UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

RESEARCH BULLETIN 53

THE RELATION OF TEMPERATURE TO BLOSSOMING IN THE APPLE AND THE PEACH

(Publication Authorized August 18, 1922)

COLUMBIA, MISSOURI

AUGUST, 1922

UNIVERSITY OF MISSOURI

COLLEGE OF AGRICULTURE

Agricultural Experiment Station

Relation of Temperature to Blossoming in the Apple and the Peach

F. C. Bradford

Observation of the responsiveness of plants to certain temperatures and of the poleward progress of vegetative activity more or less concurrently with the advance of warm weather led to the formulation many years ago of the doctrine of thermal constants. According to this theory a given stage in the development of any plant is reached when that plant has received a certain amount of heat, regardless of the time required or of the temperatures involved. For each plant and for each successive stage there was assumed to be a definite heat requirement, which generally received a mathematical expression in the form of so-called "heat units." The unit was a degree on one of the several thermometer scales. However taken, temperature observations were generally reduced to terms of average or mean daily temperatures. The readings for all the days involved in the period in question were combined and the sum called the "thermal constant," since it was assumed to be constant for the plant wherever and whenever grown. Units based on this system may be designated "day-degrees" to distinguish them from the "hour-degrees" obtained by computation from hourly temperatures.

Enunciated first, probably, by Reaumer[29] in 1735, the original conception has been modified by later workers. Adanson[2] pointed out that temperatures below freezing do not reverse plant activity and discarded them from his summations. Others used as bases of calculation some still higher temperature, at which vegetative activity supposedly began. The number of heat units for one day was obtained by subtracting the base temperature from the actual —mean or maximum as the case might be—thermometer reading for that day; consequently this has been called the "remainder system." Later graduated values were assigned to various temperatures in recognition of accelerated growth at certain temperatures. The Livingstons,[22] particularly, have worked out a scale of weighted temperature values based on the principle of Van't Hoff and Arrhenius, pointing out, however, that the purely physical processes involved in growth are not governed by this principle. This system they called the "exponential." More recently Livingston[21] evolved a third system called "physiological", based on Lehenbauer's observations of root growth in maize at various temperatures. This system differs from the others in that it recognizes an optimum temperature above which the values assigned decrease. It is put forward, evidently, only as tentative, since Livingston states several qualifications of its applicability.

Progress in plant physiology and particularly the recognition that numerous factors influence plant growth have modified the original conception of thermal constants. Numerous objections to the original conception have been stated aptly by Schimper,[31] and its rigid application is not often attempted, except in the use of growing season summations to characterize various regions, as exemplified by Merriam's[24] work on life zones, and Swingle's[33] on the date palm. Ihne,[18] though inclined to consider phenological observations a measure of the weather, expressly repudiates the assignment of definite thermal constants to any plant.

Unfortunately there has survived a supposed connotation between the old thermal constant conception and phenology which has retarded the study of phenological observations in ways that might otherwise have been attempted. One purpose of the present paper is to point out how the thermal constant conception, though full recognition be accorded the many objections to it, still may furnish, in connection with phenological observations, a valuable tool in the study of the response by plants to some of the factors composing climate. The comparative meagerness of the available data and the limited number of localities they represent preclude the possibility of formulating much that is conclusive, and this paper can be regarded only as suggestive of what might be attempted with abundant data for the same plant under many conditions.

PHENOLOGY OF FRUIT TREES IN NORTH AMERICA

Systematic observations on the blossoming of fruit trees at various points in North America began, perhaps, in 1817 when Bigelow[7] compiled a list of the dates of blossoming of the peach at various points from Fort Claiborne, Alabama, to Montreal. Early reports of the Smithsonian Institution and of the Army Signal Service, the forerunner of the present Weather Bureau, contain many scattered observations on blossoming dates. Following the recognition of the importance of cross pollination in many fruits, blossoming data have been published by a number of agricultural experiment stations. Since these were intended merely to show the overlapping in blossoming seasons of horticultural varieties, complementary temperature data are not ordinarily available and study of them shows little beyond: (1) a general similarity in sequence of species and of varieties, (2) differences between places in the average lengths of the blossoming seasons and in the intervals between the blossoming of the several fruits, and (3) a general, though not uniform, recession of the blossoming dates with increased latitude and altitude.

The Initial Date.—Those who have attempted to fit thermal constants to phenological observations on perennial plants have found much perplexity in fixing an initial date for temperature summations. Some have computed from leaf fall in the previous autumn, some from the coldest period of the winter (which is, in many cases, early in February) and some from the date when the average daily temperature rises above the freezing point. Others, as Fritsch,[15] have considered the precise date of little importance and have used January 1, as a matter of convenience. This is, perhaps, the most commonly used starting point.

It is interesting that in many plants heat summations from this date to blossoming are not the same everywhere. Waugh[34] found in 1898 a general tendency for blossoming at lower summations in the north with the "American wild plum", than in the south. More pronounced differences are evident in the summations for the Late Crawford peach at Pomona, California, and at Wauseon, Ohio, shown in Table 1. These are compiled from reports of the California Agricultural Experiment Station[9, 10, 11] and from the Mikesell records.[25] Though the California figures are calculated from monthly means of daily maximum temperatures and the Ohio figures from daily maximum readings, errors arising from this cause must be slight in proportion; and the great differences shown in heat summations to blossoming actually exist. The highest summation from January to blossoming for any of the 27 years of the Ohio records is 925, considerably below the lowest shown here for Pomona and the minimum for Wauseon is barely more than one-fourth the maximum for Pomona.

TABLE 1.—HEAT SUMMATIONS IN DAY-DEGREES (MAXIMUM ABOVE 43) FOR THE LATE CRAWFORD PEACH FROM JANUARY 1 TO BLOSSOMING IN OHIO AND IN CALIFORNIA.

Year	Wauseon, Ohio		Pomona, California	
	Date of first blossoming	Day-degrees	Date of first blossoming	Day-degrees
1894	Apr. 17	745	Mar. 15	1222
1895	May 2	860	Mar. 2	1266
1896	Apr. 23	650	Mar. 20	2217
1902	Apr. 29	804	Apr. 1	2329
1903	---------------	--------	Mar. 25	1895
Average	(27 yrs.)	732	(5 yrs.)	1786

There may be, then, a considerable and consistent inequality in heat summations from January 1 to blossoming for the same fruit grown at points differing considerably in climate. This is in accord with observations of Palladin,[27] who records similar differences in many plants at Brussels and at Petrograd; these differences were much more pronounced in the early blossoming than in the late blossoming plants. According to one view, advanced by Linsser[20] the total heat requirements for any stage of plant development are not identical at all places, but their proportion to the total heat summation of the year is everywhere constant. In other words, there is supposed to be an acclimatization so that the same function may be performed with less heat at one point than at another, but require the same proportion to the total for the year at all points. This hypothesis appears untenable, in some cases at least, since this numerical ratio between the accumulation to ripening in the peach and the total for the year varies widely, from 48.8 per cent in Alabama to 83.1 in Massachusetts.[16] Furthermore, it does not take into account seasonal variations at the same point. Seeley[32] found great fluctuations from year to year in heat accumulations for various epochs in the Late Crawford peach at Wauseon, Ohio. In some years the minimum accumulation was 70 per cent of the maximum for the same period, in another 50 and in one, only 38. Evidently, then, Linsser's constant or "aliquot" will not explain such differences as those in summations in California and in Ohio from January 1 to blossoming. Finally, since heat accumulations at one point may vary considerably from year to year, if carried to extremes this hypothesis implies a rather remarkable prescience in the plant.

The differences between localities in heat accumulations to blossoming may be due in part to different normal temperature distributions. Price[28] demonstrated an acceleration in blossoming of peach and plum with high temperatures; yet his data show that the twigs held at the lower temperatures, though they required a longer time for blossoming, actually received in some cases less total heat (in day-degrees). In some localities it is possible that even before blossoming there occur temperatures high enough to exercise an inhibitory effect, or, perhaps, the winters are not cold enough to make subsequent high temperatures fully effective. Twigs of ash and linden cut before the end of the rest period were kept by Weber[35] in a dormant state in a warm greenhouse for 15 months; at the end of this time most of the buds opened normally.

VARIABILITY IN SUMMATIONS TO BLOSSOMING

Since fruit bud differentiation in several fruits is first evident about July 1, it has been suggested that summations should be computed from this time to blossoming in the following spring. If this date is used for beginning computations on the apple and on the plum in Wisconsin, there is apparently a closer agreement from year to year than when summations are made from January 1; this has been interpreted to indicate July 1 as the proper starting point.[30] Much of this apparent agreement, however, is due to the tendency of meteorological elements to average alike over long periods. Summations calculated from July 1 to the following May 1, the approximate date of fruit bud opening, fit very nearly as closely as those figured to the dates of actual blossoming. The ratio between the smallest summation and the largest is, in the Doney plum, 86.8 per cent; in the calendar summations, the check, it is 82.9 per cent.

The very fact that the Doney plum came into blossom in 1904 with 4,494 day-degrees from July 1 while in 1901 the accumulation was 5,174, or 680 more, suggests that in the latter year some heat was received when it was ineffective in forwarding blossoms or was received in surplus quantities or that at some periods in the cycle heat is not a controlling factor.

Indeed, something of the sort may be deduced from the data published by Sandsten. If the summations from successive dates be averaged and their respective mean deviations determined, it becomes evident that the ratio betwen the average of the summations and the mean deviation (in other words, the variability of the summations) changes and that it does not diminish in strict accordance with the tendency of meteorological values toward greater uniformity with increasing time. This is shown in Table 2, arranged from Sandsten's data for the Forest Garden plum, where the ratio just mentioned is designated the coefficient of variability. The "coefficient of variability" used in this paper is calculated from the mean, rather than from the standard, deviation, to lessen the effects of extreme variations.[37]

TABLE 2.—HEAT SUMMATIONS IN THE FOREST GARDEN PLUM AT MADISON. WISCONSIN, 1900-1905 INCLUSIVE.
(Compiled from data by Sandsten[30])

To blossoming from	Mean of summations	Average deviation	Coefficient of variability
July 1.	4836	181	3.74
Aug. 1	3608	157	4.35
Sept. 1	2416	71	2.93
Oct. 1	1540	97	6.29
Nov. 1	893	80	8.96
Dec. 1	678	61	9.99
Jan. 1	667	70	10.49
Feb. 1	662	71	10.72
Mar. 1	653	63	9.64
Apr. 1	523	58	11.08
Sept. 1 (omitting Nov., Dec., Jan., and Feb.)	2159	50	2.31

The significance of these coefficients is more apparent if they are studied beginning with the coefficient for January 1. On either side of this (December and March) are lower values, signifying greater agreement in summations beginning at other times and suggesting that temperature accumulations from this date are not altogether effective in advancing blossoming. In summations beginning March 1 there is closer agreement; and the high variability from April 1 may be interpreted to mean that advancement toward blossoming has begun, in some years at least, by that time. The difference in coefficients between November 1 and October 1 is striking and suggests that, beginning possibly about November 1, the temperatures received are not ordinarily effective. The greatest agreement in summations in the whole series is in those dating from September 1; the low coefficient at this point is remarkable. If, however, the November, December, January and February temperatures are omitted the coefficient of variability in summations from this date is diminished even further.

From August 1 and July 1, though these months in themselves usually show relatively slight variability in their temperature summations, the coefficients of variability are higher. Their low value as compared with that of March is due to the longer period covered, and their significance is probably slight.

Here, then, though caution must be observed against inferring too much, there seems to be reason to consider tentatively for this fruit at Madison: (1) that temperature deficiency during July and August is not a limiting factor in any ordinary season, (2) that it becomes in some measure a limiting factor during September and October, (3) that temperature is ineffective during November, December, January and February, possibly because there is not enough heat received to have any appreciable effect and (4) that about March 1 it again becomes for a time a determining factor. Under other conditions, of course, very high temperatures may become limiting.

Even though these indications be true for the Forest Garden plum, caution should be exercised in applying them to another plant, for example a Japanese plum, in Wisconsin, or to the same plum in another locality. In other words, significant dates for phenological data may conceivably differ with the plant and with the locality. Angot[3] carried this idea of flexibility to the extreme, stating that the significant date varied not alone with the plant and the locality but also from year to year. Evidence is introduced in this paper indicating the variation of the significant date with plant and with locality; as to the yearly variation in the same plant and in the same locality the evidence is less clear. If, however, the chemical composition of the plant be considered to have an influence, as seems quite plausible, the effective date may vary as well. Furthermore, the stage of blossom development attained in the fall has been shown by Magness[23] to vary from year to year in the same variety. Consequently some variation in opening in the spring might be expected even in seasons that present practically the same temperatures.

