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RESPONSE OF SWEET CORN TO VARYING TEMPERATURES FROM TIME OF PLANTING.
MAGOON, C.A. ; CULPEPPER, C.W.   1 OF 1

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RESPONSE OF SWEET CORN TO VARYING TEMPERATURES FROM TIME OF PLANTING TO CANNING MATURITY

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INTRODUCTION

In an earlier paper (*13*) [1] on the relation of seasonal conditions to quality in sweet corn, attention was drawn to the fact that the length of time required for Golden Bantam and Stowell Evergreen varieties to reach canning maturity at the Arlington Experiment Farm, Rosslyn, Va., near Washington, D. C., varied with the date of planting, those plantings made between June 7 and July 28, 1924, having matured in a fairly uniform period of time, whereas those made earlier than June 7 or later than July 28 required progressively longer periods to reach canning maturity as the times of planting were farther and farther removed from these dates. These results suggested to the writers that any particular variety or strain of corn might have a definite quantitative temperature requirement, and that a study of these temperature relations might yield results of value to growers, breeders, and canners of sweet corn.

The question is often raised as to how early or how late sweet corn may be planted with safety in a particular region, and sometimes as to whether corn may be grown at all. Furthermore, the adaptation of strains to the needs of a particular climate and other considerations make it desirable to know as much as possible about the temperature relations of this crop. With this in mind, an analysis was made of the climatological and field data assembled during the progress of experimental work prior to 1927, which proved of such interest that a new series of plantings was made during the season of 1927 to check on previous findings and to provide more carefully collected temperature data.

[1] Italic numbers in parentheses refer to Literature Cited, p. 39.

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SOURCES OF DATA

Climatic, field, and analytical data on sweet corn grown at the Arlington Experiment Farm were available for the season of 1922, when 15 different varieties were studied; for 1924, when Golden Bantam and Stowell Evergreen were grown; for 1925, when representatives of the various types, nine in all, were studied; and for 1927, when Golden Bantam and Stowell Evergreen were again grown.

The temperature data for 1922, 1924, and 1925 were taken from the official reports of the United States Weather Bureau at Washington, D. C., the observatory of which was located approximately 1 mile from the experiment plots. During the season of 1927, in addition to the official Weather Bureau data, thermograph records of both air and soil temperatures were kept at a station located in the midst of the corn.

In addition, two sets of data were available from the sweet-corn section of Maine, one for the season of 1925 and the other for that of 1926 from the region adjacent to Auburn. Field data were supplied in part by George Bradley, superintendent of a commercial canning plant at Auburn, and in part were collected in the field by the senior writer. Temperature records were secured at the gatehouse of a water-power plant at Lewiston, just across the Androscoggin River from Auburn.

Samples for chemical analysis and field data from Ames, Iowa, for the seasons of 1925 and 1926 were supplied through the courtesy of A. T. Erwin, of the Iowa Agricultural Experiment Station, and temperature records were secured from the official reports.

Material for this study was likewise supplied through the courtesy of A. H. Olin from field records and temperature readings taken in the neighborhood of a commercial plant at Mount Morris, N. Y., about 36 miles south of Rochester.

THE TEMPERATURE BASE LINE

In attempting to determine the temperature requirements of a crop it is necessary first of all to establish the proper minimum-temperature base line from which temperature values may be calculated. It has been the custom among most students of the temperature relations of plants to use 40° F. (4.44° C.) as the base line, it being considered that below this point physiological processes are practically at a standstill. While this temperature may serve fairly satisfactorily as a base line in the general study of plant geography as affected by climate (*9*, *10*), it seems reasonable to question whether it can be used properly in studying the temperature relations of specific crops, except in those cases where 40° is known to be close to the minimum temperature for the crop under consideration. Peas, for instance, may usually be planted as early in the spring as the ground can be worked, and they succeed best where relatively cool temperatures prevail during the growing season. Corn, on the other hand, can not be planted profitably until the ground is well warmed by the sun, and it succeeds under hot, moist conditions. The differences in the response of these two crops to environmental conditions seem to be due primarily to differences in the level and range of effective temperatures. Obviously, therefore, the base line to be used in the study of temperature relations of corn should not be the same as that used in the study of peas or other crops having a different temperature minimum.

Lehenbauer (*8*), in the report of his studies on corn seedlings held at constant temperatures, indicated the minimum temperature of corn to be near 12° to 14° C. (53.6° to 57.2° F.). More recently Erwin (*5*) recorded the observation that, other conditions being favorable, sweet-corn seed sprouts promptly when the soil temperature is about 55° F. (12.78° C.), and he made use of this temperature as the base line for effective-temperature summations in his work on pumpkins.

In the present study it was decided to work from different temperature base lines in order to see what summations from these various levels would reveal. The method followed was similar to that used by MacDougal (*12*), the total heat exposures above the various base lines being calculated not from the daily means but from the hourly temperature readings and summated as degree-hours. In brief, the plan here followed consisted in growing the corn under widely varying conditions of temperature, which was made possible by planting at intervals throughout the season in the same field from the same lot of seed. The temperatures above various base lines were then summated as degrees-Fahrenheit hours. The base lines chosen were 40°, 45°, 50°, 55°, and 60° F. That base line whose summations showed the smallest standard deviation from the mean was considered to be the best starting point for studies on the response of the corn to different temperatures. The Fahrenheit scale was used because official Weather Bureau temperatures are presented as Fahrenheit values and field records are usually expressed in the same way.

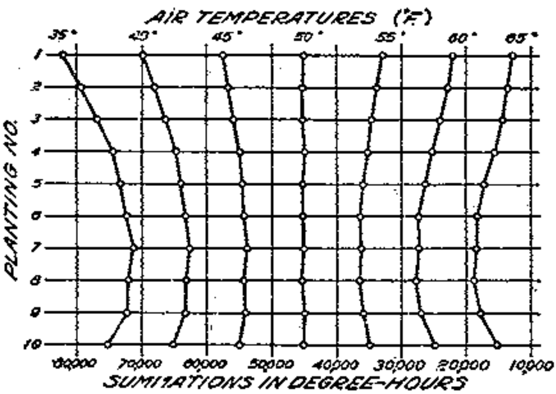

FIGURE 1.—Theoretical air-temperature summations in degree-hours above various base lines for Golden Bantam sweet corn planted at intervals of 10 days at the Arlington Experiment Farm, Rosslyn, Va., beginning April 15 of a normal year. The data are based on the normal mean temperatures for this station, and a summation of 45,000 degree-hours above a proper temperature base line is arbitrarily assumed to be a true summation for the corn used

The principle here involved is made clear by the following hypothetical case. It is assumed that a series of plantings was made at 10-day intervals throughout the season, beginning on April 15 of a year whose daily mean temperature corresponded to the 50-year average for Washington, D. C. The dates of the various plantings are assumed to be as given in Table 1. These dates of canning maturity for the various plantings in the present case were determined by assuming that 50° F. was the proper base line and 45,000 degree-hours was the temperature requirement to bring the corn to canning maturity. The results are presented in Table 1 and illustrated in Figure 1.

TABLE 1.—*Theoretical air-temperature summations for Golden Bantam sweet corn planted at assumed intervals of 10 days, beginning April 15 of a normal year, at the Arlington Experiment Farm, Rosslyn, Va.*

[Based on data of the normal mean temperature for this station. A summation of 45,000 degree-hours above an appropriate base line is arbitrarily assumed to be a true summation for the corn used]

Date of planting	Date of canning maturity	Degree-hours above base line of—						
		35° F.	40° F.	45° F.	50° F.	55° F.	60° F.	65° F.
Apr. 15	July 26	82,104	69,744	57,384	45,021	32,784	21,912	12,936
Apr. 25	July 28	79,308	67,968	56,568	45,168	33,768	22,920	13,512
May 5	July 31	76,800	66,240	55,680	45,120	34,560	24,030	14,376
May 15	Aug. 4	74,448	64,608	54,768	44,928	35,088	25,248	15,528
May 25	Aug. 10	73,248	63,888	54,528	45,168	35,808	26,448	17,088
June 4	Aug. 17	72,216	63,216	54,216	45,216	36,216	27,216	18,216
June 14	Aug. 25	71,232	62,472	53,712	44,962	36,082	27,202	18,322
June 24	Sept. 5	71,976	63,096	54,216	45,336	36,456	27,576	18,696
July 4	Sept. 18	72,238	63,168	54,048	44,928	35,808	26,788	17,668
July 14	Oct. 5	75,192	65,112	55,032	44,952	34,872	24,792	16,096
Mean summation		74,887	64,951	55,015	45,080	35,144	25,410	16,144
Standard deviation		3,567	2,375	1,186	141	1,179	1,971	2,123

It will be noted that the summations above the 50° F. base line have a standard deviation from the mean of only 141 degree-hours, which is less than that of any other base line. An examination of the curves in Figure 1 shows that for the 50° base line the curve is practically a straight line, whereas the summations for base lines both above and below 50° yield curves that deviate more and more from a straight line as higher or lower base lines are used.

It is apparent that this method for determining the proper base line is reliable where temperature alone is the factor involved. In reality the response that sweet corn shows to varying conditions is not quite so simple as this; but that the principle is sound for the study of actual experimental findings will be evident from the data to be presented.

METEOROLOGICAL DATA FOR 1924 AND 1927

In order to facilitate the correlation of seasonal factors with the temperature requirements of the corn, as indicated by the experimental results about to be considered, certain meteorological data for 1924 and 1927 are presented in Figures 2 and 3. Figure 2 is based on the records of the United States Weather Bureau at Washington for the growing season of 1924, and Figure 3 is based on temperature and rainfall records for the season of 1927 made in the cornfield at the Arlington Experiment Farm. Sunshine and day-length data were taken from the official Weather Bureau report for Washington covering the same period.

The season of 1924 was especially favorable for observing the effect of seasonal conditions on the behavior of sweet corn, as already recorded (*13*). During the latter half of April and the first part of May the temperatures were about normal for this region. The remainder of May and the first half of June, however, were abnormally cool, the maximum temperature often falling below the normal mean for the period. From the middle of June to the first of September the temperature did not vary greatly from normal. September was abnormally cool, and October showed the usual fluctuations. The

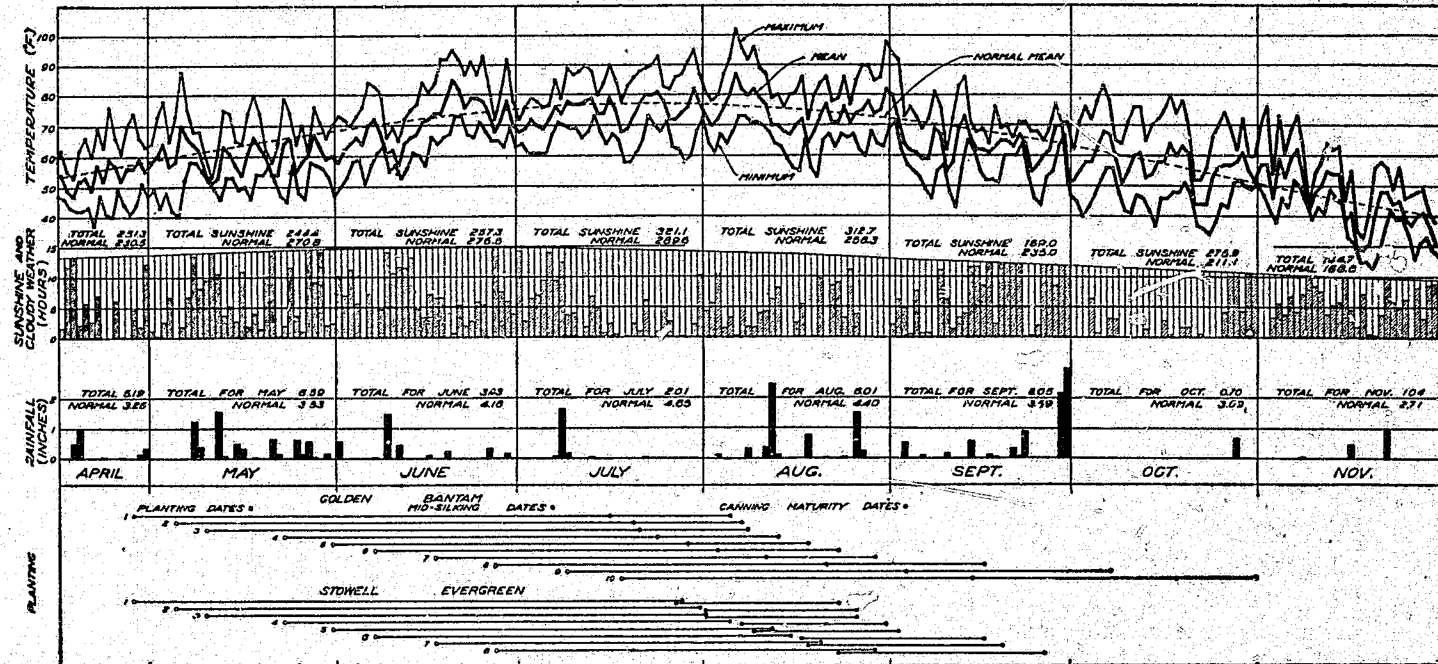

FIGURE 2.—Meteorological data for the season of 1924 at the Arlington Experiment Farm, Rosslyn, Va., and their relation to sweet-corn plantings. (See footnote to Table 5 for explanation of overlapping dates in the case of Stowell Evergreen)

