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SOIL TEMPERATURE

A Guide to Timely Cotton Planting

THE AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
TEXAS AGRICULTURAL EXPERIMENT STATION
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in Cooperation with the
UNITED STATES DEPARTMENT OF AGRICULTURE

Summary

A uniform stand of cotton with desirable spacing between plants is imperative for mechanizing cotton production. Since such a stand requires precise planting operations, both equipment improvements and planting practices are important. The relatively short growing season on the Texas High Plains emphasizes the need of obtaining a satisfactory stand at the first planting.

Soil temperature is a valuable guide in planting cotton. Good cotton stands more likely will be obtained when the minimum soil temperature at an 8-inch depth averages 60° F. or above for the 10 days preceding planting.

Soil temperatures were observed with cotton plantings during a 7-year period, 1952-58, to determine their value as a guide in finding the optimum time to plant cotton at Substation No. 8, Lubbock, Texas. The data obtained support the following conclusions:

1. Minimum soil temperatures at an 8-inch depth for the 10-day period before planting were useful as a planting guide.

2. Cotton seedlings emerged in 5 to 9 days when the preplanting soil temperatures at 8-inch depths averaged 60° F. or above for 10 days. It took as many as 15 days for the seedlings to emerge when the average soil temperature was below 55° F.

3. The total percentage of seedling emergence was highest when the average minimum soil temperature was in the 60 to 70° F. temperature range and decreased rapidly when temperatures were outside this range. Good stands can be expected with two out of three plantings under these conditions, while in colder soils the odds are one out of five.

4. Using soil temperatures, rather than the currently recommended dates as a planting guide, result in earlier plantings when favorable growing conditions prevail and in later plantings when unfavorable conditions exist. Planting on the basis of soil temperature did not reduce yields in this study.

5. The 7-year average date when minimum soil temperatures at the 8-inch depth averaged 60° F. for the previous 10 days was May 3. The earliest date was April 23 and the latest was May 16.

6. The highest average lint yields were obtained in 5 of the 6 years of study by planting on or after the date the soil temperature reached the recommended average of 60° F.

7. Fiber characteristics were not affected adversely by delaying plantings until the soil reached the recommended 60° F.

Contents

Soil Temperature - A Guide to Timely Cotton Planting

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COTTON SHOULD BE PLANTED at the earliest feasible date in areas with relatively short growing seasons such as the Texas High Plains. The mean frost free period at Lubbock is 205 days (1) and the mean summer temperatures are 67.7, 76.2, 79.1, 78.1 and 71.3 for May, June, July, August and September, respectively (6). A minimum of about 200 frost free days with a mean summer temperature of 77°F. is necessary for satisfactory cotton production (2). Thus, in the High Plains area, cotton should be planted at the earliest date when the probability of obtaining a satisfactory stand is relatively high. The earliest date a stand can be obtained depends on seasonal conditions from year to year.

Temperature is a major factor in seed germination. Cottonseed germinates poorly at temperatures lower than 70°F., and the seedlings grow more slowly and less vigorously at these low temperatures than those which germinate at 70° to 85°F. (4). Thus, planting in cold soil not only results in a lower germination percentage but also in delayed emergence and weakened plants that are more susceptible to seedling diseases. Therefore, soil temperature may be considered as a guide to determine the earliest feasible planting date for cotton in a given season. These investigations were initiated in 1952 at Substation No. 8, Lubbock, Texas to determine the relationship between soil temperature, seedling emergence and yield. Crop maturity and fiber property data also were obtained.

Experimental Procedure

SOIL TEMPERATURE

Soil temperatures were recorded from early April through May at 2, 4, 6 and 8-inch depths in 1952, 1953 and 1954 with a dial stem-type thermometer. From 1955-58 temperatures were obtained only at the 8-inch depth. The soil temperatures from 1953-58 also were obtained with a continuous recording thermometer.

CULTURAL PRACTICES

Cotton was planted at intervals of 7 to 10 days to obtain a range of soil temperatures. The seedling rates, seed types and varieties used in the experiments are shown in Table 1. A shallow furrow planter was used for all plantings except in 1952 when the plots were hand planted and in 1958 when the plateau and the shallow furrow planters were used. Replicated plots were used in 1952-55 and large unreplicated plots, 6 to 8 rows wide, were used during the last 3 years.

