7	69.0	68.6	60.2
Average		69.0(3)	67.6(4)	68.3(4)	67.9(3)	62.1(2)	69.1(3)	68.6(3)	66.0(4)
December	6 a.m.	61.4	58.2	60.2	59.6	57.1	63.2	63.8	54.8
	9 a.m.	60.7	57.5	59.5	59.4	58.3	63.3	63.8	60.2
	12 N[1]	63.0	59.9	60.7	60.2	58.4	63.8	63.9	69.3
	3 p.m.	65.1	62.5	61.3	61.4	58.4	64.2	64.1	71.2
	6 p.m.	65.7	63.5	61.5	61.3	58.3	64.2	64.1	64.3
	9 p.m.	64.4	62.5	61.5	60.9	58.1	64.0	64.0	59.6
	12 M[2]	63.1	61.2	61.3	60.5	58.1	64.0	63.9	57.3
	3 a.m.	62.1	60.0	61.0	60.2	58.0	63.7	63.8	56.0
Average		63.2(3)	60.7(4)	60.8(4)	60.4(4)	58.1(3)	63.8(3)	63.9(3)	61.6(4)

A bare soil warms up more quickly than a grass or straw cover in the spring. This may be important in the growth and development of young citrus trees. However, grass and straw covers do not show the high temperature fluctuations in the summer which may also play a vital role in the growth of trees. The influence of surface covers on frost damage due to low soil temperatures as well as on the growth and development of citrus trees is yet to be determined.

Maximum air temperature usually occurred between 2 and 3 p.m. each day; minimum air temperatures occurred about 6 a.m. Temperatures under a soil mulch at 3 inches usually lagged 1 to 3 hours behind the air temperatures. Soil temperatures at 3 inches under grass cover failed to show marked daily minimum and maximum temperatures; however, soil temperature at 3 inches under a straw cover showed broad minimum and maximum with a 1 to 3-hour lag behind air temperatures.

Relatively small fluctuations in soil temperatures occurred at the 9-inch depth under all covers. However, the soil mulch showed the greatest daily fluctuations. Grass and straw-mulched plots showed small and somewhat comparable fluctuations at the 9-inch depth. Average soil temperatures at 9 inches were lowest under straw-mulched plots rather than the grass plots. This was in contrast to soil temperatures at a depth of 3 inches. Such an occurrence was probably due to a relatively high soil moisture content under the straw mulch plots and a much lower soil moisture content under the grass. Minimum and maximum soil temperatures at 9 inches often lagged 6 hours behind air temperatures. Temperatures under the soil mulch showed broad daily minimum and maximum fluctuations. Temperatures at 9 inches under grass and straw-mulch plots failed to show marked daily minimum and maximum fluctuations.

Soil temperatures at a depth of 1-inch under the soil-mulch plots fluctuated greatly during the day. Some of the differences between the 1 and 3-inch depths reported in Table 1 are caused by the differences in the number of years of data. Data from the same years indicated that in the

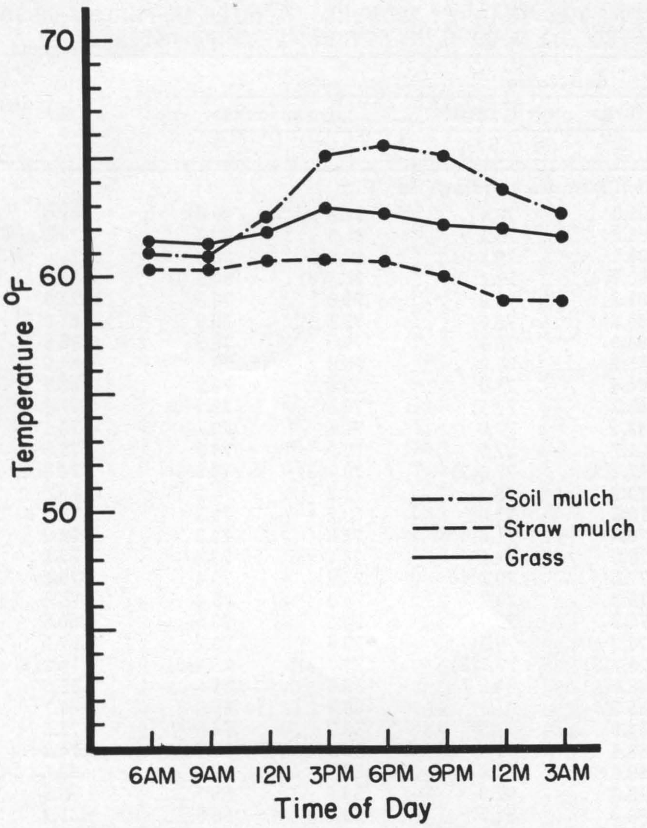


Figure 6. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of January.