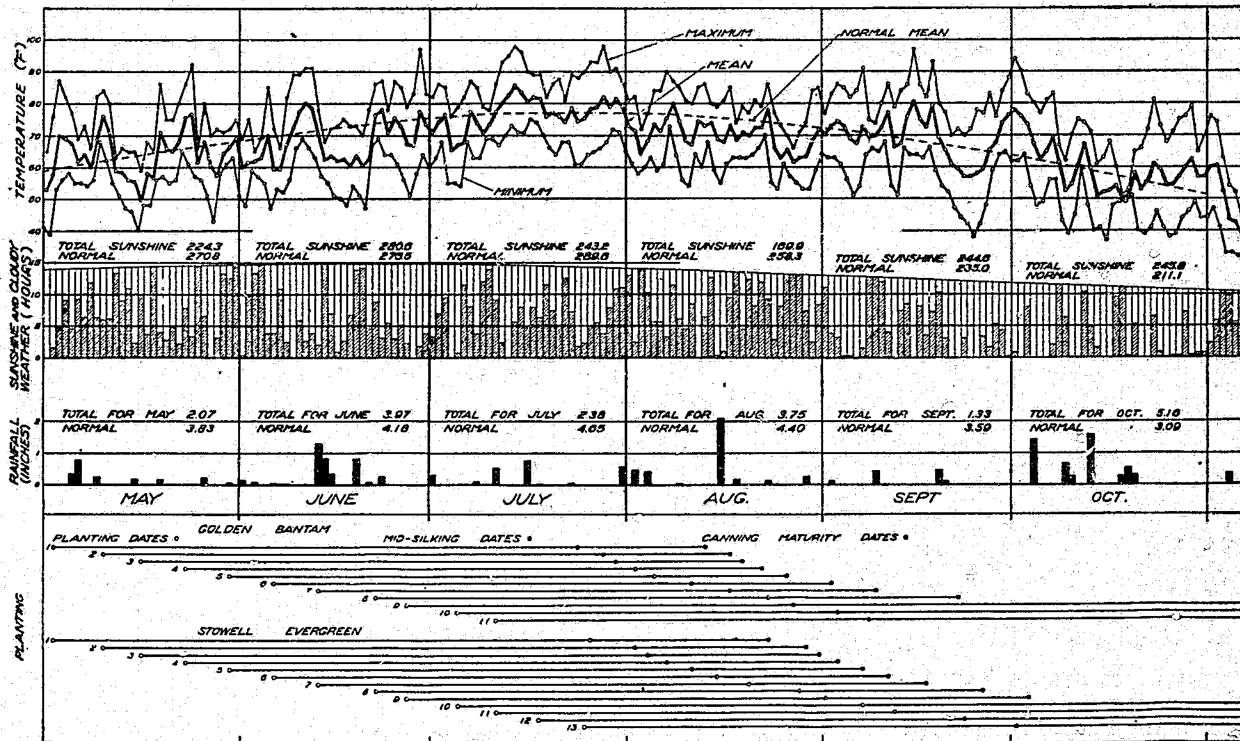

FIGURE 3.—Meteorological data for the season of 1927 at the Arlington Experiment Farm, Rosslyn, Va., and their relation to sweet-corn plantings

rainfall for this period is of particular interest. May was abnormally wet. The rainfall for June was a little below normal but was fairly well distributed. July, with the exception of one abundant rain about the 8th of the month, was practically rainless, and the drought continued well into August. From about the 12th of this month to the end of the active growing season the rainfall was abundant and well distributed. The effect of these conditions, particularly of the rainfall, was very sharply defined in the vegetative response of the corn, as was set forth in some detail in the paper already cited (*13*), and its influence on the temperature-summation data of Stowell Evergreen corn will be seen. (P. 16.)

The season of 1927 was an excellent "corn season." While during the latter part of June and the first week of July the temperature for the most part was somewhat below the 50-year average curve for this period, and the same was true for most of August, this was not sufficient to interfere seriously with the development of the corn. With respect to the rainfall the totals for the various months were somewhat short of normal, but the rain was well distributed, and at no time during the season did the corn suffer for lack of moisture.

RESULTS WITH GOLDEN BANTAM IN 1924

The data of Table 2 show the temperature summations in degree-hours above the base lines 40°, 45°, 50°, 55°, and 60° F. for 10 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during the season of 1924. These summations are based on recorded air temperatures, and two sets of data are given, one for the period from planting to canning maturity and the other from date of planting to the mid-silking date. The former period is given first consideration because it is believed to represent more accurate data. The tagging of ears during the silking period, necessary for their later identification when sampling is done for chemical analysis and canning experiments, often results in the marking of incipient ears that never mature, which in some cases are sufficient in number to affect appreciably the determination of the true mean silking date for a particular plot. These data are included here, however, because they show differences and indicate factors operative in the behavior of corn that need consideration in any physiological study of this crop.

Considering now the data for the periods from planting to canning maturity, it is to be noted that the lengths of these periods varied from 73 days for the seventh planting to 99 days for the first, and 105 days for the tenth planting.

TABLE 2.—*Air-temperature summations for Golden Bantam sweet corn grown at the Arlington Experiment Farm, 1924*

Planting No.	Date of planting	Mid-silking date	Canning maturity date	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	Apr. 28	July 16	Aug. 5	68,228	56,182	44,598	33,254	23,052	51,234	41,622	32,429	23,503	15,890
2	May 5	July 20	Aug. 7	67,240	55,797	44,719	33,815	23,830	51,156	41,857	32,940	24,213	16,386
3	May 10	July 21	Aug. 8	65,279	54,322	43,685	33,210	23,607	49,133	40,320	31,844	23,546	16,101
4	May 23	July 24	Aug. 13	63,961	53,964	44,170	34,332	24,833	46,409	38,796	31,401	23,982	16,881
5	May 31	July 29	Aug. 18	63,241	53,634	44,085	34,536	25,183	46,450	39,207	32,067	24,949	17,948
6	June 7	Aug. 3	Aug. 23	63,127	53,749	44,492	35,067	25,776	46,690	39,687	32,769	25,832	18,864
7	June 17	Aug. 11	Aug. 29	61,801	52,711	44,[illegible]	35,177	26,366	48,125	41,388	34,707	27,978	21,260
8	June 27	Aug. 21	Sept. 16	64,131	54,301	44,649	34,865	25,591	46,168	39,471	32,792	26,044	19,411
9	July 9	Sept. 3	Oct. 7	66,033	55,148	44,568	34,105	24,557	47,871	41,051	34,268	27,340	20,600
10	July 18	Sept. 14	Oct. 31	67,191	54,779	43,839	31,876	22,224	46,147	39,080	32,118	25,105	18,467
Mean summation				65,023	54,459	44,244	34,024	24,502	47,941	40,248	32,734	25,249	18,180
Standard deviation				2,202	1,047	454	1,022	1,308	1,981	1,149	1,042	1,546	1,881

It is seen in the 40° F. column (planting to canning maturity) that the summations from the first to the seventh plantings gradually decrease and then progressively increase for the later plantings. In the 45° column the same tendency is shown, but the differences are not so marked, whereas in the 50° column there is a striking agreement in the number of degree-hours required for all plantings. Continuing to the 55° column, it is seen that differences again appear but in the reverse order from those in the 40° and 45° columns, whereas in the 60° column the differences are more marked than in the 55° column. These results may be grasped a little more readily, perhaps, from curves based on these figures as presented in Figure 4.

Figure 4 shows that although the planting dates ranged from April 28 to July 18, and the corresponding range of dates when the corn came to canning maturity was from August 5 to October 31, all plantings used practically the same amount of heat above 50° F., the average for the 10 plantings being 44,244 degree-hours, with a standard deviation of only 454 degree-hours from this average. It would ap-

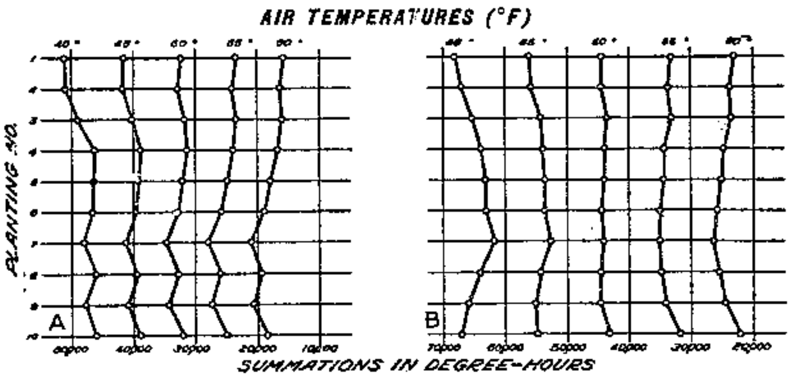

FIGURE 4.—Curves of air-temperature summations in degree-hours above various base lines for the periods, (A) from planting to mid-silking and (B) from planting to canning maturity, for 10 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during the season of 1924

pear from this that 50° air temperature for the Golden Bantam corn grown at the Arlington Experiment Farm during 1924 was the proper minimum-temperature base line from which to calculate effective temperature summations. It is to be noted that these practical findings agree in striking manner with the theoretical data presented in Table 1 and illustrated in Figure 1.

Turning now to the data and curves for the period from planting to mid-silking, two features deserve notice; one, the irregularity of the results, and the other, the indication that a different minimum-temperature base line should be used in the summations for this period. That irregularities may be expected in data for this period has already been mentioned. It seems evident that, as will be shown later, drought may have influenced these results, for moisture conditions for some of these plantings were very severe. The point worthy of particular note is the fact that 45° F. instead of 50° seems to be the proper base line to be applied in summations for these periods. The average summation of temperature above the base line of 45° is 40,248 degree-hours, with a standard deviation of 1,149 degree-hours.

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It would appear that the response of the corn to environmental temperature conditions for the period from mid-silking to canning maturity differed from that for the period from planting to mid-silking. How much of this difference is due to error of the method can not be stated, but that this is not an isolated case will be indicated by the figures for another year as well as for another variety of corn.

RESULTS WITH GOLDEN BANTAM IN 1927

AIR-TEMPERATURE SUMMATIONS

Before presenting the data on Golden Bantam for 1927 it should be explained that during the season some of the plantings of this variety particularly suffered very heavily in the field from injury to the ears by blackbirds and ear worms. This injury interfered not only with the collection of adequate samples in those cases but also with the accurate determination of the dates when the plots as entities came to canning maturity. The data for the period from planting to canning maturity may therefore be subject to some error, and the

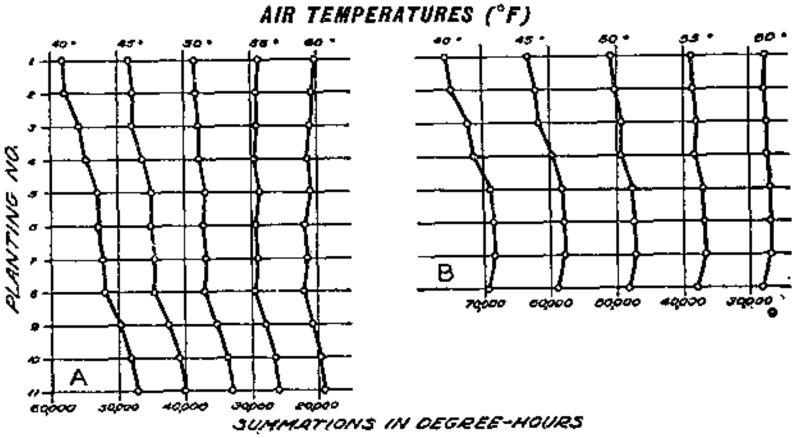

FIGURE 5.—Curves of air-temperature summations in degree-hours above various base lines for 11 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for 8 plantings of the same series for the period from planting to canning maturity. The last three plantings of this series did not reach canning maturity

reader is cautioned against placing too much reliance on this part of the data. On the other hand, records for the period from planting to mid-silking are as accurate as it was possible to make them. The data are presented in Table 3 and Figure 5.