The land was bedded, irrigated, and cultivated before it was planted. Recommended irrigation and cultural practices were followed during the growing season. Plots were harvested with a single roll machine stripper 3 to 4 weeks after frost.

SAMPLING PROCEDURES

Stand counts were taken on the first or second day of initial emergence and again 7 to 10 days later. Counts were taken in each replicated plot and at three locations across the rows of the unreplicated plots. These data are percentages of the seed which produced seedlings. Plant survival data were obtained from plant stand counts after harvesting. These counts were made in the same plots used for early stand determinations. The appearance date of the first bloom was recorded. Earliness was determined by counts of open and unopened bolls at a given date. Yields were taken from one-hundredth of an acre in the replicated plots and from one-

TABLE 1. VARIETIES, TYPE OF SEED, GERMINATION DATA AND SEEDING RATES USED FOR SOIL TEMPERATURE PLANTING STUDIES

Year	Variety	Type of seed	Laboratory germination, percent	Seeding rate, pounds per acre
1952	Stormmaster	Fuzzy	84	39
		Machine delinted	77	39
		Acid delinted	73	39
1953	Stormmaster	Acid delinted		30
1954	CA 119[1]	Fuzzy	75	28
		Machine delinted	71	28
		Acid delinted	86	28
1955	CA 119	Fuzzy	75	26
		Machine delinted	72	26
		Acid delinted	86	26
1956	CA 119	Machine delinted	64	22
1957	CA 119	Machine delinted	70	30
1958	Paymaster 101	Acid delinted	80	20

[1]An experimental stormproof cotton strain developed by the Texas Agricultural Experiment Station, Substation No. 8, Lubbock, Texas.

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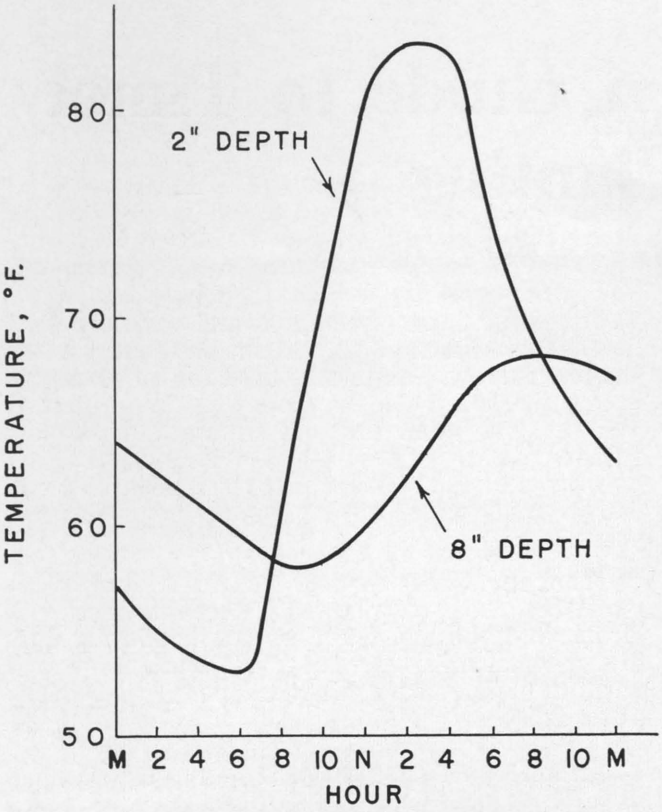

Figure 1. Typical daily soil temperatures for April 24, 1955 at 2 and 8-inch depths in Amarillo fine sandy loam, Lubbock, Texas.

tenth of an acre in the demonstration plots. All samples were ginned on a 32-saw laboratory gin. Lint percent, grade, staple and fiber properties were obtained from a representative sample of the harvested cotton.

