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as Influenced by Certain Post-Blossoming Environmental Factors

By V. R. GARDNER, T. A. MERRILL and W. TOENJES

MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
SECTION OF HORTICULTURE
EAST LANSING

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SUMMARY

Data are presented on fruit setting of the Delicious apple in many of the more important apple-growing sections of the United States and Canada and also in other parts of the world.

Fruit setting of this variety is shown to be lighter in Michigan and adjacent portions of the Great Lakes area than elsewhere.

The evidence indicates that environmental conditions during a short period immediately following full bloom are controlling factors in influencing fruit setting. The first week or 10 days is shown to be particularly important in this connection.

The data point clearly to the importance of three environmental factors during this period:

1) **Temperature.** The total "effective" (i.e. above 42° F.) day-degrees in southern Michigan, where setting is characteristically light, for the 7-day period following full bloom is 130-150; for sections where setting is heavy enough to call for thinning it is 200-250.

2) **Sunlight.** The total gram-calories of radiation received per square centimeter in southern Michigan during this 7-day period averages 2,550; in sections where setting is so heavy that thinning is required it averages 3,000 to 4,000.

3) **Spray materials.** In most sections where fruit setting of this variety is heavy no fungicides are used: most sections employing fungicides to control scab in the pre-blossoming, blossoming and fruit setting periods now use lime-sulfur or wettable sulfur. The one is highly toxic, the other is mildly toxic. Certain copper-containing materials and fermate are still less toxic.

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The data on fruit setting presented in this publication are for the 1947-48, and in a few instances earlier, seasons. The manuscript was actually placed in the printer's hands in June 1949. The following observations on fruit setting in Michigan in the spring of 1949 are pertinent.

The blossoming season in Michigan in 1949 was comparatively early. The fruit-setting period was characterized by exceptionally

bright sunny weather, weather comparable to that of the Pacific Northwest and other areas where this variety characteristically sets well. In the Fremont orchard where most of the experiments reported were conducted, the blossoms were opening May 1. Fruit setting in the Delicious in this orchard, as well as in other parts of the state has been heavy. The gram-calories of radiation recorded per square centimeter at East Lansing, during the first week of May was 3,232; for the second week in May the figure was 3,136.

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Fruit Setting in the Delicious Apple as Influenced by Certain Post-Blossoming Environmental Factors

By V. R. GARDNER, T. A. MERRILL and W. TOENJES

Delicious is one of the most widely distributed and extensively grown of apple varieties. It is the dominant variety in a number of important producing areas in the United States and ranks well up in the list in parts of South America, South Africa and Australia. The very fact that it is so widely grown is in itself evidence that, generally speaking, the tree grows well, is productive and that the fruit meets with a relatively high degree of consumer acceptance. Nevertheless, there are areas where, though the trees grow well, yields are low. This is mainly for the reason that a small percentage of its blossoms set and mature fruit as compared with those of other standard varieties. Nowhere is this characteristic more accentuated than in the Great Lakes region. Throughout this area it has the reputation of being an erratic or shy bearer. The experience that many growers have had with it has been so unsatisfactory that in some instances trees have been top-worked or removed entirely and replaced with more productive kinds.

Failure to set fruit satisfactorily in the case of apples is usually associated with pollination difficulties, and many experiments have been conducted to determine pollination requirements of the Delicious variety. They have shown that under most conditions the variety is self-sterile, though there are records of satisfactory crops being obtained where pollen of other varieties has not been available or where there have been few bees for pollen transfer. Thus Musser (42) writes: "Some years ago we had a rather large block of Delicious in which there were no pollinator trees. Some years we would get a very heavy set on this variety without putting bouquets in this block and other years we would get practically no set, although weather conditions under both heavy and light set seemed to be very favorable for bee movement and pollination." Similar behavior has been reported in

Australia (53). However, in the Great Lakes area the same provisions for cross pollination are made by producers as in other areas where yields are much heavier. For instance, a typical Delicious performance in southeastern Michigan is that of a 10-acre, 20-year-old block near Metamora with 35 McIntosh interplanted for pollination purposes. The trees are large, vigorous, thrifty, well cared for and capable of producing 5,000 bushels per year. Yet in 1947 when blossoming was heavy, when weather conditions in the orchard were reasonably favorable for pollination, when 150 buckets containing branches of other varieties were provided as an extra source of pollen and when 20 colonies of bees were moved in to effect cross pollination the total crop was 375 bushels. Furthermore in portions of this orchard hand pollination did not result in much of an increase in set of fruit (22). It is evident, therefore, that some factor or combination of factors operates to reduce fruit setting and therefore yields in this area that are not present, at least to the same degree, where there is a better set. Among the environmental and growth factors that are known to influence, or may be suggested as influencing, fruit setting are the following: 1) temperature (including frost), atmospheric humidity, precipitation, wind and the relative abundance or scarcity of pollinating insects during the blossoming period, 2) weather conditions, particularly temperature, moisture supply, available nutrient supply, atmospheric humidity and sunlight during the post blossoming period (a period of perhaps a month, until the so-called "June" drop), 3) relative growth status and vigor of tree, considered along with the scarcity or abundance of bloom, 4) residual influence of the past season's cropping, time of defoliation and autumn weather conditions.

Some of these factors will be discussed very briefly, others in more detail.

METHODS OF PROCEDURE

Answers to a number of the questions just raised regarding the influence of environmental factors in fruit setting in general and in some instances for the Delicious apple have been supplied by previous experimental work. Citations to these findings are all that is required. Answers to others have been obtained by new experimental tests in Michigan. Answers to still others have been sought through the cooperation and collaboration of many observers and investigators in many other states and in a number of foreign countries.

GROWTH STATUS AND RELATIVE VIGOR OF TREE

It has long been observed that extremely weak and likewise extremely vigorous apple trees produce few or no blossoms and those blossoms set little or no fruit. Trees a little less weak or a little less vigorous may blossom freely and set fruit sparingly. Those in a more normal condition set better. In a New York study Heinicke (30) found that 41.6 percent of the spurs with large leaves on vigorous limbs set fruit compared with only 15.7 percent of those on weak limbs and having small leaves. Thirty-eight percent of the spurs making more than 1 centimeter of growth one year set fruit the following season, compared with 18 percent for those making less than 1 centimeter of growth. More recently Blake (3) has emphasized the importance of the growth status of the whole tree and especially its spurs and buds as a factor of importance in the setting of Delicious blossoms in New Jersey. Cooper (14) in Arkansas has found that with both Ben Davis and Yellow Transparent varieties the larger blossoms on the thicker spurs with the greater number of leaves set a higher percentage of fruits than do those on the weaker spurs. In the writers' plots in Michigan general tree vigor had considerable influence on fruit setting (Table 9), though less than it did on number and percentage of fruit spurs differentiating flower buds.