Considering first the figures for the period from planting to canning maturity, it is noted that the planting dates ranged from May 2 to July 11 and that the length of time from planting to canning maturity varied from a known period of 103 days in the first to a close estimate of 88 days in the fifth, sixth, and seventh plantings. Here similar tendencies with respect to variation in the summations are shown, as in the data for 1924, with the difference that 60° F. instead of 50° is indicated as the proper minimum-temperature base line for the period from planting to canning maturity. The average degree-hour summation above 60° for the first eight plantings is 27,413, with a standard deviation of only 437 degree-hours,

TABLE 3.—*Air-temperature summations for Golden Bantam sweet corn grown at the Arlington Experiment Farm, 1927*

Planting No.	Date of planting	Mid-silking date	Canning maturity date	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	May 2	July 24	Aug. 13	75, 694	63, 264	50, 890	38, 808	27, 735	58, 179	48, 269	38, 415	28, 852	20, 255
2	May 10	July 28	Aug. 17	74, 765	62, 123	50, 199	38, 550	27, 723	57, 775	47, 653	38, 249	29, 119	20, 747
3	May 16	July 30	Aug. 19	72, 259	61, 651	49, 308	38, 053	27, 467	55, 858	47, 770	37, 947	29, 211	21, 080
4	May 23	Aug. 2	Aug. 22	71, 553	59, 696	49, 263	38, 267	27, 445	54, 788	46, 272	37, 778	29, 421	21, 515
5	May 30	Aug. 5	Aug. 26	69, 016	38, 336	47, 666	37, 110	27, 035	53, 121	44, 961	36, 811	28, 765	21, 091
6	June 6	Aug. 11	Sept. 2	68, 580	58, 020	47, 465	36, 999	27, 047	53, 043	45, 123	37, 208	29, 366	21, 869
7	June 13	Aug. 17	Sept. 9	68, 328	57, 768	47, 210	36, 736	26, 772	52, 290	44, 490	36, 692	28, 952	21, 512
8	June 22	Aug. 23	Sept. 22	69, 334	58, 893	48, 454	38, 065	28, 081	52, 132	44, 572	37, 012	29, 461	22, 038
9	June 27	Aug. 27							49, 812	42, 492	35, 172	28, 033	20, 754
10	July 5	Sept. 3							48, 091	40, 890	33, 691	26, 509	19, 574
11	July 11	Sept. 8							47, 224	40, 144	33, 064	26, 011	19, 232
Mean summation (8 plantings)				71, 191	59, 969	48, 807	37, 823	27, 413	54, 648	46, 139	37, 514	29, 143	21, 267
Standard deviation (8 plantings)				2, 866	2, 099	1, 337	772	437	2, 406	1, 468	668	266	596
Mean summation (11 plantings)									52, 938	44, 785	36, 549	28, 518	20, 882
Standard deviation (11 plantings)									3, 435	2, 589	1, 726	1, 135	859

In comparing the figures and curves for the period from planting to mid-silking with the theoretical data of Table 1 and Figure 1, it is noted that, taken in their entirety, the responses of the various plantings to temperature conditions did not conform to the theoretical, in that while the first eight plantings behaved "normally" the results of the last three plantings were out of line with expectations. For this reason it was thought best to analyze the data on two bases, one including the first eight plantings and the other including the entire group. The explanation of the "abnormal" trends in the curves for the last three plantings will be discussed later.

If the data of the first eight plantings are studied it will be found that, as in 1924, the greatest uniformity in the summations fell in the column 5° lower than that for the period from planting to canning maturity, that is, in the 55° F. column. The average summation for the first eight plantings here was 29,143 degree-hours, with a standard deviation of only 266 degree-hours.

Comparing these results with those for the season of 1924, it is apparent that this corn grown at the Arlington farm during 1927 developed within a different temperature range from that grown in 1924, since the base line in 1927 was 10 degrees higher than that in 1924. The reason for this difference can not be assigned with certainty. The seed in both cases was purchased from the same mid-western seedsman and to all appearances was of excellent quality with respect not only to uniformity in size, color, and weight of the seed itself but also to the vigor and unformity of the plants derived therefrom. To what extent seasonal factors may have affected the results for the two years can not be stated definitely; but since Stowell Evergreen grown in the same fields under identical conditions did not show this difference in behavior it is probable that the explanation is to be sought in some other factor. It is believed, from the results obtained from various strains of Golden Bantam, which will be presented later, that this difference in behavior in the two years was due to strain differences in the seed.

One feature of the results for the period from planting to mid-silking is worthy of special note, namely, the progressive lessening of the summations in all temperature columns for the last three plantings, as seen in the second set of figures of Table 3 and the curves of Figure 5. Similar results were obtained with Stowell Evergreen, as will be shown presently. It will be noted that the ninth, tenth, and eleventh plots of corn were planted on June 27, July 5, and July 11, respectively, a season when soil temperatures were approaching the highest level of the season. The effect of the increase of soil temperatures would be to speed up the germination of the seed and thus cut down progressively the length of the growing period. It is possible that length of day and perhaps other factors also contributed to this result. If the data of the series from planting to mid-silking are considered as a whole, it is seen that the standard deviation is smallest for the 60° F. base line instead of for the 55° base line, as is the case when the first eight plantings only are considered. This result, as will be seen from the curves of Figure 3, is due to the "abnormal" trends in the curves for the last three plantings.

SOIL-TEMPERATURE SUMMATIONS

In the region where this work was done, mean soil temperatures in the early spring lag considerably behind the mean air temperatures. As the season advances the curve of the soil temperatures gradually approaches that of the air temperatures, until in July it reaches and crosses it. For a considerable period thereafter the mean soil temperatures remain above those of the air.

In planning the work for 1927 it was thought that summations based on soil-temperature data might be of value in the present study, as much of the activity of the corn plant is carried on underground, particularly during the early growing period. Soil temperatures throughout the entire season were therefore recorded, and the summations for Golden Bantam corn based on these records are presented in Table 4 and illustrated in Figure 6.

Two observations are to be made from these data when compared with those for air temperature—(1) that the minimum-temperature

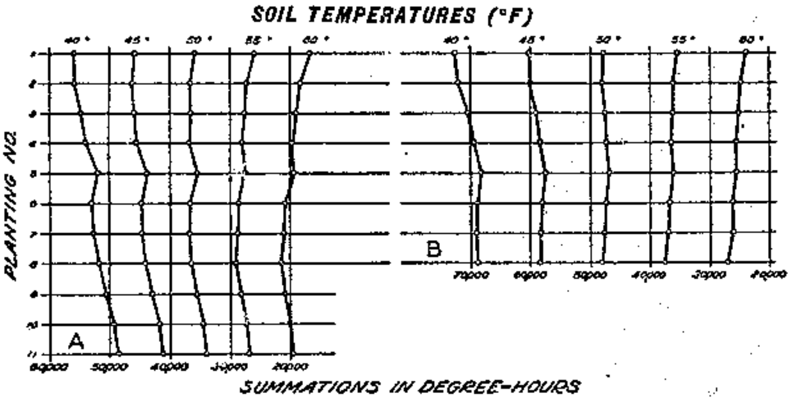

FIGURE 6.—Curves of soil-temperature summations in degree-hours above various base lines for 11 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for 8 plantings of the same series for the period from planting to canning maturity. The last three plantings of this series did not reach canning maturity

base line is lower than in the air-temperature data; and (2) that the data of both periods, that is, from planting to canning maturity and from planting to mid-silking, indicate the same base-line temperature, 50° F. The average summation above this temperature for the period from planting to canning maturity is 47,532 degree-hours, with a standard deviation of 406 degree-hours. For the period from planting to mid-silking the average summation for the first eight plantings is 36,381 degree-hours, with a standard deviation of 454 degree-hours.

The difference in air and soil temperatures during the growing season explains, in part at least, the differences in indicated base lines as determined from the air-temperature and soil-temperature data. It is plain that, since in the early part of the season the response of the corn is influenced by soil temperatures more than by air temperatures, the air-temperature base lines as here determined do not represent the true physiological minimum temperature for corn, which

TABLE 4.—*Soil-temperature summations for Golden Bantam sweet corn grown at the Arlington Experiment Farm, 1927*

Planting No.	Date of planting	Mid-silking date	Canning maturity date	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	May 2	July 24	Aug. 13	72,627	60,147	47,812	35,407	23,968	55,794	45,714	35,779	25,774	16,735
2	May 10	July 28	Aug. 17	72,011	60,011	48,011	36,143	24,874	55,838	46,238	36,638	27,170	18,301
3	May 16	July 30	Aug. 19	70,537	59,017	47,497	36,076	25,051	54,775	45,655	36,535	27,514	18,889
4	May 23	Aug. 2	Aug. 22	69,426	58,386	47,346	36,308	25,457	53,938	45,208	36,658	28,020	19,569
5	May 30	Aug. 5	Aug. 26	68,122	57,442	46,762	36,082	25,529	51,854	43,694	35,534	27,374	19,841
6	June 6	Aug. 11	Sept. 2	68,876	58,026	47,345	36,665	26,075	52,761	44,721	36,681	28,641	20,683
7	June 13	Aug. 17	Sept. 9	68,881	58,204	47,523	36,843	26,132	52,493	44,573	36,653	28,733	20,874
8	June 22	Aug. 23	Sept. 22	68,839	58,400	47,959	37,519	26,987	51,692	44,132	36,572	29,012	21,452
9	June 27	Aug. 27							50,424	42,984	35,544	28,104	20,664
10	July 5	Sept. 3							49,153	41,834	34,513	27,193	19,831
11	July 11	Sept. 8							48,409	41,212	34,011	26,811	19,519
Mean summation (8 plantings)				69,915	58,704	47,532	36,380	25,509	53,643	45,003	36,381	27,780	19,480
Standard deviation (8 plantings)				1,642	955	406	630	894	1,686	868	454	1,059	1,539
Mean summation (11 plantings)									52,466	44,187	35,920	27,668	19,628
Standard deviation (11 plantings)									2,501	1,626	944	954	1,338

must be below that given, and would be below the air-temperature base line in any region or season where the soil-temperature gradient is normally below that of the air. Since the corn plant carries on physiological activities both in the soil and in the air, and since the soil and air temperature gradients vary continuously with respect to each other, it is impossible at the present stage of knowledge to evaluate these data in such a way as to give a true and accurate value for the actual physiological minimum temperature. It is apparent, however, that this value would lie within the limits given in the soil and air-temperature data unless there were other interfering factors.

In the summations based on soil temperatures, as pointed out in the discussion of those based on air temperatures, there is observed a progressive lessening of the summations of the last three plantings.

RESULTS WITH STOWELL EVERGREEN IN 1924

The differences in the seasonal conditions for 1924 and 1927 are reflected in the summation data for Stowell Evergreen. Table 5 and Figure 7 present the results obtained for 1924.

