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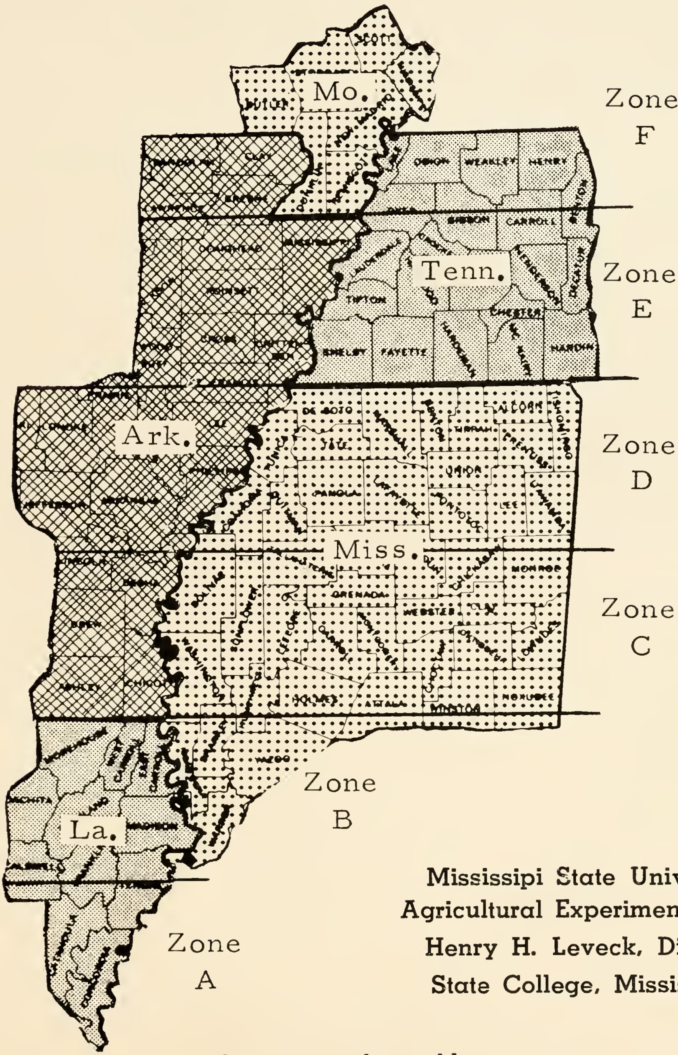
Soil Temperatures And Cotton Planting In The Mid-South



Mississipi State University
Agricultural Experiment Station
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in cooperation with
the U. S. Department of Commerce Weather Bureau and the Agricultural Experiment Stations and Cooperative Extension Services in Arkansas, Missouri, Louisiana and Tennessee

FIVE BASIC STEPS BEFORE PLANTING

Soil temperature is a key in timing cotton planting operations. The FIVE BASIC STEPS listed below give a practical approach to the problem of "When to Plant".

1. Study the soil temperature probability tables on pages 8, 9, 10. See when favorable temperatures normally occur in your area.

2. Keep well informed on current weather conditions and soil temperature trends. Daily advisories are issued by the U. S. Weather Bureau Agricultural Weather Service. Radio and television stations and newspapers distribute the advisories through the Mid-South.

3. Give particular attention to the long range forecasts and agricultural weather advisories which cover periods up to two weeks.

4. When conditions approach favorable limits, make frequent soil temperature reading over your entire fields. For seed of **average quality,** the **average** soil temperature at the 2-inch level should be about 68°F.
   a. An early morning minimum temperature of 60°F is equivalent to the 68°F average
   b. A 10 a.m. reading of 68°F on a clear day is equivalent to the 68°F average.

5. Remember, soil temperature should average 68°F or higher during germination and emergence. This means **69°F or higher for about 10 days after you** plant, not just on the day that you plant.

If these soil temperature factors, as well as soil moisture conditions, appear favorable, you will minimize these planting risks and your chances for success will be increased.

