

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

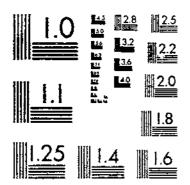
AgEcon Search http://ageconsearch.umn.edu aesearch@umn.edu

Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.



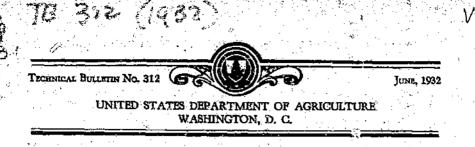
START

۹



1.0 1.0 1.1 1.1 1.25 1.4 1.4 1.6

MICROCOPY RESOLUTION TEST CHART NATIONAL BUREAU OF STANDARDS-1963-A MICROCOPY RESOLUTION TEST CHART NATIONAL BUREAU OF STANDARDS-1963-A



RESPONSE OF SWEET CORN TO VARYING TEM-PERATURES FROM TIME OF PLANTING TO CANNING MATURITY

By C. A. MAGOON, Senior Bacleriologisl, and CHARLES W. CULPEPPER, Physiologist, Division of Horticultural Crops and Diseases, Bureau of Plant Industry

CONTENTS

| Assults with Golden Battara in 1924 | Air-temperature summations. Soil-temperature summations. Results with Stowell Evergreen in 1024. Air-temperature summations. | 2 4 7 10 13 15 17 17 | Data from corn grown in New York General discussion | 22 24 26 32 33 |
|-------------------------------------|---|---|--|----------------------------|
|-------------------------------------|---|---|--|----------------------------|

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. 108322°-32---1

いいまたという

が日本時にある。またい

APL Lines

SOURCES OF DATA

ъź

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 While this temperature may serve fairly satisfactorily as standstill. 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 a³ constant temperatures, indicated the minimum temperature of corn to be near 12° to 14° C. (53.6° to 57.2° F.). More recently Erwin (δ) 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

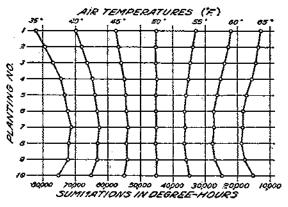


FIGURE 1.—Theoretical air-temperature summations in degree-hours above various base lines for Golden Bantam sweet corn planted at intervals of 10 days at the Arlington Experiment Farm, Rosslyn, Vs., beginning April 15 of a normal year. The data are based on the normal mean temperatures for this station,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

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 Fahrenheitscale was used because official Weather Bureau temperatures are presented as Fahrenheit values and field records are usually expressed in the same way.

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 degreehours was the temperature requirement to bring the corn to canning maturity. The results are presented in Table 1 and illustrated in Figure 1.

TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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 degies-hours above an appropriate base line is arbitrarily assumed to be a true summation for the corn used]

| | | Degree-hours above base line of- | | | | | | | | | | |
|---|--|--|--|---|--|---|--|--|--|--|--|--|
| Date of plant- Date of can ing maturit | 35° F. | 40° F. | 45° F. | 50° ¥. | 55° F. | 60° F. | 65° F. | | | | | |
| Apr. 15. July 28. Apr. 25. July 28. May 5. Suly 31. May 15. Aug. 4. June 4. Aug. 10. June 4. Aug. 17. June 4. Sept. 5. June 24. Sept. 18. July 4. Oct. 5. | 74, 448 73, 243 72, 216 71, 232 71, 976 72, 238 | 69, 744 67, 968 68, 240 64, 663 63, 888 63, 216 62, 472 63, 096 63, 168 65, 112 | 57, 384 56, 568 55, 680 54, 708 54, 528 54, 216 53, 712 54, 213 54, 048 65, 032 | 45, 021 45, 108 45, 100 44, 028 45, 153 45, 216 44, 962 45, 333 44, 928 44, 928 44, 928 | 32, 784 33, 768 34, 569 35, 808 35, 808 36, 216 38, 082 38, 456 35, 805 34, 872 | 21, 912 22, 920 24, 020 25, 248 25, 248 25, 248 27, 218 27, 278 27, 578 27, 782 27, 782 | 12, 936 13, 512 14, 376 15, 528 17, 668 18, 216 18, 322 18, 696 17, 668 15, 096 | | | | | |
| Mean summation Standard deviation | 74,887 | 64, 951 2, 375 | 55, 015 1, 186 | 45,080 141 | 35, 144 1, 179 | 25, 410 1, 971 | 16, 144 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 daylength 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

4

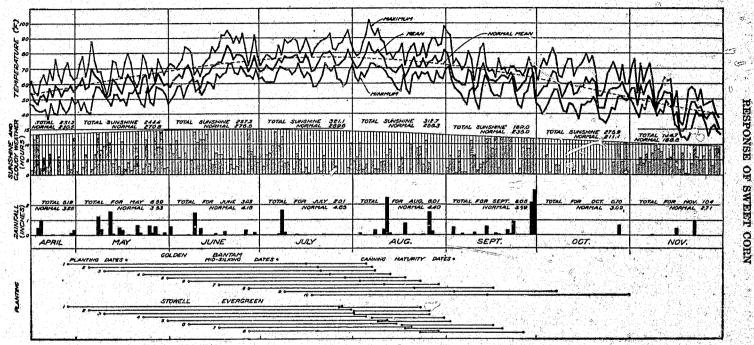


FIGURE 2.—Meteorological data for the season of 1924 at the Arlington Experiment Farm, Rosslyn, Va., and their relation to sweet-corn plantings. (See footnote to Table 5 for explanation of overlapping dates in the case of Stowell Evergreen)

S. 1

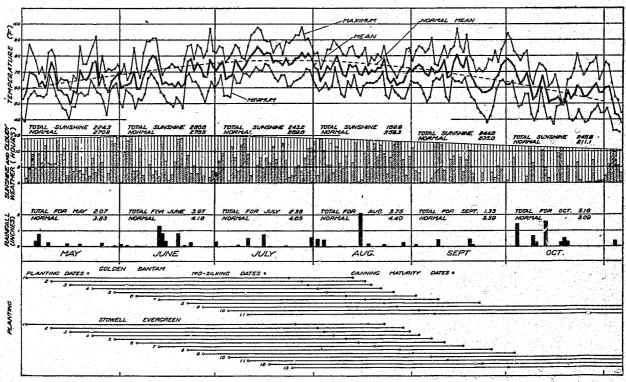
 $\mathfrak{a}_{\mathfrak{X}}$

ê S

534

CJT

0



 H^{*}

言語 な

23

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

0

0

13

SB.