Results and Discussion

SOIL TEMPERATURE

The fluctuation of soil temperature at the 2 and 8-inch depths for a typical clear day are shown in Figure 1. The daily variations of minimum soil temperatures at 2 and 8-inch depths are shown in Figure 2. Similar fluctuations are shown by Russel (5). Lower soil temperatures were noted after rains, clear nights or when the preceding day was cloudy. These data show that the soil temperature at the 2-inch depth fluctuated 30 degrees from the minimum to the maximum for any single day. However, this fluctuation was only one-third as much at the 8-inch depth with a higher minimum and lower maximum, Figure 1. The minimum temperature for the 8-inch depth usually occurred between 7 and 9 a.m. on clear days. The time for recording temperatures at the 8-inch depth was not as critical as it was at more shallow depths.

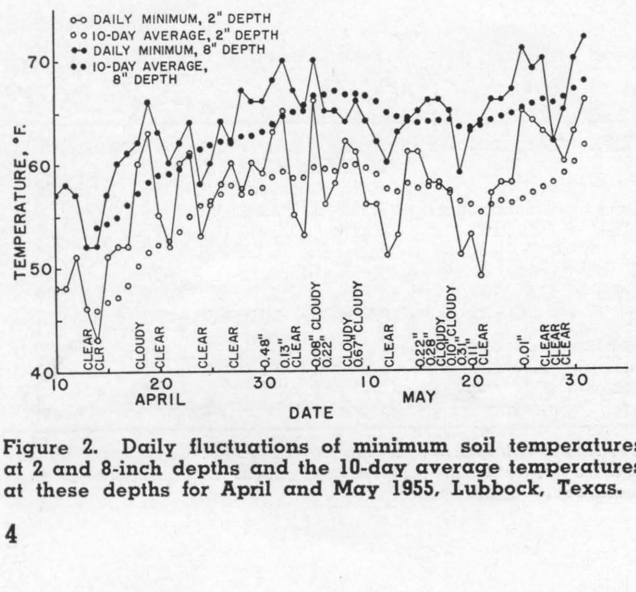

Figure 2. Daily fluctuations of minimum soil temperatures at 2 and 8-inch depths and the 10-day average temperatures at these depths for April and May 1955, Lubbock, Texas.

Since daily minimum temperatures at either depth are highly variable, more than 1 day's reading is necessary to provide a valid guide to determine the optimum time to plant cotton, Figure 2. A 10-day average for the 8-inch depth was selected as the best guide for planting cotton because the fluctuations were smaller and not as erratic as those for more shallow depths or shorter periods, Figure 3. The 10-day average of 60°F. minimum soil temperature at the 8-inch depth occurred on May 5, April 28, April 25, April 23, April 29, May 16, and May 10 in 1952-58, respectively. The mean date of occurrence was May 3.

EMERGENCE

The emergence of seedlings increased as the minimum pre-planting soil temperature rose to 66°F.; above this temperature data became more erratic and unreliable, Figure 4. The highest emergence percentage occurred when the average temperature at the 8-inch depth was between 60° and 70°F. for the 10 days before planting. The regression equation calculated for emergence on the average minimum soil temperature at the 8-inch depth for 10 days before planting was $E = 4.358\ T - 0.07577T^2 - 0.001116T^3 - 251.67$, where E is the percent of seed to emerge and T is the soil temperature. From this equation maximum emergence occurs when the 10-day average minimum temperature reaches 65°F. before planting. However, the regression curve is relatively flat within the 60° to 70°F. soil temperature range. The low multiple correlation coefficient, $R^2 = 0.289$, was expected because a number of other factors affecting germination and emergence could not be held constant in field tests. For example, seed quality varied from year to year and rains during the emergence period and subsequent diseases also increased the emergence variability. In 1954 the percentage of seed emergence varied widely between two plantings even though the 10-day average temperature before planting was approximately the same. On May 3, when 2.20 inches of rain fell during the emergence period, only 13 percent of the seed emerged. Sixty percent emergence was obtained from the May 27 planting when no rain fell during the emergence period.