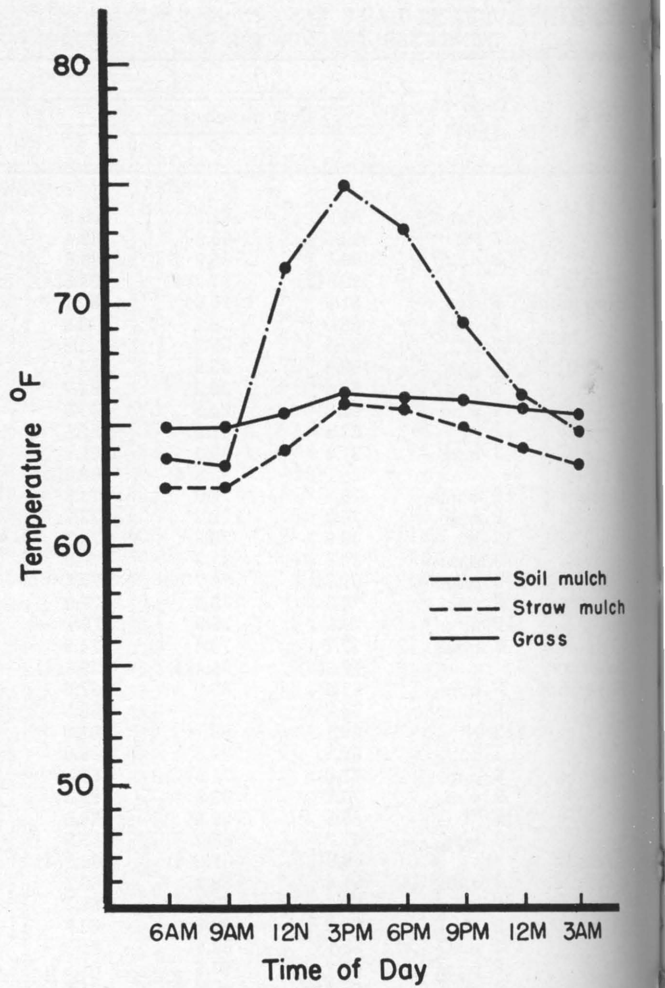


Figure 8. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of March.

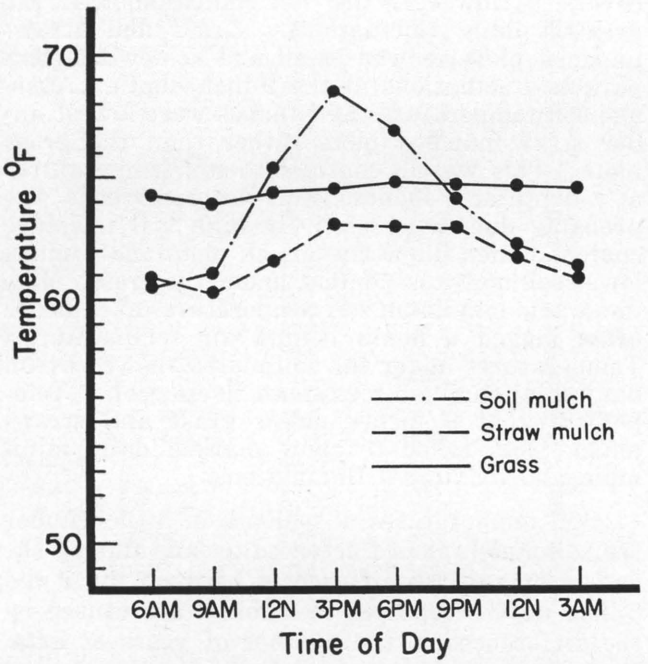


Figure 7. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of February.

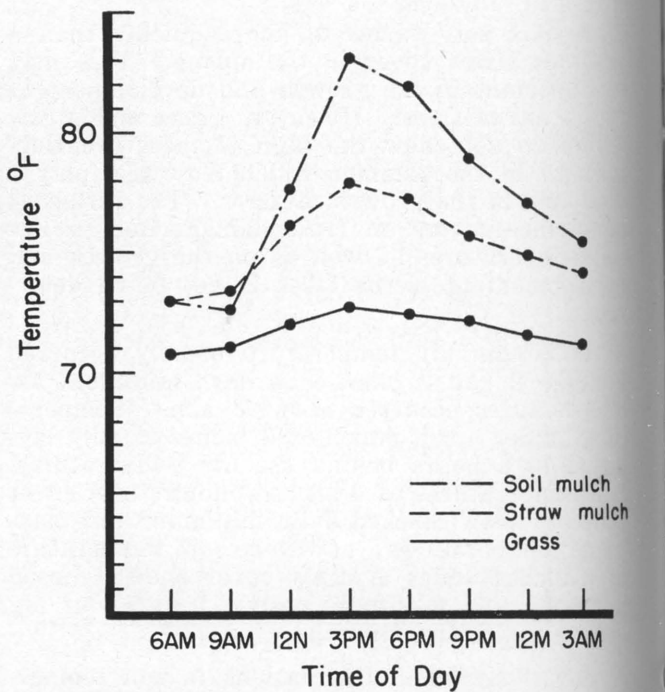


Figure 9. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of April.

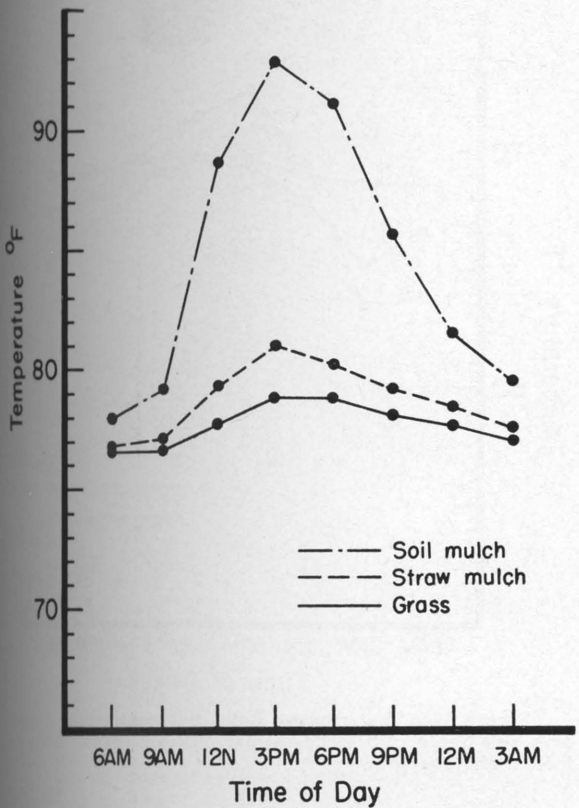


Figure 10. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of May.