ACKNOWLEDGEMENTS

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SOIL TEMPERATURES AND COTTON PLANTING IN THE MID-SOUTH

By J. A. RILEY, D. H. NEWTON, J. W. MEASELLS, D. A. DOWNEY and LEONARD HAND[1]

Competition in the fiber market today demands that cotton growers produce a high quality crop at a minimum cost. Planting is the first pivot point in the series of production decisions. Modern cotton planters cannot afford the luxury of frequent replanting.

Pre-emergence weed control practices, along with the cost of the planting operation, make replanting expensive. The supply of high quality seed is limited and the farmer may have to use a lower quality if he replants. Today's mechanical equipment can plant a field in a relatively short time. These factors make it economically practical for the planter to wait until he has a good chance to obtain a satisfactory stand at the first planting.

Getting a stand of cotton depends on many different variables, but the primary weather elements are moisture and temperature. It is relatively easy to see if the soil is too wet or too dry. However, it is not easy to see if it is too cold.

We know that cottonseed will develop properly at a temperature of 68° F or higher. But we also know that soil temperature is a variable thing. It varies according to geographical location, time of year, time of day, depth below the surface, and soil characteristics. We need to know what effect the **maximum, minimum,** and **average** soil temperatures have on cottonseed development.

Extensive soil temperature measurements have been made in the field by the U. S. Weather Bureau, the Mid-South State Agricultural Experiment Stations, and the U. S. Department of Agriculture. The purpose of this bulletin is to help the Mid-South cotton planter use available soil temperature information to decide when to plant his crop.

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Soil Temperature and Seedling Development

Laboratory tests have defined three temperature thresholds for cottonseed germination and seedling growth. The minimum temperature is near 60° F, the maximum is about 102° F and the optimum is in the 85° F to 95° F bracket. Research at the Delta Branch of the Mississippi Agricultural Experiment Station showed that emergence averaged 93 percent with a soil temperature of 70° F, about 75 percent with 65° F, and around 10 percent with 60° F.

Seed quality is a **major** factor in the way soil temperature effects seed development. High quality seed was used in the experiment which gave 75 percent emergence with 65° F average soil temperature. With seed of average quality, the soil temperature should be around 68° F. For a good rate of emergence with low quality seed, the soil temperature should average 70° F or higher.

Low temperatures have a direct detrimental effect on cotton seedlings. This varies from lethal in the case of freezing temperatures to a condition that merely slows growth in less extreme cool weather.

Freeze damage is rare, but when it does occur, the farmer has no choice; he must replant. Injury resulting from low temperatures that are above freezing is called chilling damage. This occurs much more frequently than freeze damage, and since it usually does not kill all of the seedlings, the farmer must decide whether to replant or not.

Dr. M. N. Christiansen of the Delta Branch Experiment Station has found two distinctly different types of chilling damage resulting from different sequences of cold weather. In one test, the temperature of germinating seed was held in the 40° F to 50° F range for six days and then raised to 86° F. Here, the tip of the primary root was destroyed but many lateral roots sprouted to help take its place. Seedling development showed a definite time lag compared with growth under favorable temperatures.

In the other test, the temperature was held at 86° F for one day, dropped to 40°F to 50° F for six days, and then raised back to 86° F. Here, the outside layers of the primary root were destroyed. Seedling development was drastically reduced as compared with growth under favorable temperatures. Disease resistance of seedlings with this injury was also greatly reduced.

Planters should seek to avoid either type of chilling damage, but of the two, the greatest injury results when the seedlings have been subjected to a short period of favorable temperature before the onset of low temperature.

The optimum soil temperature for cottonseed germination is between 85° F and 95° F. Obviously the Mid-South farmer cannot wait for this. Cotton planted late in the season is more vulnerable to some insects, early summer dry spells, early fall rains, and early winter freezes. The farmer must balance the chance of being caught by low soil temperatures against the chance of waiting too long. Timing is the key factor in planting cotton.