There are not only sizable differences from tree to tree in the same orchard and from orchard to orchard in the same area in rate of growth, earliness in coming into bearing, fruit setting and crop yields, but differences in these respects among different areas. Characteristically, Delicious trees grow very rapidly, come into bearing at an early age and are precocious in certain sections of The Argentine and in New South Wales. Thinking that possibly the leaves might be materially larger on trees grown in those sections tracings were obtained of large random samples of leaves from young fruiting trees at the Bathurst Experimental farms through the cooperation of C. G. Savage, Chief of the Division of Horticulture of the Department of Agriculture for New South Wales (Australia). Another set of tracings of the leaves of young vigorous Delicious trees well into bearing were obtained from Mendoza, Argentina, through the cooperation of Dr. R. C. Nelson, and still another set from Dr. Emiliano J. MacDonaugh of the Universidad National de la Plata, Argentina. Planimeter measurements of their areas showed them to be of about the same size as leaves on vigorous

Michigan-grown trees of the same age that do not set fruit well. It may be concluded that while at least moderate vigor of tree is more or less of a prerequisite to good setting, it does not guarantee (proper cross pollination is assumed in this and the following discussion) good setting and trees that set well do not have especially large leaves.

Related to plane of nutrition, growth status and vigor as they influence fruit setting is the question of relative number of blossoms. Of two trees of essentially the same vigor, one of which produces a very heavy and the other a light crop of blossoms, the one may be expected to set better than the other. Sometimes the heavier loss of potential fruits from the blossoms that are borne comes immediately after the blossoming period; sometimes it comes later, e.g. at the time of the June drop. The Anjou pear is particularly sensitive in this respect. Characteristically it blossoms very heavily and sets fruit lightly. However, with heavy pruning to thin the blossoms a good set and a good crop may be obtained (31). Exact experimental data are not available on the behavior of the Delicious apple in this respect, but observation leads to the belief that it follows the general pattern. Incidentally this observation is supported by the experience of one of Michigan's most successful producers of this particular variety, Mr. A. L. Darbee of East Jordan.

RESIDUAL EFFECT OF PAST SEASON'S CROPPING

Somewhat more exact information is available on the influence of one season's production on fruit setting the following spring. Thus Goff (25) has reported higher percentages of defective pistils and poor setting of fruits in trees of the American varieties of plum following a heavy than a light or moderate crop. Blake and associates (7) attribute much of the June drop in the peach to exhaustion of food reserves stored up the previous autumn. Speaking for the Stanthorpe area of Queensland, Australia, Summerville (53) says: "Setting is somewhat irregular, but we have no evidence of biennial regularity. The last two seasons, for example have been heavy crops. We connect the crop rather with the weather prevailing the preceding autumn than with any other one factor. . . . it is the general opinion of our field men that the supply of moisture and nutrients during the autumn profoundly affects the laying down and development of bud initials . . . ".

While there may be some residual influence of one season's crop on setting of fruit the following season in the case of certain varieties of apples as grown in Michigan and other portions of the Great Lakes

area, varieties that often set and bear very heavy crops, it is doubtful if such an influence is often of importance in the Delicious apple as it grows here. Seldom does it mature a crop of sufficient size to have such a residual weakening effect.

ENVIRONMENTAL INFLUENCES DURING THE BLOSSOMING PERIOD

The importance of favorable weather during the blossoming season from the standpoint of obtaining a good set of fruit is well recognized. If low temperatures or rain interfere seriously with the activity of pollinating insects, a good set cannot be expected. Possibly this indirect influence of weather during this particular period is greater than its effect on physiological processes within the plant. There is little activity on the part of honey bees, the most important pollinating agent for the apple, when the temperature is below 57° - 58° F., and they do not work much when there is considerable wind.

TEMPERATURE (INCLUDING FROST)

Tables 1a, b and c and 2a, b and c present data on temperature conditions during, preceding and just following the full bloom stage, together with fruit-setting percentages for the Delicious apple, for locations in the U. S. and Canada in the spring of 1947 and for four other locations in the seasons of 1940, 1941 and 1946—all told, 41 records. The records are assembled in classes for locations where fruit setting is low (less than 5 percent), medium (5 to 10 percent) and high (over 10 percent).

Data on actual frost occurrence are not available in every instance. It may be assumed, however, that frost was possible whenever the minimum temperature fell to 37° F. or below and probable whenever it went to 34° F. or below (though minima of 32° F. or above would not have been accompanied by frost if the skies were cloudy or if there was much air movement. On the basis of this assumption it is evident from the following tabulation that frost could have been an important

Percent setting of Delicious	No. season's records	Total No. nights trees were in bloom	No. times temperature fell below 38°F.	No. times temperature fell below 35°F.
0–5	11	50	5	3
5–10	15	75	4	0
10–up	16	80	10	3

factor in reducing the set of fruit in the low-setting, as compared with the better-setting locations. However, in only 1 of the 11 locations having a poor set were minimum temperatures below 32° F. registered, and in six of them the temperature never fell below 40° F. during the blossoming period. Plainly frost was not responsible for poor setting in most of the locations where records were obtained.

Of probably greater significance are the figures for maximum temperatures during the blossoming period. They were substantially higher at the locations where setting was good than where it was poor. The following summary shows the number of day-degrees above 57° F. during the 5-day blossoming period for the different locations. They

Percent setting of Delicious	No. season's records	Total No. days in blooming periods	Total No. days when temperature was above 57°F.	Total day-degrees above 57°F.	Average day-degrees above 57°F. per station
0–5	11	55	45	533	48
5–10	14	70	69	1176	84
10–above	16	80	78	1296	81

afford some measure of the favorableness of conditions for cross pollination to be effected by bees. These summary and average figures, however, do not tell the whole story. Reference to Table 1a, b, c shows

TABLE 1A—*Temperature conditions during the 5-day blossoming period at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Blossoming period	Percent flowers setting fruit	Daily minimum temperatures	Daily maximum temperatures	Total day-degrees above 57°F.
E. Lansing, Mich.[1]	1947	5/25–5/29	4.3	44–45–41–40–39	61–65–66–55–57	21
Gr. Rapids, Mich.[2]	1947	5/25–5/29	4.2	46–50–46–40–37	62–61–62–53–50	14
Wooster, O.[3]	1947	5/19–5/23	1.13	53–55–49–45–49	78–64–70–71–79	77
Arendtsville, Pa.[4]	1947	5/15–5/19	2.3	48–45–30–27–29	67–58–49–52–64	18
Newark, Del.[5]	1947	4/28–5/2	2.5	37–42–58–59–50	56–68–82–80–66	68
Campbell, Mo.[6]	1947	4/16–4/20	3.7	43–38–48–56–47	61–62–72–73–69	52
Mt. Grove, Mo.[7]	1947	4/29–5/3	4.0	56–58–51–50–48	81–83–67–64–73	83
Vineland, Ont.[8]	1947	5/27–5/31	4.2	41–47–44–39–44	66–61–66–60–69	37
Blue Ridge, Ga.[9]	1947	4/26–4/30	4.2	45–40–46–59–58	70–77–79–76–72	89
Doniphan, Kan.[10]	1947	5/ 6–5/10	4.1	57–50–52–50–62	72–64–63–66–74	54
Pittsfield, Ill.[11]	1940	5/ 1–5/5	4.25	36–37–37–37–51	57–44–45–60–74	20
Average						48