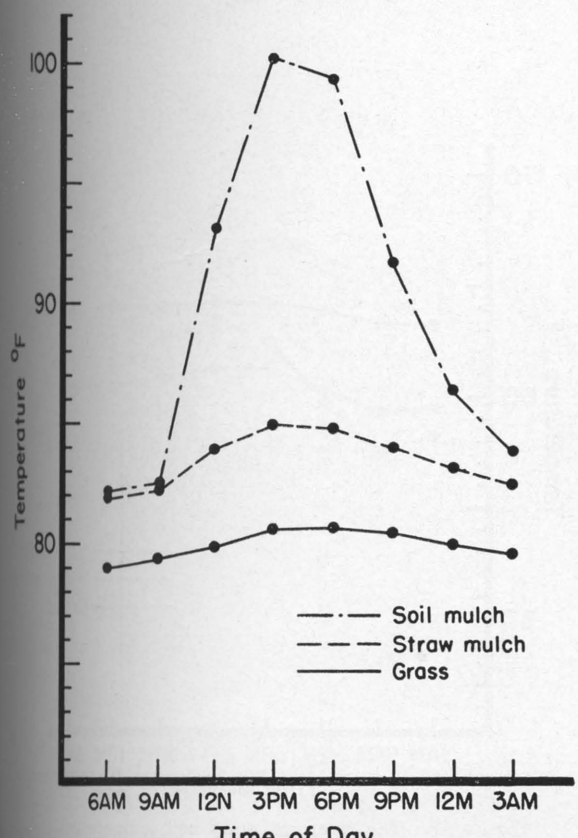


Figure 11. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of June.

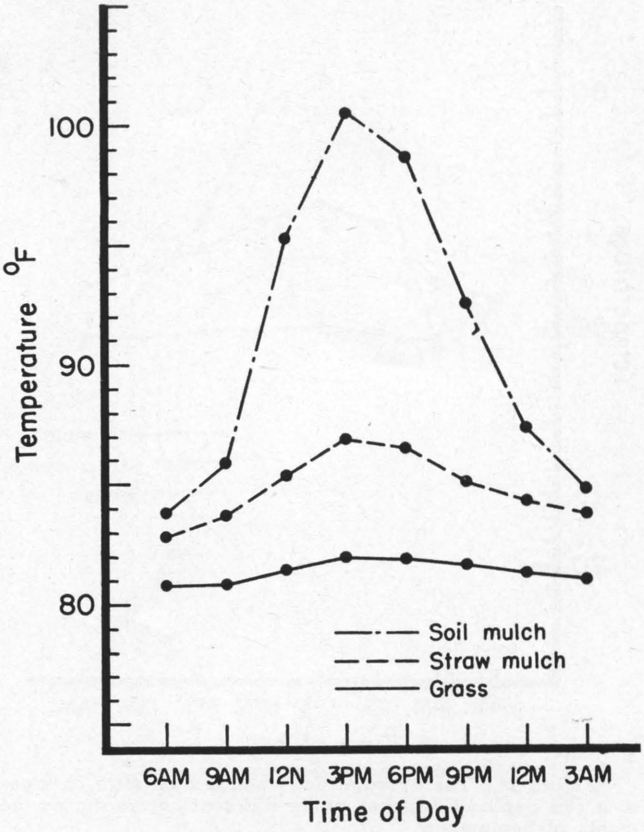


Figure 12. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of July.

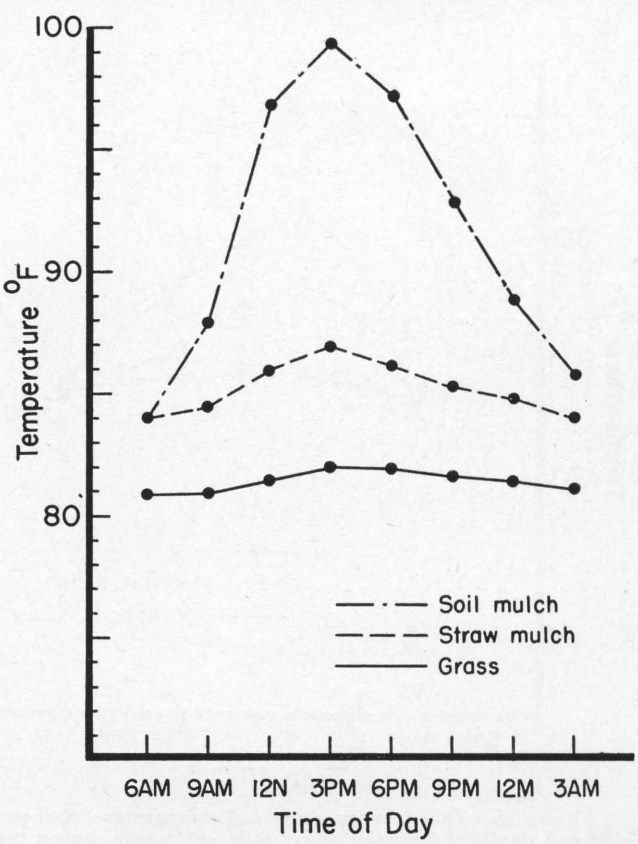


Figure 13. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of August.