THE APPLE AND THE PEACH IN OHIO

A study covering a number of seasons at one point has certain advantages over studies of a few seasons at many points. If, for example, the date when temperatures become effective be conceived to vary from place to place there is no satisfactory way of ascertaining this date from scattered observations unless the minimum accumulation to blossoming observed at any point be subtracted from the accumulations at other points and the dates computed from the day-degree remainders. This is, in effect, shaping the problem to fit the answer. In observations at one point over a series of years a certain degree of variation in other limiting factors is presumably reduced and if there is any validity in the thermal constant conception it should appear in observations of this sort.

The publication by the United States Weather Bureau of the Mikesell records,[25] comprising phenological observations on numerous plants at Wauseon, Ohio, over a period of 30 years, together with daily meteorological records, makes possible a rather critical comparison of heat accumulations and phenological observations.

Since these records cover a longer period than any other available data they are analyzed here and used in the study of the records of the Missouri Agricultural Experiment Station, which cover a much shorter time.

Methods Used.—Heat accumulations may be measured in various ways. In the work reported here the simple summations of temperature to blossoming, both maximum and mean, above several thermometric points, were computed. In addition one series was computed on the exponential system. For each series the yearly summations were averaged, the mean deviations from the averages determined and variability coefficients derived by dividing the mean deviations by the averages of the total accumulations. Occasional trials showed no material relative changes in coefficients resulting from the use of standard or mean deviations. The coefficients derived by the several methods are shown in

TABLE 3.—VARIABILITY COEFFICIENTS OF HEAT SUMMATIONS FROM JANUARY 1 TO BLOSSOMING AT WAUSEON, OHIO, AS CALCULATED ON DIFFERENT BASES.

Base	System	Apple	Peach
32°F. Max.	Remainder	7.69	8.26
43°F. Max.	Remainder	8.79	9.80
50°F. Max.	Remainder	10.48	12.73
43°F. Mean	Remainder	12.20	16.06
40°F. Max.	Exponential	10.38	9.97

The magnitude of the variability seems to vary inversely with the number of units involved; for this reason the lower variability resulting from the use of 32° as the base point is not necessarily significant. Since this comparison did not show any base-point or system to be markedly superior to any other, the series based on maximum temperature above 43° was chosen for most of the further computations. This system appeared to give intermediate values and its results would be comparable with other work which has been based on the same temperature.

Temperature observations taken according to conventional meteorological methods are not true records of plant temperatures and since the disparity between the two varies no corrections can be applied. For present purposes, however, since in sunshine twigs are generally warmer than the air, maximum air temperatures probably approximate those of the plant more closely than mean air temperatures. For other seasons or for other temperature ranges or in other climates mean temperatures might be preferable. However, even on summer stages for the peach at Wauseon, Seeley[32] found less variation in computations involving maximum than in those involving mean temperatures, though it is true this lower figure may be due to the larger number of units involved.

Calculations.—Though it seems unlikely that heat deficiency is a limiting factor with apples or peaches in Ohio during the summer months, computations were made from July 1 to blossoming the following year. From these figures the summations from other dates to blossoming were readily secured and the respective variability coefficients determined. As a check on these, summations to April 28 and to May 7, the average blossoming dates of the peach and of the apple, respectively, were similarly computed. These may be considered as measures of the independent variability of the weather and are valuable for comparison with the variability to the actual dates of blossoming.

If heat accumulations are plotted vertically and a horizontal scale be adopted for time such that the spread of the projections of blossoming dates on the abscissa is equal in length to the spread of the projections of the accumulations on the ordinate, mathematical expression of the trend of the line connecting blossoming dates is possible. This is, in effect, done when the coefficient of variability in accumulations to blossoming is divided by the coefficient of variability to the average date of blossoming. With perfect uniformity in total day-degrees to blossoming the line would be horizontal; with perfect uniformity in totals to a given date the line would be vertical. With an equal degree of uniformity in both it would be at a slope of 45°. This would be the case were coefficients of variability to blossoming and to average date of blossoming equal.

In short, the numerical ratio obtained by dividing the coefficient of variability in summations to blossoming by the coefficient of variability in summations to average date is the tangent of the angle with the horizontal made by a smooth line connecting the dates of blossoming. When this ratio is above one, the angle is greater than 45° and nearer vertical. In other words, the agreement is closer with the average date than in the total accumulations.

Accordingly the figures in the columns headed "Tangent" in Table 4 are in reality tangents of slopes of lines connecting the graphical positions of the blossoming dates. The value 0.94 for the apple indicates a slope of approximately 43° for this line—practical neutrality. The value 0.51 indicates a slope of approximately 27.° In the peach the 1.47 value indicates a slope of 56°, nearer vertical than horizontal. However, even without expression in degrees, the tangents serve for comparison.

TABLE 4.—VARIABILITY COEFFICIENTS OF HEAT ACCUMULATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AND IN THE PEACH AT WAUSEON, OHIO.

Beginning date	Apple			Peach		
	To actual blossoming	To average date of blossoming	Tangent	To actual blossoming	To average date of blossoming	Tangent
July 1	4.55	5.36	0.85	5.27	5.00	1.05
Aug. 1	5.63	6.45	0.87	6.22	6.34	0.98
Sept. 1	7.37	7.86	0.94	8.04	7.66	1.05
Oct. 1	9.33	11.11	0.84	9.71	10.59	0.92
Nov. 1	11.08	13.80	0.80	7.77	14.33	0.54
Dec. 1	13.65	15.47	0.88	9.55	16.94	0.56
Jan. 1	8.79	15.64	0.56	9.80	16.37	0.60
Feb. 1	8.48	15.78	0.54	11.34	16.73	0.68
Mar. 1	9.79	16.76	0.58	13.40	17.51	0.76
Mar. 15	7.93	15.51	0.51	14.91	15.60	0.95
Apr. 1	14.70	15.79	0.93	25.22	17.09	1.47

Indications.—The lower the tangent the more significant, presumably, is the coefficient for the corresponding period. Consequently the low variability coefficients for the summer and autumn months lose their weight and those of some of the later dates become more significant.

An interesting difference between the apple and the peach is revealed by inspection of the tangents. The lowest value in the peach is in the summations figured from November 1; in the apple the lowest value is in the figures dating from March 15. This difference seems to indicate that, under the conditions obtaining at Wauseon, high temperatures during winter are effective in promoting growth in the peach, but not in the apple.

In the apple the period of effective temperatures seems more definitely fixed than in the peach. From January 1 to March 15 in the apple the tangents change but little, with the smallest figure on March 15. It should be considered, however, that heat accumulations are small during this time and can affect the total variability but little. Other things equal, such changes as do occur as the date of summations moves backward should, through augmenting somewhat the total of day-degrees involved, reduce the variability. Therefore even the slight difference in tangents shown may be significant in the apple. The occurrence of the lowest figure on March 14 does not signify that the rest period ends then. It is, in a sense, an average date and means that, broadly speaking, advancement starts in half the years at that time. Consequently the end of the rest period must be earlier.

In the peach, the succession of low values is in the reverse order and so far as this array affords evidence, the decrease from January 1 or December 1 may be due merely to the longer period and the consequently greater total of units involved. In either case, however, it seems clear that the peach becomes responsive to high temperature earlier than the apple and that its earlier blossoming is not necessarily due to a lower total requirement of heat. The low temperature of the ordinary winter at Wauseon would keep the trees dormant and microscopic study of buds for several years might show no development during this time, unless the period of investigation happened to include a mild winter. Dormancy of the peach in the north and in the south may be quite different; in the one case imposed by low temperature and in the other by the rest period. Johnston[19] found that the moisture content of peach buds in Maryland increases after January 1 in a definite relationship to the "sum of the effective daily mean temperature above 43°."

Seasonal Differences.—Illustration of the difference between the two types of fruit is found in the graphs of heat accumulations from January 1 in 1890 and in 1912, shown in figure 1. These years are selected because they represent respectively the maximum and the minimum accumulations of heat from January 1 to March 1. In 1912, with little accumulation of heat prior to April 1, the apple came into blossom very close to the peach both in time and in heat accumulations. This year, in fact, marked the

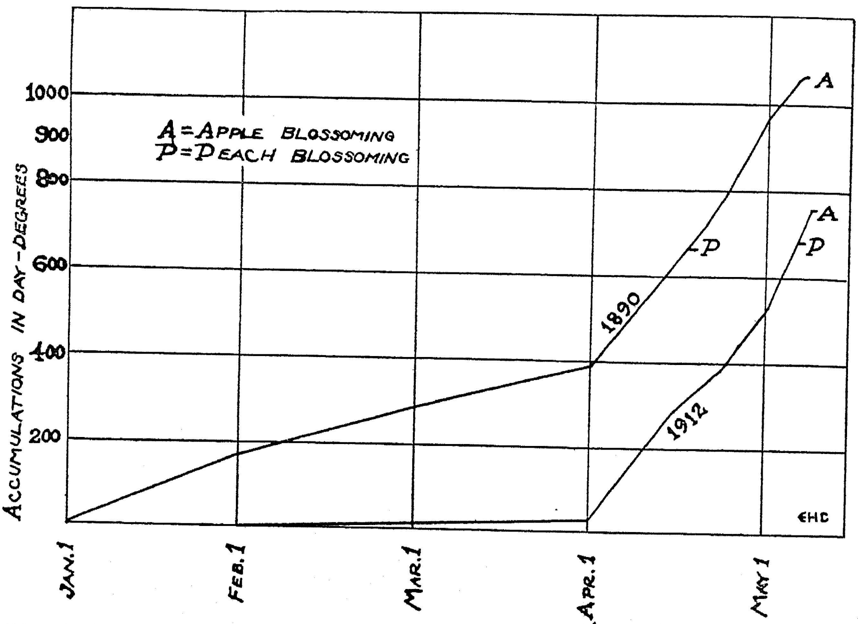

Fig. 1.—Blossoming of peach and apple in years of maximum and of minimum accumulation on March 1, at Wauseon, O.

lowest summation to blossoming for the apple. In 1890, with considerable heat accumulation throughout the winter months, the peach came into blossom earlier, but with substantially the same heat accumulation as in 1912. The apple, however, though its date of blossoming was nearly the same as in 1912, had received 300 day-degrees more of heat. This difference is about the same as the margin by which the accumulation to April 1 in 1890 exceeded that of 1912. This may be interpreted to signify that in 1912 practically all the heat received came when it was effective, while in 1890 much of it was ineffective for the apple. Apparently the peach started from dormancy earlier than the apple in 1890, while in 1912 there was little difference, because the low temperatures held both dormant.

Since these two winters were so widely different, it seems logical to infer that localities with average winters differing (as do these extreme types) would show for regions with mild winters a considerable spread in blossoming season between the peach and the apple—well known to be the case—while those with cold winters would show little or no difference. In extreme cases the peach and the apple may bloom simultaneously. This condition occurred at Wauseon in 1895, following a cold January and February and was closely approached in other years, invariably following winters of small heat accumulations. Indeed, in 1912 which, according to Hedrick[17] was not an unusual blossoming season, at Geneva, New York, blossoming in the apples began a day ahead of the peaches. The same phenomenon occurred in 1905 at Columbia, Missouri. The variations sometimes reported in the sequence of blossoming in other fruits may be due to similar causes.