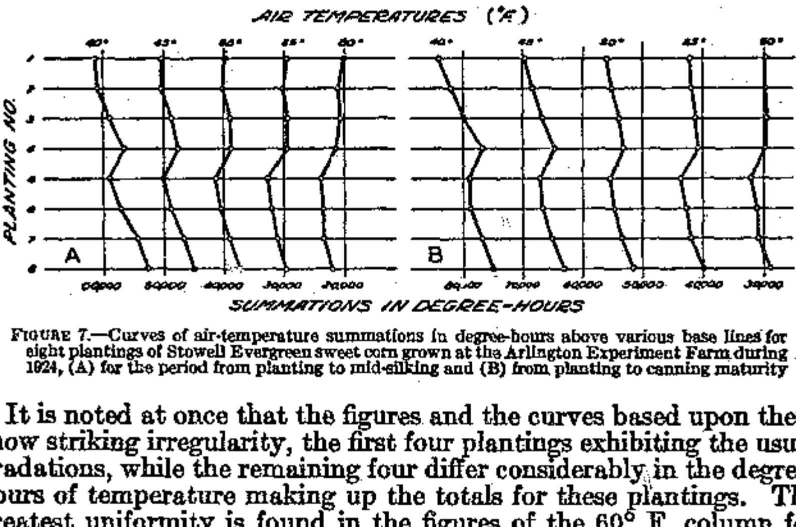

FIGURE 7.—Curves of air-temperature summations in degree-hours above various base lines for eight plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1924, (A) for the period from planting to mid-silking and (B) from planting to canning maturity

It is noted at once that the figures and the curves based upon them show striking irregularity, the first four plantings exhibiting the usual gradations, while the remaining four differ considerably in the degree-hours of temperature making up the totals for these plantings. The greatest uniformity is found in the figures of the 60° F. column for the period from planting to canning maturity, the average summation for the eight plantings being 30,131 degree-hours, with a standard deviation of 1,064 degree-hours. The aberrant results obtained for the last four plantings find their explanation in the effect of drought conditions on the corn. Field records show that the corn of the fifth planting came to silking during the most trying part of the summer, these plants requiring three weeks to complete approximately the silking process, whereas earlier plots of corn derived from the same lot of seed required but two weeks to accomplish the same result. The sixth and seventh plantings required 18 and 17 days, respectively. The striking effects of the drought on the vegetative activities of the corn, such as stunting of growth, decreasing the yield, etc., were particularly noticeable in the plantings of Stowell Evergreen. Attention was drawn to this in the report previously mentioned (*13*, *p. 1048–1049*).

TABLE 5.—*Air-temperature summations for Stowell Evergreen sweet corn grown at the Arlington Experiment Farm, 1924*

Planting No.	Date of planting	Mid-silking date	Period from mid-silking to canning maturity[1]	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	Apr. 28	July 28	July 27 to Aug. 23	84,085	69,728	55,846	42,093	29,630	61,351	50,259	39,626	29,261	20,019
2	May 5	July 31	Aug. 1 to 26	82,127	68,426	55,117	41,865	29,677	60,997	50,388	40,141	30,096	20,951
3	May 10	Aug. 1	do	79,998	66,783	53,915	41,092	29,286	58,868	48,745	38,939	29,323	20,580
4	May 23	Aug. 5	Aug. 7 to 31	76,888	64,853	53,087	40,842	29,680	56,571	47,524	38,698	29,522	21,283
5	May 31	Aug. 12	Aug. 9 to Sept. 2	78,961	67,106	55,386	43,662	31,975	58,868	50,001	41,221	32,566	23,802
6	June 7	Aug. 15	Aug. 17 to Sept. 16	78,849	66,699	54,749	42,728	31,138	57,215	48,778	40,431	32,033	23,641
7	June 17	Aug. 20	Aug. 18 to Sept. 19	76,913	65,143	53,541	41,900	30,821	54,430	46,633	38,864	31,046	23,315
8	June 27	Aug. 29	Aug. 23 to Sept. 26	75,071	63,205	51,535	39,857	28,840	52,663	45,006	37,427	29,659	22,066
Mean summation				79,111	66,493	54,147	41,755	30,131	57,620	48,417	39,418	20,438	21,955
Standard deviation				2,947	2,071	1,417	1,171	1,054	3,034	1,913	1,186	1,289	1,476

[1] In order to determine the temperature summations for the period from mid-silking to canning maturity in this series it was necessary to make use of the data from chemical analyses along with the field records to establish the exact periods to be summated.

The figures and curves for the planting to mid-silking period show similar irregularities. The minimum-temperature base line is not so readily determined as in other series, but it is apparent that it lies close to 50° F., the average summation for this column being 39,418 degree-hours, with a standard deviation of 1,186 degree-hours. Here again is illustrated the lower effective temperature range of the corn for the planting to mid-silking period as observed in the case of the Golden Bantam variety.

RESULTS WITH STOWELL EVERGREEN IN 1927

AIR-TEMPERATURE SUMMATIONS

In Table 6 are given the air-temperature summations above various base lines for Stowell Evergreen grown at the Arlington Experiment Farm during 1927. Two sets of data are again given, one for the period from planting to canning maturity and the other for the period

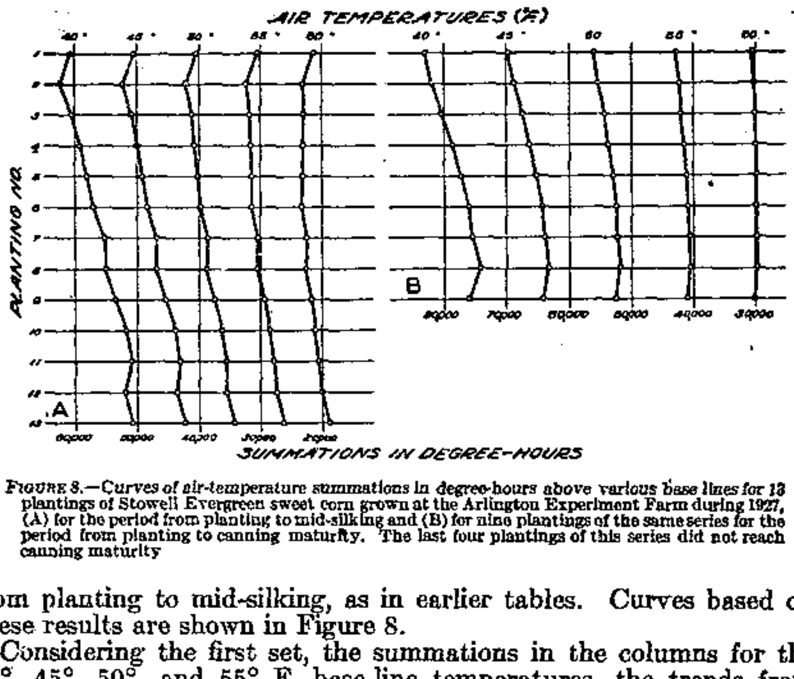

FIGURE 8.—Curves of air-temperature summations in degree-hours above various base lines for 13 plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for nine plantings of the same series for the period from planting to canning maturity. The last four plantings of this series did not reach canning maturity

from planting to mid-silking, as in earlier tables. Curves based on these results are shown in Figure 8.

Considering the first set, the summations in the columns for the 40°, 45°, 50°, and 55° F. base-line temperatures, the trends from higher to lower summations with successive plantings are again observed, whereas in the 60° column the summations are strikingly uniform for all plantings. The average summation for the nine plantings is 29,924 degree-hours, with a standard deviation of only 250 degree-hours from this average. It would appear from this that 60° air temperature should be considered the minimum-temperature base line for these plantings. This is in agreement with the findings of 1924 for this variety.

TABLE 6.—*Air-temperature summations for Stowell Evergreen sweet corn grown at the Arlington Experiment Farm, 1927*

Planting No.	Date of planting	Mid-silking date	Canning maturity date	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	May 2	July 26	Aug. 23	83, 235	69, 605	56, 031	42. 749	30, 497	60, 792	50, 522	40, 308	30, 385	21, 428
2	May 10	Aug. 2	Aug. 29	82, 106	68, 682	55, 318	42, 241	30, 085	62, 552	52, 378	42, 254	32, 404	23, 312
3	May 16	Aug. 4	Aug. 31	80, 270	67, 336	54, 439	41, 958	29, 898	60, 545	50, 851	41, 194	31, 738	22, 887
4	May 23	Aug. 7	Sept. 3	78, 738	66, 262	53, 808	41, 508	29, 861	59, 238	50, 002	40, 788	31, 711	23, 085
5	May 30	Aug. 11	Sept. 7	77, 237	65, 117	53, 007	41, 028	29, 695	57, 964	49, 084	40, 214	31, 449	23, 099
6	June 6	Aug. 15	Sept. 11	76, 050	64, 290	52, 535	40, 880	29, 826	56, 964	48, 444	39, 929	31, 488	23, 418
7	June 13	Aug. 20	Sept. 17	75, 536	63, 895	52, 258	40. 720	29, 729	55, 172	46, 892	38, 614	30, 394	22, 474
8	June 22	Aug. 28	Sept. 26	74, 152	63, 267	51, 784	40, 482	29, 729	55, 080	46, 920	38, 760	30, 618	22, 709
9	June 27	Sept. 1	Oct. 3	76, 027	64, 195	52, 474	40, 957	29, 995	53, 540	45, 500	37, 460	29, 445	21, 729
10	July 5	Sept. 7							51, 827	44, 027	36, 227	28, 455	20, 992
11	July 11	Sept. 12							50, 903	43, 223	35, 543	27, 890	20, 534
12	July 18	Sept. 23							51, 815	43, 656	35, 540	27, 545	19, 961
13	July 25	Oct. 1							50, 650	42, 415	34, 297	26, 372	18, 915
Mean summation (9 plantings)				78, 150	65, 850	53, 517	41, 391	29, 924	57, 983	48, 955	39, 947	31, 070	22, 682
Standard deviation (9 plantings)				3, 140	2, 255	1, 474	771	250	3, 041	2, 221	1, 464	916	692
Mean summation (13 plantings)									55, 926	47, 224	38, 548	29, 992	21, 888
Standard deviation (13 plantings)									4, 070	3, 272	2, 521	1, 894	1, 434

In the figures for the planting to mid-silking period, irregularities are noted. With the exception of the figures for the first planting, which clearly reflect the abnormally high temperatures prevailing at and for some time after the date of planting of this plot (fig. 8), the summations for the first nine plantings are fairly uniform in the 60° F. column, the average for these plantings being 22,682 degree-hours, with a standard deviation of 692 degree-hours. However, there are only slightly greater irregularities in the 55° column, the average for the first nine plantings being 31,070 degree-hours, with a standard deviation of 916 degree-hours.

It is to be noted that the irregularity showing in the figures for the first planting does not appear in the summation for the period from planting to canning maturity, this lower summation than the average

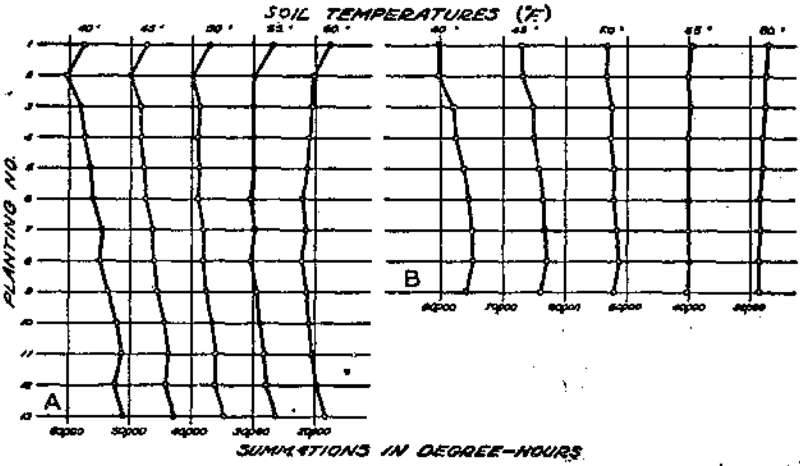

FIGURE 9.—Curves of soil-temperature summations in degree-hours above various base lines for 13 plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for nine plantings of the same series for the period from planting to canning maturity. The last four plantings of this series did not reach canning maturity

of the eight plantings being offset by the greater temperature requirement from mid-silking to canning maturity.

Beyond the eighth planting is again observed the gradual lessening in the total amount of heat required by the corn, which was noted in the corresponding results with Golden Bantam already shown.

The indicated minimum-temperature base line here is 60° F. instead of 55° as in the case of the 1924 Stowell Evergreen, the proper base line for both the planting to canning maturity and the planting to mid-silking periods being apparently the same. Whether this indicates strain differences in seed may be questioned. The results obtained from summations based on soil temperatures seem to indicate no difference. The results for both periods here indicate a base line of 55°, which corresponds exactly with the results obtained with Stowell Evergreen in 1924.

SOIL-TEMPERATURE SUMMATIONS

Soil-temperature summations above the various base lines for Stowell Evergreen in 1927 are presented in Table 7 and Figure 9.