Soil temperatures have very large seasonal variations. The temperature at the 2-inch level normally reaches the upper 60s by the middle of April in the Louisiana Delta and by the last of April in the Missouri Bootheel. You notice we say "normally" but "normal weather" does not always occur. Large cold air masses from Canada occasionally drift this far south as late as May. When they are preceded by clouds that block the sunshine and surface moisture that cools the ground by evaporation, soil temperatures tumble.

A late cold spring is one of the greatest weather worries of the Mid-South planter. Weather records of 1960 illustrate this point. During the period May 11-13, soil temperatures dropped into the high 40s in the Missouri Bootheel, extreme northeast Arkansas and northwest Tennessee, and into the low 50s as far south as the Mississippi and Louisiana Delta areas. About one-third of the Mississippi Delta crop had to be replanted. A conservative estimate would score this at well over a million dollar loss in this one area.

Why Soil Temperatures Vary

Radiant heat from the sun is the main source of energy that warms the soil. Radiant heat from the ground and evaporation of moisture from the ground are the two main features that carry away heat from the soil. Basically, soil temperature is a result of the balance between the incoming and outgoing heat energy.

When strong sunlight shines on cool soil, the soil warms rapidly. In areas of no rain and little cloudiness, soil temperatures follow a regular pattern. In the Mid-South, rainfall and cloudiness are frequent but variable and thus soil temperatures do not follow a regular pattern.

During the spring, the sun rises a little higher in the sky each day. If there were no clouds, a little more heat would be received each day. Cloudiness normally decreases from March through May in the Mid-South. The dual effect of the altitude of the sun and the amount of cloudiness give twice as much heat from

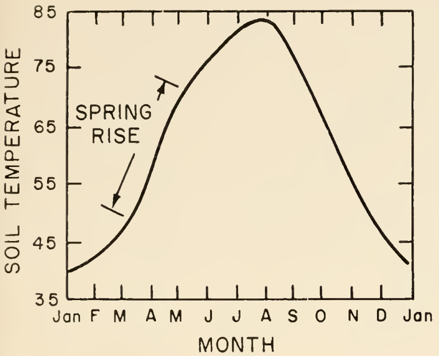

Figure 1—Average monthly 4-inch soil temperature near Northeast Arkansas Experiment Station, Keiser, Arkansas.

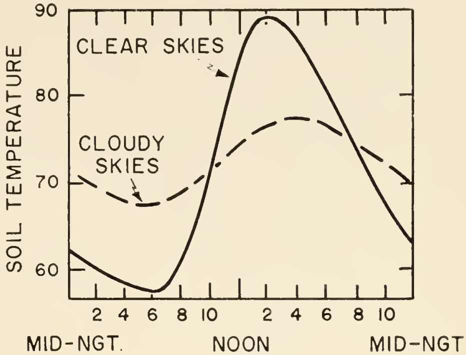

Figure 2—Hourly 4-inch soil temperature in May near Keiser, Arkansas with clear skies and cloudy skies.

the sun in late May as in early March.

Figure 1 shows the month-to-month variation of average soil temperature at the 4-inch depth near the Northeast Arkansas Experiment Station at Keiser. Springtime is a period of rapid rise, and it is easy to see how an extensive period of cloudy wet weather can temporarily delay the normal rise of soil temperature.

The spring temperature rise shown in Figure 1 means that the soil acts as a storehouse of heat. Clouds keep much of the sun's heat from ever reaching the ground. Also much of the heat that does reach the ground is given off by radiation and used up by evaporation and plant growth.

Surprisingly, much of the heat is stored in the ground during the rising part of the seasonal soil temperature cycle and given off during the cooling part. About 5000 calories of heat are stored under each square centimeter of soil each spring and summer. To make this a more practical figure, the heat stored by each acre of soil is equivalent to that available from 8000 gallons of gasoline. If you could utilize the heat stored under each acre of ground, you could use it to drive your pickup truck about 100,000 miles.

On a smaller scale, we have the same rising and falling soil temperature cycle each day. Figure 2 shows the hour-to-hour variation during the spring at the Northeast Arkansas Experiment Station. The solid line shows the changes under clear skies. The dashed line shows the much smaller changes that occur with cloudy skies.