If a certain validity be assumed for the thermal constant conception, the rather wide difference from year to year in the summations from any given date to blossoming suggest that the higher figures may be due to accumulations occurring during periods when they are ineffective or in greater quantities than can be fully effective—and of course other factors than temperature may intervene. To facilitate comparison, data for the years of maximum and of minimum accumulations from January 1 to blossoming in the peach and in the apple are arranged in Table 5. It is interesting and significant that these years are not identical for the two fruits, only three duplications occurring. In both fruits the minimum accumulations from January 1 to blossoming average practically the same in relation to the maximum, but here the similarity stops. In the peach the years of lowest summation from January 1 to blossoming generally succeed periods of considerable accumulation in November and December, the accumulations preceding the years of minimum accumulation being in fact 141 per cent of those preceding the maximum. In the apple it is apparently a matter of indifference, since the November and December accumulations preceding the minimum and the maximum years average practically the same. It should be stated that the

TABLE 5.—ANALYSIS OF ACCUMULATIONS IN YEARS OF GREATEST AND OF LOWEST SUMMATIONS FROM JANUARY 1 TO BLOSSOMING IN THE PEACH AND IN THE APPLE AT WAUSEON, OHIO.
(In day-degrees)

Year	Jan. 1 to blossoming	Previous Nov. 1 to Jan. 1	Jan. 1 to Mar. 1	Jan. 1 to Mar. 15	Mar. 15 to blossoming
		Peach			
		Years of Minimum Summations			
1910	632	363	14	112	520
1908	588	180	18	104	484
1900	627	305	86	100	527
1896	650	286	50	57	593
1891	594	296	125	142	452
		Years of Maximum Summations			
1902	804	184	52	144	660
1898	834	266	72	198	636
1895	860	222	31	45	815
1893	853	150	13	104	749
1887	870	195	80	213	657
		Apple			
		Years of Minimum Summations			
1912	752	195	6	6	746
1908	791	302	18	104	687
1905	787	290	13	15	772
1896	779	286	12	57	722
1886	803	217	83	196	607
		Years of Maximum Summations			
1901	1005	259	42	66	939
1894	1217	323	124	324	893
1890	1052	296	294	327	725
1889	1056	308	70	148	908
1887	1079	195	80	213	866
		Averages			
		Peach			
Min.	618	286	59	103	515
Max.	844	203	49	141	703
		Apple			
Min.	781	258	26	56	707
Max.	1081	276	122	215	866
		Minimum in per cent of Maximum.			
Peach	73.2	141	120	73	73
Apple	72.2	93	21.0	26	82

two years of greatest heat accumulation in November and December were followed by crop failures in the peach, constituting two out of the three in the 30 years of record. These facts, together with the low variability coefficient in the peach summations from November 1 (Table 4) indicate that rather marked accumulations of heat in November and December have some influence in the forwarding of Late Crawford peach blossoms toward opening, but are not important in the King apple.

Johnston[19] found that the relation between temperature accumulations from January 1 and moisture content of peach fruit buds, though constant in any one year, varies from year to year; and that "certain conditioning influences that are operative during or preceding dormancy apparently 'predetermine' the exact relationship between air temperature and the moisture content of the buds for the period following dormancy."

The averages in Table 5 show an excess of heat during January and February of the years of minimum accumulation for the peach, but inspection of the detailed figures shows that this is of doubtful significance, since it is due to a high value in one year only. The low ratio of the minimum to the maximum years (21 per cent) in the apple, however, apparently signifies that the apple is unresponsive at this time and that heat accumulations during this period merely swell the total without having any marked effect in advancing the blossoms. The same negative relationship appears in the figures to March 15 for the apple (16 per cent) while the figures for the peach change markedly and assume the same relationship as the total accumulations. The similarity in the relationship in the peach of the years of maximum to those of minimum accumulations from January 1 to blossoming, from January 1 to March 15 and from March 15 to blossoming suggests that the same influences are operative during all three periods; in other words, that development is progressing. In the apple the change at this time is abrupt—from 28 to 86 per cent—the accumulations from March 15 to blossoming being more nearly alike as between maximum and minimum years than those from January 1 and closer than in the peach—86 as compared to 73 per cent.

Assuming, for the reasons given above, November 1 to mark the commencement of possible effective temperatures in advancing the peach toward blossoming and March 15 for the apple, data for the five years of maximum summations for these respective periods in each fruit are assembled in Table 6 to show their relation to the temperatures of October, September and August preceding.

TABLE 6.—TEMPERATURE SUMMATIONS FROM DATE OF POSSIBLE EFFECTIVENESS IN RELATION TO TEMPERATURE OF PREVIOUS MONTHS, AT WAUSEON, OHIO.

Year	Peach: Nov. 1 to blossoming	Peach: Oct.	Peach: Sept.	Peach: Aug.	Year	Apple: Mar. 15 to blossoming	Apple: Oct.	Apple: Sept.	Apple: Aug.
			Years of Minimum Accumulation						
1911-12	879	554	979	1203	1910-11	669	647	979	1245
1910-11	782	647	979	1245	1908-09	694	699	1202	1249
1907-08	768	380	932	1190	1907-08	687	380	932	1190
1906-07	878	326	1154	1326	1901-02	706	740	1063	1350
1890-91	890	502	839	1213	1885-86	707	430	952	1075
			Years of Maximum Accumulation.						
1897-98	1100	882	1270	1211	1900-01	939	940	1174	1448
1894-95	1082	620	1109	1361	1893-94	893	597	1048	1317
1893-94	1068	597	1048	1317	1888-89	908	476	958	1289
1891-92	1071	587	1201	1254	1887-88	903	460	990	1284
1883-84	1104	378	866	1137	1883-84	892	378	866	1137
				Averages					
Min. yrs.	839	481	977	1235	----------	693	579	1026	1222
Max. yrs.	1085	613	1099	1256	----------	907	550	1072	1295
			Minimum in per cent of Maximum.						
Peach	77	78	89	98		76	105	96	94

These figures suggest, though not very strongly, a tendency toward an association between lower temperatures in October and a low summation from November 1 to blossoming in the peach. In the apple there is little or no appearance of any relationship. This difference may possibly be associated with some effect of the high October temperatures in prolonging or of the low temperatures in breaking the rest period in the peach, while in the apple at this time they have, ordinarily, no apparent effect. However, since rainfall in September is likely to be important in connection with September and October temperatures, no clear evidence is afforded by the data in Table 6 as to the effects of October temperature, though the essential similarity in September and August summations indicates that temperature variations in these months have little effect on these fruits in this locality.

MISSOURI RECORDS

Rather complete phenological records of numerous varieties of apples and peaches were kept at the Missouri Agricultural Experiment Station from 1905 to 1918 inclusive, with the exception of the blossoming records for 1910. This was an early season and the records show most varieties in full bloom on March 28 but the dates of first blossoming are not recorded; consequently this year is omitted from calculations reported here.

Through the kindness of Mr. George Reeder, of the United States Weather Bureau, temperature records for the period covered by the phenological data have been made available. These observations were made at the Weather Bureau office, about one-fourth mile from the University Orchard in which the phenological observations were taken.

An interesting commentary on the hazards of peach growing in this section is the appearance of blossoming dates for peaches for only 8 of the 13 years of the record. Since the observations were made with considerable care it is safe to presume that no blossoms appeared in other seasons during this period. Compared with the 27 crops in 30 years at Wauseon, Ohio, and with the uninterrupted, though brief, sequence reported from Pomona, California, they suggest that this particular section may be termed a no-man's land for the common varieties of peach, being subjected to the hazards of both northern and southern types of winter injury, (extreme cold and untimely warm weather respectively) while regions north and south are subject ordinarily to only one form. Because of the scarcity of data no attempt is made here to study extensively the climatic relations of the peach in central Missouri.

The comparative brevity of the period for which data are available at Columbia increases the difficulty of formulating any hypothesis as to the periods of effective temperatures. Similarly, though data are available for a considerable number of varieties, the brevity of the record for each makes varietal comparisons rather uncertain. However, some generalizations seem safe. The warmer winter months at Columbia make the average heat summations up to the date of blossoming greater than those at Wauseon, though the difference is not so marked as that between California and Ohio for the peach. Since the comparison in Table 7 between summations at blossoming at Columbia and at Wauseon is between the King apple at Wauseon and the Fameuse at Colum-

TABLE 7.—AVERAGE TEMPERATURE ACCUMULATIONS (MAX. ABOVE 43°) FROM JANUARY 1 TO BLOSSOMING IN THE APPLE AT WAUSEON, OHIO, AND AT COLUMBIA, MO.

To	Wauseon, Ohio King Apple	Columbia, Missouri Fameuse Apple
February 1	36	122
March 1	72	261
March 15	127	389
April 1	254	646
Blossoming	912	950

bia, the actual difference in any one variety would be somewhat greater. It is interesting that Fameuse blossomed in 1895, apparently a normal season, on April 1 at Paso Robles, California, with a day-degree accumulation of 1421 from the first of January[9]; in 1902 the blossoming at Pomona, California, was on April 5 with an accumulation of over 2300 day-degrees[10] and in 1903 on April 15 with an accumulation of about 2273 day-degrees.[11]

Varietal Differences.—Of the varieties for which data are available for all the years of record, Minnesota, Fameuse and Primate are the earliest blossoming; Rome, Ralls and Ingram the latest. Data are presented in Table 8 showing the coefficients of variability in summations to blossoming in these varieties from dif-

TABLE 8.—VARIABILITY IN DAY-DEGREE SUMMATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AT COLUMBIA, MO., COMPUTED FROM MAXIMUM TEMPERATURES ABOVE 43°F.

	Oct. 1	Nov. 1	Dec. 1	Jan. 1	Feb. 1	Feb. 15	Mar. 1	Mar. 15	Apr. 1
Early blossoming									
Minnesota	7.82	8.95	8.96	9.41	8.98	8.21	8.68	16.78	--------
Fameuse	7.91	8.21	8.32	9.15	9.15	7.99	7.69	13.45	--------
Primate	7.48	8.81	9.28	10.90	10.24	9.51	10.41	15.56	--------
Av.	7.77	8.66	8.85	9.75	9.46	8.57	8.93	15.26	--------
Weather	8.33	11.87	16.58	18.11	20.89	20.09	22.46	18.41	--------
Late blossoming									
Rome	7.61	9.27	9.27	10.32	10.49	10.18	9.82	8.41	29.65
Ralls	7.84	9.01	10.42	10.14	11.21	11.12	11.23	8.69	23.79
Ingram	7.58	9.01	7.68	8.15	8.63	9.60	8.76	9.62	27.74
Av.	7.68	9.10	9.12	9.54	10.11	10.29	9.94	8.91	27.06
Weather	6.65	8.50	9.46	9.37	10.62	9.89	9.88	7.01	15.15

ferent dates on the 43° maximum basis. The variability in the weather to average data of blossoming as compared with the Ohio figures is generally greater in the early blossoming varieties and lower in the late blossoming. Much of this difference may be attributed to the smaller number of years considered, since 1912 was marked by great deficiency in temperature until near the average date of blossoming for the early varieties, but was more nearly normal by the average date for the late blossoming varieties. Omission of this year from the record would reduce the variability in the summations to the average date of the early blossoming varieties very materially. The lower variability in the Columbia figures to the average date for the late blossoming varieties may be due to the greater number of day-degrees involved or it may be accidental. The probable error of the mean from January 1, is, for Columbia ±40, as compared with ±21 for Wauseon.

As they stand, the figures in Table 8 show, though not at all clearly, the same general tendencies in the early blossoming varieties as those appearing in the Wauseon data, with the apparently significant date earlier. Those for the late blossoming varieties, however, show no agreement greater than that in the weather to their average date of blossoming. The drop to 8.91 on March 15 might be significant were it not for the even lower figure (7.01) for the weather check. Though the low value of the latter is obviously accidental, it precludes the attachment of any significance to the former.

Another way of comparing these two groups of apple varieties is through coefficients of correlation between accumulations and the date of blossoming, somewhat after the manner used by Aoki and Tazika[4] in the sweet cherry. In this case any relationship would be shown by a negative correlation. As shown in Table 9 the correlation, wherever there is one, is stronger in the early

TABLE 9.—COEFFICIENTS OF CORRELATION BETWEEN HEAT ACCUMULATIONS (ABOVE 43°, MAX.) AND DATE OF FIRST BLOSSOMS IN APPLE AT COLUMBIA, MO.

Period of accumulation	Early blossoming varieties	Late blossoming varieties
January	0.174±0.13	0.168±0.18
February	—0.369±0.16	—0.142±0.11
March	—0.856±0.05	—0.510±0.14
February 15—March 15	—0.473±0.15	—0.065

blossoming varieties. Since the time interval between the periods of accumulation considered and the blossoming is shorter in the early blossoming than in late blossoming varieties, there is less opportunity for disturbing variations in the unmeasured interval and the correlation would be expected to be greater in the former. However, even with this allowance, there seems some indication that the date of effective temperatures is earlier in the early blossoming than in the late blossoming varieties.

