Heat Unit System for Predicting Optimum Peanut-Harvesting Time

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THE logical time to dig a peanut crop is when the maximum weight of saleable nuts is available on the plants. Digging too early will result in a reduced yield due to a large number of the pods being immature. Immature pods lose about one-half of their weight during the curing process. Digging too late, however, can be just as serious; as the yield is reduced due to field losses of the overmature pods. From the yield curve shown in Fig. 1, it can be seen that the digging time for maximum yields extends over a relatively short period. Digging a week too early (157 days) resulted in a yield reduction of approximately 300 lb per acre while digging a week too late (178 days) resulted in a yield reduction of approximately 500 lb per acre.

The need for a simple, objective method for determining the optimum digging time has been recognized for many years, but research efforts have not as yet produced such a method. Shibuya (7)* describes many factors that influence the fruiting process, but makes no attempt to relate these factors to a correct time to dig. Pickett (4) bordered on the problem while describing the composition of developing peanut seed. Shear and Miller (5, 6) have investigated the effect of planting and digging time on shelling percentage, extra large nuts, etc. A method for predicting maturity of corn has been described by Gilmore and Rogers (1) based on daily air-temperature measurements. Thornthwaite (8) and Katz (2) describe similar methods for determining when to plant and harvest green canning peas.

Studies were begun by the author in 1958 to collect pertinent information that might be used to develop a method for determining the correct time to dig peanuts.

Materials and General Methods of Experiment

Data were collected during the months of September and October, 1958, 1959, and 1960 from plots located at the Central Crops Research Station, Clayton, N.C. Seed of the N.C. 2 variety were used. Plots consisted of ten or more rows, 20 ft long, spaced 36 in. apart. Single plants were spaced 12 in. apart in the rows. The seed were planted by hand the last of April as soon as frost danger had passed. Cultivating, fertilizing and dusting were handled by the same equipment and at the same time as for the peanut crop in the remainder of the field. The field was in a three-year rotation of peanuts-tobacco-corn.

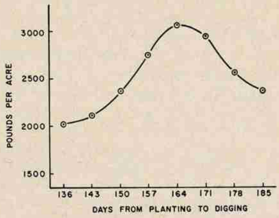

FIG. 1 Average yield in pounds per acre at 10 percent moisture content (N.C. 2 variety grown at Clayton, N.C., 1959-60).

Twenty-four plants were dug weekly from the first week in September until the last week in October. Four plants from each of six plots were selected. Plants on either side of a removed plant were skipped in later selections as the pods on these plants were disturbed when the earlier plant was removed. Diseased plants and border plants were also skipped in the sample selection.

Each plant was removed by loosening the soil with shovels. All pods were removed from the plant and soil and deposited in paper bags. In 1958 a sample of soil was collected from several plant locations to determine soil moisture content. The 24 bags of pods were taken into the laboratory as soon as the field collections were completed.

Each pod was shelled and classified according to the following specifications:

Class 0 Insect or disease damaged.

Class 1 Kernels not fully developed. Inside of hulls fleshy. (Very immature)

Class 2 Kernel fully developed with thick white skin. Inside of hull white or light brown. (Immature)

Class 3 Kernel fully developed with thin, pink skin and inside of hull dark brown, or black. (Mature)

Class 4 Kernel fully developed with thin *brown* skin and inside of hull black. (Overmature)

In 1958 all insect and disease-damaged nuts were placed in Class 4. The use of Class 0 was begun in 1959.

After classifying the pods, the kernels and shells from each plant were placed in a separate container to facilitate moisture content determinations. In 1959 and 1960, the nuts were further divided according to class number so that more information could be gained about moisture content and total dry weight of the nuts in each class.

Moisture was removed from the kernels and shells in a forced-draft, hot-air oven operated 48 hours at 160 F.

All results given in this paper are the average values from the 24 plants collected at each weekly sampling period. Moisture content values were computed on the wet basis. When referring to the whole peanut, *i.e.*, the kernel and the shell, the word "pod" has been used.