TABLE 7.—*Soil-temperature summations for Stowell Evergreen sweet corn grown at the Arlington Experiment Farm, 1927*

Planting No.	Date of planting	Mid-silking date	Canning maturity date	Degree-hours above base line indicated from planting to canning maturity					Degree-hours above base line indicated from planting to mid-silking				
				40° F.	45° F.	50° F.	55° F.	60° F.	40° F.	45° F.	50° F.	55° F.	60° F.
1	May 2	July 26	Aug. 23	80,360	66,680	53,145	39,540	26,901	57,616	47,296	37,121	26,876	17,597
2	May 10	Aug. 2	Aug. 29	80,283	66,843	53,403	40,095	27,391	60,266	50,066	39,866	29,798	20,329
3	May 16	Aug. 4	Aug. 31	78,040	65,200	52,360	39,940	27,483	57,987	48,387	38,787	29,607	20,382
4	May 23	Aug. 7	Sept. 3	77,605	65,125	52,645	40,167	27,884	57,641	48,401	39,161	29,923	20,872
5	May 30	Aug. 11	Sept. 7	76,443	64,326	52,205	40,085	28,000	56,693	47,813	38,933	30,053	21,300
6	June 6	Aug. 15	Sept. 11	75,493	63,635	52,075	40,215	28,445	56,063	47,443	39,023	30,503	22,065
7	June 13	Aug. 20	Sept. 17	75,014	63,376	51,736	40,096	28,425	54,088	46,408	38,128	29,848	21,629
8	June 22	Aug. 28	Sept. 26	74,896	62,831	51,311	40,009	28,514	54,775	46,188	38,148	30,295	22,139
9	June 27	Sept. 1	Oct. 3	76,026	64,148	52,268	40,419	28,707	53,636	45,596	37,556	29,516	21,484
10	July 5	Sept. 7							52,163	44,303	36,565	28,765	20,873
11	July 11	Sept. 12							51,359	43,680	35,999	28,319	20,547
12	July 18	Sept. 23							52,406	44,247	36,086	27,928	19,771
13	July 25	Oct. 1							51,168	42,892	34,611	26,362	18,250
Mean summation (9 plantings)				77,129	64,685	52,350	40,063	27,972	56,596	47,511	38,525	29,602	20,866
Standard deviation (9 plantings)				2,099	1,403	650	238	611	2,047	1,36[illegible]	858	1,056	1,388
Mean summation (13 plantings)									55,112	46,5[illegible]	37,691	29,061	20,557
Standard deviation (13 plantings)									2,872	2,130	1,536	1,322	1,363

Considering the data for the period from planting to canning maturity, it is noted that the curves of the soil-temperature summations do not differ materially from those of the air temperatures. The appropriate base line indicated here is 55° F., 5 degrees below that of the indicated air-temperature base line—such a difference as has been noted in previously considered data. The average summation for the nine plantings in the 55° column is 40,063 degree-hours, with a standard deviation of only 238 degree-hours.

In the case of the data for the period from planting to mid-silking for the first nine plantings, the smallest standard deviation is found in the 50° F. column, where the mean summation is seen to be 38,525 degree-hours, with a standard deviation of 858 degree-hours. This is a lower base line than would be expected, considering the data that have already been presented, and the standard deviation is likewise unduly great. Inspection of the curves of Figure 9, however, reveals the explanation for this and indicates that in this case, as in the curves for the period from planting to canning maturity, 55° is the indicated base line, the aberrant results in the case of the first planting of the series being responsible for the higher standard deviation in the 55° column than in the 50° column. The reason for this abnormally low summation for the first planting has already been discussed. The mean summation for the 55° column is 29,602 degree-hours and the calculated standard deviation 1,056 degree-hours.

DISCUSSION OF RESULTS WITH GOLDEN BANTAM AND STOWELL EVERGREEN IN 1924 AND 1927

On the basis of the experimental findings set forth, what may be concluded as to the minimum-temperature base line for sweet corn? It must be recognized, of course, that temperature is but one of the factors influencing the behavior of corn in the field, and before an absolute evaluation can be made of the influence of one factor the others must be taken into consideration. The amount and distribution of the rainfall has a tremendous influence on crop activities, as every farmer and investigator knows. The amount of sunshine that the corn receives has an effect on photosynthesis in the plant, and the factor of variable day length must be considered in this connection also. That varieties differ in their time requirements for growth and maturity is well known. Obviously, therefore, the temperature needs of all can not be the same, and it is clear that absolutely uniform results are not to be expected from any set of experiments where these variable factors are not under complete control.

In the experiments here recorded practical field conditions prevailed. The different plots of corn for both seasons were grown, however, in different portions of the same field with no essential difference in cultural practices except that the Golden Bantam was thinned to a distance of 8 to 10 inches in the row, and the Stowell Evergreen plants were spaced 12 to 14 inches. The seed for both seasons was obtained from the same seedsman but, in all probability, was from different seasons' plants for the different years, as was indicated by the difference in the vegetative character of the plants for the two years. The periods covered were essentially the same for both seasons, so that the day-length factor was practically constant for one series of plantings as compared with the other series. Within each series the day-length factor, of course, was variable. No measure of the light intensity as influencing photosynthetic activity was available except the inadequate record of the hours of sunshine and cloudiness, which at present can not be evaluated accurately for this purpose.

If a series of plots of corn planted at intervals of a week or 10 days could be grown with all conditions uniform except those of temperature and time, in view of the results reported by Livingston and Livingston (*10*), and as clearly illustrated by the hypothetical case earlier considered, it would be expected that temperature summations above a proper minimum base line would be uniform for all plots, and that summations of temperature above or below this proper base line would be lacking in uniformity, for the reason that if too low a base line were chosen the summations would include an excess of temperature above that required by the corn, whereas if the base line chosen were too high the summations would not be a sufficient measure of the temperature needs of the crop. It is believed, therefore, that the striking uniformity in the summations of temperature above certain base lines found in the present study indicates rather conclusively the proper base lines for these different corns.

On these grounds it seems reasonable to assume that for the Golden Bantam variety grown at the Arlington Experiment Farm during 1924 the minimum air-temperature base line was 50° F. for the period from planting to canning maturity, considered as a whole, with a slightly lower minimum for growth up to the flowering stage and a slightly higher minimum for the storage of the starch and other carbohydrates in the grain until canning maturity at least was reached. The 1927 Golden Bantam responded to environmental conditions in a similar manner, but its minimum air temperature for the period from planting to canning maturity for some reason was 10 degrees higher. The minimum soil temperature for this corn was 50°, and the base line was the same for the two periods considered.

The minimum air-temperature base line for Stowell Evergreen for both 1924 and 1927 was 60° F., with the same sort of variation with the age of the corn as shown by the Golden Bantam. The minimum soil temperature for the 1927 Stowell Evergreen was 55°.

The minimum-temperature base line for sweet corn, therefore, has been found to differ, not only with different varieties but also with different strains of the same variety, and the amount of heat required to bring the corn to canning maturity has been found to differ likewise with variety and strain. The effectiveness of the temperature in bringing the corn to canning maturity has also been found to be influenced by drought, by soil temperature at planting time, and probably also by day length, light intensity, and possibly other factors.

It seems reasonable to conclude also that since certain varieties and strains of sweet corn have lower minimum temperature requirements than other varieties and strains, such low minimum temperature corns might be planted earlier in the season than those having a higher minimum, and thus be better suited for cultivation in regions having short growing seasons.

TEMPERATURE SUMMATIONS FOR DIFFERENT VARIETIES

It may be of interest to consider the temperature requirements of corns grown at the Arlington farm and at other places during these and other seasons. In Table 8 are shown the summations for different varieties of sweet corn grown at the Arlington farm during 1922, 1925, and 1926.

TABLE 8.—*Air-temperature summations for different varieties of sweet corn grown at the Arlington Experiment Farm, 1922, 1925, and 1926*

[Based on data for the period from planting to canning maturity]

Year and variety	Degree-hours above base line of—				
	40° F.	45° F.	50° F.	55° F.	60° F.
1922					
Golden Bantam	58,923	50,187	41,452	32,746	24,179
Howling Mob	62,067	52,861	43,646	34,460	25,413
Dreer Golden Giant	60,853	51,997	43,152	34,321	25,596
Charlevoix	67,818	57,772	47,717	37,691	27,804
Morse Golden Cream	63,950	54,624	45,289	35,978	26,773
Kelly Hybrid	65,821	56,135	46,440	36,769	27,209
Hickox Improved	63,905	54,579	45,244	35,933	26,723
Potter Excelsior	67,261	57,455	47,640	37,849	28,169
Vaughn Bantam Evergreen	69,321	59,155	48,980	38,829	28,789
Mammoth Sugar	69,044	58,878	48,703	38,552	28,512
Old Colony	71,934	61,408	50,673	40,362	29,962
Narrow-Grained Evergreen	72,170	61,524	50,869	40,244	20,790
Country Gentleman	68,912	58,746	48,571	38,420	28,380
Stowell Evergreen	74,819	63,823	52,808	41,818	30,973
1925					
Golden Bantam (Stokes)	63,637	54,397	45,157	35,931	26,861
Stowell Evergreen (Stokes)	76,101	65,061	54,021	42,997	32,219
Guatemalan (U. S. D. A.)	91,292	77,749	64,274	51,149	38,399
Second Early Adams (dent; Bolgiano)	65,958	56,478	46,998	37,532	28,222
1926					
Golden Bantam (Stokes)	64,308	54,950	45,558	36,177	27,488
Stowell Evergreen (Iowa)	79,425	67,547	55,635	43,734	32,523
Stowell Evergreen (Arlington Experiment Farm)	81,337	69,219	57,067	44,926	33,475
Country Gentleman (Iowa)	74,646	63,608	52,535	41,475	31,106

Since the minimum-temperature base lines for all these varieties are not known, the full significance of these summations can not be completely determined, but some interesting comparisons are possible. It is noted that in the case of Stokes strain of Golden Bantam grown during the seasons of 1925 and 1926 the summations above 55° F. differ for the two years by only 246 degree-hours, the average summation being 36,054 degree-hours. This suggests 55° as the probable minimum air-temperature base line for this strain, as both above and below this base line the summations differ much more widely.

The same variety, but from a different source, grown during 1922 at none of the base lines used in these tests, shows a summation approaching that of the corn just mentioned, and obviously indicates a distinct strain difference in seed. It is of interest to note that this corn required less temperature to reach canning maturity than any other variety or strain of the same variety grown during the period of 1922 to 1927, with the single exception of the 1924 Golden Bantam above the base line of 60° F.

In Table 8 are shown summations also for four different plantings of Stowell Evergreen. Considerable variation is seen in the summations above the 60° F. base line, with a range of 2,502 degree-hours between the strain grown in 1922 and the Arlington Experiment Farm strain grown in 1926. It is of interest that the Stokes strain of 1925 and the Iowa strain of 1926 vary by only 304 degree-hours in their temperature requirements above the 60° base line, the average summation for these two plantings being 32,371 degree-hours. This suggests the possibility that the seeds of these two plantings were derived from plants of the same strain.

Some idea of the relative temperature needs of other varieties of sweet corn may be obtained from a comparison of their summations for the year 1922 with those of the Golden Bantam and Stowell Evergreen. They were grown in the same field under as nearly identical environmental conditions as were practicable.

Within the 1925 group attention is called particularly to the very great summations of prevailing temperature in the case of the Guatemalan corn, which were far in excess of those of any variety of sweet corn studied by the writers.

The summations for the two plantings of Country Gentleman for the period from planting to canning maturity were much greater for the 1926 corn than for the corn grown in 1922.

The response of different strains to temperature conditions above various base lines in 1927 is shown clearly in the summations of Table 9.

TABLE 9.—*Air-temperature summations for different pedigreed strains of Country Gentleman and Golden Bantam sweet corn grown at the Arlington Experiment Farm, 1927*

[Based on data for the period from planting to canning maturity]

Variety and strain	Degree-hours above base line of—				
	40° F.	45° F.	50° F.	55° F.	60° F.
Country Gentleman:					
No. 1	74,019	62,544	51,181	39,999	29,350
No. 2	72,769	61,610	50,494	39,507	29,025
No. 3	74,605	63,010	51,552	40,255	29,539
Golden Bantam:					
No. 1	68,491	58,170	47,851	37,582	27,718
No. 2	68,491	58,170	47,851	37,582	27,718
No. 3	70,893	60,212	49,533	38,904	28,681

These data were obtained from plants of pedigreed strains of the Country Gentleman and Golden Bantam varieties, the seed of which were kindly supplied by G. N. Hoffer of the Indiana Agricultural Experiment Station. These corns were grown side by side in the same field, and environmental conditions were identical for all. The three strains of Country Gentleman vary within a range of about 500 degree-hours above the 60° F. base line and take an intermediate position between those considered in Table 7. This variation is not great but nevertheless is well defined. More striking are the figures for the three strains of Golden Bantam, for No. 1 and No. 2 showed exactly the same temperature requirements, whereas No. 3 required considerably more heat to bring it to canning maturity than its associates in the test.