Different Temperature Basis.—Since it seems possible that the late blossoming of some varieties may be due to lack of response to certain temperatures which are effective with the early blossoming varieties, variability coefficients based on a higher minimum, 50°, are presented in Table 10. Here, curiously enough in view of the Wauseon results, the variability for the early blossoming varieties is generally decreased, though the variability of the weather is increased. The full significance of this is not clear though the study of the records for single years which follows may explain it in part. In the late blossoming varieties the variability in summations to blossoming generally decreases somewhat, while that of the summations to the average date increases. The changes are too slight, however, to be indicative. One possibly significant change is in the figures for March 15 where the variability increases enough to give the tangent a value of 0.7034. Of itself this is not sufficiently low to have much weight, but in con-

TABLE 10.—VARIABILITY IN DAY-DEGREE SUMMATIONS FROM VARIOUS DATES TO BLOSSOMING IN THE APPLE AT COLUMBIA, MO., COMPUTED FROM MAXIMUM TEMPERATURES ABOVE 50°F.

	Nov. 1	Dec. 1	Jan. 1	Feb. 1	Feb. 15	Mar. 1	Mar. 15	Apr. 1
Early blossoming								
Minnesota	10.55	8.45	8.31	8.59	9.81	10.59	15.96	....
Fameuse	10.04	8.78	9.47	8.61	7.45	6.92	13.37	....
Primate	9.42	9.38	8.95	7.81	8.41	8.30	13.12	....
Av.	10.00	8.87	8.91	8.34	8.56	8.60	14.15	....
Weather	14.44	20.69	21.45	24.22	24.09	25.86	23.17	....
Late blossoming								
Rome	11.51	9.34	8.96	9.50	9.34	8.94	8.42	34.14
Ralls	10.10	10.59	9.94	10.65	9.93	9.33	8.10	27.76
Ingram	10.61	8.69	7.72	8.46	9.36	8.89	10.65	31.73
Av.	10.74	9.54	8.87	9.54	9.54	9.05	9.06	31.21
Weather	8.73	9.80	8.28	10.10	10.81	10.66	12.88	21.07

nection with the condition shown for this date in Table 8 it may have some meaning.

Seasonal Differences.—Some interesting weather variations with related responses are shown by the graphs of yearly accumulations shown in figures 2, 3 and 4. These are grouped more or less at random, the chief aim being to present the years of peach blossoming in two diagrams.

The first four years of the record are shown in figure 2. Two of the four, 1906 and 1907, were rather high in accumulations to March 15 and diverged widely from that time; the 1905 curve

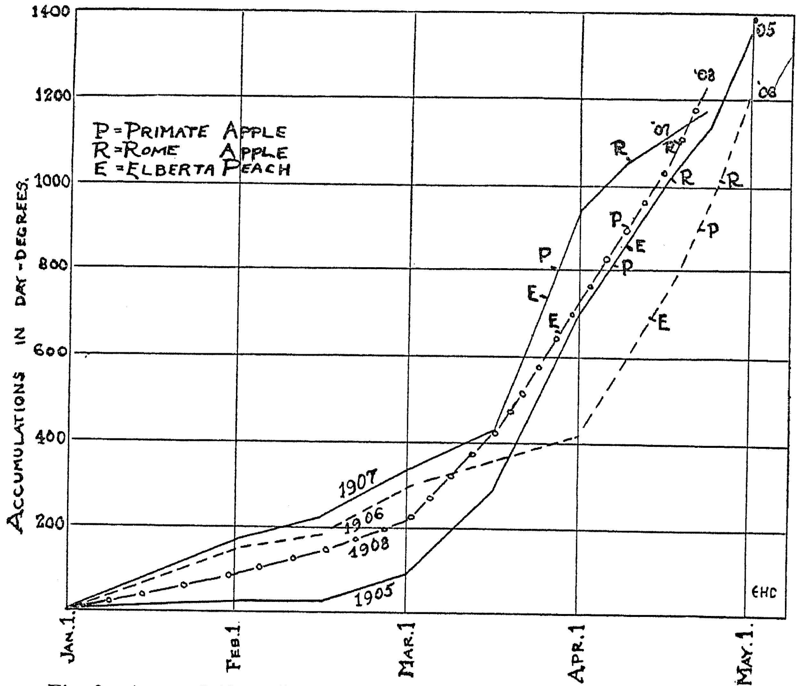

Fig. 2.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

shows a markedly low winter accumulation followed by rapid advance; 1908 is noteworthy for steadiness of the accumulation from March 1. Another interesting relationship is the identity of accumulations about March 15 of the two pairs of curves. The agreement in these pairs in the accumulations to blossoming for Rome and the agreement in summations from March 15 are remarkably close. The tangent in this case is 0.244. The agreement in Primate is even closer, the tangent being in fact 0.222, but the agreement is not within the same pairs as in Rome. In both cases of blossoming at the lower summation the accelerating influence of high temperature is apparent in the steepness of the gradient.

The 1906 and 1908 curves are rather close to parallel for some time and blossoming of Primate occurs at the same level on them. The Elberta peach blossoms at a lower level on the 1908 curve. These curves crossed about March 10 and accumulations then were identical, but the more rapid rise from that point in 1908 evidently had more effect on Elberta than on Primate. Comparison of the 1905 and 1908 curves indicates the effect of the sharp rise after March 15 in hastening the development of the Primate blossoms.

In 1905 the Primate apple blossomed ahead of the Elberta peach. The arrangement in the figure shows that this was due to Elberta being late in blossoming rather than Primate being early. This was the year of very little accumulation until after March 1. Apparently the cold weather held the peach dormant until high temperatures could become effective on the apple, as in Ohio in 1912, shown in figure 1. It should be stated, however, that a considerable amount of winter-killing of buds occurred during the winter of 1904-1905 and that the blossoming of Elberta as recorded is doubtless later than it would have been with a full crop, since generally the more advanced buds are more readily killed. Furthermore, Chandler[13] mentions a mild form of winter injury which retards, but does not prevent blossoming. Even with this allowance, however, the closeness of Elberta and Primate is indicative of the influences mentioned.

It is interesting that Morgan[26] working at Ithaca, New York, reported the apple to start development earlier in the spring than the peach but that the peach rapidly overtook it. This might well be the case if the investigation were carried on in such years as 1905 or where the common season resembles the 1905 season. On the other hand Drinkard[14] in Virginia reported more advancement during the winter in the peach than in the apple. Assuming the peach to require higher temperatures than the apple it might start later than the apple in seasons that are cool, but with warm temperatures it starts before the apple.

In figure 3 are presented curves for the remaining years for which peach blossoming dates are available, with that for 1912 added for comparison. The successive spring freezes of 1921 destroyed apple blossoms so extensively that blossoming records were not taken, consequently the curve for that year is not carried beyond the blossoming of Elberta, which occurred before any damage had been inflicted and is therefore reliable. At first glance the high accumulations for Elberta in 1909 and 1911 are outstanding and apparently inconsistent. These years, however, were characterized by a considerable amount of winter killing of buds, the damage in 1909 in Elberta at Columbia amounting, according to Chandler,[12] to 97.3 per cent. Data are not available on the extent of the damage to Elberta in 1911, but since it ranged from

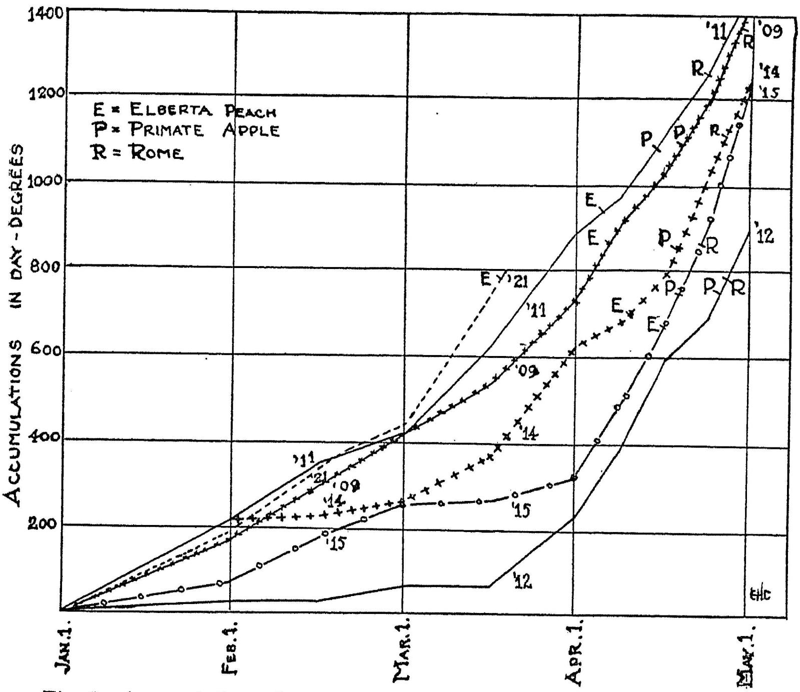

Fig. 3.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

29.8 per cent to 79 per cent in other varieties, it must have been considerable. These dates, then, represent the opening of only a very small portion of the total number of blossoms and these, presumably, those that were least advanced during the winter and would be the last to open in the spring. With these allowances, the line connecting the blossoming dates of Elberta would become nearly horizontal, signifying a rather close agreement in totals to blossoming.

In Rome the differences in day-degrees at blossoming are in the same order as the differences on March 15 with one exception.

This is on the 1909 curve where Rome seems unduly late in blossoming. Since yield records are not available for this variety the amount of bloom this year cannot be stated. That Rome was "out of step" in this case is shown by the fact that this was the only year in the record when Ingram blossomed ahead of Rome. If this were due to scarcity of crop so that the only blossoms appearing were terminals—as is sometimes the case—this discrepancy would be explained. However, even with this allowance, the agreement is very little greater in summations from March 15 to May 1.

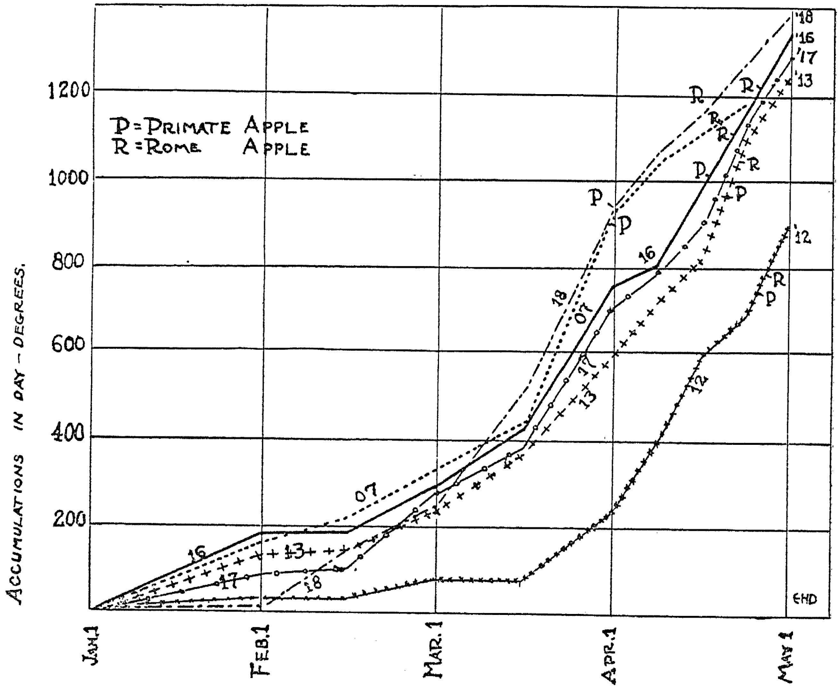

Fig. 4.—Accumulations (in day-degrees) to blossoming at Columbia, Mo.

In figure 4 are shown graphs for years in which no blossoming dates for the Elberta peach are available; to these 1907 is added because of its close similarity to 1918 after March 1. These graphs are strikingly similar, excepting the 1912 curve. In 1913, 1916 and 1917 Primate appears to have been retarded by a week of cool weather in early April, though its extreme lateness in 1917 can be only partly explained in this way. Here again, sparseness of the crop may be a partial explanation, since study of the spurs of this tree in the orchard shows very little blossoming in that year. The blossoming of Rome at a comparatively low accumulation in 1913 may be explained by the rapid rise in temperature subsequent to April 15.