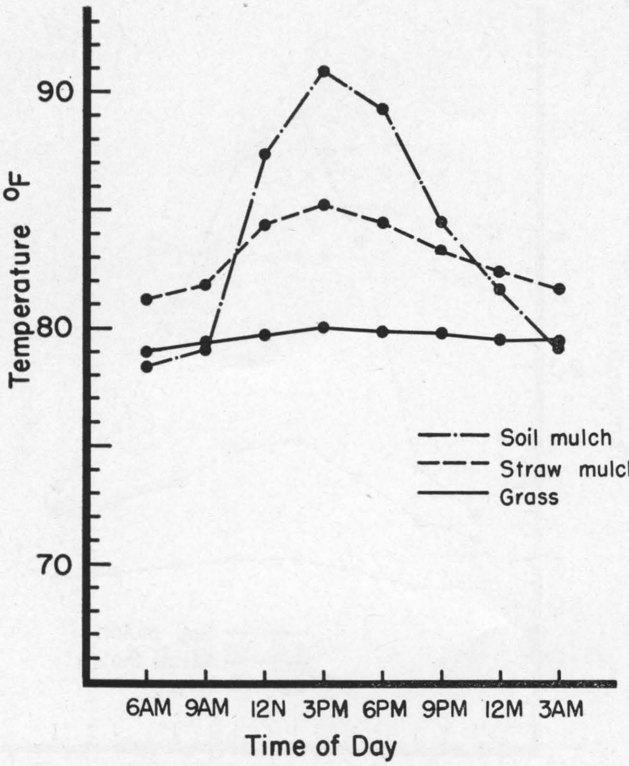


Figure 14. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of September.

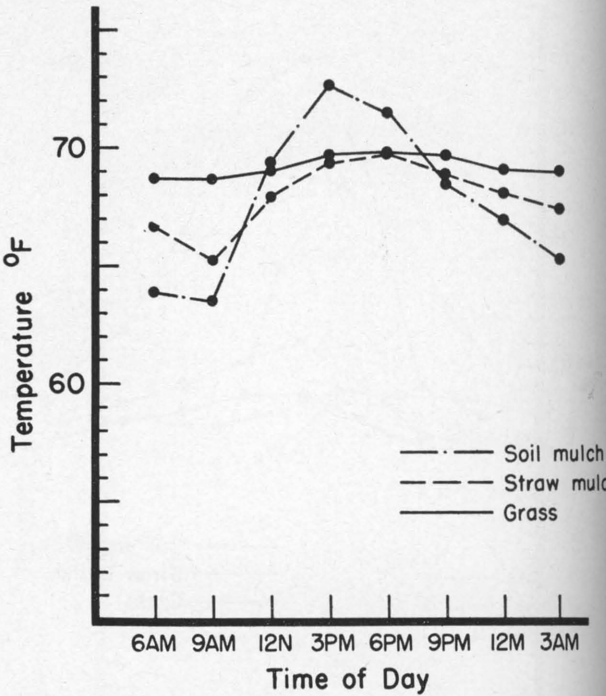


Figure 16. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of November.

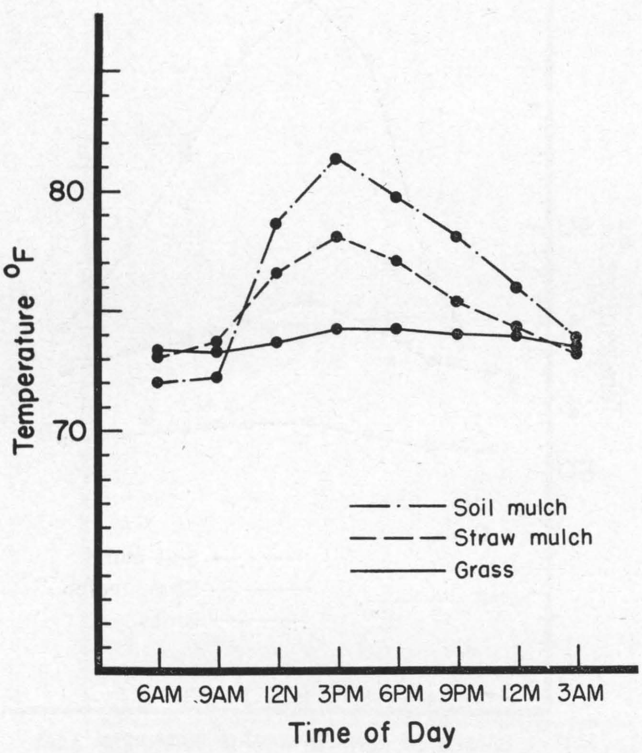


Figure 15. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of October.