[1]Temperature records for East Lansing, Mich.
[2]Temperature records for Grand Rapids, Mich.
[3]Temperature records for Akron, O.
[4]Temperature records for Arendtsville, Pa.
[5]Mean of the temperature records for Baltimore, Md., and Philadelphia, Pa.
[6]Mean of the temperature records for Cairo, Ill., and Memphis, Tenn.
[7]Temperature records for Springfield, Mo.
[8]Temperature records for Toronto, Ontario.
[9]Temperature records for Chattanooga, Tenn.
[10]Temperature records for St. Joseph, Mo.
[11]Temperature records for Springfield, Ill.

TABLE 1B—*Temperature conditions during the 5-day blossoming period at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Blossoming period	Percent flowers setting fruit	Daily minimum temperatures	Daily maximum temperatures	Total day-degrees above 57°F.
Stephensville, Tex.[1]	1947	4/19–4/23	5.0	50–45–50–64–69	80–75–83–84–84	122
College Park, Md.[2]	1947	5/ 3–5/7	5.5	51–53–52–52–45	70–72–63–69–70	59
Pittsfield, Ill.[3]	1941	4/25–4/29	7.96	38–44–50–55–55	64–71–76–80–81	87
Lafayette, Ind.[4]	1947	5/11–5/15	6.3	39–50–58–52–52	76–80–78–72–85	116
Kentville, N. S.[5]	1947	5/26–5/30	6.6	39–42–52–56–	78–72–59–72–	53 +
Yakima, Wash.[6]	1947	5/ 8–5/12	6.6	56–45–46–40–50	75–66–75–81–90	102
Wenatchee, Wash.[6]	1947	4/27–5/1	6.7	41–38–38–35–49	86–75–68–69–85	98
Montague, Tex.[1]	1947	4/20–4/24	7.0	45–50–64–69–48	75–83–84–84–80	118
Hood River, Ore.[7]	1947	4/16–4/20	7.3	54–52–51–47–44	79–63–62–62–60	41
Stillwater, Okla.[8]	1947	4/13–4/17	7.7	41–48–41–36–37	49–65–65–51–66	25
Harrow, Ont.[9]	1947	5/24–5/28	8.0	55–50–44–39–51	62–66–71–65–68	47
Pullman, Wash.[10]	1947	5/ 2–5/6	8.1	46–41–43–43–46	76–77–77–79–83	107
Knoxville, Tenn.[11]	1947	4/20–4/24	8.3	57–50–48–51–59	82–69–79–78–77	100
Clemson, S. C.[12]	1947	4/23–4/27	8.5	46–53–60–55–49	69–79–85–73–80	101
Average						84

[1]Temperature records for Fort Worth, Tex.
[2]Temperature records for Washington, D. C.
[3]Temperature records for Springfield, Ill.
[4]Temperature records for Indianapolis, Ind.
[5]Temperature records for Kentville, N. S.
[6]Temperature records for Yakima, Wash.
[7]Temperature records for Hood River, Ore.
[8]Mean of the temperature records for Tulsa and Oklahoma City, Okla.
[9]Temperature records for Toledo, O.
[10]Temperature records for Spokane, Wash.
[11]Temperature records for Knoxville, Tenn.
[12]Temperature records for Spartanburg, S. C.

TABLE 1C—*Temperature conditions during the 5-day blossoming period at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Blossoming period	Percent flowers setting fruit	Daily minimum temperatures	Daily maximum temperatures	Total day-degrees above 57°F.
Mesilla Valley, New Mexico[1]	1946	4/ 5–4/9	10.2	54–56–58–46–43	84–84–81–81–82	127
Columbia, Mo.[2]	1947	5/ 2–5/6	10.4	50–47–53–44–46	57–76–76–67–77	68
Lincoln, Neb.[3]	1947	5/ 6–5/10	10.8	41–36–42–35–54	62–63–60–65–75	40
Vancouver, Wash.[4]	1947	4/15–4/19	10.6	50–46–50–50–47	84–81–72–60–62	74
Amherst, Mass.[5]	1947	5/23–5/27	11.7	45–53–62–57–49	80–87–77–76–71	106
Fruitland, Ida.[6]	1946	4/21–4/25	11.9	39–30–35–46–54	59–64–72–83–92	84
Durham, N. H.[7]	1947	5/28–6/1	12.9	49–56–43–34–40	82–74–68–66–78	83
Austin, Colo.[8]	1947	4/20–4/25	14.8	37–46–42–34–35	80–77–72–62–54	63
Brushy Mt., N. C.[9]	1947	4/13–4/17	19.4	51–51–52–57–43	71–68–69–76–62	61
Brushy Mt., N. C.[9]	1947	4/18–4/22	33.8	36–45–50–50–46	71–79–79–70–64	78
Orono, Me.[10]	1947	5/30–6/3	16.6	46–40–44–56–44	70–66–81–59–63	54
Storrs, Conn.[11]	1947	5/20–5/24	16.8	48–53–53–54–47	77–63–64–77–83	79
Auburn, Ala.[12]	1947	4/15–4/19	17.7	56–60–46–39–47	66–75–60–71–80	67
Logan, Utah[13]	1947	5/ 4–5/8	20.7	55–53–54–57–59	85–84–85–86–83	137
Stoneville, Miss.[14]	1947	4/15–4/19	21.2	57–54–41–41–52	78–71–68–75–83	90
Medford, Ore.[15]	1947	4/18–4/22	17.2	43–46–37–32–35	71–67–62–66–71	52
Average						81

[1]Temperature records for Roswell, N. Mex.
[2]Temperature records for Columbia, Mo.
[3]Temperature records for Lincoln, Neb.
[4]Temperature records for Vancouver, Wash.
[5]Temperature records for Amherst, Mass.
[6]Temperature records for Boise, Idaho.
[7]Temperature records for Concord, N. H.
[8]Temperature records for Austin, Colo.
[9]Mean for the temperature records of Charlotte and Asheville, N. C.
[10]Temperature records for Oldtown, Me.
[11]Temperature records for Storrs, Conn.
[12]Temperature records for Auburn, Ala.
[13]Temperature records for Logan, Utah.
[14]Temperature records for Greenville, Miss.
[15]Temperature records for Medford, Ore.

that at Newark, Delaware, Mountain Grove, Missouri, and Blue Ridge, Georgia, the total day-degrees above 57° F. during the 5-day blossoming periods were 68, 83 and 89, respectively, while at Lincoln, Nebraska, Orono, Maine, and Medford, Oregon, they were 40, 54 and 52, respectively. Percentages of Delicious blossoms setting fruit at the first three locations were 2.5, 4.0 and 4.2, compared with 10.8, 16.6 and 17.2 at the latter three locations. It is very doubtful if there were more than 30 hours at any of these heavy-setting locations during which bees would fly freely, and the total number of pollinating hours was more probably less than 20.