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 rainles, 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 degreehours above the base lines 40°, 45°, 50°, 55°, and 60° F. for 10 plant-ings 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.

| Plant- | | | Canning maturity | Degree-ho | urs aboye ing to c | base line in anning ma | ndicated in aturity | om plant- | Degree-ho | urs above ing to | base line /r mid-silkin | ndicated in 8. | om plant- |
|---|---|---|------------------|---|---|---|--|---|--|--|---|--|--|
| ing No. | Date of planting | Mid-silking date | date | 40° F. | 45° ₽. | 50° F. | 55° F. | 60° F. | 40° F. | 45° F. | 50° F. | 55° F. | -c0° F. |
| 1 2 3 4 5 6 7 8 9 10 | Apr. 28 May 5 May 23 May 31 June 7 June 17 June 27 June 27 July 9 July 8 | July 16 July 20 July 20 July 24 July 29 Aug. 3 Aug. 11 Sept. 3 Sept. 14 | Aug. 5 | 68, 228 67, 240 65, 279 63, 901 63, 241 63, 127 61, 801 64, 131 64, 131 66, 033 67, 191 | 56, 182 55, 797 54, 322 53, 964 53, 634 53, 634 53, 749 52, 711 54, 301 55, 148 54, 779 | 44,558 44,719 43,685 44,170 44,085 44,170 44,085 44,492 44,15 44,688 43,339 | 33, 254 33, 815 33, 210 34, 332 34, 536 35, 067 35, 177 34, 865 34, 105 31, 876 | 23, 052 23, 830 23, 833 24, 833 25, 776 25, 581 24, 557 24, 557 24, 224 | 51, 234 51, 156 49, 133 46, 409 46, 450 46, 690 48, 125 46, 168 47, 871 46, 147 | 41, 622 41, 857 40, 320 38, 796 39, 207 39, 687 41, 388 39, 471 41, 051 39, 080 | 32, 429 32, 940 31, 844 31, 401 32, 067 32, 769 34, 707 32, 792 34, 208 34, 208 32, 118 | 23, 503 24, 213 24, 546 23, 962 24, 949 25, 832 27, 978 26, 044 27, 340 25, 105 | 15, 890 16, 386 16, 101 16, 881 17, 948 18, 864 21, 260 19, 411 20, 600 18, 467 |
| | an summation | | | 65, 023 2, 202 | 54, 459 1, 047 | 44, 244 454 | 34, 024 1, 022 | 24, 502 1, 308 | 47, 941 1, 981 | 40, 248 1, 149 | 82, 734 1, 042 | 25, 249 1, 546 | 18, 180 1, 881 |

5

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

TECHNICAL BULLETIN \$12, U.S. DEFT. OF AGRICULTURE

00

C

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

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-

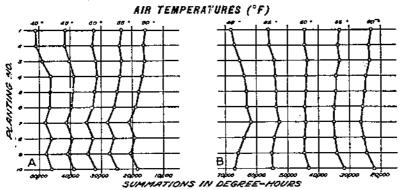


FIGURE 4.—Curves of air-temperature summations in degree-hours above various base lines for the periods, (A) from planting to mid-silking and (B) from planting to canning maturity, for 10 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during the season of 1924

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 minimumtemperature 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.

108322°---32-----2

÷~.

10 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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 midsilking. 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

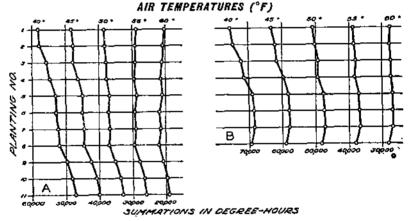


FIGURE 5.—Curves of air-temperature summations in degree hours above various base lines for 11 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-sliking and (B) for 8 plantings of the same series for the period from planting 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 degreehour summation above 60° for the first eight plantings is 27,413, with a standard deviation of only 437 degree-hours,

| Plant- | lant- ing Date of planting Mid-silking No. | | Canning maturity | Degree | | ve base li to canning | ne indicate maturity | ed from | Degree-hours above base line indicated from planting to mid-silking | | | | |
|---|---|--|---|--|--|--|--|--|--|---|---|--|---|
| No. | | date | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | |
| 1 2 3 4 5 6 7 8 9 10 11 | May 2 May 10 May 16 May 20 June 6 June 21 June 22 June 27 July 5 July 11 | July 24 July 28 July 30. Aug. 2. Aug. 5. Aug. 11. Aug. 17. Aug. 27. Aug. 27. Sept. 3. Sept. 8. | Aug. 13. Aug. 17. Aug. 17. Aug. 29. Aug. 26. Sept. 2. Sept. 9. Sept. 22. | 75, 694 74, 765 72, 259 71, 553 09, 016 68, 580 68, 328 69, 334 | 63, 264 62, 123 61, 651 59, 606 38, 336 58, 020 57, 788 58, 893 | 50, 890 50, 199 49, 308 49, 263 47, 666 47, 465 47, 210 48, 454 | 38, 808 38, 550 38, 053 38, 267 37, 110 36, 999 36, 738 38, 065 | 27, 735 27, 723 27, 467 27, 445 27, 035 27, 047 26, 772 28, 081 | 58, 179 57, 775 55, 858 54, 788 53, 121 53, 043 52, 290 52, 132 49, 812 49, 812 48, 091 47, 224 | 48, 209 47, 653 47, 770 46, 272 44, 961 45, 123 44, 490 44, 572 42, 492 40, 890 40, 144 | 38, 415 38, 249 37, 947 37, 778 36, 811 37, 208 36, 692 37, 012 35, 172 33, 691 33, 064 | 28,852 29,119 29,211 29,421 28,765 29,366 28,952 29,461 28,033 26,609 26,011 | 20, 255 20, 747 21, 060 21, 515 21, 090 21, 660 21, 670 22, 038 20, 754 19, 574 19, 232 |
| Me | an summation (8 plan ndard deviation (8 pla an summation (11 pla ndard deviation (11 pl | tings) ntings) ntings) ntings) antings) | • | 71, 191 2, 866 | 59, 969 • 2, 099 | 48, 807 1, 337 | 37, 823 772 | 27, 413 437 | 54, 648 2, 406 52, 938 8, 435 | 46, 139 1, 468 44, 785 -2, 589 | 37, 514 668 36, 549 1, 726 | 29, 143 266 28, 518 1, 135 | 21, 287 596 20, 882 859 |

1

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

12 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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 midwestern 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 midsilking 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.