Linear regression calculated for the emergence percentage as affected by preplanting 10-day average minimum soil temperature in the 50 to 66°F. range was $E = 1.663T - 59.76$ with a coefficient of correlation, $r = 0.523$, where E is the emergence percentage and T is the soil temperature. Linear regression shows that emergence increased 1.7 percent for each degree of rise in the preplanting 10-day average of minimum soil temperature up to 66°F. The linear regression line almost paralleled the curvilinear regression through this temperature range, Figure 4. The low coefficient of correlation resulted from the unmeasured variables described above.

An analysis of emergence percentage as affected by planting dates is shown in Figure 5. The calculated linear regression was $E = 0.292P + 27.65$ with $r = 0.416$, where E is the percentage of emergence and P is the planting date. The increase in emergence was approximately 1 percent for every 3.5 days that plantings were delayed. If a satisfactory stand is defined as 40 percent emergence of the seed planted, the odds of obtaining satisfactory stands are two successful plantings out of three, for the commonly recommended planting dates, May 10 to 30. Before May 10, the odds are only one successful planting out of three. A similar analysis by 10-day average soil temperatures at the 8-inch depth before planting shows that the odds for successful plantings are 2 out of 3 in the 60° to 70°F. range and 1 out of 5 in soils colder than 60°F.

The preplanting temperature was more reliable in predicting the number of days required to establish a stand than in predicting the seedling emergence. The lower the soil temperature the greater the number of days necessary for the seedlings to emerge, Figure 6. The emergence period was slightly less than 15 days when the 10-day average temperature was below 55°F. and was about 6 days when the temperature reached 70°F. The number of days required for seed emergence decreased beyond 70°F. as 10-day average minimum soil temperatures increased, although the relative amount of seeds which emerged as seedlings was erratic. When the preplanting average temperature reached 60°F., emergence occurred in less than 9 days. The regression equation for time of emergence on temperature is $D = 52.0 - 0.5347T - 0.010{,}56T^2 - 9.000{,}124T^3$ with $R^2 = 0.627$ where D is the number of days and T is the soil temperature.

Mean soil temperatures at the seed level during the emergence period were above 70°F. after a 10-day average minimum preplanting temperature of 60°F. was reached at the 8-inch depth, Figure 7. Linear regression indicates that the soil temperature surrounding the seed during emergence average approximately 1 degree lower for each degree decrease in the preplanting 10-day average minimum soil temperature at the 8-inch depth. Recent findings of Johnson et al (3)

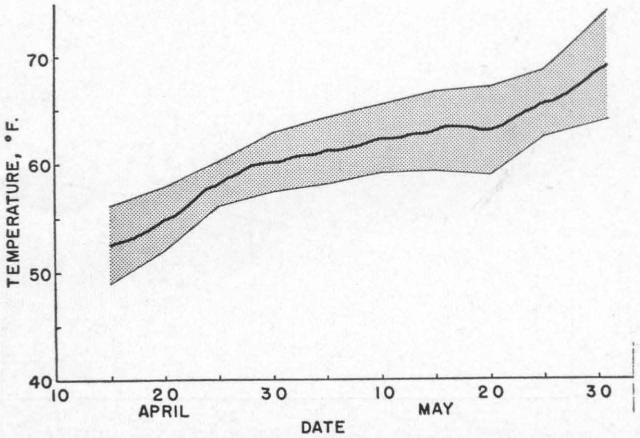

Figure 3. Ten-day average mean of the minimum soil temperatures at the 8-inch depth for the 1952-58 period, Lubbock, Texas. Note the variation shown by the standard deviation (shaded areas). Approximately two-thirds of the cases would fall within plus or minus one standard deviation from the mean.

have shown that a higher emergence percentage and a shorter emergence period resulted when the temperature surrounding the seed was held at, or averaged 70°F., than when the temperatures were held at or averaged 65°F. and 60°F. A regional study (7) of the effect of soil temperature on cottonseed emergence and stands has shown that emergence increased and stands were better as the soil warmed.

PLANT SURVIVAL

The survival of cotton seedlings varied from season to season. In 1957 plant survival was poor when the preplanting soil temperature average was below 60°F.

FIRST BLOOM

The first bloom appeared 65 to 95 days after planting in cold soils with a lower than 60°F.