WIND VELOCITY, RAIN, ATMOSPHERIC HUMIDITY

Precipitation data are available for all of the locations for which records are presented. There was some rainfall during the blossoming period at some of them, but in no instance was it great or prolonged enough to be considered as a factor of any considerable importance in limiting the setting of fruit. Data on wind velocity and atmospheric humidity are not available.

In most instances observations of the cooperators obtaining the fruit setting records indicated that bees, also trees of other pollinating varieties, were present in sufficient numbers to provide adequately for cross pollination.

ENVIRONMENTAL INFLUENCES DURING THE FRUIT-SETTING PERIOD

There is a period of approximately a month following full bloom during which the apple fruit either sets or fails to set. This includes the first or initial drop, one of blossoms whose ovaries undergo little or no enlargement, and the second or "June" drop that comes after the ovaries have undergone considerable enlargement. In the case of the Delicious variety it is sometimes the early and sometimes the later, but usually the early, drop that accounts for the greater loss of potential fruits. The trees are subject to the same environmental factors during this fruit-setting period as during the blossoming period, except of course pollination has been effected and certain factors that influence the activity of pollinating insects—wind velocity, temperature and rain—either have less influence or they operate in a different way on the fruit-setting process. Wind velocity and precipitation during this period can probably be dismissed as seldom reducing fruit set in the

apple, though conceivably extreme drought or high wind velocity combined with high temperature and low atmospheric humidity might lead to dropping, as it often does in midsummer in the case of the tomato and certain other fruits.

TEMPERATURE

Frost during the fruit-setting period can destroy the developing fruits, just as, earlier, it can destroy the antecedent blossoms or blossom buds. Furthermore the critical temperature is higher than it is for the blossoming and preblossoming period. Data on daily minimum and maximum temperatures during the 7-day period, starting with full bloom, are presented in Tables 2a, 2b and 2c for 36 different locations for the spring of 1947 and for 4 other locations (one of them for 2 successive seasons) for earlier years. Minimum temperatures were low enough at one of these stations—Arendtsville, Pennsylvania—to account for the loss of some developing fruits from frost. The fact that one of the lowest fruit-setting percentages recorded in the table is for that station lends support to the supposition that frost actually was a factor in that instance. It is doubtful if it was a factor of importance in any of the other 40 records.

TABLE 2A—*Temperature conditions during the 1-week period starting with full bloom at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Date of full bloom	Percent flowers setting fruit	Daily minima	Daily maxima
E. Lansing, Mich.[1]	1947	5–27	4.3	41–40–39–37–42–56–43	66–55–57–60–75–62–58
Gr. Rapids, Mich.[2]	1947	5–27	4.2	46–40–37–40–45–58–48	62–53–50–61–74–65–65
Wooster, O.[3]	1947	5–21	1.13	49–45–49–56–46–46–39	70–71–79–78–69–71–68
Arendtsville, Pa.[4]	1947	5–17	2.3	30–27–29–33–38–48–55	49–52–64–75–86–87–74
Newark, Del.[5]	1947	4–30	2.5	58–59–50–49–52–50–51	82–80–66–60–69–62–68
Campbell, Mo.[6]	1947	4–18	3.7	46–56–47–45–50–60–57	72–79–69–56–70–82–73
Mt. Grove, Mo.[7]	1947	5–1	4.0	51–50–48–55–48–53–41	67–64–75–79–72–77–65
Doniphan, Kan.[8]	1947	5–8	4.1	42–34–50–49–69–55–51	63–66–74–74–80–79–81
Vineland, Ont.[9]	1947	5–29	4.2	44–39–44–50–50–46–42	66–60–69–61–56–64–66
Blue Ridge, Ga.[10]	1947	4–28	4.2	46–59–58–54–48–49–46	79–76–72–76–68–60–84
Pittsfield, Ill.[11]	1940	5–3	4.25	37–37–51–62–57–52–46	76–80–81–82–73–82–81

[1]Temperature records for E. Lansing, Mich.
[2]Temperature records for Grand Rapids, Mich.
[3]Temperature records for Akron, O.
[4]Temperature records for Arendtsville, Pa.
[5]Mean of the temperature records for Baltimore, Md., and Philadelphia, Pa.
[6]Mean of the temperature records for Cairo, Ill., and Memphis, Tenn.
[7]Temperature records for Springfield, Mo.
[8]Temperature records for St. Joseph, Mo.
[9]Temperature records for Toronto, Ont.
[10]Temperature records for Chattanooga, Tenn.
[11]Temperature records for Springfield, Ill.

TABLE 2B—*Temperature conditions during the 1-week period starting with full bloom at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Date of full bloom	Percent flowers setting fruit	Daily minima	Daily maxima
Stephenville, Tex.[1]	1947	4–21	5.0	50–64–69–48–47–46–56	83–84–84–80–58–67–68
College Park, Md.[2]	1947	5–5	5.5	52–52–45–39–35–35–37	63–69–70–56–54–52–74
Pittsfield, Ill.[3]	1941	4–27	7.96	50–55–55–59–62–58–59	75–80–81–82–73–82–81
Lafayette, Ind.[4]	1947	5–13	6.3	58–52–52–62–61–57–52	78–72–85–76–77–69–75
Kentville, N. S.[5]	1947	5–28	6.6	39–42–52–50–44–33–55	78–72–59–72–64–74–58
Yakima, Wash.[6]	1947	5–10	6.6	46–40–50–44–34–49–49	75–81–80–73–74–79–72
Wenatchee, Wash.[6]	1947	4–29	6.7	38–35–49–49–39–48–43	68–69–85–79–79–84–85
Montague, Tex.[1]	1947	4–22	7.0	64–69–48–47–46–56–62	84–84–80–58–67–68–74
Hood River, Ore.[7]	1947	4–18	7.3	49–48–40–33–34–49–47	59–61–60–70–72–61–65
Stillwater, Okla.[8]	1947	4–15	7.7	41–36–37–47–45–43–44	65–51–67–75–68–63–77
Harrow, Ont.[9]	1947	5–26	8.0	44–39–51–39–37–42–57	71–65–68–68–63–71–65
Pullman, Wash.[10]	1947	5–4	8.1	43–43–46–57–52–48–44	77–79–83–87–64–61–65
Knoxville, Tenn.[11]	1947	4–22	8.3	48–51–59–56–47–41–49	79–78–77–78–66–75–79
Clemson, S. C.[12]	1947	4–25	8.5	60–55–49–55–54–60–62	85–73–80–78–76–81–81

[1]Temperature records for Fort Worth, Tex.
[2]Temperature records for Washington, D. C.
[3]Temperature records for Springfield, Ill.
[4]Temperature records for Indianapolis, Ind.
[5]Temperature records for Kentville, N. S.
[6]Temperature records for Yakima, Wash.
[7]Temperature records for Hood River, Ore.
[8]Averages of the temperatures record for Tulsa and Oklahoma City, Okla.
[9]Temperature records for Toledo, O.
[10]Temperature records for Spokane, Wash.
[11]Temperature records for Knoxville, Tenn.
[12]Temperature records for Spartanburg, S. C.