RESPONSE OF SWEET CORN

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

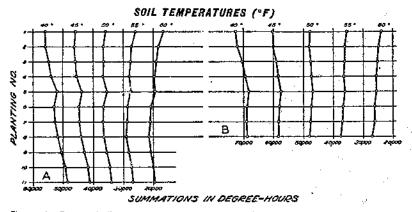


FIGURE 6.—Curves of soil-temperature summations in degree-hours above varions base lines for 11 plantings of Golden Bantam sweet corn grown at the Arlington Experiment Farm during 1927. (A) for the period from planting to mid-silking and (B) for 8 plantings of the same series for the period from planting 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

| Date of planting Mid-silking date | Canning maturity | Degree-h | ours above ing to c | base line in anning me | dicated fro iturity | m plant- | Degree-hours above base line indicated from planting to mid-silking | | | | | |
|---|--|--|--|---|--|--|---|---|---|--|---|---|
| e of planting | Mid-silking date | date | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | 40° F. | 45° F. | 50° F. | 55° F, . | . 60° F. |
| 2 10 16 23 8 18 12 27 5 | Sept. 3 | Aug. 13 Aug. 17 Aug. 19 Aug. 22 Aug. 26 Sept. 2. Sept. 9 Sept. 2 Sept. 2 | 72, 627 72, 011 70, 537 69, 426 68, 122 68, 811 68, 881 68, 839 | 60, 147 60, 011 59, 017 58, 386 57, 442 58, 028 58, 204 58, 204 58, 400 | 47, 812 48, 011 47, 497 47, 346 46, 762 47, 345 47, 623 47, 959 | \$5, 407 36, 143 36, 076 36, 308 36, 682 36, 683 36, 683 36, 843 37, 519 | 23, 968 24, 874 25, 051 25, 557 26, 075 26, 132 26, 987 | 55, 794 55, 838 54, 775 53, 938 51, 854 52, 701 52, 493 51, 602 50, 424 49, 103 48, 400 | 45,714, 46,238 45,655 45,208 43,604 44,721 44,573 44,132 42,984 41,212 | 35, 779 36, 638 36, 638 36, 635 36, 653 36, 653 36, 653 36, 653 36, 653 36, 572 35, 544 34, 613 | 25, 774 27, 170 21, 514 28, 020 27, 374 28, 641 28, 733 29, 012 28, 104 27, 193 27, 193 28, 104 27, 193 28, 811 | 16, 735 18, 301 18, 869 19, 369 19, 341 20, 663 20, 874 21, 452 20, 664 19, 831 19, 519 |
| umation (8 plant deviation (8 plan umation (11 plan | tings) ntings) ntings) | | 69, 915 1, 642 | 58, 704 955 | 47, 532 | 86, 380 630 | 25, 509 894 | 53, 643 1, 686 52, 466 2, 501 | 45, 003 868 44, 187 1, 626 | 86, 381 454 35, 920 944 | 27, 780 1, 059 27, 668 954 | 19, 480 1, 539 19, 628 1, 338 |
| | 0. 6. 3. 9. 9. 7. 7. 1. mation (8 planticity) (8 planticity) (8 planticity) (8 planticity) (8 planticity) (8 planticity) (1 planticit | 0 | July 24. Aug. 13. 0. July 28. Aug. 17. 6. July 30. Aug. 17. 3. Aug. 2 Aug. 19. 6. July 30. Aug. 19. 3. Aug. 5. Aug. 22. 6. Aug. 17. Sept. 2. 6. Aug. 17. Sept. 2. 7. Aug. 17. Sept. 9. 2. Aug. 17. Sept. 9. 2. Aug. 22. Sept. 2. 7. Sept. 3. Sept. 3. 1. Sept. 8. Sept. 8. | July 24 | July 24 | July 24 | July 24 | July 24 | July 24 | July 24 | July 24. Aug. 13. 72, 627 60, 147 47, 812 35, 407 23, 968 55, 794 45, 714 35, 779 0. July 24. Aug. 13. 72, 627 60, 147 47, 812 35, 407 23, 968 55, 794 45, 714 35, 779 0. July 28. Aug. 17. 72, 627 60, 147 47, 812 35, 407 23, 968 55, 794 45, 714 36, 633 0. July 28. Aug. 19. 70, 537 59, 017 47, 497 36, 076 25, 051 54, 775 45, 655 36, 633 36, 633 31 Aug. 25. Aug. 26. 68, 326 58, 386 47, 344 36, 605 26, 076 52, 269 51, 854 44, 721 36, 653 32. Aug. 25. Aug. 26. 68, 876 58, 026 47, 345 36, 605 26, 075 52, 269 51, 854 44, 721 36, 653 32. Aug. 11. Sept. 2. 68, 891 58, 200 47, 959 37, 510 26, 987 51, 602 <t< td=""><td>40° F. 45° F. 50° F. 55° F. 60° F. 40° F. 45° F. 55° F. 60° F. 40° F. 45° F. 55° F. 55° F. 60° F. 40° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 55° F. 60° F. 45° F. 55° F.</td></t<> | 40° F. 45° F. 50° F. 55° F. 60° F. 40° F. 45° F. 55° F. 60° F. 40° F. 45° F. 55° F. 55° F. 60° F. 40° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 55° F. 60° F. 45° F. 55° F. 55° F. 55° F. 60° F. 45° F. 55° F. |

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

5

i,

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.

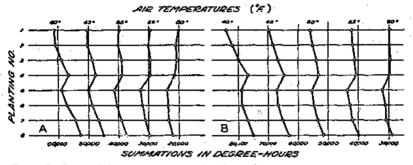


FIGURE 7.—Curves of air-temperature summations in degree-hours above various base lines for eight plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1924, (A) for the period from planting to mid-silking and (B) from planting to canning maturity

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 degreehours 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 1,964 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).