DATA FROM CORN GROWN IN IOWA

Temperature summations have been made for different varieties of sweet corn grown at the Iowa Agricultural Experiment Station, Ames, Iowa, during 1925 and 1926. The field data for these corns and samples for chemical analysis were supplied through the courtesy of A. T. Erwin of that station. The planting, mid-silking, and sampling dates were derived from the field records, and canning maturity was determined from the results of chemical analysis of the samples prepared from the corn at different stages of maturity. The temperature data are based on the official Weather Bureau reports for Des Moines, which is approximately 30 miles south of Ames and has a normal mean temperature about 1½ degrees above that for Ames. (See normal temperature curves in Figure 10.) The summations, therefore, are probably a little higher than would have been obtained had actual Ames records been used. It is believed, however, that these differences are not great enough to affect seriously the results obtained. Slight errors in these summations may likewise be present, due to the fact that they are based on the daily mean temperature rather than on the hourly readings as in the Arlington Experiment Farm data. The summations for the period from planting to canning maturity are presented in Table 10, and the curves of the temperatures for the growing seasons of 1925 and 1926 are shown in Figure 10.

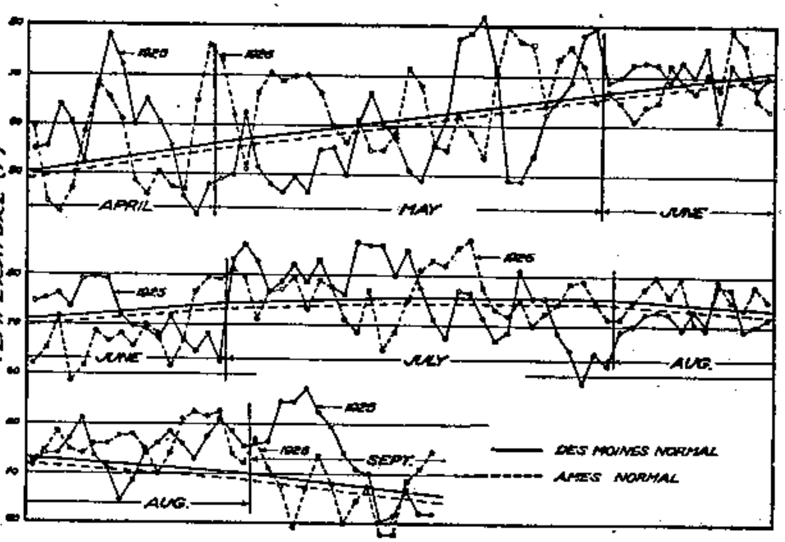

FIGURE 10.—Mean daily temperature curves for Des Moines, Iowa, during the period from April 16 to September 15, inclusive, for the years 1925 and 1926. Curves for the normal mean temperatures for Des Moines and Ames, Iowa, are also shown. (Data from U. S. Weather Bureau records)

TABLE 10.—*Air-temperature summations for sweet corn grown at Ames, Iowa, 1925 and 1926*

[Based on data for the period from planting to canning maturity]

Year and variety	Degree-hours above base line of—				
	40° F.	45° F.	50° F.	55° F.	60° F.
1925					
Golden Bantam	73,856	61,858	50,060	39,122	28,164
Golden Giant	82,784	69,756	56,338	44,078	31,800
Golden Evergreen	87,644	73,824	59,626	46,766	33,768
Stowell Evergreen	88,736	74,806	60,418	47,510	34,392
1926					
Golden Bantam	67,620	56,892	46,020	35,256	25,020
Country Gentleman	82,476	69,228	56,796	43,992	31,716
Stowell Evergreen	91,848	77,076	63,084	48,720	34,908

It is seen at once that the Golden Bantam corns grown during these two seasons differed considerably in their response to temperature conditions, that grown in 1925 showing a summation above the assumed minimum temperature of 50° F. 4,040 degree-hours greater than that grown during 1926. There is no close agreement in the summations above any base line considered, and it seems safe to assume that these corns represent two distinct strains. The two plantings of Stowell Evergreen, on the other hand, showed summations above the assumed base line of 60° for the two seasons varying by only about 500 degree-hours. It would appear that the seed of these two plots was derived from the same strain of corn.

Comparing these figures of Table 10 with those obtained at the Arlington farm from Iowa seed (Table 8), it is found that the Stowell Evergreen grown in Iowa in 1926 had a temperature summation above the 60° F. base line approximately 2,400 degree-hours greater than that grown at the Arlington farm during the same season. Whether the seed of these two plantings was derived from the same lot is not known. In the case of the Country Gentleman variety, however, the Iowa-grown corn required only slightly over 600 degree-hours more than that grown at the Arlington farm, considering 60° as the probable proper base line.

The possible relation of regional factors to the behavior of the corns can not be proved conclusively, but the fact that the Iowa figures shown here are always somewhat higher than those obtained at the Arlington farm should be noted in passing.

DATA FROM CORN GROWN IN MAINE

The study of corn grown in Maine was confined to different strains of one variety of sweet corn—Crosby—in the portion of the Androscoggin River Valley lying between Rumford on the north and Durham on the south, a farming section characterized by widely varying types of soils and topographical conditions. In some instances the corn was grown on very light sandy soils, in others on heavy clay loams; it was also grown on all intermediate types of soil. The elevations of the different farms varied by as much as 500 feet in some instances. Obviously, it was not possible to secure accurate temperature records on all these farms, and it was necessary to rely on the official records of the nearest Weather Bureau station, located at the gatehouse of the Union Water Power Co., at Lewiston. This station is not in the center of the region concerned, but is approximately 5 miles from the southern boundary. Auburn lies directly across the river from Lewiston, and the farms listed under this name lie within a radius of about 5 miles from the Weather Bureau station. North Turner is about 12 miles north of this point, Livermore Falls approximately 30 miles to the northeast, and Dixfield approximately 35 miles north of the station. It is inevitable, therefore, that the summations for these more distant locations, based on the Lewiston temperature data, should be slightly too high. This influence of distance from the recording station will be noted in the data to be presented, but is not sufficiently great to affect the results seriously.

These summations are for the period from planting to the date of delivery to the factory. Theoretically, corn as delivered at the factory should be at a very definite stage of maturity, and in the majority of cases this condition is closely approximated. However, weather conditions sometimes interfere with the harvesting of the crop at the appointed time, and in a few individual cases the operation of other factors may result in the corn being delivered when slightly immature or slightly overmature. Small errors in summations may arise from these causes, but it is believed that in the present cases these errors are very small.

Data for two seasons will be given; those for 1925, when figures from 10 different farms in the region about Auburn were obtained, and for 1926, when corns from 72 farms within the larger area were included in the study.

The summations are based on hourly temperature readings made throughout the season.

Table 11 shows the results obtained for the season of 1925 in the Auburn region.

TABLE 11.—*Air temperature summations for different strains of Crosby sweet corn grown near Auburn, Me.*

[Based on data for the period from planting to canning maturity]

Strain and farm	Degree-hours above base line of—				
	40° F.	45° F.	50° F.	55° F.	60° F.
Burnham & Morrill Clark strain:					
James farm	70,007	55,642	41,961	28,560	17,630
Sanborn farm	69,816	55,535	41,914	28,550	17,630
Early Crosby strain:					
Rodmond farm	59,506	47,498	36,013	24,512	15,274
Johnson farm	67,534	53,856	40,388	28,063	17,321
Ellis strain:					
Packard farm	63,621	51,082	39,070	26,986	16,763
Flanders farm	62,565	49,833	37,698	25,627	15,678
Mower farm	67,458	53,850	40,844	27,928	17,221
Finn strain:					
Taber farm	59,664	47,845	36,554	25,080	15,368
Osgood farm	61,851	49,249	37,301	25,363	15,417
Harper farm	63,401	50,742	38,610	26,456	16,324
Average	64,542	51,513	39,086	26,713	16,432

Four strains of Crosby corn are represented in these figures. Differences in strains as regards their response to temperature conditions are indicated, but the data are too few to warrant general conclusions on this point. Differences in soil conditions on which the corns were grown and in elevation doubtless account for the variations noted within each group. The average summations for the 10 fields of corn calculated above the various base lines should be noted.

Table 12 shows the results obtained from 72 different farms during the season of 1926 within the larger area mentioned.

TABLE 12.—*Temperature requirements of different strains of Crosby corn grown in Maine, 1926*

[Based on temperature data for Lewiston for the period from planting to canning maturity]

Strain and locality	Field No.	Degree-hours above base line of—				
		40° F.	45° F.	50° F.	55° F.	60° F.
Ellis strain:						
Dixfield	1	66,222	51,918	37,960	25,220	14,894
	2	64,975	50,980	37,707	25,132	14,871
	3	65,302	51,118	37,446	24,848	14,632
	4	65,495	51,311	37,888	25,310	14,884
	5	62,760	49,169	36,087	24,034	14,233
	6	67,601	52,729	38,232	25,827	14,976
	7	62,239	48,839	36,244	24,283	14,397
	8	62,239	48,839	36,244	24,283	14,397
	9	65,578	51,515	37,683	25,146	14,886
	10	64,698	50,885	37,323	24,922	14,742
	11	66,552	52,103	37,857	25,239	14,910
	12	64,539	50,664	37,220	24,765	14,619
	13	63,729	50,016	36,783	24,538	14,536
	14	66,219	51,675	38,006	25,224	14,894
	15	66,230	51,914	37,897	25,189	14,890
	16	65,437	50,839	37,277	24,962	14,787
	17	65,578	51,515	37,713	25,146	14,886
	18	65,084	51,224	37,501	25,117	14,871
Average		65,029	50,958	37,393	24,925	14,737
Livermore Falls	1	61,016	48,033	35,435	23,800	14,171
	2	63,747	50,112	36,955	24,658	14,602
	3	64,782	50,684	37,331	24,951	14,800
	4	61,494	48,571	35,896	24,211	14,470
	5	64,880	50,509	37,381	24,976	14,747
	6	63,810	50,320	37,031	24,801	14,710
	7	64,127	50,789	37,307	24,937	14,772
Average		63,401	49,859	36,762	24,619	14,610
North Turner	1	60,232	48,108	35,599	24,045	14,358
	2	62,520	49,559	36,574	24,602	14,642
	3	64,199	50,608	36,938	24,613	14,556
	4	63,119	49,957	36,63[illegible]	24,507	14,641
	5	61,876	49,238	36,249	24,835	14,441
	6	65,878	51,815	37,833	25,196	14,916
	7	62,557	50,161	36,932	24,784	14,708
	8	64,678	50,837	36,928	24,552	14,536
	9	61,104	48,095	35,281	23,708	14,136
	10	63,729	50,366	36,783	24,538	14,536
Average		62,989	49,874	36,575	24,488	14,537
Auburn	1	58,647	46,842	34,658	23,419	13,998
	2	62,733	49,784	36,571	24,478	14,473
	3	67,606	52,774	38,281	25,341	14,946
	4	60,242	47,764	35,100	23,630	14,123
	5	63,729	50,366	36,783	24,538	14,530
	6	61,482	48,761	36,016	24,279	14,492
Average		62,407	49,281	36,234	24,281	14,428
Average for Ellis strain		63,870	50,276	36,672	24,672	14,622
Burnham & Merrill Clark strain:						
North Turner	1	63,654	50,761	36,416	24,479	14,612
	2	65,232	53,771	38,415	25,386	14,961
	3	63,962	50,409	37,031	24,801	14,710
	4	69,132	53,930	38,455	25,416	14,991
Average		65,500	52,218	37,579	25,016	14,819
Auburn	1	65,332	51,439	37,357	24,862	14,787
	2	68,156	54,103	38,281	25,241	14,946
	3	62,692	49,559	36,574	24,602	14,642
Average		65,393	51,700	37,404	24,901	14,792
Average for Burnham & Merrill Clark strain		65,454	51,996	37,504	24,967	14,807

TABLE 12.—*Temperature requirements of different strains of Crosby corn grown in Maine, 1926*—Continued