In the spring, the temperature at seed depth averages 18° F higher in the afternoon than in the early morning. To use the soil temperature correctly in your planting schedule, you must take into account this daily cycle. Three different soil temperature measurements have been used in planting recommendations: **Maximum, Minimum** and **Average.** Each measurement is related to the rate of cottonseed development, but each relationship is different.

Figure 3 indicates how the three different readings are related to seedling development. For example, let us say the soil temperature is 70° F and all other conditions are favorable for planting. If the **minimum** temperature (bottom curve) is 70° F, emergence requires the least amount of time, somewhere around 4 days. If the **average** temperature is 70° F, the time required for emergence is about one week. If the **maximum** temperature is 70° F, the time required for emergence is the greatest, probably 10 days or so.

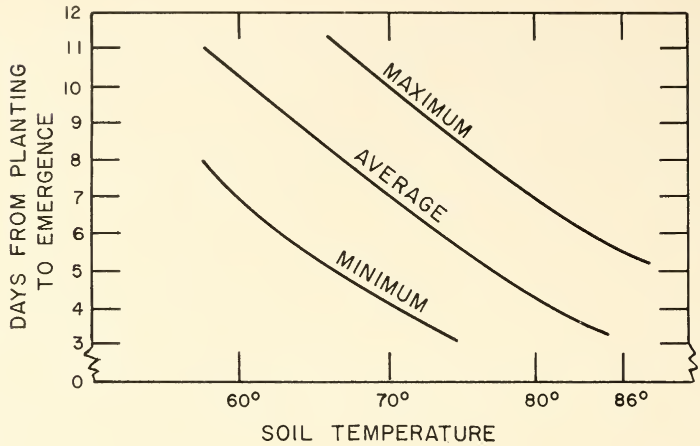

Figure 3—Relation of maximum, minimum and average soil temperature to the number of days required from planting to emergence.

The average temperature is based on two readings, both the maximum and minimum. For this reason, we think it is a more useful measurement for a planting schedule than either the maximum or minimum readings.

When measuring soil temperatures in your own fields, remember that the time of day strongly influences the reading. As shown is Figure 2, the 10 a.m. reading is close to the average between the maximum and minimum. When listening to soil temperature reports on the radio and television, use the **average** soil temperature for planting. If you use the maximum or minimum, you should make adjustments by fitting the reading into the daily pattern shown on Figure 2.

Soil temperatures also vary according to the depth below the surface. Soil conducts heat rather slowly, thus a difference in extreme values is smaller in the lower levels. Also maximum and minimum temperatures occur later at the lower levels. This time lag applies to both seasonal and daily changes.

Figure 4 shows monthly readings at several depths at the Southeast Experiment Station, Sikeston, Missouri. Summer temperatures at the one-inch level are much higher than at the 6-foot level. Winter temperatures near the surface are correspondingly cooler than deeper levels. Average temperatures at shallow levels rise faster than in greater depths. The 68° F average temperature mentioned as a desirable planting temperature refers to the 2-inch level.

When measuring soil temperatures in your own fields, check to see if the soil is unusually cold 6 to 10 inches below the surface. If it is cold, heat will have to be carried down from seed level to warm lower depths.

The average monthly soil temperature at the 2-inch depth is similar to the average monthly air temperature. On a day-to-day basis, however, there are important exceptions.

Figure 5 shows the daily averages of soil and air temperatures at the Northeast Louisiana Experiment Station in Saint Joseph for April 7-19, 1963. The average soil temperature is 7° F higher than the average air temperature on April 13-14. North winds on these two days carried cold air over Saint Joseph. To a lesser extent, the same thing happened April 7-8. On April 10-11 and April 17-18, the reverse was true. Southerly winds raised