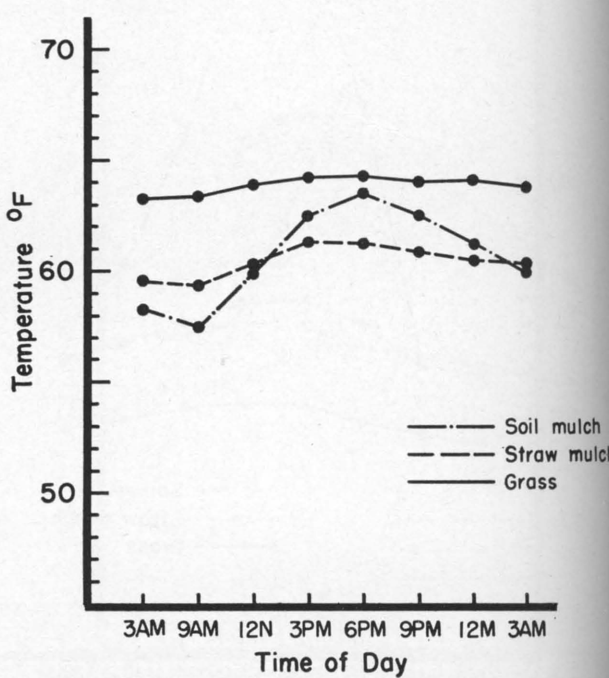
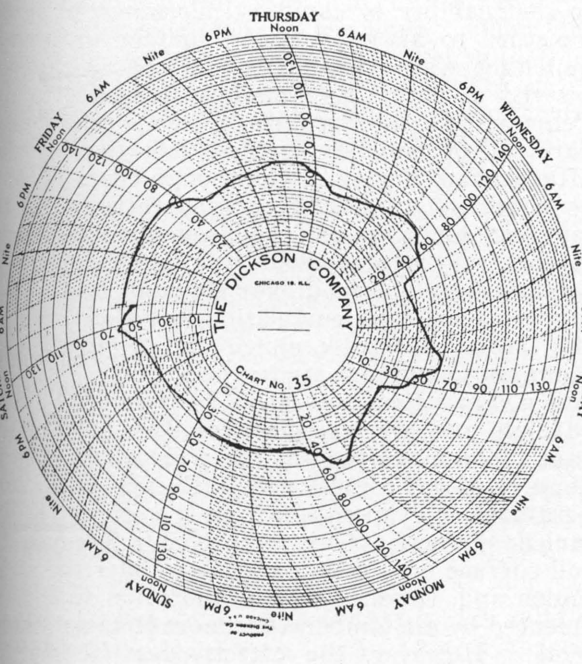
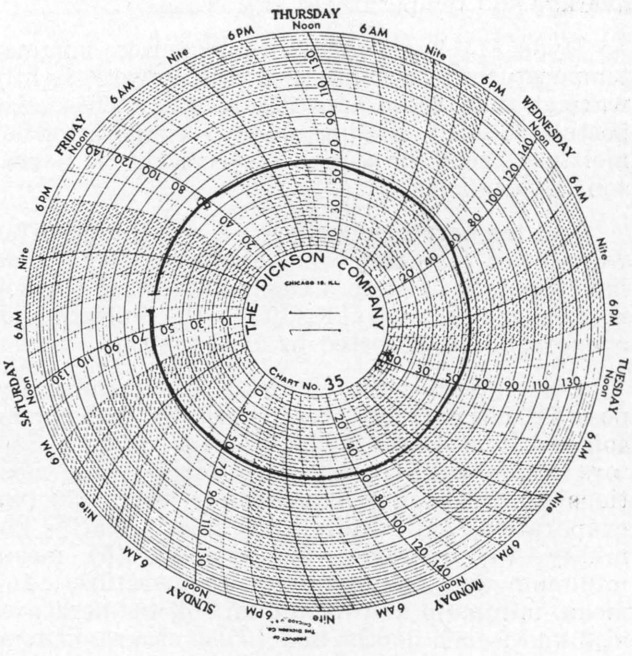


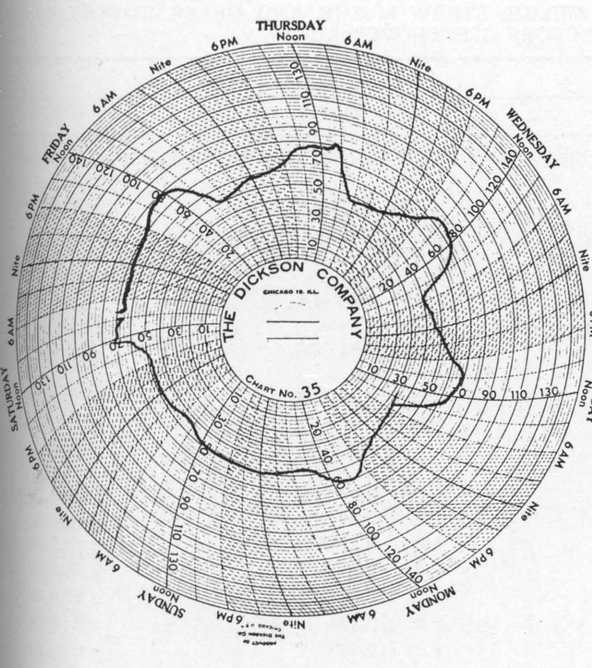
Figure 17. The average daily soil temperature changes at a soil depth of 3 inches under different covers during the month of December.