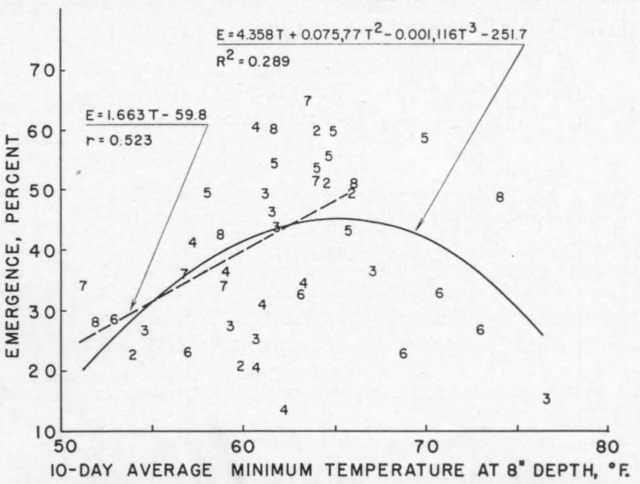

Figure 4. Emergence of cotton seedlings for cotton plantings at different soil temperatures before planting. The emergence is expressed as percent of seed planted. The data points are the center of each single digit which designate the year of data, "2" is 1952 data, "3" is 1953, etc. Curvilinear regression is shown for the entire temperature range of the studies and linear regression is shown for the temperature of 51° through 66° F.

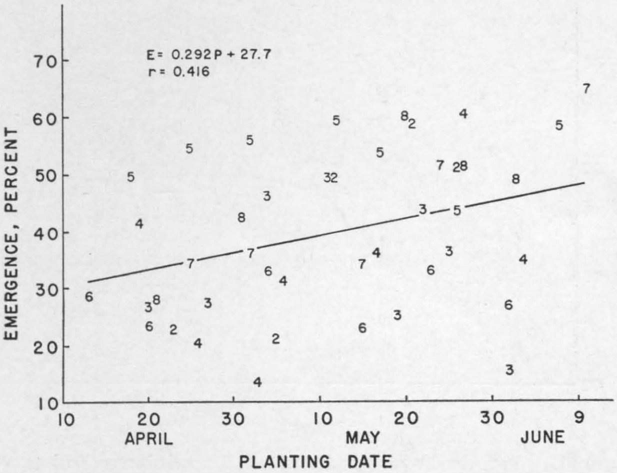

Figure 5. Cotton seedling emergence for plantings by date. The emergence is expressed as the percentage of seed planted. The data point is the center of each individual digit which designates the data year.

average. But when the temperature went above the 60°F. average, the first bloom appeared between 46 and 68 days after plantings were made. This indicates more rapid plant development in warmer soils and that the length of time to first bloom decreases between early and late plantings.

EARLINESS

The percentage of open bolls on a given date in the fall varied considerably with seasons. In 1957 little cotton was open on October 16 as compared with 1953, 1954, 1955 and 1958. Usually the earlier the cotton was planted the greater was the percentage of open bolls on a given date in the fall. The earliest crops generally were those which had been planted in late April or early May. The crop produced from the May 24 planting in 1957 was the earliest and had the highest yield although cold soil temperatures prevailed until the latter part of May. This was the first planting date that the average 60°F.

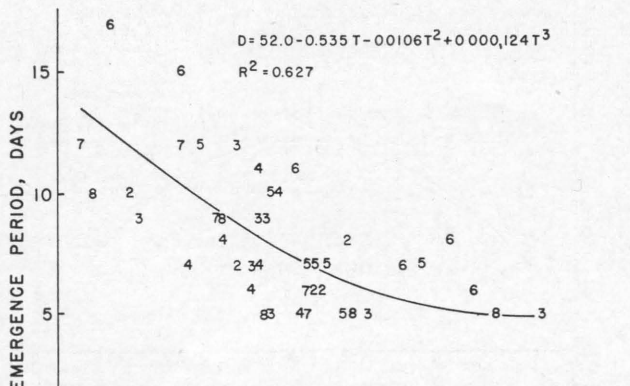

Figure 6. Emergence period from planting to initial emergence of cotton seedlings for plantings at different soil temperatures. The data point is the center of each single digit which is keyed to the year.

preplanting temperature was reached. The earliness of the crop was not affected appreciably by delayed planting until the average 60°F. preplanting temperature occurred. However, on a pounds-of-lint per acre basis, the differences between the amount of open cotton produced by plantings made before the 60°F. temperature was reached was not necessarily greater than that produced by plantings made after the 60°F. temperature was reached.