The evident retarding effect of the cold weeks in early April in 1913, 1916 and 1917 and the absence of influence of these weeks on Rome, though it is clearly responsive to high temperature, raises an interesting question. Since the buds of Primate, which was retarded, were more advanced at these periods than those of Rome, which apparently was not retarded, it seems quite possible that optimum temperatures vary as the buds advance toward opening. The decrease in the rate of the temperature rise in 1907 after Primate was in blossom and Rome presumably well advanced, seems to have had a retarding effect.

There is a rather strong trend toward uniformity in summations to blossoming in these curves, if 1912 be disregarded. This does not, however, necessarily signify that temperatures of January and February are effective, since the accumulations are very much alike on March 1 or even on March 15. Here again, plotting the curves with March 1 as the starting point or, for Rome, March 15, secures much greater agreement.

Considering all graphs shown, and making the allowances indicated, there is a rather marked tendency for uniformity in summations from January 1 to blossoming, in the Elberta peach. Where the uniformity appears in the blossoming of the apples it is accompanied by an approximate uniformity in the accumulations at some date subsequent to January 1. Nowhere, however, is there clear evidence pointing to uniformity or difference in the end of the rest period between the early and the late blossoming apples. The graphs in figure 3, contrasting warm springs with a very cold spring, suggest a difference in the rest period.

In Table 11 are assembled data showing the fluctuating difference between 30 varieties of apple for all the years of record. Included in this are all the varieties for which data are complete; in most cases the records are from the same trees throughout. The seasonal difference in dates of first bloom (range) is shown to vary from 5 to 27 days and the average deviation from 0.97 to 4.75 days. That this difference between the first and last blossoming variety is little more—or is even less—constant when expressed in terms of heat is shown by comparison of the maximum range in day-degrees (519) with the minimum (187). The gen-

TABLE 11.—VARIATIONS IN BLOSSOMING AMONG THIRTY APPLE VARIETIES AT COLUMBIA, MO.

	Days				Day-degrees			
Year	Aver. date of blos.	Range	Duration of bloom in earliest variety	Aver. deviation	Aver. accumulation	Range	Aver. deviation	Aver. daily acc. during blos.
1905	99.6	24	22	2.85	898.7	519	69.5	21.6
1906	111.2	13	12	1.69	926.4	415	51.1	31.9
1907	87.9	22	21	3.14	886.8	323	48.4	14.7
1908	101.4	14	12	1.87	943.6	342	45.1	24.4
1909	111.2	18	13	3.32	1191.3	419	52.3	23.3
1911	104.7	18	20	2.89	1109.8	380	61.4	21.1
1912	115.7	8	16	1.25	766.0	193	30.0	24.1
1913	109.5	12	12	1.80	964.9	315	48.6	26.3
1914	111.2	11	10	1.59	976.1	359	51.7	32.6
1915	111.0	5	6	0.97	879.6	187	36.4	37.4
1916	107.9	13	13	1.47	1059.1	279	40.3	21.5
1917	111.7	20	8	2.81	1100.0	313	63.4	15.6
1918	100.3	27	33	4.75	1087.3	418	69.1	15.5
Av.	106.4	15.8	14.5	2.34	983.8	343	51.3	23.8

eral accelerating effect of high temperature is evident in the average of the daily temperature accumulations during the three shortest ranges, 31.3,° and during the three longest, 17.3.°

No constant on the basis used here will measure the difference between blossoming in the earliest apple and the latest. It is quite likely that an exponential or a "physiological" system would measure this brief span more closely. It is, however, quite as probable that conditions before the blossoming of the earliest apples vary from season to season and that this event may find the late blossoming variety at various stages. When the early blossoming variety is not held back by unfavorable weather the late blossoming kind will lag behind; when the early blossoming variety is retarded the difference will be less, other things equal. This indicates a difference in date of effective temperatures. However, it is noteworthy that no matter how much the season is retarded and how small the range between the varieties, the early-blossoming kinds bloom first and the late-blossoming varieties bloom last. This indicates a difference in temperature requirements.

Leaf and Fruit Buds Compared.—Apparently the opening of blossoms and the unfolding of leaves respond somewhat differently to a given set of conditions. Bailey[5] says that in the southern states plum flowers "tend to appear wholly in advance of the leaves, and they are borne upon short stalks, or may be nearly or quite sessile. In the North, the flowers and leaves are generally coetaneous, and the flower stalks are usually longer." Ballard and Volck[6] report that spraying with nitrate of soda in February hastened the opening of flowers but not of leaf buds, in apples and pears. Table 12 shows the variability in summations to appearance of the first fully formed leaf at Wauseon, Ohio. Since the period of record is not identical with that for blossoming the figures are not strictly comparable. However, the differences between the values of the tangents in Tables 4 and 12 seem considerable enough to signify some difference between leaves and blossoms in their responses. In some years blossoms preceded leaves; other years showed the opposite condition.

TABLE 12.—VARIABILITY IN DAY-DEGREE SUMMATIONS (MAXIMUM, ABOVE 43°) TO DATE OF THE APPEARANCE OF THE FIRST FULLY FORMED LEAF IN THE APPLE AT WAUSEON, OHIO.

Summations beginning	Variability in summations	Variability in summations to average date	Tangent
September 1	7.30	7.47	0.98
October 1	9.05	10.23	0.88
November 1	10.21	15.74	0.65
December 1	11.74	17.69	0.66
January 1	11.90	18.60	0.64
February 1	11.28	17.73	0.64
March 1	11.41	17.63	0.65
April 1	16.42	19.09	0.86

The data for Columbia record a somewhat different phase of vegetative development, namely, the opening of the leaf buds. Very rare indeed in these records is the case where the opening of the first blossom precedes the opening of the first leaf bud; almost invariably the leaf buds open before the blossoms. The margin of difference varies, however. In three typical early blossoming varieties the average difference for 13 years is 7 days; in three typical late blossoming varieties it is 11 days. The late blossoming varieties blossomed on the average 13 days after the opening of the first bloom; their leaves appeared, on the average, 10 days after the opening of the first leaf bud.

Evidence from Microscopic Examination.—Explanation of much of the lack of agreement among the variability coefficients of the several varieties represented in Tables 8 and 10 is found through microscopic examination of flower buds at various times during the winter. Typical photomicrographs of preparations made by Mr. V. R. Boswell are shown in Plates I, II and III. Oldenburg and Primate represent the earliest blossoming varieties; Rome, Daru and Cilligos the latest. The two last are included since they have been used extensively in the apple breeding work of the Missouri Station. Daru blossoms at about the same time as Ingram; Cilligos is the latest blossoming of all varieties under observation.

Plate I shows the stages reached by several varieties on February 2, 1920. Oldenburg is clearly more advanced than the other varieties. In the other cases, the correspondence between development on this date and the order of blossoming is not so close. Fameuse, the second earliest in blossoming, is no farther advanced than Daru, the second latest in blossoming. Gano and York, mid-season varieties, are apparently at the same stage as Cilligos, the latest of all.

In Plate II are shown the stages on three dates, November 2, 1921, January 28, 1922, and February 20, 1922, for three varieties, Oldenburg, Primate and Wealthy. The first two are distinctly early in blossominng; Wealthy might be classed either among the last of the early blossoming or among the earliest of the mid-season varieties. Here the advancement of Oldenburg in November is marked; this appears clearly to be a factor in its early blossoming since subsequent samples show relatively slight development. The other early blossoming variety, Primate, shows a quite different condition. Its November stage is not advanced; indeed, Daru, one of the latest blossoming, shows equal or greater pistil development on this date. Its changes through the winter, however, are notable and suggest that this variety has a factor producing early blossoming quite different from or more intense than that evident in Oldenburg. Wealthy, equally or more advanced in early November, does not develop as rapidly through the winter.

Plate III records the development of the buds in three late blossoming varieties sampled on the same dates as those of the early blossoming varieties shown in Plate II. Daru, the second latest in blossoming of all the varieties shown, is among the more advanced on November 2. Its lateness is due apparently to its lack of responsiveness to temperatures with which Primate develops. Rome presents an anomaly in that it is perhaps the least advanced in November and apparently advances little or none to February 20; nevertheless it comes into blossom ahead of Daru and Cilligos.

The winter of 1921-1922 in Columbia was mild in the sense that there was little very cold weather. However, as measured in day-degrees above 43° it was not warmer than the ordinary season; the monthly accumulations from November to February inclusive being respectively 345, 167, 92 and 178. November accumulations were below the average (426) and December above (39), January somewhat below the average (122) and February somewhat above (139). The samples shown here, however, were gathered on February 20, when the accumulation for the month had reached 102 day-degrees only and before the warmest weather of the month. Consequently such development as is shown to be connected with temperature for this winter may be regarded as normal for this locality.

Evidently, then, early blossoming in apples involves at least two factors: first, the stage of advancement reached at the approach of winter, as exemplified by Oldenburg; second, ability to develop through the winter, as shown by Primate. Late blossoming, presumably, is due to the absence of both these factors or to the presence of strong inhibitors of the second. The ideal late blossoming variety as represented by Cilligos is backward in development in the fall and advances little through the winter. It is plausible that mixed inheritance of these factors gives the mid-season blossoming shown by the majority of commercial varieties, though Daru appears to have one factor for earliness despite its late blossoming. This seems the more likely since its crosses with Delicious now growing in the Experiment Station grounds include only very few late blossoming varieties, a smaller percentage than those shown by the majority of the crosses involving Ingram, another late blossoming variety.

The behavior of the late blossoming varieties indicates either a requirement of higher temperatures for advancement or the temporary presence of a development-inhibiting factor that is absent in the early blossoming kinds. If late blossoming is due to a higher temperature requirement, the difference between late and early blossoming kinds should be diminished by forcing in a greenhouse. If late blossoming is due to the persistence of the rest period in some form these differences should decrease as the season advances. Table 13 shows the results obtained by forcing twigs of Primate (hypothetically without or over the rest period)and of Rome (hypothetically still in the rest period). The stages observed in the two varieties differ, but comparison is possible. Though the buds started March 3 were kept in a cooler house than that used for the two earlier lots, enough cooler apparently to retard Primate, Rome started in a shorter time. The lower temperatures actually retarded the early blossoming variety more than the late blossoming. This, with the progressive shortening of the period of forcing in Rome, indicates the rest period as a factor rather than a differential temperature requirement.

TABLE 13.—NUMBER OF DAYS INVOLVED IN FORCING BLOSSOM BUDS OF PRIMATE AND ROME APPLES, 1922.

Date forcing started	Days to blossoms open in Primate	Days to buds starting in Rome
February 16	17	15
February 25	14	14
March 3	20	13

Comparison of Plates IV and V shows that the difference between varieties are greater when they are forced in the greenhouse than when the buds develop in the orchard. This points in the same direction as the evidence just cited.

Other Considerations.—Analysis of the records of 42 trees for which data are complete shows no relation between the date of terminal bud formation on shoots and the date of spur blossoming in the spring, the correlation coefficient being 0.085 ± 0.04. It is possible, however, that comparison of trees under different cultural conditions might show a relation of this sort, though it is doubtful if it should not be considered an associated rather than a causative condition.

Incidentally the relation to cross pollination of differences in blossoming may be mentioned. Comparison of the figures in the column headed "Range" with those in that headed "Duration of bloom in earliest variety" in Table 11 shows that in eight years of the thirteen recorded the earliest variety was out of bloom before the latest blossoming came in. In two years the date of last blossom in the one and of first bloom in the other were identical. In one only was the overlapping sufficient to ensure abundant cross pollination. In this section, then, when very early blossoming kinds are planted with very late blossoming kinds, cross pollination can be ensured only by a third variety, intermediate in blossoming season. This will provide pollination for the early blooming kinds with its first blossoms and for the late blooming with its last blossoms. Most of the commercial varieties grown in Missouri fall into the intermediate class in blossoming and may be counted on with safety so far as cross pollination is concerned. However, it is possible that the reputation of the Rome for light bearing in Missouri, though in Ohio it has not met that objection, is due to the greater extent of the blossoming season in Missouri so that Rome may in some seasons be in bloom alone while in Ohio the difference ordinarily would be less marked.