Strain and locality	Field No.	Degree-hours above base line of—				
		40° F.	45° F.	50° F.	55° F.	60° F.
Early Crosby strain:						
Livermore Falls	1	65,332	51,439	37,357	24,926	14,787
	2	66,006	51,913	37,751	25,192	14,916
Average		65,669	51,676	37,554	25,059	14,851
North Turner	1	64,982	51,209	37,231	24,901	14,770
	2	66,008	51,466	37,350	24,775	14,617
Average		65,495	51,337	37,291	24,838	14,693
Auburn	1	61,457	48,415	35,525	23,799	14,161
Average for Early Crosby strain		64,757	51,473	37,048	24,719	14,650
Finn strain:						
Livermore Falls	1	60,352	48,029	34,916	23,549	14,093
	2	66,901	52,289	38,032	25,232	14,886
	3	65,732	51,809	37,381	24,976	14,815
Average		64,328	50,709	36,776	24,586	14,598
Nolan Early Crosby strain:						
North Turner	1	64,227	50,274	36,645	24,422	14,481
	2	61,261	48,449	35,742	24,080	14,358
	3	62,256	49,311	36,475	24,585	14,640
	4	61,654	48,761	36,016	24,279	14,492
	5	64,652	50,608	36,938	24,613	14,556
	6	64,093	50,458	37,015	24,733	14,617
	7	62,986	49,275	35,893	23,916	14,176
	8	65,276	50,972	37,056	24,627	14,556
	9	65,059	50,995	37,205	24,761	14,617
	10	61,602	48,353	35,375	23,722	14,136
Average		63,297	49,746	36,438	24,374	14,463
Roake strain:						
Auburn	1	60,242	47,642	34,967	23,581	14,100
	2	60,584	47,764	35,100	23,6[illegible]0	14,123
	3	61,146	48,128	35,305	23,711	14,135
	4	61,402	48,291	35,395	23,749	14,141
	5	63,041	49,212	35,776	23,885	14,208
Average		61,283	48,187	35,309	23,707	14,141
Martin strain:						
Auburn	1	61,769	48,735	35,847	24,078	14,322
Grand average		63,816	50,264	36,644	24,684	14,581

In view of the factors contributing to variations in results that have been pointed out, one is impressed by the striking uniformity in the summations above the various base lines. Variations due to distance from the weather-recording station are shown most satisfactorily in the figures for the Ellis strain and amount to a few hundred degree-hours between the group nearest to and that farthest from the recording station.

The temperature requirements of the different strains did not vary widely, though the Roake corn used somewhat less heat than any of the others.

In comparing the averages for this season (1926) with those for 1925 it is seen that all strains matured with less heat in 1926 than they required the previous year. It is possible that the smaller number of observations in 1925 may be partly responsible for this variation, but it is not believed that this accounts for all the difference. The 1925 season in this region was one including prolonged drought, and it is probable that here, as in the case of the Stowell Evergreen grown at the Arlington farm in 1924, the normal rate of development was retarded from this cause and a higher temperature summation resulted.

In order to evaluate these results for future use it is necessary to know something about the minimum temperature base line for Crosby corn. A limited number of plantings of Crosby corn have been made at the Arlington farm, and their temperature requirements will be shown later; but it is not possible from the data to tell what is the minimum-temperature base line for this variety. It is well known, however, that Maine growers of sweet corn are narrowly restricted as to planting dates because of the short growing season. Too early planting results in the rotting of the seed in the ground, and late planting exposes the corn to the danger of killing frost before it arrives at canning maturity. Practical experience has shown that it is necessary for Maine growers to plant their corn at a time when the prevailing temperature is close to the minimum for this crop. On this basis, it is possible to determine reasonably closely the minimum temperature for Crosby corn.

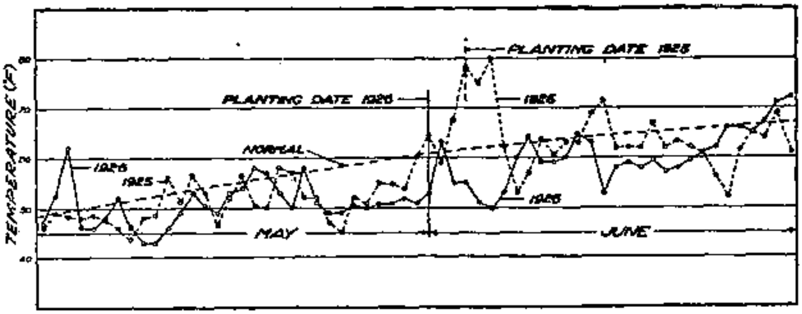

FIGURE 11.—Mean hourly temperature curves for Lewiston, Me., during May and June, 1925 and 1926, as recorded at the Union Water Power Co.'s gatehouse. The normal temperature curve for this station is also shown

In Figure 11 are shown the mean daily temperature curves based on hourly readings for Lewiston for May and June, 1925 and 1926, with the average date of planting each year.

For both seasons the temperature during May was, for the most part, below normal for that region. For about 10 days during the middle of the month the air temperature averaged well above 50° F. and then fell slightly below this point for a short time before swinging upward. Plantings were made shortly after the temperature began to move upward again. The practical experience of these farmers indicated an air temperature of close to 50° as unsafe for the germination of the corn, and a study of the chart shows that the soil temperature at the time of planting must have been fairly close to 50°. A personal communication from a representative of one of the corn-canning companies operating in this region states that normally May 25 is about the average planting date for this region. The normal temperature curve for this date stands at about 57°. It seems reasonable to conclude, therefore, that 55° air temperature or 50° soil temperature is close to the minimum-temperature base line for Crosby corn. Assuming this to be the case, it is found by reference to Tables 11 and 12 that the air-temperature requirement of Crosby corn for the period from planting to delivery of corn to the cannery averaged 26,713 degree-hours above 55° in 1925 and 24,584 degree-hours in 1926. For comparison with these results the data obtained from different strains of Crosby corn grown at the Arlington farm are presented in Table 13.

TABLE 13.—*Air-temperature summations for different strains of Crosby corn grown at the Arlington Experiment Farm, Rosslyn, Va., 1922, 1926, and 1927*

[Based on data for the period from planting to canning maturity]

Year and strain	Degree-hours above base line of—				
	40° F.	45° F.	50° F.	55° F.	60° F.
1922					
Early Crosby	65,274	55,588	45,893	36,227	28,700
1926					
Burnham & Morrill Clark strain (from Maine)	62,465	53,505	44,253	35,112	26,703
Crosby (from Minnesota)	65,226	55,686	46,054	36,433	27,504
1927					
Crosby No. 28697	66,593	56,393	46,203	36,118	26,486
Early Crosby No. 28693	66,022	55,942	45,872	35,898	26,352
Minnesota Crosby No. 28695	66,022	55,942	45,872	35,898	26,352
Average	65,267	55,509	45,691	35,948	26,683

Comparing the Maine-grown corn with that grown at the Arlington farm, it is seen that from the 55° F. base line the average summations are considerably less; that is, 24,584 degree-hours as against 35,948 degree-hours. These results, however, include data for several strains grown in different years in each case.

In order to get a strict comparison of the behavior of corn grown in Virginia and in Maine, attention is called to the data of the Burnham & Morrill Clark strains grown in these two regions from the same lot of seed. Comparison of the data from the 55° F. base line shows that corn grown in Maine reached canning maturity with a temperature summation of 24,967 degree-hours, as against 35,112 degree-hours for that grown at Arlington farm, a difference of 28.9 per cent. If comparison is made of the data at the lower base lines it is found that the difference becomes progressively less as lower base lines are used, until the two gradients cross, giving at the 40° base line a summation greater for the Maine-grown corn. This might seem to throw doubt on the validity of the use of the 55° base line in this consideration, but it must be noted that in Maine there is a greater accumulation of ineffective low temperature than in Virginia, and possibly a greater accumulation in ineffective high temperature in Virginia than in Maine, which would tend to explain, in part at least, these differences in results.

From the data presented it is concluded that for Crosby corn 55° F. is the most appropriate base line. From the use of this line with the Maine and Virginia data it appears, as has already been suggested, that the response to temperature conditions of the corn grown in Maine is distinctly different from that grown in Virginia. As factors probably important in contributing to this result may be mentioned difference in length of day (which provides for longer periods of photosynthetic activity), a lower rate of respiration under Maine conditions, and a better balance between photosynthesis and transportation of manufactured plant products, as suggested by Livingston and Livingston (*10*).

DATA FROM CORN GROWN IN NEW YORK

There remain to be considered only a few data on corn grown at Mount Morris, N. Y., during 1926. So few are the data that they would not be presented here but for the fact that they show again how much more economical of temperature are corns grown in the northern latitudes of the country. The variety here was Red-leaved Evergreen,[2] which was planted on June 1 and came to canning maturity on October 13. The air-temperature summations for this corn are

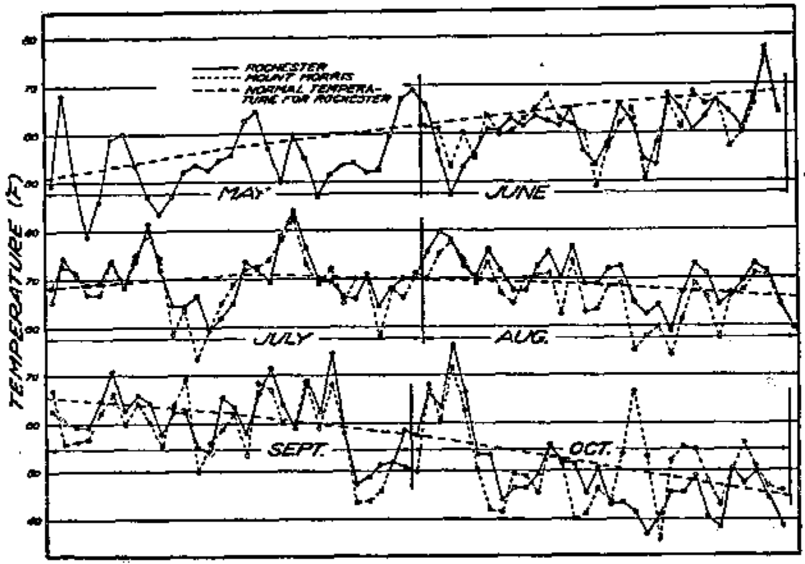

FIGURE 12.—Mean daily temperature curve for Rochester, N. Y., for the period from May 1 to October 31, 1926, inclusive, and for Mount Morris, N. Y., for the period from June 1 to October 31, inclusive, of the same year from data for Rochester taken from the U. S. Weather Bureau records and data for Mount Morris taken from field records

as follows: At 40° F., 75,113 degree-hours; at 45°, 59,129 degree-hours; at 50°, 43,673 degree-hours; at 55°, 29,404 degree-hours; at 60°, 16,868 degree-hours.

In order to interpret these figures properly it is necessary to know something of the minimum-temperature base line of this corn. It is regretted that more information on the temperature requirements of this particular variety in various parts of the country is not available, but a brief study of local conditions where this corn was grown serves to throw light on this point. In the present case temperature records were begun on the day of planting and continued through the growing season. In Figure 12 these records are charted; and to throw some light on conditions prior to the planting date, the records for Rochester, N. Y., where the nearest Weather Bureau station is located, are also charted for the season of 1926, and the normal

[2] According to information obtained from growers of this corn, it is a late variety closely resembling Stowell Evergreen.

temperature curve is also shown. The daily mean temperature at Rochester and Mount Morris averaged about the same during this season with the exception of August, when the Mount Morris temperatures averaged a little lower than those of Rochester. It is believed, therefore, that the normal temperature curve for Mount Morris would not differ greatly from that for Rochester.

This corn was planted when the air temperature was a little above 60° F., and during this season the temperature for the first three weeks of June averaged close to this temperature. A personal communication from a representative of one of the canning companies operating in this region states: "We have not been able to plant any corn here in the Mount Morris district much before May 20." Data from another source place the average planting date, prior to the invasion of the territory by the European corn borer, at about May 20. The chart shows that the normal temperature for this date is about 58.5°, only slightly below the average temperature of the first three weeks in June, 1926. While this does not prove the minimum air temperature of this corn to be 60°, it does indicate that this can not be far from the minimum. The summation above this base line was 16,868 degree-hours, which was far less than that of any variety grown at the Arlington farm during the years these studies have been carried on.

GENERAL DISCUSSION

The value of any system for determining the response of plants to their temperature environment must be dependent upon its appropriateness when applied to practical conditions. Experience has indicated that absolutely uniform and exact results are not to be expected from any system, for the reason that many and widely varying factors are involved, and it is extremely difficult if not impossible at the present stage of knowledge to evaluate the influence of any one factor in plant behavior as distinct from that of all other factors. The present use of the system of "remainder" indices and the determination of the minimum standard deviation from the mean summations above various base lines is not entirely satisfactory, since here, as in the use of other systems, it is impossible to rule out entirely the effect of prolonged drought and some other variable influencing factors, which, in the present case, tend to increase the standard deviation and obscure its significance. It is believed, however, that much of the objection to, and the inconsistencies of, the remainder system may be eliminated by the use of suitable temperature base lines, and it is believed that the present method of determining these base lines will be found useful and reasonably satisfactory in the study of crop behavior.