| Flant- ing | Date of planting | Date of planting Mid-silking date Period from mid silking to canning | | | | ve base lir anning ma | | Degree-hours above base line indicated from | | | | | |
|---------------|--|--|--|--|--|--|--|--|--|--|--|--|--|
| No., | Late of building | MIG-SHAING GOV | maturity 1 | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. |
| 12345078 | Apr. 28 May 5 May 10 May 23 June 7 June 17 June 27 | July 28. July 31. Aug. 1. Aug. 5. Aug. 12. Aug. 16. Aug. 20. Aug. 20. | July 27 to Aug. 23 Aug. 1 to 26 Aug. 7 to 31 Aug. 9 to Sept. 2 Aug. 17 to Sept. 16 Aug. 18 to Sept. 19 Aug. 23 to Sept. 26 | 84, 085 82, 127 79, 998 76, 888 78, 961 78, 849 76, 913 75, 071 | 69, 728 68, 426 66, 783 64, 853 67, 106 66, 699 65, 143 63, 205 | 55, 846 55, 117 53, 915 53, 087 55, 386 54, 749 53, 541 51, 535 | 42, 093 41, 865 41, 092 40, 842 43, 862 42, 728 41, 900 39, 857 | 29, 630 29, 677 29, 286 29, 680 31, 975 31, 138 80, 821 28, 840 | 61, 351 60, 997 58, 868 58, 571 58, 868 57, 215 54, 430 52, 663 | 50, 259 50, 388 48, 745 47, 524 50, 001 48, 778 46, 633 46, 006 | 39, 626 40, 141 38, 939 38, 696 41, 221 40, 431 38, 864 37, 427 | 29, 281 30, 096 29, 323 27, 522 32, 566 32, 033 31, 046 29, 659 | 20, 019 20, 951 20, 560 21, 253 23, 802 23, 641 23, 315 22, 066 |
| Me Sta | an summation ndard deviation | | | 79, 111 2, 947 | 66, 493 2, 071 | 54, 147 1, 417 | 41, 755 1, 171 | 80, 131'. 1, 054 | 57, 620 3, 034 | 48, 417 1, 913 | 39, 418 1, 186 | 20, 438 , 1, 289 | 21, 958 1, 476 |

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

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 chamical analyses along with the field records to establish the exact periods to be summated.

1

ULTURE

16

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

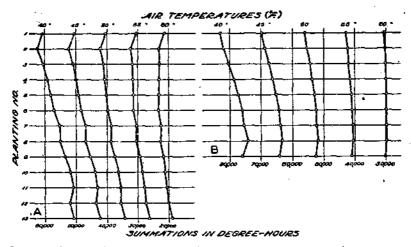


FIGURE 8.—Curves of air-temperature summations in degree-hours above various base lines for 13 plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for nine plantings of the same series for the period from 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.

108322°-32-3

| ant- | Date of planting Mid-silking date Canning | | | Degree | -hours abo planting t | vé base lin co canning | e indicated maturity | 1 from | Degree-hours above base line indicated from planting to mid-silking | | | | |
|---|---|---|---|---|---|--|---|---|---|--|--|--|--|
| ng To, | Date of planting | Mid-silking date | Canning maturity date | 40° F. | 45° F. | 619 F. | 55° F. | 60° F. | 40° F. | 45° F. | 50° F. | 55°≥F. | 60° F. |
| 1 2 3 4 5 6 7 8 9 10 11 12 13 | May 16 May 23 May 30 | Aug. 2. Aug. 4. Aug. 7. Aug. 11. Aug. 11. Aug. 20. Aug. 20. Aug. 28. Sept. 1. Sept. 7. | Aug. 31 Sept. 3 Sept. 7 Sept. 11 Sept. 17 Sept. 26 | 80, 270 78, 738 77, 237 76, 050 75, 536 74, 152 76, 027 | 69, 605 88, 682 67, 336 66, 262 65, 117 64, 200 63, 895 63, 267 64, 195 | 56, 031 55, 318 54, 439 53, 808 53, 808 53, 808 53, 808 53, 808 53, 808 52, 258 51, 784 52, 474 | 42, 749 42, 241 41, 058 41, 508 41, 508 40, 880 40, 720 40, 482 40, 957 | 30, 497 30, 085 29, 688 29, 695 29, 695 29, 826 29, 729 29, 729 29, 995 | 00, 792 62, 552 69, 545 59, 238 57, 904 56, 654 55, 172 55, 680 53, 540 53, 540 53, 540 51, 827 50, 903 51, 815 50, 650 | 50, 522 52, 378 50, 851 50, 002 49, 084 48, 444 46, 920 45, 500 44, 027 43, 223 43, 656 42, 415 | 40, 308 42, 254 41, 194 40, 788 40, 214 39, 029 38, 614 38, 760 37, 460 38, 227 35, 543 35, 543 35, 540 34, 297 | 30, 385 32, 404 31, 738 31, 711 31, 448 30, 394 30, 618 29, 445 28, 455 27, 580 27, 545 28, 372 | 21, 42 23, 31 23, 36 23, 69 23, 47 23, 47 23, 47 21, 77 20, 55 18, 91 18, 91 |
| Me Sta Me Sta | an summation (9 plant ndard devlation (9 plan an summation (13 plan ndard devlation (13 plan | ings) ntings) ntings) antings) | • | 78, 150 3, 140 | 65, 850 2, 255 | 53, 517 1, 474 | 41, 391 771 | 29, 924 250 | 57, 983 3, 041 55, 928 4, 070 | 48, 955 2, 221 47, 224 3, 272 | 39, 947 1, 464 38, 648 2, 521 | 81, 070 916 29, 992 1, 894 | 22, 64 61 21, 88 1, 42 |

| ŕ | TABLE 6.—Air-temperature | summations f | or Stowell | Evergreen | sweel corn gro | own at the At | lington Exp | periment F | arm, 192 | 7 |
|---|--------------------------|----------------|------------|--------------|-----------------|---------------|-------------|------------|----------|---|
| | TABLE 0 to remperature | ounineuronio j | or Didagon | Liver yi con | 00000 00110 910 | | | | | |

In the figures for the planting to mid-silking period, irregularities With the exception of the figures for the first planting, are noted. 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

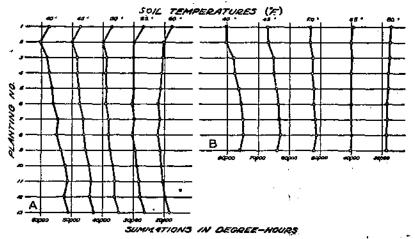


FIGURE 9.—Curves of soil-temperature summations in degree-hours above various base lines for 13 plantings of Stowell Evergreen sweet corn grown at the Arlington Experiment Farm during 1927, (A) for the period from planting to mid-silking and (B) for nine plantings of the same series for the period from 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 require-

ment 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. Wh this indicates strain differences in seed may be questioned. Whether 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 symmations above the various base lines for Stowell Evergreen in 1927 are presented in Table 7 and Figure 9.