Table 14 shows the blossoming dates of several peach varieties, selected to permit comparison with dates for the same varieties at points with winters considerably milder than those at Columbia. For compactness these are expressed in days of the year rather than of the month. Though the list for most years at Columbia is more extensive than those given for Alabama or California, the range in blossoming represented is less in every case. In other words, just as the blossoming of the apple in distinctly cold sections has a narrower range than at Columbia, so the peach at Columbia has a narrower range than at points farther south. Cool weather during the peach blossoming season at Auburn, Alabama, may have prolonged the season of 1911 to an unusual length, but the normal blossoming range of the varieties named in this paper is apparently as great or greater than the maximum recorded for Columbia.[36] The range shown for Pomona, California, is apparently normal for that point.

The slight difference between all varieties at Columbia in 1907, the year of earliest blossoming for which an approximately complete record is available, indicates that the rest period as a factor in the date of blossoming in the peach is not operative here. This was a year of rather high temperature from January on. A considerably greater number of varieties than is here reported showed almost as close agreement in blossoming in 1921, when the season was even earlier than that of 1907. Any differences in the rest period which might be concealed by the retarding effect of an ordinary winter on the earliest varieties should become evident in these seasons of exceptionally high late winter temperatures, as soon as growth is possible. The third year of closeness in blossoming, 1906, was characterized by rather low accumulation during winter, with a rapid advance about the time of blossoming. The spread of the year of greatest range is due apparently to unequal winter-killing of blossoms and to the slow accumulation of temperature, which brought out minor differences in response to heat or merely delayed the opening of those varieties which had fewest buds. In warmer climates it seems quite possible that these differences in blossoming are due to differences in the termination of the rest period, particularly since the Peen-to peaches there blossom much earlier than those recorded in Table 14, and almonds in January or February.

TABLE 14.—PEACH BLOSSOMING DATES (IN DAYS OF YEAR) AT VARIOUS POINTS.

Variety	Columbia, Mo.									Auburn Ala.	Pomona Calif.			
	1905	1906	1907	1908	1909	1911	1914	1915	1921	1911	1894	1895	1902	1903
Alexander	98	102	82	90	101	95	--	--	--	--	78	76	--	88
Briggs Red	98	103	83	90	96	92	--	--	--	--	78	63	--	91
Carman	98	102	83	85	--	95	98	107	76	52	--	--	--	--
Champion	97	103	82	86	94	94	99	107	76	52	--	--	--	--
Chinese Cling	100	102	83	86	96	93	97	106	75	46	71	64	84	77
Crawford Early	--	102	82	80	96	93	96	108	--	35	74	62	91	84
Crawford Late	99	102	83	86	--	96	94	--	--	--	72	60	91	69
Elberta	98	102	82	85	95	92	97	107	74	45	--	--	--	--
Family Favorite	99	102	82	85	95	93	--	--	--	44	--	--	--	--
Foster	101	102	82	--	96	95	100	109	--	--	72	63	95	74
Globe	--	103	82	86	96	95	--	--	--	46	--	--	--	--
Heath Cling	97	104	82	84	95	96	103	--	--	--	72	66	91	69
Henrietta	102	103	82	88	97	--	--	--	--	--	--	65	--	--
Lemon Cling	--	102	83	88	96	93	103	105	--	--	--	73	--	--
Mayflower	--	--	--	--	--	95	100	105	--	57	--	--	--	--
Mountain Rose	--	--	--	--	--	--	98	107	75	--	76	60	91	77
Oldmixon Cling	98	102	82	86	96	97	94	108	--	--	72	63	94	87
Oldmixon Free	98	102	82	85	95	95	97	--	--	--	84	66	95	74
Salway	98	103	83	85	96	92	103	107	76	46	73	66	61	91
Smock	91	103	82	86	95	101	104	--	--	52	79	63	--	77
Sneed	99	102	83	87	95	93	--	--	--	52	--	--	--	--
Susquehanna	102	103	83	86	--	96	--	--	--	50	72	63	--	69
Thurber	99	102	82	86	95	--	--	--	--	43	--	--	--	--
Yellow St. John	98	103	82	86	99	96	--	--	--	--	72	63	64	79
Range	12	4	2	11	8	10	10	5	3	23	14	17	35	23

SUMMARY

1. The amount of heat, as measured in day-degrees, received by peaches from January 1 to the time of blossoming, varies with the season and even more with the locality.

2. The agreement in temperature accumulations to blossoming from year to year at any one place varies with the length of the time for which they are measured indicating that ordinary temperatures are not always effective or that temperature is not always a limiting factor.

3. Variability in temperature accumulations from various dates to blossoming at Wauseon, Ohio, follows different orders in the King apple and the Late Crawford peach, indicating that the latter is responsive to high temperatures when the former is not.

4. The average temperature accumulation from January 1 to blossoming in the apple is somewhat greater at Columbia, Mo. than at Wauseon, Ohio, but much less than at Pomona, Calif.

5. Varietal differences in blossoming at Columbia, Mo., indicate that the early blossoming varieties of apple become responsive to ordinary temperatures earlier than the late blossoming. There are, however, some inconsistencies which are not explained by any mathematical analysis attempted.

6. Microscopic examination of blossom buds indicates that there are at least two factors governing the season of blossoming at Columbia, Mo. Oldenburg blossoms early chiefly because the buds are well advanced in the fall, Primate because the buds develop through the winter. Daru is well advanced in the fall but does not develop through the winter and blossoms late. Cilligos is backward in the fall and does not advance through the winter; it is the latest blossoming variety observed. The mid-season varieties apparently have a mixed genetic constitution in this respect.

7. Observations on branches forced in the greenhouse indicate that late blossoming is connected with rest period influences rather than with differential temperature requirements.

8. Varietal differences in the peach at Columbia appear to be masked, but may become evident farther south, in the same manner as differences apparent in the apple at Columbia are masked farther north.

ACKNOWLEDGMENTS

Acknowledgments are due Professors V. R. Gardner, H. D. Hooker, Jr., and W. J. Robbins of the University of Missouri; to Dr. E. J. Kraus of the University of Wisconsin, for valuable aid and suggestions; to Mr. George Reeder of the United States Weather Bureau, for the temperature records for Columbia; to Mr. V. R. Boswell of the University of Missouri, for assistance in computations, for the sections used in the study of bud development and for the photomicrographs; and to those whose interest and care resulted in the accumulation of the phenological records for Columbia.

LITERATURE CITED

1. Abbé, C., U. S. D. A. Weather Bur. Bul. **36** (1905).
2. Adanson, Cited by Abbé.
3. Angot, A., Cited by Abbé.
4. Aoki, S. and Tazika. Y., Journ. Met. Soc. Japan. Apr. 1921, Abs. in U. S. D. A. Monthly Weather Rev. **49**. 609 (1921).
5. Bailey, L. H., The Evolution of Our Native Fruits, p. 199, N. Y. (1898).
6. Ballard, W. S. and Volck, W. H., Journ. Agr. Res. **1**:437 (1914).
7. Bigelow, J., Amer. Jour. Sci. **1**:76 (1820).
8. Bradford, F. C., Oreg. Agr. Exp. Sta. Bul. 129 (1915).
9. Calif. Agr. Exp. Sta. Ann. Rept. 1894-1895. p. 379.
10. Calif. Agr. Exp. Sta. Ann. Rept. 1902-1903. pp. 187-190.
11. Calif. Agr. Exp. Sta. Ann. Rept. 1903-1904. pp. 175-188.
12. Chandler, W. H., Mo. Agr. Exp. Sta. Res. Bul. 8 (1913).
13. Chandler, W. H., Proc. Am. Soc. Hort. Sci. **12**:118 (1915).
14. Drinkard, A. W., Jr., Va. Agr. Exp. Sta. Ann. Rept. 1909-1910. pp. 159-197.
15. Fritsch, K., Cited by Abbé.
16. Gardner, V. R., Bradford, F. C. and Hooker, H. D., Jr., Fundamentals of Fruit Production, N. Y. (1922).
17. Hedrick, U. P., N. Y. Agr. Exp. Sta. Bul. 407 (1915).
18. Ihne, E., Ueber Beziehungen zwischen Pflanzenphänologie und Landwirtschaft p. 9, Berlin (1909).
19. Johnston, E. S., Paper before Botanical Society of America. Toronto, Ont. Dec. 29, 1921.
20. Linsser, C., Cited by Abbé.
21. Livingston, B. E., Physiol. Res. **1**:8 (1916).
22. Livingston, B. E. and Livingston, G. J., Bot. Gaz. 56:5 (1913).
23. Magness, J. R., Oreg. Agr. Exp. Sta. Bul. 139 (1916).
24. Merriam, C. H., U. S. D. A. Bur. Biol. Survey, Bul. 10 (1898).
25. Mikesell, T., U. S. D. A. Mo. Weath. Rev. Sup. **2** (1915).
26. Morgan, W. M., Thesis. Cornell Univ. 1902—Cited by Wiegand, K. M., Bot. Gaz. 41:373 (1906).
27. Palladin, V. J., Plant Physiology. Eng. ed. by Livingston. Phila. (1918).
28. Price, H. L., Va. Agr. Exp. Sta. Ann. Rept. 1909-1910. p. 206.
29. Reaumur, R. A. F. de., Mem. Acad. des Sciences. 1735 p. 545. cited by Abbé.
30. Sandsten, E. P., Wis. Agr. Exp. Sta. Bul. 137 (1906).
31. Schimper, A. F. W., Plant Geography upon a Physiological Basis p. 37. Oxford, 1903.
32. Seeley, D. A., U. S. D. A. Mo. Weather Rev. 45:354 (1917).
33. Swingle, W. T., U. S. D. A. B. P. I. Bul. 53 (1904).
34. Waugh, F. A., Vt. Agr. Exp. Sta. Ann. Rept. 11:270 (1898).
35. Weber, F., Sitzungsber. d. Akad. d. Wiss. Wien. 125, 330 (1916).
36. Williams, P. F. and Price, J. C. C., Ala. Agr. Exp. Sta. Bul. 156 (1911).
37. Yule, G. U., Introduction to the Theory of Statistics, p. 146, London (1919).

Plate I.—Blossom buds of apple on February 2, 1920.

Oldenburg	Fameuse
Gano	York
Daru	Cilligos

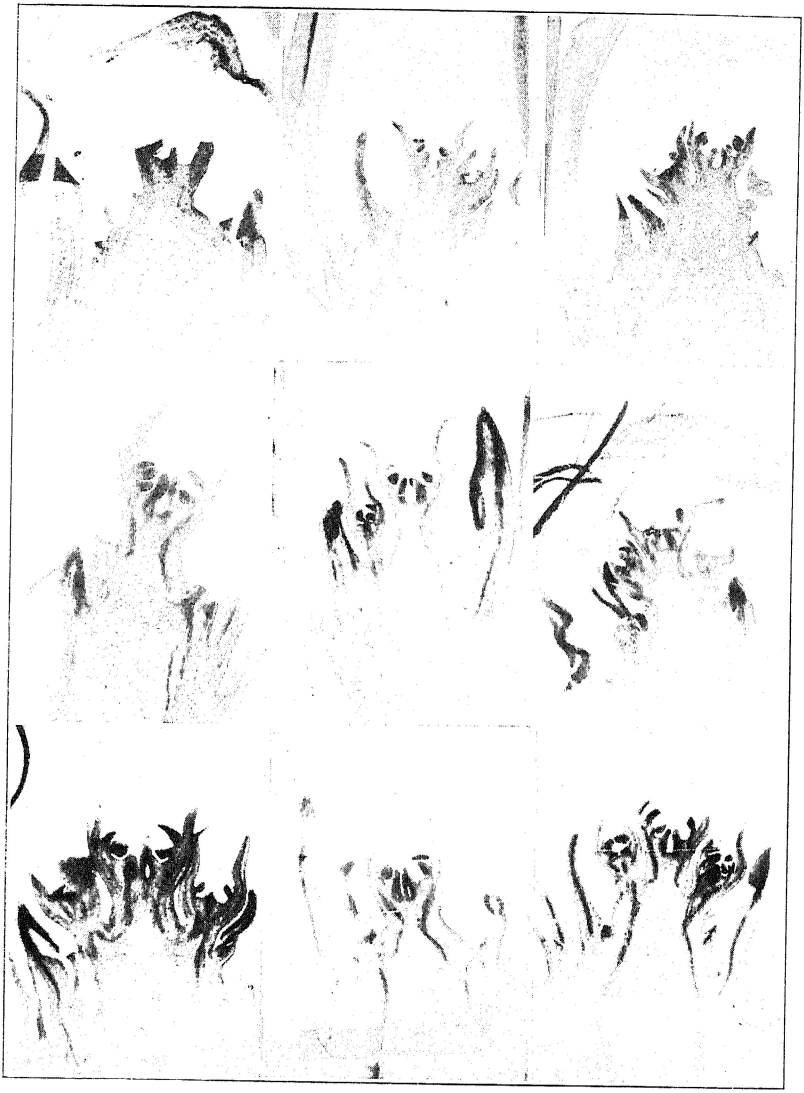

Plate II.—By rows: left to right, Oldenburg, Primate, Wealthy; top to bottom, November 2, 1921, January 28, 1922, February 20, 1922.