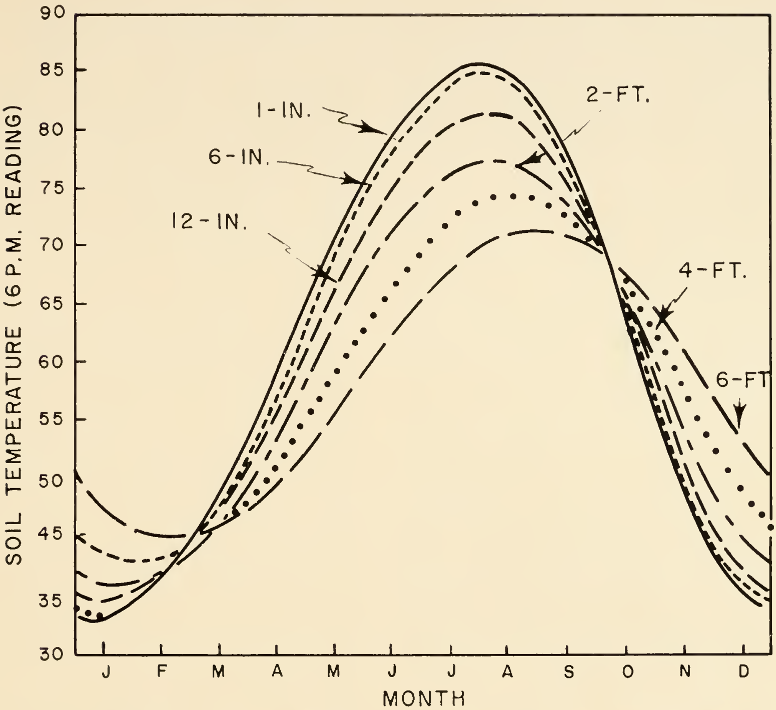

Figure 4—Soil temperatures near the Southeast Missouri Experiment Station, Sikeston, Missouri. 1951-1963, 6 p.m. readings.

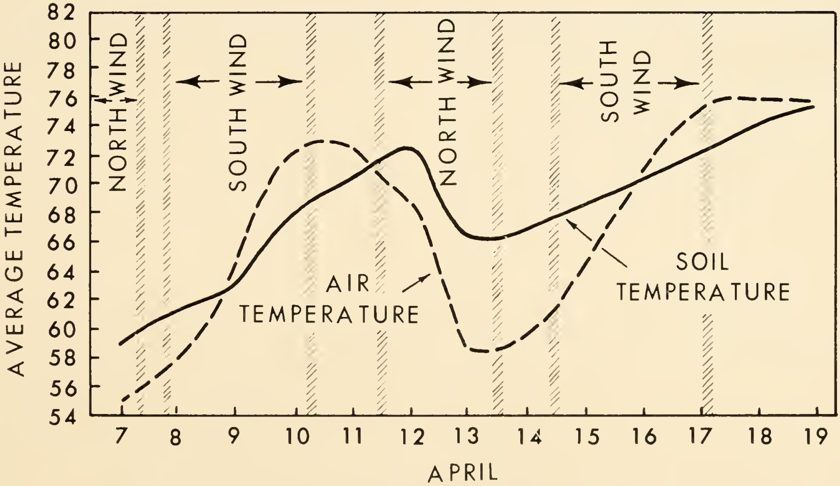

Figure 5.—Average daily 2-inch soil temperature and air temperature at the Northeast Louisiana Experiment Station, Saint Joseph, Louisiana, April 7-19, 1963. North winds give lower air temperature; south winds give higher air temperatures.

the air temperature above the soil temperature.

From this, we can see that a warm day does not necessarily indicate a warm soil and a cool day does not always indicate a cool soil.

In addition to the variations of time and depth mentioned above, other factors cause soil temperatures to vary from spot to spot in the same field at the same time. The type of soil, the slope of its surface and its moisture content all cause spot-to-spot variation.

If the temperature of the soil is increased one degree, it has been proven that more heat is generally required to raise the temperature of a clay soil than a sandy soil. This is also true if the soil is saturated with water, but in this case wet sandy soil requires nearly twice as much heat as dry sandy soil and wet clay about three and one-half times as much heat as dry clay. Also, water does not drain through clay as fast as sand and the heat used in evaporating the moisture cools the clay.