TABLE 2C—*Temperature conditions during the 1-week period starting with full bloom at selected stations, as related to fruit setting in the Delicious apple*

Location	Year	Date of full bloom	Percent flowers setting fruit	Daily minima	Daily maxima
Mesilla Valley, N. Mex.[1]	1947	4–7	10.2	56–58–46–43–45–41–49	84–81–81–82–73–77–86
Columbia, Mo.[2]	1947	5–4	10.4	53–44–46–40–44–40–44	76–67–77–64–63–65–69
Lincoln, Nebr.[3]	1947	5–8	10.8	42–35–54–54–55–52–57	60–65–76–74–76–77–89
Vancouver, Wash.[4]	1947	4–17	10.6	50–50–47–42–41–40–45	72–60–62–88–72–66–62
Amherst, Mass.[5]	1947	5–25	11.7	62–57–49–48–63–46–37	77–76–71–81–86–66–68
Fruitland, Ida.[6]	1946	4–23	11.9	35–46–54–39–32–37–34	72–82–92–73–68–75–70
Durham, N. H.[7]	1947	5–30	12.9	43–34–40–55–42–34–42	68–66–78–78–65–72–75
Austin, Colo.[8]	1947	4–22	14.8	42–34–35–32–32–40–44	72–62–54–66–72–68–59
Raleigh, N. C.[9]	1947	4–15	19.4	52–57–43–36–45–50–51	69–76–62–71–79–79–69
Raleigh, N. C.[9]	1947	4–20	33.8	50–50–46–44–51–59–51	79–79–64–70–79–82–68
Orono, Me.[10]	1947	6–1	16.6	44–56–44–46–47–43–40	81–59–63–68–71–72–73
Storrs, Conn.[11]	1947	5–22	16.8	53–54–47–57–54–48–47	64–77–83–76–73–70–76
Auburn, Ala.[12]	1947	4–17	17.7	46–39–47–51–51–48–47	60–71–80–78–60–68–72
Logan, Utah[13]	1947	5–6	20.7	54–57–59–46–41–42–44	86–86–83–68–59–56–55
Stoneville, Miss.[14]	1947	4–17	21.2	41–41–52–59–48–43–54	68–75–83–78–65–74–84
Medford, Ore.[15]	1947	4–20	17.2	37–32–35–36–38–36–39	62–66–71–72–72–82–86

[1]Temperature records for Roswell, N. M.
[2]Temperature records for Columbia, Mo.
[3]Temperature records for Lincoln, Nebr.
[4]Temperature records for Vancouver, Wash.
[5]Temperature records for Amherst, Mass.
[6]Temperature records for Boise, Ida.
[7]Temperature records for Concord, N. H.
[8]Temperature records for Austin, Colo.
[9]Averages of the records for Charlotte and Asheville, N. C.
[10]Temperature records for Oldtown, Me.
[11]Temperature records for Storrs, Conn.
[12]Temperature records for Auburn, Ala.
[13]Temperature records for Logan, Utah.
[14]Temperature records for Greenville, Miss.
[15]Temperature records for Medford, Ore.

TABLE 3A—*Total day-degrees above 42° F. maximum at selected stations for 7-day, 14-day and 30-day periods, starting with full bloom*

Location	Year	Date of full bloom	7-day Total	14-day Total	30-day Total
East Lansing, Mich.	1947	5–27	135	354	835
Grand Rapids, Mich.	1947	5–27	136	379	894
Wooster, O.	1947	5–21	212	400	943
Arendtsville, Pa.	1947	5–17	191	457	.....
Newark, Del.	1947	4–30	201	350	915
Campbell, Mo.	1947	4–18	207	427	995
Mt. Grove, Mo.	1947	5–1	205	402	923
Doniphan, Kan.	1947	5–8	223	471	919
Vineland, Ont.	1947	5–29	148	296	761
Blue Ridge, Ga.	1947	4–28	221	450	1111
Pittsfield, Ill.	1940	5–3	215	436	938
Average.	.....	.....	190	402	923

TABLE 3B—*Total day-degrees above 42° F. maximum at selected stations for 7-day, 14-day and 30-day periods, starting with full bloom*

Location	Year	Date of full bloom	7-day Total	14-day Total	30-day Total
Stephenville, Tex.	1947	4–21	230	535	1157
College Park, Md.	1947	5–5	144	396	1036
Pittsfield, Ill.	1941	4–27	261	479	1094
Lafayette, Ind.	1947	5–13	238	450	998
Kentville, N. S.	1947	5–28	184	299	767
Yakima, Wash.	1947	5–10	239	514	1137
Wenatchee, Wash.	1947	4–29	255	520	1170
Montague, Tex.	1947	4–22	221	504	1123
Hood River, Ore.	1947	4–18	156	349	792
Stillwater, Okla.	1947	4–15	171	343	932
Harrow, Ont.	1947	5–26	176	397	921
Pullman, Wash.	1947	5–4	222	407	939
Knoxville, Tenn.	1947	4–22	238	453	1037
Clemson, S. C.	1947	4–25	260	501	1160
Average.	.....	.....	214	439	1019

TABLE 3c—*Total day-degrees above 42° F. maximum at selected stations for 7-day, 14-day and 30-day periods, starting with full bloom*

Location	Year	Date of full bloom	7-day Total	14-day Total	30-day Total
Mesilla Valley, N. Mex.	1946	4–7	270	521	1137
Columbia, Mo.	1947	5–4	187	462	950
Lincoln, Nebr.	1947	5–8	222	429	883
Vancouver, Wash.	1947	4–17	188	357	799
Amherst, Mass.	1947	5–25	227	453	981
Fruitland, Ida.	1946	4–23	238	447	913
Durham, N. H.	1947	5–30	208	424	958
Austin, Colo.	1947	4–22	159	452	1003
Brushy Mt., N. C.	1947	4–17	202	438	960
Brushy Mt., N. C.	1947	4–22	222	392	989
Orono, Me.	1947	6–1	194	384	933
Storrs, Conn.	1947	5–22	225	428	896
Auburn, Ala.	1947	4–17	195	542	1139
Logan, Utah	1947	5–6	198	386	854
Stoneville, Miss.	1947	4–17	233	486	1118
Medford, Ore.	1947	4–20	217	465	992
Average	.....	.....	212	442	969