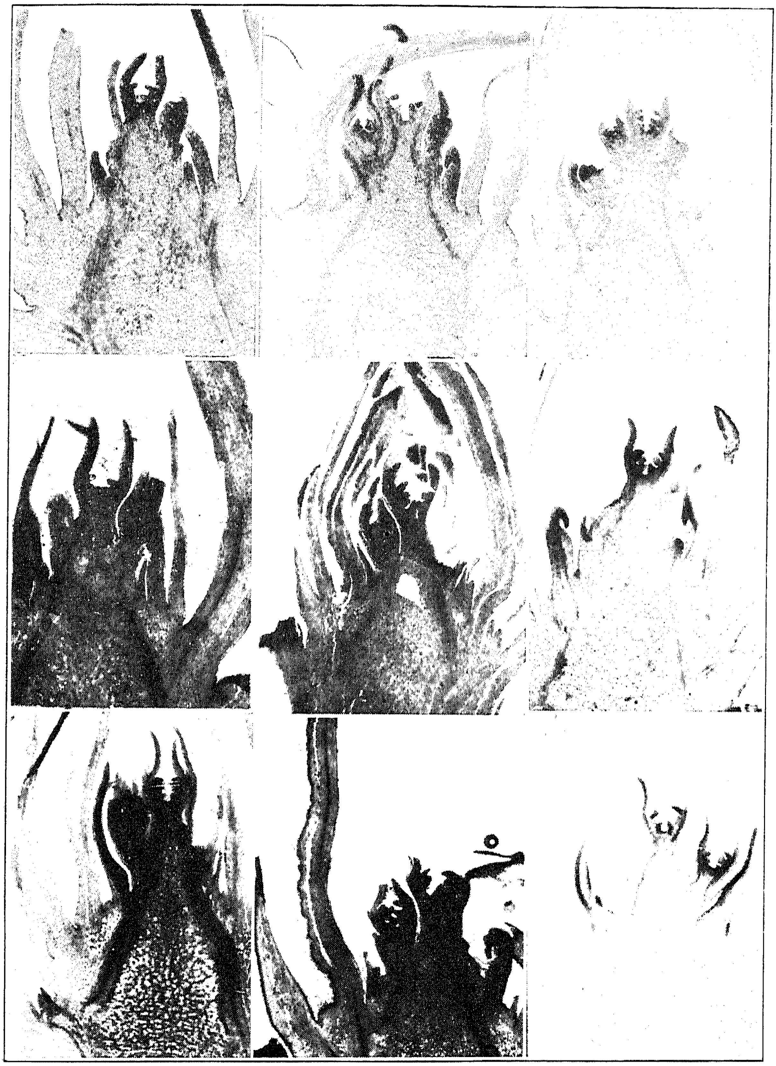

Plate III.—By rows: left to right, Rome, Daru, Cilligos; top to bottom, November 2, 1921, January 28, 1922, February 20, 1922.

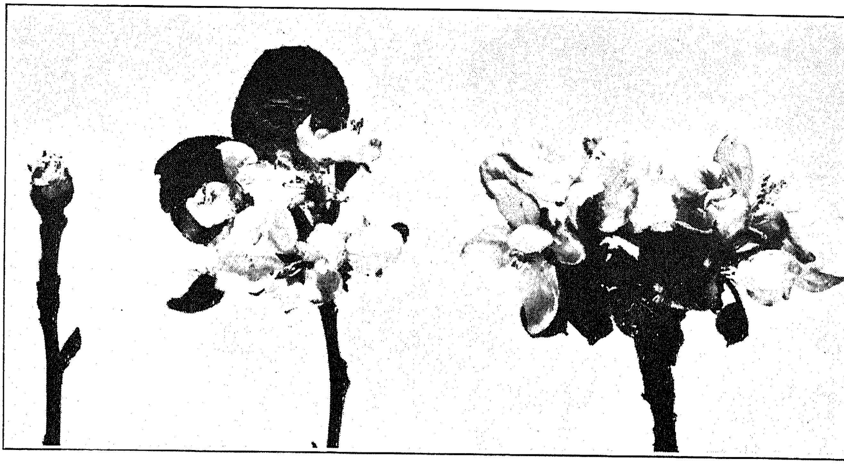

Plate IV.—Buds developing out of doors, 1920. Left to right: Cilligos, Fameuse, Oldenburg.

Plate V.—Buds forced in greenhouse, photographed March 6, 1922. Cilligos (1), Rome (2) (3), Daru (4), Oldenburg (5), Primate (6), Fameuse (7).

APPENDIX

Methods.—In the calculations reported in this paper, the date of first blossoming has been used. Though this standard is open to some objections, as, for example, a probable fluctuation with the total quantity of blossoms in the tree, it is less subject to change through varying judgments of different observers than is the date of full bloom.

Several commentators have mentioned the variability in blossoming found in young trees. This may be explained by the fact that often in young trees all the blossoms are on terminal shoots, which open markedly later than blossoms on spurs and if recorded without qualifications may well cause a considerable change in the relative order of blossoming. Phenological records in the apple should distinguish clearly between blossoms on spurs and those on shoots. All samples used in microscopic study were gathered from spurs which had blossomed at least once.

Since progress in phenological studies depends on the availability of data, temperature and phenological records for Columbia, Missouri, are appended.

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.
(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Alexander	114	114	94	107	115	109	116	114	113	113	109	--	--
Arkansas	98	111	86	101	108	104	113	108	111	111	106	112	101
Arkansas Beauty	99	110	86	100	108	101	116	109	111	111	108	108	102
Arkansas Black	101	113	88	102	116	107	115	109	111	112	107	111	104
Ashton	97	111	86	102	108	112	118	112	112	112	109	--	--
Autumn Streaked	99	110	--	99	109	106	--	107	112	111	106	109	97
Bailey Sweet	97	110	84	101	107	101	115	107	111	109	105	108	104
Balagh	100	111	86	100	--	103	--	--	112	112	109	113	104
Baldwin	100	111	--	103	114	107	116	110	112	112	109	--	96
Battyani	--	113	93	98	--	103	116	110	112	--	108	--	107
Batullen	98	92	--	98	113	102	116	109	112	112	108	114	101
Ben Davis	99	111	85	101	113	102	115	109	111	111	108	110	102
Ben Hur	--	--	87	104	113	107	116	110	112	110	107	110	96
Black Ben Davis	98	111	--	103	--	101	119	109	112	--	--	--	106
Blenheim	108	114	95	104	116	106	118	112	113	113	--	114	108
Bosnian	105	112	89	103	--	109	--	--	113	--	110	--	105
Brier	95	110	87	99	109	--	--	--	112	112	106	113	96
Canada Reinette	99	111	87	101	109	108	115	112	--	--	--	--	--
Champion	100	110	87	103	--	105	118	110	112	111	109	--	104
Cilligos	117	120	91	113	--	118	115	121	117	116	117	--	--
Clark	99	111	--	101	113	106	116	118	113	--	109	--	--
Clayton	99	111	88	102	112	104	116	110	112	--	108	--	--
Collins	102	110	86	101	109	102	114	109	111	110	107	111	107
Czar Thorn	99	111	85	99	108	104	116	109	--	111	109	109	--
Daru	114	116	105	112	124	112	121	113	107	--	114	--	121
Delaware Red	--	116	88	104	--	-	115	112	115	111	--	--	105
Delicious	--	113	87	104	113	104	116	113	112	111	107	113	102
Devonshire Duke	--	112	87	102	--	106	118	110	116	111	--	113	--
Doctor	101	113	90	101	115	105	115	112	112	111	109	111	106
Downing Blush	--	113	87	102	--	108	118	109	110	--	--	--	--
Eper	115	116	99	103	--	112	--	113	114	113	114	113	108
Fameuse	96	110	86	98	108	104	115	107	109	111	107	108	91

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.
(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Faust's Rome Beauty	113	115	99	107	119	105	--	114	113	113	109	--	--
Gano	98	111	86	102	113	103	116	110	111	112	109	114	101
Ginnie	103	111	88	104	114	106	118	110	112	--	108	111	96
Gold Medal	100	114	87	102	113	105	119	111	115	112	109	--	102
Golden Russet	95	120	85	102	--	108	116	--	109	111	106	109	92
Greening	102	111	87	102	116	106	117	111	--	--	--	--	--
Grimes	98	112	87	101	108	106	115	109	110	112	107	111	97
Heidorn	--	115	--	107	116	106	115	111	112	112	112	113	105
Hubbardston	99	111	86	103	114	100	115	112	114	111	108	113	97
Huntsman	101	114	86	100	114	107	115	109	110	113	107	112	101
Imperial Janet	117	117	106	110	--	119	121	119	118	--	115	--	--
Ingram	115	120	104	109	118	118	121	119	119	114	118	128	111
Jeffries	--	--	--	--	--	106	116	110	112	111	107	113	96
Jonathan	97	110	86	102	112	102	116	107	111	110	108	109	97
July	100	112	87	100	--	111	116	111	114	112	109	110	106
Kansas Greening	110	115	108	107	--	111	118	111	112	112	--	--	108
Kartacs	--	116	108	106	118	--	--	115	115	113	110	114	104
King David	--	--	--	--	117	104	115	110	112	111	109	112	103
Lady	116	115	99	108	--	--	--	--	--	111	114	121	--
Lady Carter	99	110	87	101	113	--	--	--	110	--	108	113	102
London	--	115	88	104	112	--	--	--	117	112	109	--	--
Late Duchess	97	109	87	98	107	--	--	--	109	112	106	121	92
Longfield	100	111	95	100	109	--	--	--	115	--	112	--	106
Lou	98	109	87	100	105	--	--	--	--	108	--	108	--
Louise	100	111	86	101	111	--	--	--	112	112	109	112	96
Magyar	105	111	88	103	--	--	--	110	112	112	109	114	106
Maiden Blush	99	110	87	98	108	107	115	108	110	110	107	109	95
Marin	97	110	86	100	109	104	115	107	109	111	105	109	97
Melon	97	110	88	99	108	105	116	108	--	--	--	--	--
Menagera	97	109	86	100	108	101	114	109	108	110	108	109	91
Metitt	100	112	84	102	110	108	115	111	112	111	--	109	96
Miller Boy's Favorite	104	112	87	102	115	109	115	110	110	--	--	--	--
Minkler	98	110	85	99	107	102	119	107	108	109	107	108	96
Minnesota	91	107	85	96	103	100	114	107	108	110	105	108	90
Missing Link	--	--	87	104	110	104	116	108	109	--	107	--	--
Missouri	98	110	85	102	112	103	116	109	111	109	106	112	97
Mosher	110	112	87	104	110	106	118	110	112	112	109	110	--
Mc Intosh	100	111	87	102	109	105	117	110	112	111	109	113	--
Nelson Sweet	100	112	87	103	114	106	116	110	112	113	--	--	--
Noble Savar	99	111	86	100	109	--	118	109	112	112	109	114	--
Nyack	101	114	88	103	115	110	102	111	112	--	--	--	--
Nyari Piros	105	112	86	99	109	104	115	110	109	114	107	--	100
Ohio Beauty	110	113	90	102	--	105	116	111	113	111	111	112	103
Ohio Pippin	99	110	85	100	112	103	116	108	113	111	108	109	97
Oldenburg	94	110	86	98	107	102	114	107	110	--	106	--	97
Olive	99	112	87	102	111	106	--	111	112	113	109	114	--
Ontario	102	113	86	103	117	108	118	112	113	112	--	--	--
Opalescent	--	--	--	106	116	110	117	114	113	111	--	--	107
Payne Keeper	--	--	93	105	114	106	117	113	112	113	109	114	98
Peach	--	118	--	104	--	107	112	112	113	112	110	113	--
Picket	100	110	86	99	110	105	--	--	110	112	109	109	96
Ponyik	104	115	95	105	--	--	118	--	114	113	110	--	106
Primate	97	110	87	99	107	--	114	109	107	110	106	112	90

DATES OF FIRST BLOSSOMING IN APPLE AT COLUMBIA, MO.