YIELDS

In 5 out of 6 years the highest lint yields were obtained from plantings made after the 60°F. 10-day average soil temperature was reached at the 8-inch level. The above average yields usually were obtained from plantings made when preplanting soil temperature averaged between 60° and 65°F., Figure 8.

GRADES AND STAPLE LENGTHS

Grades and staple lengths were not affected materially by the date of planting or soil temperature at planting time. The extremely early or late plantings had the lowest grades in years when there were grade differences.

OTHER FIBER PROPERTIES

Only small differences were noted in the relationship of the upper half mean fiber length to the planting date or soil temperature at planting time. However, the early, or cold soil, plantings tended to produce a fiber with a slightly shorter upper half mean length than that produced by plantings made when the soil temperature range was 60° to 65°F. Fiber length uniformity did not vary noticeably because of the planting time.

Seasonal variations caused greater differences in fiber strength than did the planting times. Fiber strength from plantings made in the 60° to 65°F. soil temperature planting range generally was as high as the fiber strength of earlier plantings.

Fiber fineness, as indicated by micronaire measurements, was affected by season, variety and planting date. Plantings in the 60° to 65°F. soil temperature range generally had satisfactory micronaire readings except in 1957 when all readings were low.

Soil Temperature as a Planting Guide

Cotton planting should be delayed until a 60°F., 10-day average minimum soil temperature at the 8-inch depth is reached. Using soil temperature as a guide results in earlier plantings more often than when optimum dates are used. This guide should be used only to establish the earliest feasible time for planting. Soil temperature is not a determining factor for late season plantings.

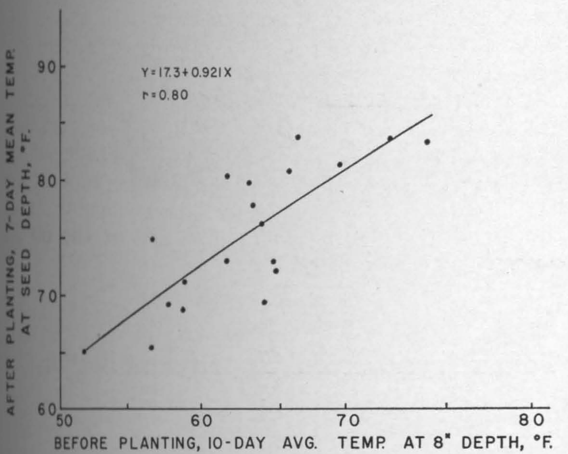

Figure 7. Correlation of 7-day average soil temperature at seed depth during emergence period with 10-day average minimum soil temperature at the 8-inch depth before planting.

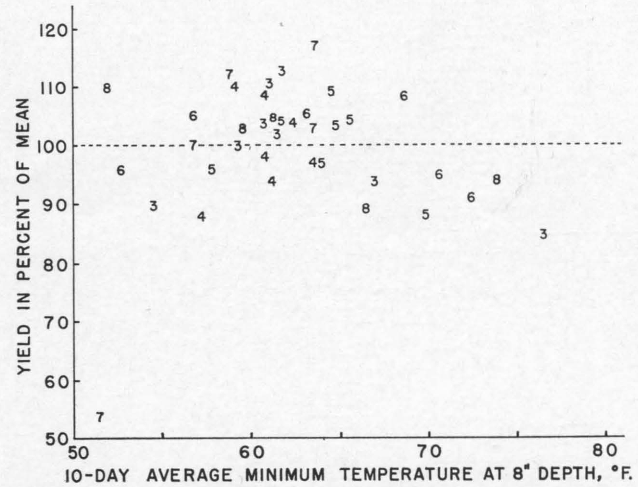

Figure 8. Scatter diagram of acre lint yield plotted as percent mean yield against the preplanting 10-day average of minimum soil temperature at the 8-inch depth. Data point is the center of each individual digit keyed in the year: "3" is for 1953, "4" for 1954, etc.