Results

The method described by Gilmore and Rogers (1) used daily maximum and minimum temperatures with corrections to compute the number of effective heat units for corn seed to germinate and grow to the stage of silking. The corrections were for temperatures below the lower cardinal temperature and for temperatures above the optimum cardinal temperature. From the description given by Gilmore and Rogers (1), the author set up the following equation for computing the effective heat units occurring daily:

$$\text{Effective heat units} = \frac{T_{max} + T_{1c} + \Delta T_{1c}}{2} - T_{1c} - \Delta T_{oc}$$

Where T_{max} = maximum daily air temperature (deg F)

T_{1c} = lower cardinal temperature

ΔT_{1c} = correction for temperatures below the lower cardinal point and equal to only the positive values of $T_{min} - T_{1c}$

T_{min} = minimum daily air temperature

ΔT_{oc} = correction for temperatures above the optimum cardinal point and equal to only the positive values of $T_{max} - T_{oc}$

T_{oc} = optimum cardinal temperature

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* Numbers in parentheses refer to the appended references.

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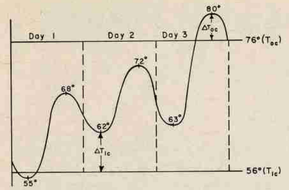

FIG. 2 Daily maximum and minimum temperature curve for three days in May, 1958.

This equation is based on the following assumptions:

1 That all daily minimum temperatures below the lower cardinal point should be considered as being the lower cardinal temperature in computing the daily mean, because no perceptible growth takes place below this temperature.

2 That temperature units below the lower cardinal temperature do not contribute to plant growth and should therefore be subtracted from the daily mean if the results are to be *effective* heat units.

3 That temperatures over the optimum cardinal point cause plant growth to decrease or stop and therefore must be corrected for by subtracting from the daily mean ΔT_{oc}

4 That use of maximum and minimum daily temperatures, rather than other more precise measurements, such as computing the area under the temperature curve, would make the method more readily usable since the growers could measure the maximum and minimum temperatures or secure them from the nearest weather station.

The terms ΔT_{1c} and ΔT_{oc} are defined as being the positive value of $T_{min} - T_{1c}$ and $T_{max} - T_{oc}$, respectively. This restriction is simply the mathematical procedure to accomplish assumptions 1 and 3 above. For example, compute the effective heat units for three days in May, 1958, assuming $T_{1c} = 56$ F and $T_{oc} = 76$ F. The daily maximum and minimum temperatures are as follows:

Day 1: $T_{max} = 68$ F
$T_{min} = 55$ F

Day 2: $T_{max} = 72$ F
$T_{min} = 62$ F

Day 3: $T_{max} = 80$ F
$T_{min} = 63$ F

Fig. 2 shows the relationship of these temperatures to the lower and optimum cardinal temperatures.

Effective heat units (*EHU*) for the first day are computed as follows: Since T_{min} is 55 F and below T_{1c} the term $T_{min} - T_{1c}$ gives a negative value and by definition ΔT_{1c} goes to zero. Therefore, the first part of the equation which is simply the computation of the daily mean becomes

$$\frac{T_{max} + T_{1c} + \Delta T_{1c}}{2} = \frac{68 + 56 + 0}{2} = 62$$

The maximum reading of 68 F is below the T_{oc} so the term $T_{max} - T_{oc}$ will likewise be negative and ΔT_{oc} will by definition go to zero. The effective heat units for day 1 are then:

$$EHU_1 = \frac{T_{max} + T_{1c} + \Delta T_{1c}}{2} - T_{1c} - \Delta T_{oc}$$

$$= \frac{68+56+|55-56|-56-|68-76|}{2}$$

$$= \frac{68 + 56 + 0}{2} - 56 - 0$$

$$= 62 - 56 = 6\text{ehu}$$

For Day 2, the computations are:

$$EHU_2 = \frac{72+56+|62-56|-56-|72-76|}{2}$$

$$= \frac{72 + 56 + 6}{2} - 56 - 0$$

$$= 11 \text{ ehu}$$

For Day 3, the computations are:

$$EHU_3 = \frac{80+56+|63-56|-56-|80-76|}{2}$$

$$= \frac{80 + 56 + 7}{2} - 56 - 4$$

$$= 11.5 \text{ ehu}$$

It should be noted that proper correction for minimum temperatures above the optimum cardinal point has not been provided for in this equation.

In order to check this method on the three years of data collected, it was necessary to establish the lower cardinal temperature (T_{1c}) and the optimum cardinal temperature (T_{oc}) for peanuts. The literature revealed some very good work by Lehenbauer (3) on corn, but very little on other crops and none on peanuts. The author set up an experiment in the laboratory to gain some information on the lower and optimum cardinal points for peanut

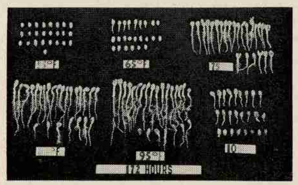

FIG. 3 Peanut seed germination and growth response to 172 hours of constant temperatures of 55, 65, 75, 85, 95 and 105 F.