| int- | Date of planting | Mid-silking date | Canning maturity* | Degree | hours abo planting to | o canning | e indicated maturity | l from | Degree | hours abo plantin | g to mid-s | e indicateo liking | l from |
|---|--|--|---|--|---|---|--|--|---|---|---|---|--|
| ng Io. | Date of planting | Mid-silking date | date | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. | 40°. F. | 45° F. | 50° F. | 55° F. | 60° F, |
| 1 2 3 4 5 6 7 8 9 10 11 12 | May 2 May 10 May 16 May 23 June 6 June 22 June 22 June 27 July 5 July 11 July 18 | Aug. 7. Aug. 11. Aug. 15. Aug. 20. Aug. 28. Sept. 1. Sept. 12. Sept. 12. Sept. 23. | Sept. 7 Sept. 11 Sept. 17 Sept. 26 Oct. 3 | 78,040 ,77,005 ,70,443 75,403 75,014 ,74,896 ,76,026 | 66, 680 86, 843 65, 200 65, 125 64, 326 63, 635 63, 635 63, 635 63, 376 62, 831 64, 148 | 53, 145 53, 403 52, 360 52, 645 52, 205 52, 075 51, 736 51, 311 52, 208 | 39, 540 40, 085 39, 940 40, 107 40, 107 40, 215 40, 215 40, 096 40, 009 40, 419 | 26,901 27,391 27,483 27,884 28,000 28,445 28,425 21,514 28,707 | 57, 516 60, 266 57, 987 57, 641 56, 603 54, 683 54, 683 54, 683 54, 683 54, 775 53, 636 54, 163 51, 359 51, 359 51, 168 | 47,2888 48,387 48,383 487,443 487,443 45,383 45,383 45,383 45,383 45,383 45,383 44,43,383 45,383 44,43,435 44,43,383 44,43,43544,43,435 44,43,435 44,43,43544,43,435 44,43,435 44,43,43544,435 44,43,435 44,43544,435 44,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,43544,435 44,45544,455 44,45544,455 44,45544,455 44,45544,455 44,45545 44,45545 44,45545 44,455 44,45545 44,45545 44,455 44,45545 44,455 44,45545 44,455 44,45545 44,455 44,45545 44,455 455 455 455 455 455 455 455 45 | 87, 121 30, 868 38, 787 39, 101 38, 933 99, 023 38, 128 37, 558 35, 569 36, 086 34, 611 | 26, 870 29, 768 29, 607 29, 923 30, 053 30, 603 29, 848 30, 295 29, 516 28, 765 28, 319 27, 928 26, 362 | 17,53 20,33 20,85 21,30 22,00 22,00 22,14 21,44 20,5 19,7 18,2 |
| St | July 25 ean summation (9 plan andard deviation (9 pla ean summation (13 pla | mtings) | | 77, 129 2, 099 | 04, 685 1, 403 | 52, 350 650 | 40,063 238 | 27,972 611 | 58, 598 2, 047 55, 112 2, 872 | 47, 511 1, 36 40, 508 2, 130 | 28,525 858 37,691 1,536 | 25,602 1,056 29,061 1,322 | 20,8 1,3 20,5 1,3 |

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

C

8

20

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 38,525degree-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 That varieties differ in their time requirements for growth and also. 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 daylength 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

| Year and variety | · Di | etteć-pónus | sbove ba | se line ci | |
|---|--|--|--|---|--|
| Ten and Asters | 40° F. | 45° F. | 50° F. | 55° F. | |
| 1922 | · · · · · | | ······ | [] | |
| Golden Bantam | 62,067 60,853 67,818 63,950 65,821 65,921 63,905 67,261 69,044 71,934 | 50, 187 52, 861 51, 997 57, 772 54, 624 56, 135 57, 455 59, 155 59, 155 59, 155 61, 408 61, 524 58, 746 63, 823 | 41,452 43,456 43,152 47,717 45,244 47,540 48,244 47,680 48,703 50,859 48,571 52,808 | 36, 769 35, 933 37, 849 38, 829 38, 829 38, 552 40, 382 | 24, 179 25, 413 25, 596 27, 804 26, 773 26, 728 28, 169 28, 512 28, 662 20, 790 23, 380 30, 973 |
| Goldan Bantam (Stokes) Stowell Evergreen (Stokes) Guatemalan (U. S. D. A.) Second Early Adams (dent; Bolgiano) 1928 | | 54, 397 63, 061 77, 749 56, 478 | 45, 157 54, 021 64, 274 40, 998 | 35, 931 42, 997 51, 149 37, 532 | 26, 861 32, 219 38, 399 28, 222 |
| Golden Bantanı (Stokes) Stowell Evergreen (Iowa) Stowell Evergreen (Arlington Experiment Farm) Comtry Gentleman (Iowa) | 64, 308 79, 425 81, 337 74, 610 | 54, 950 67, 547 69, 219 63, 608 | 45, 858 55, 635 57, 067 82, 535 | 38, 177 43, 734 44, 923 41, 475 | 27, 488 32, 523 33, 476 81, 106 |

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

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 24 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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

| | Ð | egree-hour | s above ba | se lize of | - |
|-----------------------------|--|--|---|--|--|
| Variety and strain | 40° F. | 45° F. | 50° F. | 55° F.\ | 60° F. |
| Country Gentlemau: No. 1 | 74, 019 72, 769 74, 605 68, 491 68, 491 70, 893 | 62, 544 61, 610 63, 010 58, 170 68, 170 60, 212 | 51, 181 50, 194 51, 552 47, 851 47, 851 49, 533 | 39, 999 39, 507 40, 255 37, 582 37, 582 38, 904 | 29, 350 29, 025 28, 539 27, 718 27, 718 23, 681 |

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

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 sam-

pling 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 tem-perature 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.

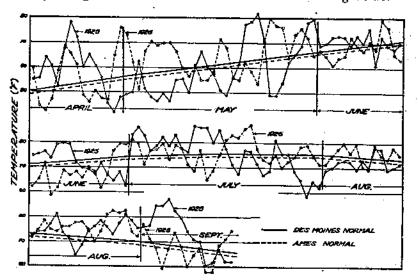


FIGURE 10.—Mean daily temperature curves for Des Moines, Iowa, during the period from April 16 to September 15, Inclusive, for the years 1925 and 1926. Curves for the normal mean temperatures for Des Moines and Ames, Iowa, are also shown. (Data from U. S. Weather Bureau records)