Color also affects temperature; dark soils absorb more heat than light colored soils. Since most Mid-South clay soils are dark colored, some clay soils become warmer than sandy soils especially in dry weather. Because of these different heating characteristics of different soils, you should measure the soil temperature in many parts of your field to be sure that you are getting a representative reading.

Probable Soil Temperature at Planting Time

Long-term weather records show that soil temperatures rise during the spring from March through May. The rise during any individual spring is usually irregular. A steady rise is very unusual. But if we average the observations over a period of years, we will see a steady rise.

For a good rate of seed development, we want the 2-inch soil temperature to average 68° F or higher for 10 days after planting date. Over a period of years, this happens in the southern Louisiana Delta by April 11 and in the Missouri Bootheel by April 26. The map on the front of the bulletin divides the Mississippi Delta cotton growing area into six zones. The critical soil temperature level occurs three days later in each zone as you move northward from Zone A.

The middle column of Table 1 shows the probable dates that the 2-inch soil temperature will begin to average 68° F for 10 days after planting date. These "average" dates give the planter some helpful information. But to use weather records for the most efficient planting schedule, the planter must also understand the chance of having "unaverage" conditions.

To plant well on the safe side, we look at the third column under the heading "Three Years in Four." In Zone A, the southern Louisiana Delta, three out

Table 1.—Probability that the 2-inch soil temperature will average 68°F for 10 days after planting date in the six cotton growing areas of the Mid-South shown on the front page.

	Probability		
Zone	One Year in Four	Two Years in Four	Three Years in Four
A	April 2	April 11	April 18
B	April 5	April 14	April 21
C	April 8	April 17	April 24
D	April 11	April 20	April 27
E	April 14	April 23	April 30
F	April 17	April 26	May 3

Table 2.—Probability that the daily minimum soil temperature (2-inch level) will go below 60°F, 55°F or 50°F on at least one day during the 10-day period following planting date in Zone C.[1]

Planting Date	Probability of at least one day below 60°F	55°F	50°F
March 20	100	100	90
March 31	100	95+	80
April 10	95+	80	50
April 20	80	50	10
April 30	50	10	5—
May 10	20	5—	5—

[1]Add 3 days for each zone to the north and subtract 3 days for each zone to the south.

of four springs, will maintain the 68° F average by April 18. In Zone F, the Missouri Bootheel, three out of four springs, will maintain the 68° F average by May 3. When these dates are used, first plantings should produce good stands three out of four years.

The first column shows the risk of early planting. If you plan to plant in the southern Louisiana Delta on April 2, there is only one out of four chances that the soil temperature fill hold a 68° F average. Is the northern zone, there is only a one out of four chance that the soil temperature will hold the 68° F average on April 17.

Soil temperatures can average 68° F or higher for a 10-day period but still include a few cold days. Table 2 shows the probability that the minimum temperature will drop below 60° F, 55° F or 50° F on at least one day during the 10-day period in Zone C. Growth is slow when the minimum temperature drops below 55° F and chilling damage occurs when it dips below 50° F.

Using Table 2, we can see the hazard of early planting quite plainly. For example, if the Zone C planter does plant on March 31, he can be sure that one day during the next 10 will drop below 60° F and almost as certain that one day will go below 55° F. On 8 out of 10 years, there will be at least one day with below 50° F and thus some chilling damage will result.

On April 10, there is a 50-50 chance of having one day below 50° F during the next 10 days. On April 20, there is a 50-50 chance of having one day below 55° F, and as late as April 30, there is a 50-50 chance of having one day below 60° F. By April 20, there is only one chance in 10 of having a temperature of 50° F or lower.

Table 2 is based on soil temperature observations at the Delta Branch of the Mississippi Experiment Station in Stoneville and represents Zone C. If you add 3 days for each zone to the north, or subtract 3 days for each zone to the south, you can apply this information to all zones. For a practical planting schedule, this information conforms with Table 1, which indicates only a small probability of chilling damage after: April 18 in Zone A, April 21 in Zone B, April 24 in Zone C, April 27 in Zone D, April 30 in Zone E, and May 3 in Zone F.