FIG. 4 Germination and plant growth after 168 hr of constant temperatures of 70, 75, 80, 85, 90, 95 and 100 F.

plant growth. Twenty-five seeds, treated with Arasan 75 fungicidal, were placed near the top of a moist paper towel which was then rolled up and the lower end immersed in a beaker of water. Two replications of 25 seeds each were placed in each of six temperature controlled chambers set at 55, 65, 75, 85, 95, and 105 F. The stage of germination and growth of the treatments after 172 hr is shown in Fig. 3.

Close inspection of the 55 F treatment did not reveal any perceptible germination. The 65 F treatment, however, showed about one-third of the seed germinated at the end of the 172-hr period. From this evidence it was concluded that the lower cardinal temperature for peanut seed was between 55 and 65 F, fully recognizing that this experiment did not approximate the actual field environment of alternating air and soil temperatures. It was considered, however, a suitable guide for this study.

Very little conclusive evidence could be gained from this experiment concerning the optimum cardinal temperature. Optimum temperatures according to Lehenbauer (3) are meaningless unless a time period be specified. The treatment at 105 F was definitely beyond the maximum cardinal temperature. Very little, if any, growth occurred after 100 hr.

Laboratory facilities did not permit carrying the experiment beyond 172 hr and therefore prevented further observations on the lower temperature treatments.

A second experiment similar to the first, but with seven temperature treatments of 70, 75, 80, 85, 90, 95, and 100 F, was conducted for a period of 168 hr and the results shown in Fig. 4. Several interesting observations were made from this experiment. A big response can be seen between the 75 and 80 treatments with gradually increasing response above 80 F.

A similar response pattern occurs in Fig. 5, which shows the average 12-hr root growth for each temperature treatment; in Fig. 6 which shows the total weight of roots for each treatment after 168 hr, and Fig. 7, which shows the total weight of tops for each treatment after 168 hr. For 168 hr 100 F produces maximum growth, but observations at the end of the experiment in-

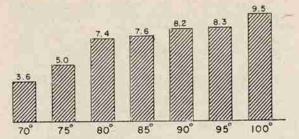

FIG. 5 Average 12-hour root growth in millimeters.

dicated that root growth was decreasing rapidly. When water is a limiting factor, maximum growth takes place at night during lower temperatures; so one would expect the optimum cardinal temperature for peanut plants grown over a five-month period, with the many variables involved, to be nearer the lower end of the 80 to 100 F range. Once again it must be recognized that these are constant temperatures and will only serve as a guide in determining the actual optimum cardinal point under field conditions.

With this background, the number of accumulated EHU were computed for the following periods:

1958 – April 21 (planting date) to October 4 (optimum digging date)

1959 – May 1 (planting date) to October 10 (optimum digging date)

1960 – April 20 (planting date) to September 30 (optimum digging date)

An IBM 650 computer was programmed, using the germination test data to set the temperature limitations. The computer calculated and/or printed the following:

1 T_{1c}
2 T_{oc}
3 Total EHU for the 1958 period
4 Total EHU for the 1959 period
5 Total EHU for the 1960 period
6 Mean of 3, 4, and 5 above
7 Variance of 3, 4, and 5 above
8 Coefficient of variation (CV) for 3, 4, and 5 above

Theoretically, if all assumptions were valid, the total EHU for each year should be the same. Therefore, the combination of T_{1c} and T_{oc} that resulted in the lowest CV was assumed to be the best estimate for future test. Table 1 shows the CVs for values of T_{1c} between 50 and 60 F and for T_{oc} between 70 and 80 F. Six combinations gave identically low CV values of 1 percent as shown in Table 2.

From the group in Table 1 the combination of 56 (T_{1c}) and 76 (T_{oc}) seem

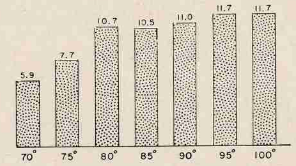

FIG. 6 Total weight of roots in grams after 168 hours.