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

 and 1926

| V | Degree-hours above base line of- | | | | | | | | | |
|---|--|--|--|--|--|--|--|--|--|--|
| Year and variety | 40° F. | 45° F. | ′ 50° F. | 55° F. | 60° F. | | | | | |
| 1925 Golden Bantam Golden Giant. Golden Evergreen. Stowell Evergreen. | 73, 856 82, 784 87, 644 88, 736 | 61, 858 69, 756 73, 824 74, 806 | 50, 060 56, 338 59, 626 60, 418 | 39, 122 44, 078 46, 766 47, 510 | 28, 164 31, 800 33, 768 34, 392 | | | | | |
| 1926 Golden Bantam Country Gentleman | 67, 620 82, 476 91, 848 | 56, 892 69, 228 77, 0 76 | 46, 020 56, 796 63, 084 | 35, 256 43, 992 48, 720 | 25, 020 31, 716 34, 908 | | | | | |

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

26 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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 It is inevitable, therefore, that the summations for these station. 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 11Air | temperature summations for different strains of Crosby sweet corn | 3 |
|-------------|---|---|
| | grown near Auburn, Me. | - |

| Strain and farm | Degree-hours above base line of- | | | | | | |
|---------------------------------|----------------------------------|---------|---------|-------------|--------|--|--|
| Susin and Iarm | 40° F. | 45° F. | 50° F. | 55° F. | 00° F. | | |
| Burnham & Morrill Clark strain: | | | | - <u></u> . | | | |
| James farm | 70, 007 | 55, 642 | 41.001 | 28, 560 | 17, 63 | | |
| Sanborn farm | 69,816 | 55, 535 | 41, 914 | 28, 550 | 17, 53 | | |
| Sarly Groshy strain: | | | | | 11,00 | | |
| Rodmond farm | 59, 506 | 47, 498 | 36.013 | 24, 512 | 15.27 | | |
| | 67, 534 | 53,856 | 40, 888 | 28,063 | 17, 32 | | |
| illis strain: | - | | | , | | | |
| Packard farm | 63, 621 | 51, 682 | 39,070 | 26, 986 | 16, 76 | | |
| Flanders farm | 62,565 | 49,833 | 37, 698 | 25, 627 | 15, 57 | | |
| TATOMOL IRLIN | 67, 458 | 53, 850 | 40,844 | 27, 928 | 17, 22 | | |
| 'inu strain: | | . 1 | | | | | |
| Taber farm | 59, 664 | 47, 845 | 36, 554 | 25,080 | 15, 35 | | |
| Osgood farm. Harper farm | 61, 851 | 49, 249 | 37, 301 | 25, 363 | 15,41 | | |
| marper larm | 63, 401 | 50, 742 | 38, 610 | 26,456 | 16, 32 | | |
| A verage | 64, 542 | 51, 513 | 39, 085 | 26.713 | 10.43 | | |

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

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.

TECHNICAL BULLETIN \$12, U.S. DEPT. OF AGRICULTURE.

TABLE 12.—Temperature requirements of different strains of Crosby corn grown in Maine, 1928

| Based on temperature data | for Lewiston for the j | period from plan | ting to canning | ; metarity] |
|---------------------------|------------------------|------------------|-----------------|-------------|
| | | 1 | | |

| | | Degree haurs above base line of | | | | | |
|---|---|--|--|--|---|--|--|
| Strain and Iscallty | Field No. | 40° F. | 40° F. 45° F. | | 55° F. | 60° F. | |
| Ellis strain: Dirfeid | 12346078910111 111131141518 11718 | 21 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 | 51, 918, 65, 958, 61, 118, 61, 311, 62, 729, 62, 729, 62, 729, 64, 839, 64, 839, 64, 839, 64, 839, 65, 835, 65, 855, 65, 914, 66, 914, 67, 915, 61, 914, 61, 914, 914, 914, 914, 914, 914, 914, 914, | 900 577 580 577 580 577 580 577 580 577 580 577 580 577 580 577 580 577 580 577 580 577 577 577 577 577 577 577 577 577 57 | 25, 220 25, 152 24, 345 25, 344 25, 351 25, 324 25, 325 25, 124 24, 785 24, 785 24, 785 24, 785 24, 785 24, 785 24, 785 24, 862 25, 117 | 14, 884 14, 871 14, 881 14, 984 14, 233 14, 276 14, 890 14, 597 14, 890 14, 596 14, 596 14, 596 14, 596 14, 596 14, 596 14, 597 14, 596 14, 597 | |
| Average | | 65, 029 | 50, 958 | 37, 393 | 24, 925 | 14, 787 | |
| Livermore Falls | 1 2 3 4 5 6 7 | 61, 016 63, 747 64, 782 61, 494 64, 880 63, 610 64, 127 | 48,033 50,112 50,684 48,571 50,509 50,320 50,789 | 35, 435 38, 965 37, 331 35, 896 87, 381 37, 031 37, 307 | 23, 800 24, 658 24, 851 24, 211 24, 976 24, 801 24, 937 | 14, 171 16, 602 14, 800 14, 470 14, 747 14, 710 14, 772 | |
| Average | | 63, 401 | 49, 859 | 36, 762 | 24, 619 | 14, 010 | |
| North Turger. | 1 2 3 4 5 6 7 8 9 10 | 60,232 82,520 64,199 61,876 85,878 85,878 85,878 81,194 61,194 61,194 63,729 | 48, 103 49, 559 50, 608 49, 957 49, 238 51, 915 50, 161 50, 837 48, 095 50, 366 | 35, 599 36, 574 36, 938 36, 63 36, 249 37, 833 36, 932 36, 932 36, 932 35, 281 36, 783 | 24, 045 24, 602 24, 613 24, 567 24, 335 25, 196 24, 784 24, 652 23, 708 24, 538 | 14, 358 14, 642 14, 556 14, 541 14, 441 14, 916 14, 706 14, 706 14, 136 14, 136 | |
| Average | | 62, 989 | 49, 874 | 36, 575 | 24, 488 | 14, 637 | |
| Anbhn | 1 2 3 4 5 6 | 58, 647 62, 733 67, 606 60, 242 63, 729 61, 482 | 48, 842 49, 784 52, 774 47, 764 50, 366 48, 761 | 34, 658 36, 571 38, 281 35, 100 36, 783 36, 016 | 23, 419 24, 478 25, 341 23, 630 24, 538 24, 279 | 13, 998 14, 473 14, 946 14, 122 14, 530 14, 492 | |
| Average | | 62, 407 | 49, 281 | 36, 234 | 24, 281 | 14,42 | |
| Average for Ellis strain | - | 63, 870 | 60, 276 | 36, 672 | 24,672 | 34,622 | |
| Burnham & Morrell Olark strain: North Turner | - 1 2 3 4 | 63, 654 65, 232 63, 962 69, 132 | 50, 761 53, 771 50, 409 53, 930 | 38, 418 38, 415 37, 031 38, 455 | 24, 479 25, 388 24, 801 25, 416 | 14, 612 14, 961 14, 711 14, 711 14, 991 | |
| A verage | | 65, 500 | 52, 218 | 37, 579 | 25, 016 | 14,81 | |
| Anburn | 1 2 3 | 65, 332 68, 156 62, 692 | 51, 439 54, 103 49, 559 | 37, 357 38, 281 36, 574 | 24,862 25,241 24,602 | 14, 78 14, 94 14, 64 | |
| Average | - | 65, 393 | 51, 700 | 37, 404 | 24, 901 | 14, 79 | |
| Average for Burnham & Morrill Clark | | 16 ° 1 | $\Gamma \rightarrow$ | 1 | 24, 987 | 14, 60 | |