While entomologists suggest 57° F. as the temperature above and below which the honey bee becomes active or inactive and hence does or does not effect pollination, physiologists regard 42° F. as an arbitrary starting or stopping point for most growth processes. Some processes in some plants proceed at lower temperatures and others in other plants may not proceed until a considerably higher temperature is reached. However, for the various physiological processes influencing fruit setting, 42° F. may probably be regarded as a base point. Furthermore it is a well established law that as the temperature rises above 42° F. these processes are greatly accelerated. There is no exact quantitative measure of this acceleration that applies to all processes in all plants but the number of day-degrees above 42° F. is regarded as a rough measure of temperature influence on them. Thus if the maximum temperature recorded one day is 62° F. it is assumed that physiologically the plant is twice as active as it is on a day when the maximum is 52° F.

The data in Table 3a, 3b, 3c reveal the total day-degrees above 42° F. recorded at the several locations for the 7-day, 14-day and 30-day periods, starting at full bloom. It will be noted that, while there was no great difference in total "effective" temperatures between the low-setting, moderate-setting and high-setting locations for the 14-day and 30-day periods, the totals for the poor-setting stations fell far below those for the other two groups during the 7-day period starting with

full bloom. It is therefore a reasonable assumption that the higher temperatures at many of the locations during the first week of the fruit-setting process exerted a favorable influence on it.

LIGHT

There is little in the literature dealing with fruit setting in the apple that furnishes much information on the influence of light on the process. There is, however, evidence of its influence on setting in a number of other species. Dunlap (18) has shown that during periods of low light intensity there is reduction in boll setting in cotton, and Bradbury and Roberts (9) have established a similar relationship between light intensity and setting in the sour cherry in Wisconsin. To one who has lived in the Great Lakes region where Delicious characteristically sets less abundantly and in certain other regions where it bears heavily, one of the more obvious differences in climate is in cloudiness. The Great Lakes region, and especially Michigan surrounded as it is by lakes, has much cloudy weather. Furthermore when the sky appears cloudless sunlight intensity appears less than in many other regions, an observation verified by pyrheliometer records. It therefore occurred to the writers that possibly the amount of sunlight, as influenced both by light intensity and length of day, reaching the trees during the period of fruit setting may have considerable influence on the process, cloudy weather and short days interfering with and bright sunny weather and long days promoting it.

U. S. Records (pyrheliometer)—Quantitative data on amount of sunlight received daily are recorded and made available regularly by the U. S. Weather Bureau for 25 stations in the continental United States. There are perhaps an equal number maintained by other agencies in the rest of the world. Exact sunlight data are therefore limited to only a few locations or areas. However, a number of the locations for which fruit-setting records in the Delicious apple were obtained and are presented in this article are close to U. S. Weather Bureau pyrheliometer stations. Furthermore it is believed that sunlight data obtained at most of the stations in the United States are at least approximate for considerable areas and that they may be used for comparative purposes for most of the United States and Canadian stations for which fruit-setting records are presented in this publication. Certainly the pyrheliometer records at East Lansing, Michigan, located only about a mile from where the East Lansing fruit-setting records

TABLE 4A—*Fruit setting in the Delicious apple in different locations as correlated with sunshine for 7-day, 14-day and 30-day periods starting with full bloom*

Location	Year	Percent flowers setting fruit	Date of full bloom	Gram-calories of sunlight, direct and diffused, received per square centimeter					
				7 Days	Departure from mean[1]	14 Days	Departure from mean[1]	30 Days	Departure from mean[1]
East Lansing, Mich.[2]	1947	4.3	5–27	2,248	−540	5,639	− 351	12,670	− 839
Grand Rapids, Mich.[2]	1947	4.2	5–27	2,248	−540	5,639	− 351	12,670	− 839
Fremont, Mich.[2]	1947	0.6	6–1	2,599	−316	5,621	− 403	13,886	− 316
Wooster, O.[3]	1947	1.13	5–21	2,621	− 57	5,135	− 147	12,549	− 369
Arendtsville, Pa.[4]	1947	2.3	5–8	3,500	+204	5,657	− 594	15,857	+ 742
Newark, Del.[5]	1947	2.5	4–30	2,810	−840	6,921	+ 91	14,166	− 715
Lexington, Ky.[6]	1947	2.9	4–28	2,477	−252	6,937	+ 644	14,011	+ 122
Trenton, Ont.[7]	1947	3.6	6–1	2,878	− 49	6,037	− 351	15,283	− 120
Campbell, Mo.[8]	1947	4.0	5–1	3,545	+462	7,913	+1589	15,751	+1300
Mt. Grove, Mo.[9]	1947	4.0	5–1	3,905	+714	8,593	+2072	17,074	+2069
Doniphan, Kan.[10]	1947	4.1	5–8	3,643	+525	6,638	+ 35	13,857	+ 19
Vineland, Ont.[11]	1947	4.2	5-29	2,846	−588	6,082	− 539	14,853	− 203
Blue Ridge, Ga.[12]	1947	4.2	4–28	2,477	−252	6,937	+ 634	14,011	+ 82
Pittsfield, Ill.[13]	1940	4.25	5–3	2,766	−167	5,161	− 832	12,634	− 798
Average	.....	3.305	.....	2,900	−122	6,355	+ 102	13,523	+ 110

[1]These departures are from the mean for the respective week, 2-week or 30-day calendar periods. Blossoming at *all* of these locations in 1947 was 1 to 3 weeks later than normal. The *normal* or *average* gram-calories of radiation received at these locations for the several periods following blossoming would be less than indicated in this table and the +departures correspondingly greater, with the −departures correspondingly less.

[2]The fruit setting figures for East Lansing and Grand Rapids are higher than average for Michigan; those for Fremont are lower. The Fremont figures, however, represent about what that orchard has been doing year after year, in spite of ample provision for cross pollination. The East Lansing and Grand Rapids figures are higher than usual for those particular orchards. The average for the three orchards may be considered as fairly representative of Michigan conditions.

[3]The radiation figures are averages for State College, Pa., Ithaca, N. Y., Toronto, Ont., and East Lansing, Mich. The data on fruit-setting were obtained by Mr. C. W. Ellenwood of the Ohio Agr. Exp. Sta. Note comment in the accompanying text about possible frost injury.

[4]The radiation figures are for State College, Pa. The data on fruit setting were obtained by Mr. F. N. Hewetson of the Pa. State Coll. Fruit Research Laboratory at Arendtsville, Pa. He states (29) that the occurrence of frost during the blossoming period probably was a factor in reducing the setting of fruit somewhat below normal.