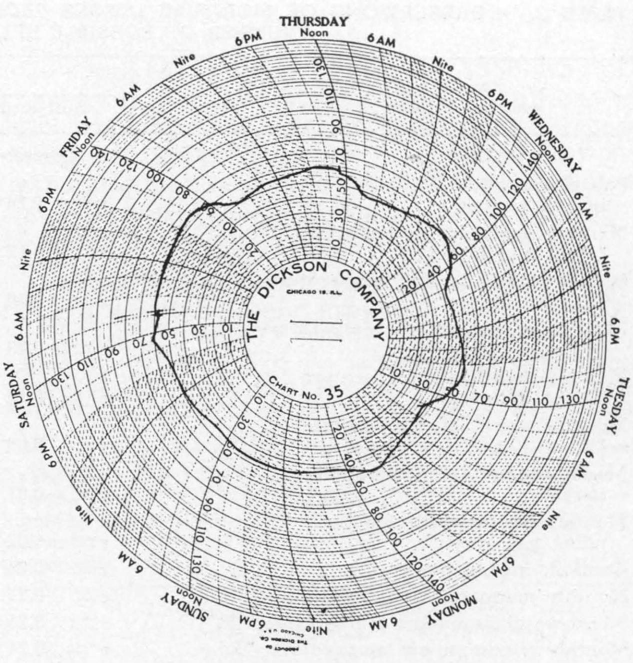
Soil temperatures—soil mulch 3 inches



Soil temperatures—grass 3 inches



Air temperatures



Soil temperatures—straw mulch 3 inches

Figure 18. Soil temperatures at 3 inches under various covers for week of December 12, 1958 to December 20, 1958.

early spring and winter the 1-inch soil depth had a higher average soil temperature; however, in the summer and fall the 3-inch depth had higher average soil temperatures.

Hyde (1) has reported that average summer temperatures at a depth of 6 inches were slightly warmer than those at a depth of 2 inches. He postulated that cooling due to evaporation of moisture from the 2-inch layer might be a reasonable explanation.

Soil temperatures between 8 and 9 a.m. often were lower than they were at 6 a.m. This could have been due also to a cooling effect of the soil surface which was a result of the initiation of evaporation as reported by Hyde (1).

Correlations were obtained to determine the possible mechanisms that might be influencing soil moisture losses under various covers. Factors which were investigated for possible relationships with soil moisture losses were: (1) pan evaporation, (2) rainfall, (3) mean relative humidity, (4) average wind velocity, (5) mean, minimum and maximum air temperatures, (6) mean, minimum and maximum soil temperatures at 3 and 9-inch depths and (7) average soil temperatures at a depth of 1 inch. The correlations obtained are reported in Table 2.

Correlations between moisture losses from soil and straw-mulched plots and the factors listed earlier were small and usually insignificant as indicated in Table 2. This indicates that the mechanisms of soil-moisture losses from soil and straw mulches were only slightly influenced by the climatic environment. This is probably due to the inability of capillary movement to supply moisture to an evaporating surface or because mulching was effective in decreasing capillary activity or both. As stated by Russell (10) and Penman (6), the process of evaporation from bare soil or mulched surfaces is extremely slow after surface drying. Even though there failed to be larger r values between evaporation from the mulched surfaces and the previously mentioned factors, several significant and highly significant r values were obtained. For example, there was a highly significant correlation between evaporation from the straw mulch and average, minimum and maximum air temperatures. The positive r values for evaporation from the soil-mulched plots and air temperatures were not significant. The magnitude of the r values may be indicative of the comparative influence of air temperatures on evaporation from the soil and straw-mulch surfaces. This is probably because the soil surface does not dry as fast under the straw mulch and, therefore, its evaporation rate is influenced by air temperature more than soil mulch plots. However, the effectiveness of mulches probably vary due to many everchanging factors. For example, straw may be more effective in storing rainfall than the soil-mulch plots. Straw mulch might also decrease surface compaction and puddling which is so evident on bare soil after irrigation or high intensity rains. The lack

TABLE 2. CORRELATIONS OF MOISTURE LOSSES FROM SOIL MULCH, STRAW MULCH AND GRASS COVERS WITH A NUMBER OF POSSIBLE RELATED FACTORS, 1955-58, WESLACO[1]

Possible related factors	Type of cover: Soil mulch	Straw mulch	Grass
	Correlations of soil moisture losses—inches per day with related factors[2]		
Pan evaporation—inches per day	r = 0.24 N.S.	r = 0.27 N.S.	r = 0.67*
Monthly mean soil temperature °F. at 3 inches[3]	r = 0.17 N.S.	r = 0.30 N.S.	r = 0.62*
Monthly minimum soil temperature °F. at 3 inches[3]	r = 0.10 N.S.	r = 0.27 N.S.	r = 0.64*
Monthly maximum soil temperature °F. at 3 inches[3]	r = 0.23 N.S.	r = 0.34 N.S.	r = 0.59*
Monthly mean soil temperature °F. at 9 inches[3]	r = 0.16 N.S.	r = 0.31 N.S.	r = 0.57*
Monthly mean soil temperature °F. at 1 inch[3]	r = 0.30 N.S.		
Monthly mean relative humidity, percent	r = −0.01 N.S.	r = 0.02 N.S.	r = 0.06 N.S.
Monthly mean wind velocity, miles per day	r = 0.02 N.S.	r = −0.11 N.S.	r = 0.03 N.S.
Rainfall, inches per month	r = 0.24 N.S.	r = 0.25 N.S.	r = 0.24 N.S.
Monthly mean air temperature, °F.[3]	r = 0.25 N.S.	r = 0.40*	r = 0.68*
Monthly minimum air temperature, °F.[3]	r = 0.25 N.S.	r = 0.39*	r = 0.71*
Monthly maximum air temperature, °F.[3]	r = 0.24 N.S.	r = 0.40*	r = 0.67*

[1]* = Highly significant. N.S. = Not significant.