Cottonseed planted at recommended soil temperatures should not be covered more than 2 inches for quick emergence and proper planting practices and equipment should be used for best results. Heavy soil-crusting rains are detrimental to cotton emergence and it is advisable to delay plantings when such rains are in immediate prospect. Long range weather forecasts also are valuable considerations at planting time. With the 10-day average minimum soil temperature at 60°F. at the 8-inch depth as a planting guide, seedlings can be expected to emerge in 9 days or less; whereas, emergence from plantings in colder soils may require 13 to 15 days. Thus, seed rotting will be reduced greatly.

Daily soil temperatures can be determined readily when the sensing element of the thermometer is placed at the recommended 8-inch depth in the center of the preplanting bed. A thin-stemmed thermometer, like a dial thermometer with a bimetalic sensing unit, can be inserted easily into the soil to the desired depth. The minimum soil temperatures should be taken daily between 7:30 and 8:30 a.m. and recorded for at least 10 days.

Acknowledgments

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Fiber tests were conducted by the fiber laboratories of the Texas Cotton Research Committee at Texas Technological College. Cotton classifications were made by the Cotton Division, Agricultural Marketing Service, U. S. Department of Agriculture, Lubbock, Texas.

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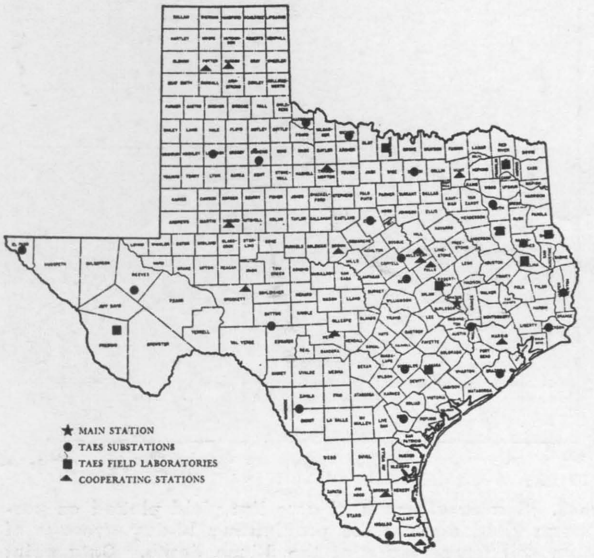
SUPPLEMENTARY DATA AVAILABLE

Tabulated data regarding the effect of soil temperature on cottonseed emergence, yields and fiber properties for the plantings used in this study for 1952-58 can be obtained from the Texas Agricultural Experiment Station, Substation No. 8, Lubbock, Texas.



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

State-wide Research

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

ORGANIZATION

IN THE MAIN STATION, with headquarters at College Station, are 16 subject-matter departments, 2 service departments, 3 regulatory services and the administrative staff. Located out in the major agricultural areas of Texas are 21 substations and 9 field laboratories. In addition, there are 14 cooperating stations owned by other agencies. Cooperating agencies include the Texas Forest Service, Game and Fish Commission of Texas, Texas Prison System, U. S. Department of Agriculture, University of Texas, Texas Technological College, Texas College of Arts and Industries and the King Ranch. Some experiments are conducted on farms and ranches and in rural homes.

OPERATION

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

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

Research results are carried to Texas farmers, ranchmen and homemakers by county agents and specialists of the Texas Agricultural Extension Service

AGRICULTURAL RESEARCH seeks the WHATS, the WHYS, the WHENS, the WHERES and the HOWS of hundreds of problems which confront operators of farms and ranches, and the many industries depending on or serving agriculture. Workers of the Main Station and the field units of the Texas Agricultural Experiment Station seek diligently to find solutions to these problems.

Today's Research Is Tomorrow's Progress