[5]The radiation figures are averages for New York City and Washington, D. C. The fruit-setting data were obtained by Dr. A. L. Kenworthy of the Delaware Agr. Exp. Sta. He states (34) that low temperatures coupled with enough wind to interfere with cross pollination probably reduced the set of fruit considerably below normal for the area. Note, however, that solar radiation in 1947 was far below normal.

[6]The radiation figures are for Nashville, Tenn. The data on fruit setting were obtained by Dr. C. S. Waltman of the Ky. Agr. Exp. Sta. He states (60) that the set of fruit on Delicious in 1947 was one of the poorest of that area for many years, attributed by him to unfavorable conditions during the blossoming season; however, Mr. W. W. Magill (37) of the Ky. Agr. Ext. Service states that normally in Kentucky Delicious sets poorly and requires "heavy pollination".

[7]The radiation figures are for Toronto, Ont. The data on fruit setting were obtained through the courtesy of Mr. C. A. Eaves of the Canadian Dept. of Agr., Ottawa, Canada. Mr. Eaves states (20) that the crop at Trenton in 1947 is to be considered as normal or possibly above for that area.

[8]The radiation figures are averages for Columbia, Mo., and Nashville, Tenn. The fruit-setting data were obtained through the courtesy of Dr. A. E. Murneek of the Mo. Agr. Exp. Station. He states (41) that the fruit setting of Delicious in the orchard in question in 1947 was typical of its usual behavior in southeastern Missouri.

[9]The radiation figures are for Columbia, Mo. The fruit-setting data were obtained by Mr. P. H. Shepherd, superintendent of the Missouri Fruit Experiment Station at Mountain Grove, Mo. Mr. Shepherd (52) states that McIntosh, King David and Jonathan trees were interplanted with the Delicious, that conditions were very favorable for pollination in 1947 and fruit setting of the Delicious apple was 30 to 50 percent better than usual in that area. This may be correlated with the fact that sunshine following full bloom was 15 to 20 percent above normal.

[10]The radiation figures are for Lincoln, Nebr. The data on fruit setting were obtained by Dr. W. F. Pickett of the Kan. Agr. Exp. Sta. and E. Abmeyer of the Northeast Kansas Experimental Fields. Dr. Pickett states (45) the set on Delicious in 1947 was fairly typical for that area. The trees blossomed very heavily and hence with just a moderate percentage of blossoms setting fruit, the crop was rather heavy.

[11]The radiation figures are for Toronto, Ont. The data on fruit setting were obtained by Dr. W. H. Upshall and Mr. O. A. Bradt of the Ontario Horticultural Experiment Station at Vineland Station, Ont., and reported as fairly typical for Ontario. Dr. Upshall reports that in both 1945 and 1946 Delicious on Malling IX rootstocks bore better crops than trees on other stocks.

[12]The radiation figures are for Nashville, Tenn. The fruit-setting data were obtained by Mr. J. E. Bailey of the Georgia Mountain Experiment Station at Blairsville, Ga. Mr. Bailey (2) states that the fruit setting in 1947 was normal for that area other seasons.

[13]The radiation figures are for Chicago. The fruit-setting data were obtained by Dr. R. L. McMunn of the Ill. Agr. Exp. Sta. Note the low set, associated with less sunshine than normal; compare with fruit-setting records from the same orchard in 1941 when there was more sunshine than normal (Table 4b).

TABLE 4B—*Fruit setting in the Delicious apple in different locations as correlated with sunshine for 7-day, 14-day and 30-day periods starting with full bloom*

Location	Year	Percent flowers setting fruit	Date of full bloom	Gram calories of sunlight, direct and diffused, received per square centimeter					
				7 Days	Departure from mean[1]	14 Days	Departure from mean[1]	30 Days	Departure from mean[1]
Stephenville, Tex.[2]	1947	5.0	4–21	3,286	+ 76	6,772	+ 461	14,304	+ 874
Holly Springs, Miss.[3]	1947	5.0	4–16	2,843	− 224	5,891	− 42	13,900	+ 602
College Park, Md.[4]	1947	5.5	5–5	4,217	+1302	7,464	+ 623	16,624	+1939
Lafayette, Ind.[5]	1947	6.3	5–13	3,063	+ 896	5,855	+ 683	13,449	+ 630
Kentville, N. S.[6]	1947	6.6	5–28	3,092	− 98	6,152	− 317	14,037	+ 135
Yakima, Wash.[7]	1947	6.6	5–10	3,170	− 668	7,916	− 172	15,396	−1033
Wenatchee, Wash.[7]	1947	6.7	4–29	4,238	+ 315	7,003	− 854	16,673	− 609
Fayetteville, Ark.[8]	1927–32	7.0	4–11	2,702	.....	5,474	.....	12,542	.....
Montague, Tex.[9]	1947	7.0	4–22	3,091	+ 208	6,651	+ 459	14,557	+ 875
Hood River, Ore.[10]	1947	7.3	4–18	3,575	+ 147	7,797	+ 686	16,008	− 168
Stillwater, Okla.[11]	1947	7.7	4–15	3,056	− 154	5,783	− 259	13,087	+ 903
Pittsfield, Ill.[12]	1941	7.96	4–27	3,572	+ 644	7,346	+1323	14,678	+2343
Harrow, Ont.[13]	1947	8.0	5–26	2,401	− 588	5,469	− 539	14,350	− 245
Pullman, Wash.[7]	1947	8.1	5–4	3,396	− 454	6,976	− 899	15,915	−2295
Knoxville, Tenn.[14]	1947	8.3	4–22	3,142	+ 182	5,839	− 70	13,797	+ 834
Clemson, S. C.[15]	1947	8.5	4–25	3,897	+ 761	7,298	+ 949	15,585	+1644
Average	.....	6.972	.....	3,296	+ 156	6,605	+ 135	14,681	+ 429

[1]These departures are from the mean for the respective week, 2-week or 30-day calendar periods. Blossoming at *all* of these locations in 1947 was 1 to 3 weeks later than normal. The *normal* or *average* gram-calories of radiation received at these locations for the several periods following blossoming would be less than indicated in this table and the +departures correspondingly greater, with the −departures correspondingly less.

[2]The 7-day and 14-day radiation figures are averages for Lincoln, Nebr., and New Orleans, La.; the 30-day data are for Lincoln, Nebr., only, those for New Orleans being incomplete for the last 16 days. The fruit-setting data were obtained by Mr. T. E. Denman of the Stephenville, substation of the Tex. Agr. Exp. Sta. Mr. Denman (17) states that *in 1946* fruit setting at Stephenville was greatly reduced because of temperatures above 100°F. during the blossoming season; such experiences are not uncommon in Northern Texas.