(Days of the year)

Variety	1905	1906	1907	1908	1909	1911	1912	1913	1914	1915	1916	1917	1918
Pumpkin Russet	99	111	88	102	117	104	116	112	109	112	--	--	100
Pumpkin Sweet	100	111	87	101	108	--	--	--	110	111	108	110	98
Ralls	113	117	106	110	121	118	121	118	116	114	111	128	117
Reagan	100	112	88	102	111	106	116	--	--	--	--	--	--
Red Astrachan	98	110	88	99	107	102	115	108	109	110	109	--	--
Red June	--	--	--	--	--	104	111	--	112	111	109	113	94
Red Stettiner	99	110	85	100	112	103	116	108	113	111	108	109	97
Rome	105	114	99	107	119	111	115	112	115	114	111	115	108
Rutherford	96	109	85	99	--	--	115	109	112	111	108	110	92
Sabadka	100	115	87	--	--	106	118	112	113	113	109	110	103
Segfu	--	112	87	104	113	110	117	112	112	112	110	110	102
Sekula	104	113	94	102	--	110	--	--	115	--	109	--	102
Selumes	100	112	85	102	107	107	115	114	111	112	108	--	98
Skelton	99	111	87	102	112	--	--	110	114	112	108	--	104
Spitzenberg	99	111	87	102	109	--	--	111	117	--	--	--	--
Standard	93	110	86	99	104	100	--	108	110	112	106	--	92
Stayman	98	110	86	101	112	106	115	110	111	111	109	112	103
Summer Calville	97	110	86	98	108	105	116	109	109	--	108	110	92
Summer King	--	--	--	--	--	--	114	113	--	113	109	112	103
Tetofski	98	110	87	103	108	106	115	109	112	110	106	110	100
Titus Pippin	102	110	86	102	114	106	115	109	111	110	108	111	105
Tudor	99	115	87	--	--	110	116	109	109	--	106	--	98
Wafer	94	112	88	102	113	114	--	110	114	112	110	112	106
Wealthy	--	--	--	104	112	104	117	109	112	111	109	110	103
White Canada	98	112	87	101	109	105	117	108	111	112	108	112	97
White Pippin	97	112	87	102	--	107	116	--	112	--	106	--	94
Wine Rubets	104	112	87	104	117	109	117	110	109	112	109	--	102
Winesap	99	111	87	102	113	104	116	110	112	111	109	109	104
Wolf River	108	113	88	102	112	109	116	110	111	111	110	113	102
Woodmansee	--	--	--	--	--	--	118	113	114	112	110	114	121
Workaroe	109	113	--	103	115	109	118	112	115	111	--	--	--
Yappa	102	112	87	102	116	106	118	108	--	--	--	--	--
Yellow Newtown	--	--	--	104	--	108	117	113	113	112	109	--	103
Yellow Transparent	--	--	--	108	113	104	117	113	113	112	108	110	105
York Imperial	99	113	88	103	113	106	116	111	--	112	--	112	--
York Stripe	103	114	88	104	116	107	117	113	--	--	--	--	--

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI
January

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	66	39	40	47	28	46	52	26	56	42	41	62	43	44
2	43	41	49	50	49	29	7	26	38	42	33	42	50	43
3	27	41	47	49	59	23	5	19	42	29	38	48	49	31
4	35	29	46	47	60	29	34	11	36	29	41	61	50	44
5	40	42	65	42	33	25	50	13	23	28	47	63	42	42
6	25	41	72	51	4	12	48	—3	20	39	42	21	56	28
7	24	43	71	52	17	35	55	2	20	54	43	29	40	21
8	32	19	54	44	33	36	47	12	24	58	30	38	54	26
9	31	40	26	52	43	29	47	29	32	40	49	49	57	20
10	10	45	33	47	42	43	68	10	38	28	40	51	52	16
11	32	35	44	36	8	42	67	3	38	44	40	37	22	9
12	15	35	43	30	18	44	31	—5	20	34	41	34	37	0
13	11	43	56	31	32	44	34	20	32	46	52	0	16	15
14	9	48	40	39	35	30	34	22	43	52	54	20	30	18
15	17	58	28	44	34	33	22	7	56	58	61	34	23	16
16	30	37	33	26	30	37	27	29	60	53	58	11	22	23
17	39	57	34	40	27	51	28	43	59	43	28	18	30	18
18	40	40	54	43	36	44	29	33	38	50	31	23	30	13
19	37	63	60	49	37	57	41	20	64	66	34	32	40	17
20	46	72	26	58	46	44	54	27	35	47	25	55	40	16
21	34	65	49	58	61	32	39	48	32	32	20	57	60	20
22	24	17	39	44	74	42	33	49	37	54	19	52	17	24
23	33	24	35	35	72	50	45	51	42	60	14	54	36	37
24	31	43	51	32	65	44	49	34	41	41	16	62	34	42
25	10	47	23	47	40	62	55	39	54	38	26	60	45	42
26	30	48	18	42	43	61	71	50	53	62	31	63	41	28
27	37	48	25	42	57	41	60	35	43	64	26	56	42	15
28	29	47	32	42	61	42	47	34	43	65	15	33	66	18
30	25	48	33	31	10	29	40	28	54	30	42	31	51	19
31	27	46	35	34	18	32	64	41	31	43	51	27	47	5

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI

February

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	15	44	37	17	43	57	81	33	14	52	48	16	6	11
2	—2	27	36	31	55	51	38	21	26	55	32	17	3	30
3	5	55	14	35	63	38	54	20	32	38	38	21	36	24
4	20	42	11	37	65	43	41	18	30	32	56	36	38	11
5	20	14	12	52	60	44	46	17	15	35	37	36	24	53
6	21	21	21	36	45	31	43	23	27	32	31	22	48	50
7	23	30	25	49	43	40	41	24	25	15	34	14	47	59
8	28	40	47	41	54	41	46	22	34	16	38	35	38	65
9	29	27	50	43	53	32	40	20	35	45	45	41	24	40
10	13	29	41	46	33	43	47	34	40	37	65	44	29	63
11	27	43	49	46	56	42	48	39	36	28	64	44	21	65
12	9	58	57	62	54	25	54	30	21	21	69	35	33	54
13	—1	51	60	54	35	42	64	37	38	22	61	21	44	59
14	24	28	43	40	36	59	54	36	52	24	49	33	35	62
15	15	28	60	38	21	63	78	41	51	38	34	43	38	30
16	30	37	60	34	25	17	76	53	61	27	51	56	56	32
17	30	36	62	39	49	17	65	53	63	54	57	52	52	36
18	35	55	66	37	46	30	39	55	69	42	55	40	33	51
19	35	61	44	23	38	39	32	45	63	27	51	55	52	60
20	34	59	43	37	54	41	26	35	38	30	54	55	33	16
21	44	57	25	34	58	26	22	30	51	48	52	59	53	19
22	47	69	26	56	54	26	31	40	34	38	50	63	64	45
23	55	54	31	49	55	10	35	52	23	17	47	37	56	69
24	51	50	35	49	35	28	43	43	26	21	34	49	37	65
25	50	45	50	48	55	43	48	39	40	32	41	43	68	63
26	60	39	54	36	56	42	39	35	40	46	35	37	62	51
27	44	32	58	31	52	33	34	38	29	53	35	32	31	42
28	63	50	61	52	65	48	29	33	22	50	40	31	41	38
29	----	----	----	71	----	----	----	27	----	----	----	38	----	----

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI
March

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	59	62	54	48	67	57	34	31	28	27	44	32	36	50
2	67	59	59	48	70	70	46	24	31	39	42	32	34	58
3	76	34	54	45	49	76	59	29	49	35	42	26	31	51
4	58	33	40	49	48	76	46	33	41	43	31	50	22	62
5	67	34	51	74	62	81	70	27	38	50	33	53	38	76
6	39	40	41	71	54	64	59	37	30	40	29	66	57	42
7	44	42	49	46	62	58	49	36	52	34	34	43	50	53
8	50	60	45	40	46	57	63	33	67	37	39	38	50	65
9	53	52	38	47	42	42	71	28	57	47	41	56	64	73
10	43	39	39	56	43	48	61	31	55	48	39	52	69	47
11	43	32	53	50	39	60	82	35	59	34	37	49	54	65
12	50	22	55	73	46	61	60	36	61	47	41	76	44	77
13	47	29	37	55	51	69	49	40	57	62	45	76	54	90
14	69	25	43	74	37	47	60	37	54	69	49	51	45	61
15	70	25	63	66	45	52	50	33	28	79	39	36	54	50
16	71	23	66	66	48	65	45	51	39	55	46	52	60	56
17	66	26	68	63	52	67	64	58	63	53	44	56	41	73
18	71	29	67	63	72	71	52	65	68	36	42	62	41	76
19	55	30	80	45	48	74	60	67	68	30	42	54	65	72
20	36	34	70	51	48	70	72	41	50	37	33	71	49	74
21	48	46	92	61	50	73	77	28	34	37	37	86	64	80
22	73	32	90	60	60	90	59	32	45	46	37	64	71	62
23	61	29	82	67	69	88	53	34	72	58	47	54	64	42
24	71	35	77	67	66	85	58	39	53	68	63	82	66	59
25	71	55	90	81	45	82	71	48	39	70	50	69	75	69
26	71	59	82	73	67	86	61	49	33	73	39	56	59	75
27	82	42	82	78	49	86	50	42	32	61	48	51	50	64
28	69	39	78	44	55	86	66	43	53	77	53	63	69	61
29	60	37	58	57	45	78	55	59	62	67	46	62	62	66
30	73	53	61	48	52	65	46	68	75	58	44	68	82	72
31	77	49	47	67	49	60	45	72	63	69	40	59	80	75

DAILY MAXIMUM TEMPERATURES, COLUMBIA, MISSOURI
April

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
1	81	55	54	57	57	71	48	50	72	57	40	52	50	79
2	72	70	63	38	56	69	69	57	79	63	46	50	54	83
3	70	74	63	60	61	74	43	65	72	46	54	61	62	51
4	58	61	70	65	85	76	47	74	50	52	71	59	54	55
5	55	56	50	65	84	56	55	80	65	60	75	56	54	54
6	55	64	50	80	76	60	63	72	69	56	76	45	59	58
7	61	73	57	69	59	73	49	55	53	46	75	36	51	60
8	86	69	47	70	48	77	57	66	46	36	77	44	46	53
9	90	72	52	54	51	75	58	67	65	46	70	50	57	48
10	74	66	51	63	59	81	62	68	48	53	69	68	70	54
11	59	78	54	59	73	63	54	77	44	49	63	82	70	53
12	62	82	47	69	61	58	78	76	43	57	58	84	57	52
13	64	66	45	79	55	72	66	74	57	62	60	70	51	64
14	53	45	52	68	64	71	53	74	68	65	71	59	59	66
15	48	54	62	68	65	68	62	65	72	72	77	68	52	61
16	46	63	45	57	80	47	70	49	77	83	81	62	73	73
17	55	69	51	61	87	42	77	44	84	83	79	65	83	65
18	61	74	44	64	78	40	61	55	79	70	76	79	83	67
19	66	77	47	81	48	42	62	53	66	51	84	76	80	55
20	75	75	56	83	51	66	61	70	63	64	78	70	62	38
21	61	81	60	80	55	78	61	73	81	84	76	55	72	50
22	64	64	65	82	54	65	58	58	82	81	78	67	81	63
23	70	61	70	79	60	40	59	68	80	67	86	65	86	63
24	73	87	78	73	69	36	60	75	60	81	84	61	81	48
25	73	80	72	75	71	42	63	65	60	81	84	57	61	45
26	59	82	57	55	82	59	75	72	64	86	78	51	53	58
27	80	86	65	48	64	77	58	67	57	81	83	61	49	58
28	85	70	81	54	80	85	76	66	66	71	85	69	54	62
29	72	77	72	52	88	91	82	57	73	58	73	73	49	55
30	73	61	47	57	51	80	72	67	84	53	73	64	54	56