[2]Soil-moisture losses were expressed in inches per day for respective months.

[3]Mean soil and air temperatures were determined by adding readings obtained at 6 a.m., 9 a.m., 12 noon, 3 p.m., 6 p.m., 9 p.m., 12 midnight and 3 a.m. during each month and dividing by total number of readings during the month. Minimum soil temperature was a summation of readings during month, usually at 6 a.m., divided by number of readings. Maximum soil temperature usually occurred at 3 p.m.

of compaction under straw may reduce the initial rate of capillarity to the soil surface. This probably would reduce the initial moisture losses under straw. However, slower surface drying may prolong the loss due to capillary conductivity over a longer period of time. Such an occurrence may help explain the possible lack of effectiveness of stubble mulch tillage in conserving soil moisture in certain dry sections of the country.

Correlations between moisture losses and different ways of expressing relative humidity and air temperatures from August 1957 to December 1958 are reported in Table 3. Air temperatures are expressed in number of hours per day above specified temperatures such as 70° F., relative humidity in hours per day above specified percentages. This method of expressing relative humidity and air temperatures are indicated in Table 4. Correlations of moisture losses versus average relative humidity and air temperatures are also reported in Table 3. Correlations of moisture losses and average relative humidity by years are reported in Table 5.

The findings may suggest that a high relative humidity decreases the effectiveness of the soil mulch, possibly by preventing a break in the capillary column. Such a condition would be possible during certain periods of year. This relationship was not consistent and may have been due to chance but the results do lend support to some of the postulated effects of wet or dry surfaces on evaporation. During the fall of 1957 and the year of 1958, the soil surface was wet most of the time because of frequent rains. As indicated in Table 5, an r value of 0.53 was obtained between evaporation from soil mulch and average relative humidity in 1958. In contrast, an r value of −0.41 was obtained in 1956. The year 1956 was extremely dry. Evaporative surface conditions in 1958 were probably exactly opposite from those existing in 1956. The r values obtained between evaporation and relative humidity in Tables 3 and 5 seem to give some support to the influence of wet and dry surfaces on evaporation.

Correlations between soil-moisture losses from the grass plots and pan evaporation, soil temper-

TABLE 3. CORRELATION OF MOISTURE LOSSES FROM SOIL MULCH, STRAW MULCH AND GRASS COVERS WITH A NUMBER OF POSSIBLE RELATED FACTORS AUGUST 1957-DECEMBER 1958, WESLACO[1]

Possible related factors	Type of cover		
	Soil mulch	Straw mulch	Grass
Average R.H. percent per month	r= 0.59*	r= 0.22 N.S.	r= 0.08 N.S.
Hours per day per month above 50 percent R.H.	r= 0.49 N.S.	r= 0.21 N.S.	r= 0.01 N.S.
Hours per day per month above 70 percent R.H.	r= 0.49 N.S.	r= 0.28 N.S.	r=−0.13 N.S.
Hours per day per month above 90 percent R.H.	r= 0.59*	r= 0.24 N.S.	r=−0.03 N.S.
Monthly mean temperature °F.	r= 0.10 N.S.	r= 0.04 N.S.	r= 0.59*
Hours per day per month above 70° F. (air temperature)	r= 0.10 N.S.	r=−0.08 N.S.	r= 0.72**
Hours per day per month above 80° F. (air temperature)	r=−0.02 N.S.	r=−0.04 N.S.	r= 0.76**
Hours per day per month above 90° F. (air temperature)	r=−0.18 N.S.	r= 0.02 N.S.	r= 0.54*

[1]Symbols: * = Significant 0.05; ** = Significant 0.01; N.S. = Not significant; R.H. = Relative humidity.

TABLE 4. RELATIVE HUMIDITY AND AIR TEMPERATURE EXPRESSED IN AVERAGE NUMBER OF HOURS PER DAY OVER AN INDICATED PERCENTAGE OR TEMPERATURE, RESPECTIVELY FROM AUGUST 1957 THROUGH DECEMBER 1958, WESLACO

Months	Average hours per day over indicated percentages or degrees F. for respective months					
	50	70	90	70	80	90
1957	— — Percent	— —		— Degrees, F. —		
August	19.4	14.8	12.5	24.0	17.1	7.7
September	21.4	17.0	14.2	21.1	12.5	4.2
October	21.7	17.5	13.5	15.8	7.1	1.0
November	22.8	19.9	17.1	9.5	2.6	0.0
December	20.4	17.0	13.7	4.8	0.1	0.0
1958						
January	21.2	18.4	15.3	1.6	0.2	0.0
February	21.6	18.9	15.9	3.1	0.5	0.1
March	21.3	18.5	14.4	5.9	1.1	0.0
April	19.6	15.9	12.7	16.8	5.9	1.1
May	22.0	17.1	13.6	20.4	8.9	1.2
June	23.7	18.4	14.4	23.6	14.6	3.6
July	22.5	16.9	13.8	24.0	13.8	4.7
August	17.6	13.9	11.3	23.5	16.3	7.5
September	23.4	21.5	17.6	23.8	11.2	2.6
October	23.9	22.9	20.7	15.6	4.0	0.2
November	22.7	20.1	16.2	9.6	0.4	0.0
December	22.3	19.9	16.8	2.5	0.0	0.0

TABLE 5. CORRELATION OF MOISTURE LOSSES FROM SOIL MULCH, STRAW MULCH AND GRASS COVER WITH AVERAGE PERCENT RELATIVE HUMIDITY BY YEARS, 1955-58, WESLACO[1]

Average relative humidity percent per month	Type of cover		
	Soil mulch	Straw mulch	Grass
	Correlation of soil moisture losses—inches per day with percent relative humidity		
1955	r= 0.23 N.S.	r= 0.10 N.S.	r= 0.17 N.S.
1956	r=−0.41 N.S.	r=−0.59 N.S.	r=−0.44 N.S.
1957	r= 0.08 N.S.	r= 0.08 N.S.	r=−0.01 N.S.
1958	r= 0.53 N.S.	r= 0.08 N.S.	r=−0.20 N.S.
Total 1955-58	r=−0.01 N.S.	r= 0.02 N.S.	r= 0.06 N.S.