Bed Shape and Soil Temperature

So far we have discussed how soil temperatures vary with time and with depth, but all of this applies to flat lands. The flat bed, or the broadcast type of land preparation, is increasing in popularity in dry areas, but in the rain belt, most farmers still use a bed of medium height. The medium bed elevates the seed and reduces water-logging damage and at the same time it increases soil temperatures.

The surface area of a flat one acre field is exactly one acre. The surface area of a bedded-up one acre field amounts to about one and one-fourth acres. Because of the additional surface

Table 3.—Two-inch soil temperatures in the row and on the flat at the West Tennessee Experiment Station, Jackson, Tennessee, April 3-May 12, 1963.

	Maximum		Minimum		Average	
Date	Flat	Row	Flat	Row	Flat	Row
April 3-12	71.8	74.5	54.5	53.4	63.2	64.0
April 13-22	75.6	78.8	57.7	56.8	66.7	67.8
April 23-May 2	70.5	71.8	56.5	55.0	63.5	63.4
May 3-12	83.1	85.8	62.6	61.7	72.9	73.8
Average	75.3	77.6	57.8	56.7	66.6	67.2

area, the bedded field is more exposed to sunlight in the daytime and radiates more heat at night.

When the sun shines directly on a surface, reflection is at a minimum. In a bedded field, part of the bed surface is at right angles to the sun most of the time. This increases the amount of heat absorbed by the surface and transmitted to the seed and root level. Also, wind hits a larger area and evaporation is greater in the bedded field, thus the soil dries faster. All this adds up to higher daytime temperatures and lower nighttime temperatures in the row than on the flat.

Table 1 summarizes 2-inch soil temperature observations at the West Tennessee Experiment Station, Jackson, Tennessee during the planting season. In the row, the maximum is higher than in flat ground. The reverse is true for the minimum. The average between the maximum and minimum shows that the row is slightly warmer, about one degree.

Although the average temperature in the row is slightly higher than in the flat bed, we must look at another measure to evaluate the temperature difference and its effect on seed germination. Little growth is made below 65° F, and so if we compare the difference in temperatures above this level, we will have a more practical measure of temperatures that affect growth.

The degree hour is sometimes used in such measurements. What is it? If the temperature at 9 a.m. is 66 degrees, we have one degree hour. If it is 67 degrees at 10 a.m., we have two degree hours. By adding the 9 a.m. and the 10 a.m. readings we have three degree hours. To calculate the total number of degree hours for a period, multiply the number of hours that the temperature was above 65 degrees by the number of degrees.

Table 4 shows the degree hour totals for the same periods shown is Table 3. During each 10-day period, the total shows more degree hours in the bed than in the flat. The April 23 — May 2 period was cool and rainy and the degree hour total was small. Even so, the percentage differences in the last column show a steady decrease as the season advances. Thus, we can assume that bedding accumulates more degree hours around planting time than later in the season. The reasons for this is — minimum temperatures are warmer in the flat than in the bed. When minimum temperatures stop dropping below the 65-degree level,

Table 4.—Degree hour totals of 2-in soil temperatures in the row and on the flat at the West Tennessee Experiment Station, Jackson, Tennessee, April 3-May 12, 1963.

	Degree Hour		Percent
Date	Flat	Bed	Difference
April 3-12	64.8	83.8	22%
April 13-22	103.6	126.3	18%
April 23-May 2	59.4	67.5	12%
May 3-12	209.8	226.8	8%
Total	437.6	503.9	13%

differences in degree hour totals between the two types of planting areas become smaller.

The usual planting procedure calls for knocking off the top of the bed at planting time. This introduces still another source of soil temperature variation. When the top 6 inches of the bed are knocked off, the newly created 2-inch level has the 8-inch level soil temperature. In April the 8-inch level averages two to four degrees lower than the 2-inch level. In the field, however, this is not a large problem as the new 2-inch level assumes the temperature of its new environment within 24 to 48 hours.

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Copies may be obtained from the Weather Bureau Office, 2488 Winchester Road, Memphis, Tenn., or from the state sources listed above.