28

RESPONSE OF SWEET CORN

| Strain and locality | Field | 1 | Degree-hou | rs above b | ase line of- | |
|---|---|---|---|--|--|---|
| 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - 1977 - | No. | 40° F. | 45° F. | 50° F. | 55° F. | 60° F. |
| Early Crosby siralà: Livermore Falls. | - 12 | 65, 332 68, 006 | 51, 439 51, 813 | 37, 357 37, 751 | 24, 926 , 25, 192 | 14 757 14 910 |
| A vorage | | 65, 669 | 51,676 | 37, 554 | 25, 059 | 14, 851 |
| North Turner. | | 64, 982 66, 908 | 51, 209 51, 466 | 37, 231 37, 350 | 24, 901 24, 775 | 14,770 14,617 |
| Average | · · · · · · · · · · · · · · · · · · · | 63, 495 | \$1, 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 | 37,049 | . 24, 719 | 14, 650 |
| Finn strain: Livermore Falls | 23 | 60, 352 66, 901 63, 732 | 48, 029 52, 289 51, 809 | 34, 916 38, 032 37, 381 | 23, 549 25, 232 24, 976 | 14,'093 14,886 14,815 |
| Average | | 64, 328 | 50, 709 | 36, 776 | 24, 586 | 14, 598 |
| North Turner | 1 2 3 4 5 6 7 8 9 10 | 64, 227 61, 261 62, 256 61, 654 64, 652 84, 003 62, 986 65, 059 61, 602 | 50, 274 48, 449 49, 311 48, 781 50, 698 50, 448 49, 275 50, 972 50, 972 50, 995 48, 353 | 36, 645 85, 742 36, 475 36, 016 36, 938 37, 016 37, 016 37, 016 37, 058 37, 058 37, 205 35, 375 | 24, 422 24, 660 24, 585 24, 279 24, 613 24, 733 24, 733 23, 916 24, 627 24, 781 24, 781 23, 722 | 14, 481 14, 358 14, 640 14, 492 14, 556 14, 617 14, 176 14, 617 14, 136 |
| A verage | | 63, 297 | 49, 746 | 36, 438 | 24, 374 | 14, 463 |
| Roake strain: Auburn | 1 2 3 4 5 | 60, 242 60, 584 61, 146 61, 402 63, 041 | 47, 542 47, 764 48, 128 48, 291 49, 212 | 34, 967 35, 100 35, 305 36, 395 35, 776 | 23, 581 23, 6.0 23, 711 23, 749 23, 885 | 14, 100 14, 123 14, 135 14, 141 14, 208 |
| A verage | | 61, 283 | 48, 187 | 35, 309 | 23, 707 | 14, 141 |
| Martin strain: Aubura | | 61, 769 | 48, 735 | 35, 847 | 24, 078 | 14, 322 |
| Grand average | | 63, 816 | 50, 264 | 36, 644 | 24, 684 | 14, 581 |

 TABLE 12.—Temperature requirements of different strains of Crosby corn grown in Maine, 1986—Continued

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 degreehours between the group nearest to and that farthest from the recording station.

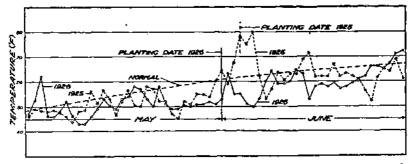
The temperature requirements of the different strains did not vary widely, though the Roake corn used somewhat less heat than any of the others.

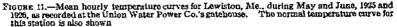
In comparing the averages for this season (1926) with those for 1925 it is seen that all strains matured with less heat in 1926 than they required the previous year. It is possible that the smaller number of observations in 1925 may be partly responsible for this variation, but it is not believed that this accounts for all the difference. The 1925 season in this region was one including prolonged drought,

30 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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.





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 corncanning 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

RESPONSE OF BWEET CORN

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

| · · · · · · · · · · · · | Degree-hours above base line of- | | | | | |
|--|----------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--|
| Year and strain | 40° F. | 45° F. | 50° F. | 55° F. ' | 60° F. | |
| 1922 Early Crosby | 65, 274 | 55, 588 | 45, 893 | 36, 227 | 28, 700 | |
| Burnham & Morrill Clark strain (from Maine) Crosby (from Minnesota) | 62, 465 65, 226 | 53, 505 55, 686 | 44, 253 46, 054 | 35, 112 36, 433 | 28, 708 27, 504 | |
| 1927 Crosby No. 28697 Early Crosby No. 28683 Minnesota Crosby No. 28685 | 66, 593 66, 022 66, 022 | 56, 393 55, 942 55, 942 | 46, 203 45, 872 45, 872 | 36, 118 35, 898 35, 898 | 26, 486 26, 352 26, 352 | |
| Average | 65, 267 | 55, 509 | 45, 691 | 35, 948 | 26, 58 | |

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

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

32 TECHNICAL BULLETIN 312, U. S. DEPT. OF AGRICULTURE

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

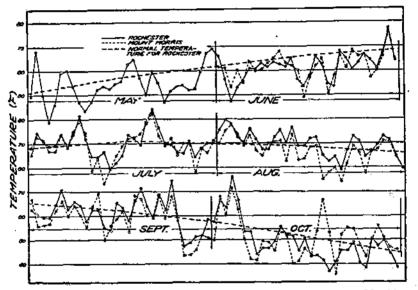


FIGURE 12.—Mean daily temperature curve for Rochester, N. Y., for the period from May 1 to October 31, 1920, inclusive, and for Mount Morris, N. Y., for the period from June 1 to October 31, inclusive, of the same year from data for Rochester taken from the U.S. Weather Bureau records and data for Mount Morris taken from field records

as follows: At 40° F., 75,113 degree-hours; at 45°, 59,129 degreehours; 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

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 The chart shows that the normal temperature for this date is 20. 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 The present use of the system of "remainder" indices and factors 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.