TABLE 1. COEFFICIENT OF VARIATION AMONG 1958, 1959, 1960, ACCUMULATED EFFECTIVE HEAT UNITS

Lower cardinal temperature (T_{1c})	Optimum Cardinal Temperature (T_{oc})										
	70	71	72	73	74	75	76	77	78	79	80 F
50	1.9					1.4					1.9
51						1.3					1.9
52						1.2					1.9
53						1.2					1.9
54	2.5	2.0	1.7	1.3	1.2	1.1	1.1	1.2	1.4	1.6	1.8
55	3.1	2.5	2.0	1.5	1.2	1.1	1.0	1.1	1.3	1.6	1.8
56	4.1	3.1	2.4	1.8	1.4	1.1	1.0	1.0	1.2	1.5	1.7
57						1.2	1.0	1.0	1.2	1.5	1.7
58						1.4	1.2	1.0	1.2	1.5	1.7
59						1.8	1.4	1.2	1.3	1.6	1.9
60	44.8					2.3					2.1

TABLE 2. EFFECTIVE HEAT UNITS FOR SIX BEST COMBINATIONS OF T_{1c} AND T_{oc}

T_{1c}	T_{oc}	1958 EHU	1959 EHU	1960 EHU	3-year mean	CV, percent
55	76	1769	1743	1734	1749	1
56	76	1614	1588	1586	1596	1
56	77	1758	1740	1722	1740	1
57	76	1460	1434	1437	1444	1
57	77	1604	1586	1573	1588	1
58	77	1454	1434	1426	1438	1

TABLE 3. AVERAGE DAILY NUMBER OF EFFECTIVE HEAT UNITS WITH MONTHLY ACCUMULATED TOTALS AT CLAYTON, N.C., USING A 56 F LOWER AND A 76 F OPTIMUM CARDINAL TEMPERATURES

Months	Monthly Totals				Daily average
	1958	1959	1960	Average	
April	195	234	215	214.8	7.2
May	289	276	238	266.0	8.6
June	286	266	298	283.2	9.4
July	354	326	327	335.7	10.8
August	318	309	354	326.8	10.5
September	252	306	300	286.0	9.5
October	209	242	234	228.2	7.4
Total	1903	1959	1961		

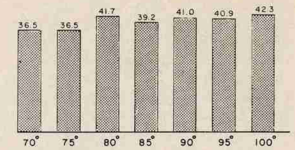

FIG. 7 Total weight of tops in grams after 168 hours.

to be surrounded with the lowest values. The three-year mean for this combination indicates that approximately 1600 effective heat units are required for a Virginia Bunch peanut of the N.C. 2 variety to develop seed at the optimum stage of harvesting. For similar soils in the peanut-growing belts, it is hypothesized that this relationship will hold true for this variety. Other varieties will undoubtedly require different numbers of effective heat units. In the future it may be desirable to refer to varieties as the 1600 variety or the 1450 variety. For temperature records taken at the Central Crops Research Station, at Clayton, N.C., for the past three years, the average number of effective heat units that could be expected per day for the months of April through October were computed as shown in Table 3.

The accumulated total for May through September amounts to about 1500 effective heat units, leaving 100 additional units to be supplied either in April or October. Since frost danger continues into the latter part of April, the popular planting date is the first two weeks of May. The digging activity under normal seasons should then begin the middle to the last of October. Killing frosts have been recorded as early as October 26.

Since samples to detect the optimum time to dig were collected only once a week, the accuracy of the prediction (1600 EHU) is limited to ±3½ days,

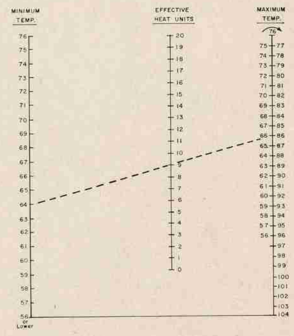

FIG. 8 Nomograph for determining effective heat units directly from daily maximum and minimum temperatures.

which would be ±26 EHU using the average daily number for October. By collecting samples daily the prediction could be made accurate to the day.

A nomograph for determining the number of daily effective heat units directly from the maximum and minimum temperatures has been prepared as shown in Fig. 8. For example, to determine the effective heat units for a day with a maximum reading of 66 F and a minimum reading of 64 F, place a straight edge connecting these points, as indicated by the dotted line, and read 9 EHU on the middle scale. Note that a day with a maximum of 86 F and a minimum of 64 F would also result in 9 EHU. For all minimum temperatures below 56 F, the 56 F point on the left-hand scale should be used.

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