It is to be noted that a base line as here determined does not mean that absolutely no growth or development will take place below that base line; but it does serve as a practical zero point. It operates to eliminate the ineffectiveness of low temperatures and the inefficiency of temperatures close to the base line. The slight effectiveness of the temperatures below the base line is mathematically balanced by the inefficiency of the temperature just above the base line. It seems to be, therefore, the best compromise that can be obtained where all the environmental factors are taken into consideration.

It may be objected that the methods employed here in the calculation of the temperature requirements of corn are too laborious for general application to the study of various crops and that sufficiently satisfactory results might have been obtained in the present case by using the daily mean temperature as the basis of calculations rather than the hourly readings. It is true that the hourly readings are not generally available and daily means must often be used if studies of this kind are to be carried on. In the case of the Iowa and the New York data presented here, only daily maxima and minima were available. It is well known, however, that the mean daily temperature, representing as it does the average of the recorded maximum and minimum temperatures, does not always give an accurate measure of the amount of heat received from the sun during the day. In endeavoring to establish the proper minimum-temperature base lines for corn, therefore, the more laborious calculations were used, in the belief that the greatest possible accuracy was required. For crops having longer growing seasons or for those less sensitive to daily temperature variations closely comparable results would doubtless be given by the use of either daily means or hourly readings as the basis of calculations. No attempt has been made in the present case to check the differences with corn.

Criticism of the material presented here may also be lodged by plant physiologists and others on the ground that in the calculations of the summation data no account was taken of so-called temperature efficiencies. Price (*14*) was among the first to emphasize the possible relation of the Van't Hoff-Arrhenius principle concerning the velocity of chemical reactions as affected by changes in temperature to the response of plants to their climatic environment. He found the principle to hold generally for the opening of the flower buds of plums, peach, apple, and other fruits, and pictured maize seedlings germinated at different temperatures, which suggested that the principle might also hold for maize. Making use of this principle in their calculations, Livingston and Livingston (*10*) prepared a table of "efficiency indices" for temperatures between 40° and 99° F., and in a careful and extensive study they proceeded to compare the results obtained by the use of these indices with those derived by the use of the time-honored direct summation methods then in common use by phenologists. It appears very significant that the two methods employed for estimating temperature effectiveness gave results agreeing within a plus or minus variation no greater than 5 per cent for most of the area of the United States. Convinced of the soundness of the view that the rate of growth in plants is a function of the temperature, and supported by the observations of Lehenbauer (*8*) on the rate of growth in maize seedlings at different temperature levels, Livingston (*9*) later developed a new set of indices which, taking into account the Van't Hoff-Arrhenius principle, recognized not only a minimum and a maximum temperature for plant growth but also an optimum temperature beyond which the rate of growth was retarded progressively until the maximum was reached. These so-called "physiological" indices have been employed by various investigators engaged in the study of the temperature relations of plants. Reports of these studies, however, by no means confirm the uniform adaptability of these indices to the interpretation of practical field data. Thus, Appleman and Eaton (*1*) reported that the physiological indices did not furnish even an approximate criterion of the temperature efficiency for the ripening processes in sweet corn. The Van't Hoff-Arrhenius principle, however, was found operative, the so-called "efficiency" or "exponential" indices of Livingston and Livingston (*10*) heretofore mentioned proving useful for their study. "Direct" summations of degree-hour units, comparable to the "remainder" summations used in this bulletin but involving the use of 40° F. as the base line, showed slightly higher figures for the late than for the early crop, but the discrepancies were thought to be due in part to the conditions under which the temperature records were secured.

In this connection it should be remembered that conditions that stimulate growth may be very different from those that determine the length of the reproductive cycle in the plant. The present study is concerned with the reproductive cycle. The reproductive processes are preceded, of course, by a period of growth which may greatly affect the yield, but the rate of growth does not necessarily determine the length of the reproductive cycle. Furthermore, the growth response of seedlings to varying conditions of temperature may be very different from the growth response exhibited by plants approaching the period of reproduction. It seems doubtful, therefore, whether the results of Lehenbauer (*8*) are applicable to the processes here under consideration.

Of particular interest is the report of work done by Hanna (*6*) on North· estern dent corn (*Zea mays*) and Mammoth Russian sunflower (*Helianthus annuus*). This investigator made careful comparison of the various temperature efficiency indices in his analysis of the responses of these plants to climatic factors and found that corn gave the best correlation with temperature when remainder indices derived from temperatures above 10° C. (50° F.) were employed. Sunflowers gave the best correlation with temperature above 0° C. (32° F.). Noting a better correlation between the growth of corn and the physiological indices than was obtained with sunflowers, he made the highly important observation that "physiological temperature efficiency indices for expressing plant growth can be of little value unless derived from observations on the particular kind of plants under consideration." This work of Hanna confirmed the observation of Lehenbauer (*8*), which seems to have been entirely ignored in the development and use of the physiological indices, that the minimum temperature for corn was close to 12° to 14° C. (53.6° to 57.2° F.). The results presented here are in striking agreement with the findings of these investigators.

These physiological temperature-efficiency indices were developed for use primarily in the study of plant geography as related to climate, and it is probable that their application to the study of the response of specific crops to temperature was not anticipated. Their chief shortcoming for such use probably lies in the fact that 40° F. (4.4° C.) is not the minimum temperature of many plants and 89.6° F. (32° C.) does not coincide with the optimum of many of them. This is indicated not only by the results of the present study with corn but also by the findings of Hanna (*6*) with corn and sunflowers, mentioned above, of Tottingham (*15, 16*) with red clover (*Trifolium pratense*), buckwheat (*Polygonum fagopyrum*) and wheat (*Triticum vulgare*), and of Hardenburg (*7*), Bushnell (*4*), and others with potatoes (*Solanum tuberosum*). Although the Van't Hoff-Arrhenius principle seems not to have been considered by some of these latter workers in the interpretation of their experimental data, it seems reasonable to question, from the reports of their findings, whether this principle is applicable in the study of storage processes, particularly in some common forage and food plants. The optimum temperature for enzymic activity varies widely in nature, and temperature conditions well suited to vegetative developments in plants may be unfavorable for other physiological activities. That the rate of respiration varies with different temperatures is, of course, well known, and that this factor enters into storage relationships must be recognized.

Boswell (*2*), in the report of his study on the influence of temperature upon the growth and yield of garden peas, made use of summations above the base line of 40° F. He stated that peas showed little if any correlation between the total degree-hours of heat above 40° and the time required to reach blossoming, but rather showed that in a given season blossoming occurs upon the reception of a fairly constant amount of heat regardless of time. It is well known that peas for best growth require a lower temperature range than corn, and the 40° base line doubtless is close to the true minimum for this crop.

In a later paper Boswell (*3*) reported on a study of the temperature influence upon chemical composition and quality of peas, in which it was noted that no consistent relationship could be observed between mean temperature and chemical composition, but there was a very good correlation between temperature summations and the starch-sugar ratios. Results were not uniform for all the seasons in which the work was done, however, and strain differences, varying nutritional conditions, and differences in day length were offered as possible explanations.

Mention has been made in this bulletin of the evident slowing down of physiological processes in corn as the result of soil-moisture deficiency, and some data have been presented in support of this. During 1930 abundant opportunity was afforded to observe the effect of drought on plant processes, and conversations with physiologists have indicated that the slowing down of plant activity as a result of water deficiency has been widely noted.

The greatly differing temperature requirements of corn grown in northern sections of the country and that grown in the experiment plots in Virginia call for further brief consideration. In the discussion of this subject in connection with the examination of the Maine data, day length and the balance between photosynthetic activity and translocation of synthesized plant products as affected by temperature levels were mentioned as probably accounting for the more economical use of temperature by the Maine-grown corn. There remain to be considered two other factors that may have had some bearing on this result.

Reference has been made to the relation of temperature levels to respiration and storage processes in plants. Since the corn grown at the Arlington farm was grown within a climatic temperature range considerably above that of Maine and western New York, it is reasonable to assume a higher rate of respiration in the corn grown in Virginia, and consequently the use of a greater amount of heat by this corn. Such an assumption is in line with the observed facts. The second consideration has been suggested by the work of Long (*11*) on the relation of light to photosynthetic activity in plants. This worker found that not only was this activity affected by different degrees of light intensity but that the quality of the light also had a very definite effect upon the rate of photosynthesis. Red light was found to be much more favorable for photosynthesis than blue. Since the rays of the sun are more oblique in the northern latitudes than in the southern, normal sunlight there contains more of light from the red end of the spectrum than does that of the more southern sections of the country. How significant this possible factor is in plant activities is not known, but if significant at all its effect would be in the direction of the observed findings of the present study. This might help to explain also the more economical use of temperature by the late plantings of Virginia-grown corn which became increasingly apparent concomitantly with the shortening of the day.

SUMMARY

This bulletin records the results of studies on the response of different varieties and strains of sweet corn to varying temperature conditions. For this work use was made of official Weather Bureau and field temperature records and data derived from plantings of corn grown at the Arlington Experiment Farm, Rosslyn, Va., near Washington, D. C., during 1922, 1924, 1925, 1926, and 1927, and from corns grown in Iowa and Maine during 1925 and 1926 and in western New York in 1926.

By using the so-called "remainder" system, summations of the prevailing temperatures above various base lines have been calculated and the results expressed in terms of degree-hours (Fahrenheit). Wherever possible, hourly temperature readings rather than the daily mean were used as the basis of calculations.

An attempt has been made to determine the temperature base line most appropriate for use with the remainder system in studying the response of corn to temperature conditions, which has been accomplished by considering as most valid that base line the summations above which showed the smallest standard deviation from the mean for corns grown under widely varying temperature conditions. To obtain data suited for this purpose, plantings of Golden Bantam and Stowell Evergreen varieties were made at intervals of a week to 10 days during 1924 and 1927 at the Arlington Experiment Farm, and the behavior of these corns with relation to the varying seasonal conditions was determined. The applicability of these data to the problem under consideration has been shown by comparison with similar data from a hypothetical case giving theoretical values. The results are set forth in tables and illustrated by graphs.

Experimental findings have been found to agree significantly well with the theoretical, though conditions of drought, abnormally high and prolonged summer temperatures, variable day length, and other factors causing variations in the summation curves have in some cases increased the standard deviations and tended to obscure somewhat their real significance.

The evidence here set forth indicates that at least where the remainder system for studying the temperature response of sweet corn is used a 40° F. air-temperature base line is much too low and suggests

the probability that this temperature is considerably below the true physiological minimum for this crop.

The most satisfactory air-temperature base line was found to vary with different varieties and strains, in the case of those corns under study falling within the range of 50° to 60° F., indicating that the amount of heat required to bring sweet corn to canning maturity varies not only with different varieties but with strains within the varieties.

With the use of soil temperatures as the basis for calculations, the most satisfactory base lines were found to fall approximately 5° F. below those for air temperatures under conditions at the Arlington Experiment Farm.

The observation that some corns apparently have lower minimum temperature requirements than others suggests that not only may such corns be particularly adapted for growing in regions having short growing seasons but might be planted at decidedly earlier dates than are commonly set for planting in various regions.

Corn subjected to drought conditions did not show as great a developmental response to prevailing temperatures as the same variety and strain enjoying ample rainfall. Thus the amount of heat required to bring the corn to canning maturity appeared to be increased.

Corn arriving at canning maturity near the close of the season showed a lower summation of effective-temperature units than that maturing earlier in the season.

With the use of the same temperature base lines for the same varieties of corn grown in Maine and New York as at the Arlington Experiment Farm, it was found that the northern-grown corn came to canning maturity with a far smaller temperature-unit summation than that grown in Virginia. Corn of an identical strain grown in Maine and at the Arlington farm during the same season yielded results agreeing closely with those just mentioned. Differences in the rate of respiration in the corn growing within different temperature ranges, differences in the length of day permitting longer periods of photosynthetic activity in the northern regions, a better balance between photosynthesis and the transportation processes in the movement of manufactured plant products, and difference in light intensity and the quality of the sunlight are suggested as possible factors involved in this result.

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