[1]N.S. = Not significant.

TABLE 6. CORRELATIONS OF AVERAGE MONTHLY SOIL TEMPERATURES WITH AVERAGE MONTHLY AIR TEMPERATURES[1]

Type of cover					
Soil mulch		Straw mulch		Grass	
Soil depth, inches		Soil depth, inches		Soil depth, inches	
3	9	3	9	3	9
r=0.89[2]	r=0.89[2]	r=0.93[2]	r=0.67[2]	r=0.90[2]	r=0.87[2]

[1]Average monthly temperature = Daily readings during month / Readings X days in month

[2]Highly significant.

ature and air temperature were not as high as might be expected. However, r values obtained were highly significant and indicate that moisture losses from the grass cover are influenced by its climatic environment as indicated in Table 2. The magnitude of the r values were approximately the same. This is due primarily to the fact that plant growth and, therefore, soil moisture utilization and/or loss by grass cover, are influenced by climatic factors.

Correlations between evapotranspiration and relative humidity and air temperatures from August 1957 to December 1958 are reported in Table 3. Correlations between evapotranspiration and average relative humidity by years are reported in Table 5. An r value of 0.76 was obtained between evapotranspiration rate and hours per day above 80° F as indicated in Table 3. The r value between evapotranspiration and mean air temperature was only 0.59. Expressing air temperatures in terms of hours per day above a specified temperature or relative humidity in hours per day above a specified percentage may have advantages but need further evaluation.

Correlations between average monthly soil temperatures at the 3 and 9-inch depths and average monthly air temperatures were highly significant under all types of covers as indicated in Table 6. Soil temperatures at 9 inches under the straw-mulched plots did not respond as quickly to air temperatures as soil temperature under the soil mulch and grass plots.

TABLE 7. CORRELATIONS OF AVERAGE HOURLY SOIL TEMPERATURES WITH AVERAGE HOURLY AIR TEMPERATURES[1]

Type of cover					
Soil mulch		Straw mulch		Grass	
Soil depth, inches		Soil depth, inches		Soil depth, inches	
3	9	3	9	3	9
r=0.90[2]	r=0.82[2]	r=0.85[2]	r=0.81[2]	r=0.81[2]	r=0.80[2]

[1]Average hourly air and soil temperatures refer to average temperatures at 6 a.m., 9 a.m., 12 noon, 3 p.m., 6 p.m., 9 p.m., 12 midnight and 3 a.m. for each month.

[2]Highly significant.

TABLE 8. GRASS YIELDS OBTAINED FROM NONFERTILIZED AND FERTILIZED GRASS PLOTS IN 1958

Nitrogen rate pounds per acre	Cutting dates 5/10/58	8/19/58	9/28/58	12/3/58	Total yield
	— — — — Yields tons per acre[2] — — — —				
0	0.21	0.83	0.24	0.22	1.50
90[1]	0.81	2.27	1.03	0.72	4.83

[1]Treatment repeated after each cutting prior to irrigation.
[2]Air-dry weight.

Correlations between average hourly fluctuations in air and soil temperatures are indicated in Table 7. The r values in Table 7 indicate the comparative responses of soil temperatures under different covers to air temperatures. The highest correlation was obtained between fluctuations in air and soil-mulch temperature, the lowest correlation between fluctuations in air and grass-soil temperatures.

The influence of different covers on soil temperature may be important in the growth and development of various crops such as citrus. Higher soil temperatures under soil mulch in the spring and relatively low soil temperatures at 9 inches under a straw mulch also may be of vital importance in the plant-growth cycle. The data indicate, however, that orchards with soil and straw mulch covers may be more susceptible to low temperatures in the winter. Research concerning the influence of these covers on citrus is needed in the Lower Rio Grande Valley.

Table 8 shows grass yields obtained from four cuttings in 1958. The fertilized grass plots produced approximately three times the yield of those receiving no fertilizer.

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Further information on monthly rainfall, relative humidity and wind velocity data for 1955-58 can be obtained from Substation No. 15, Weslaco, Texas.

Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

State-wide Research

★

The Texas Agricultural Experiment Station is the public agricultural research agency of the State of Texas, and is one of ten parts of the Texas A&M College System

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Conservation and use of water	Dairy cattle
Grasses and legumes	Sheep and goats
Grain crops	Swine
Cotton and other fiber crops	Chickens and turkeys
Vegetable crops	Animal diseases and parasites
Citrus and other subtropical fruits	Fish and game
Fruits and nuts	Farm and ranch engineering
Oil seed crops	Farm and ranch business
Ornamental plants	Marketing agricultural products
Brush and weeds	Rural home economics
Insects	Rural agricultural economics

Plant diseases

Two additional programs are maintenance and upkeep, and central services.

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