34 TECHNICAL BULLÉTIN 312, U. S. DEPT. OF AGRICULTURE

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 lows 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.

「日本のないというないないない」というないないできょうとうない

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 (\mathcal{S}) 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_{γ}) 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.

と、 はない とうない ない ない

and the second second of the second second

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) This on the relation of light to photosynthetic activity in plants. 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 How significant this possible factor is in plant activities is country. 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.

and the stand of the stand

. .

行業者のない

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. То 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 condi-The applicability of these data to the problem tions was determined. 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

38 TECHNICAL BULLETIN 312, U. S. DEPT, OF AGRICULTURE

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. 4

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.

LITERATURE CITED

| 1 | } 4 | APPLEMAN, | . C. | O., | and | Е | ATON. | S. | V. |
|---|-----|-----------|------|-----|-----|---|-------|----|----|
| | | | | | | | | | |

1921. EVALUATION OF CLIMATIC TEMPERATURE EFMICIENCY FOR RIPENING PROCESSES IN SWEETCORN. JOUR. Agr. Research 20:795-805, illus.

(2) BOSWELL, V. R.
 (2) 1927. THE INFLUENCE OF TEMPERATURE UPON THE GROWTH AND YIELD OF GARDEN PEAS. Amer. Soc. Hort. Sci. Proc. (1926) 23: 162-168.

- 1929. TEMPERATURE INFLUENCE UPON CHEMICAL COMPOSITION AND QUAL-ITY OF PEAS (PISUM SATIVUM, L.) Amer. Soc. Hort. Sci. Proc. (1928) 25:21-26.
- (4) BUSHNELL, J.
 - 1925. THE RELATION OF TEMPERATURE TO GROWTH AND RESPIRATION IN THE POTATO PLANT. Minn. Agr. Expt. Sta. Tech. Bul. 34, 29 p., illus.
- (5) ERWIN, A. T.
 - 1929. CLIMATIC AND VARIETAL FACTORS IN PUMPKIN PRODUCTION. Canner 68 (10, pt. 2) (convention number):71-72.
- (6) HANNA, W. F.

1924. GROWTH OF CORN AND SUNFLOWERS IN RELATION TO CLIMATIC CONDITIONS. Bot. Gaz. 78:200-214, illus.

(7) HARDENBURG, E. V.

[1924.] ECOLOGICAL FACTORS AFFECTING TUBER-SET IN POTATOES. Potato Assoc. Amer. Proc. (1923) 10:165-172.

- (8) LEHENBAUER, P. A.
 - 1914. GROWTH OF MAIZE SEEDLINGS IN RELATION TO TEMPERATURE. Physiol. Researches 1:247-288, illus.
- (9) LIVINGSTON, B. E.
 - 1916. PHYSIOLOGICAL TEMPERATURE INDICES FOR THE STUDY OF PLANT GROWTH IN RELATION TO CLIMATIC CONDITIONS. Physiol. Researches 1:399-420, illus.
- (10) ~ - and LIVINGSTON, G. J.
- 1913. TEMPERATURE COEFFICIENTS IN PLANT GEOGRAPHY AND CLIMA-TOLOGY. Bot. Gaz. 56:349-375, illus.
- (11) LONG, F. L.

1919. THE QUANTIFATIVE DETERMINATION OF PHOTOSYNTHETIC ACTIVITY IN PLANTS. Physiol. Researches 2:277-300.

- (12) MACDOUGAL, D. T.
 - . 1902. THE TEMPERATURE OF THE SOIL. JOUR. N. Y. Bot. Gard, 3: 125-131, illus.

(13) MAGOON, C. A., and CULPEPPER, C. W. 1926. THE RELATION OF SEASONAL PACTORS TO QUALITY IN SWEET CORN. Jour. Agr. Research 33: 1043-1072, illus.

(14) PRICE, H. L.

1911. THE APPLICATION OF METEOROLOGICAL DATA IN THE STUDY OF PHYSIOLOGICAL CONSTANTS. Va. Agr. Expt. Sta. Ann. Rpt. 1909-10:206-212, illus.

(15) TOTTINGHAM, W. E.

- 1923. TEMPERATURE EFFECTS IN PLANT METABOLISM. JOUR. Agr. Research 25:13-30, illus.
- (16)
 - 1926. TEMPERATURE EFFECTS IN THE METABOLISM OF WHEAT. Plant Physiol. 1:307-336, illus.

20

OBGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

÷.,

| Secretary of Agriculture | ARTHUR M. HYDE. |
|---|-----------------------------|
| Assistant Secretary | R. W. DUNLAP. |
| Director of Scientific Work | A. F. WOODS. |
| Director of Regulatory Work | WALTER G. CAMPBELL |
| Director of Extension Work | C. W. WARBURTON. |
| Director of Personnel and Business Adminis- | |
| tration. | |
| Director of Information | M. S. EISENHOWER |
| Solicitor | E. L. MARSHALL |
| Solicitor Weather Bureau | CHARLES F. MARVIN. Chief. |
| Bureau of Animal Industry | JOHN R. MOHLEB. Chief. |
| Bureau of Dairy Industry | O. E. REED. Chief. |
| Bureau of Plant Industry | WILLIAM A. TAYLOR, Chief. |
| Forest Service | R. Y. STUART, Chief. |
| Bureau of Chemistry and Soils Bureau of Entomology | H. G. KNIGHT, Chief. |
| Bureau of Entomology | C. L. MARLATT, Chief. |
| Bureau of Biological Survey | PAUL G. REDINGTON, Chief. |
| Bureau of Public Roads | THOMAS H. MACDONALD, Chief. |
| Bureau of Agricultural Engineering | S. H. McCrory, Chief. |
| Bureau of Agricultural Economics | NILS A. OLSEN, Chief. |
| Bureau of Home Economics | |
| Plant Quarantine and Control Administra- tion. | LEE A. STRONG, Chief. |
| Grain Futures Administration | J. W. T. DUVEL, Chief. |
| Food and Drug Administration | |
| · · · · · · · | Regulatory Work, in Charge. |
| Office of Experiment Stations | |
| Office of Cooperative Extension Work | C. B. SMITH, Chief. |
| Library | |
| | - |

This bulletin is a contribution from

Bureau of Plant Industry_____ WILLIAM A. TAYLOR, Chief. Division of Horticultural Crops and E. C. AUCHTER, Principal Horticul-Diseases. 40

U. S. GOVERNMENT PRINTING OFFICE | 1982

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C.

DND