[3]The radiation figures are for Nashville, Tenn. The fruit-setting data were obtained by Mr. S. P. Crockett of the Miss. Agr. Exp. Sta. branch station at Holly Springs, Miss.

[4]The radiation figures are for Washington, D. C. The fruit-setting data were obtained by Dr. A. L. Schroeder of the Md. Agr. Exp. Sta. He reports (50) that in 1947 the trees were 9 years old, about half of the spurs blossomed; with 5.5 percent of the flowers setting fruit a good crop was borne by the trees.

[5]The radiation figures are averages for East Lansing, Mich. and Nashville, Tenn. The fruit-setting data were obtained by Dr. C. E. Baker of the Purdue Univ. Agr. Exp. Sta. Dr. Baker reports that there was some frost injury in the orchard during the blossoming season.

[6]The radiation figures are for Boston, Mass. The fruit-setting figures were obtained by Mr. R. D. Bligh of the Experiment Station at Kentville, N. S.

[7]The radiation figures are for Twin Falls, Ida.

[8]The radiation figures are averages for Columbia, Mo. The fruit-setting data were obtained by Prof. J. R. Cooper of the Ark. Agr. Exp. Sta. and cover a period of several years. He states (14) that they may be regarded as fairly typical for Arkansas conditions, mature trees producing 10 to 15 bushels of fruit.

[9]The 7-day and 14-day radiation figures are averages for Lincoln, Nebr., and New Orleans, La.; the 30-day data are for Lincoln, Nebr., only, those for New Orleans being incomplete for the last 16 days. The fruit-setting data were obtained by Mr. U. A. Randolph of the Montague substation of the Tex. Agr. Exp. Sta. There was some rain and cloudy weather during the blossoming season.

[10]The radiation figures are for Twin Falls, Ida. The fruit-setting data were obtained by Mr. G. G. Brown of the Hood River Branch Experiment Station, Hood River, Ore. The percentage given—7.3—actually is less than the true percentage as each spur that bore fruit was counted as producing *only one* fruit, when actually a number produced two or more.

[11]The radiation figures are for Lincoln, Nebr. The fruit-setting data were obtained by Dr. F. B. Cross of the Okla. Agr. Exp. Sta. Dr. Cross (15) states that the 1947 set and crop on the Delicious were fairly typical for Oklahoma conditions—perhaps just a little lower than average.

[12]The radiation figures are for Chicago, Ill. The data on fruit setting were obtained by Dr. R. L. McMunn of the Ill. Agr. Exp. Sta.

[13]The radiation figures are for Toronto, Ont. The fruit-setting data were obtained through the courtesy of Dr. C. A. Eaves of the Canadian Central Experimental Farm, Ottawa, Canada. Dr. Eaves (20) states that the figures for fruit setting in 1947 at Harrow are probably higher than normal for that section; pollination conditions were especially favorable.

[14]The radiation figures are for Nashville, Tenn. The fruit-setting data were obtained by Dr. N. D. Peacock of the Tenn. Agr. Exp. Sta.

[15]The radiation figures are averages for Washington, D. C and Nashville, Tenn. The data on fruit setting were obtained by Messrs. A. M. Musser and H. F. Sefick of the S. Car. Agr. Exp. Station. Mr. Musser (42) states that in South Carolina the Delicious apple typically sets fruit so heavily that thinning is necessary, and that the crop in 1947 was somewhat below normal.

TABLE 4C—*Fruit setting in the Delicious apple in different locations as correlated with sunshine for 7-day, 14-day and 30-day periods starting with full bloom*

Location	Year	Percent flowers setting fruit	Date of full bloom	Gram-calories of sunlight, direct and diffused, received per square centimeter					
				7 Days	Deviation from normal[1]	14 Days	Deviation from normal[1]	30 Days	Deviation from normal[1]
Mesilla Valley, N. Mex.[2]	1946	10.2	4–7	4,045	+ 302	8,180	+ 429	18,567	+1191
Columbia, Mo.[3]	1947	10.4	5–4	4,912	+2404	8,575	+2763	17,017	+2858
Union, Nebr.[4]	1947	10.8	5–8	3,650	+ 525	6,645	+ 35	13,864	−1172
Vancouver, Wash.[5]	1947	10.6	4–17	3,472	+ 37	7,602	+ 578	15,114	− 325
Amherst, Mass.[6]	1947	11.7	5–25	3,629	+ 552	6,838	+ 521	14,497	+ 790
Fruitland, Ida.[7]	1946	11.9	4–23	3,922	+1141	8,439	− 492	17,295	+ 649
Durham, N. H.[8]	1947	12.9	5–30	3,399	+ 183	6,310	− 261	14,229	− 209
Austin, Colo.[9]	1947	14.8	4–22	2,847	−1172	7,257	− 325	15,603	− 356
Orono, Me.[10]	1947	16.6	6–1	3,209	− 31	6,173	− 335	14,357	+ 144
Summerland, B. C.[11]	1947	16.7	5–1	4,111	+ 312	6,827	− 891	16,924	−1621
Storrs, Conn.[12]	1947	16.8	5–22	2,922	− 108	6,276	+ 42	13,370	− 320
Auburn, Ala.[13]	1947	17.7	4–17	3,067	− 18	5,788	− 507	14,151	+ 534
Logan, Utah[14]	1947	20.7	5–6	3,424	.....	7,360	.....	15,656	.....
Stoneville, Miss.[15]	1947	21.2	4–17	3,820	+ 888	6,757	+ 840	.....	.....
Medford, Ore.[16]	1947	17.2	4–20	4,115	+ 381	8,110	+ 704	18,426	− 62
Brushy Mt., N. C.[17]	1947	19.4	4–15	2,862	− 30	6,318	+ 815	16,325	+2293
Brushy Mt., N. C.[17]	1947	33.8	4–20	3,207	+ 78	6,948	+ 697	15,253	+1403
Average	.....	16.082	.....	3,576	+ 339	7,103	+ 288	15,652	+ 384

[1]These departures are from the mean for the respective week, 2-week or 30-day calendar periods. Blossoming at *all* of these locations in 1947 was 1 to 3 weeks later than normal. The *normal* or *average* gram-calories of radiation received at these locations for the several periods following blossoming would be less than indicated in this table and the +departures correspondingly greater, with the −departures correspondingly less.

[2]The radiation figures are for Fresno, Calif. The data on fruit setting were furnished by Dr. J. V. Enzie of the N. Mex. Agr. Exp. Sta. Dr. Enzie states (21) that these 1946 figures were for the "on" year of the trees, when as 18-year olds they averaged 24 bushels per tree. During their "on" year, Delicious trees in the Mesilla Valley bear so heavily that the trees soon get into an alternate-bearing habit.

[3]The radiation figures are for Columbia, Mo. The data on fruit setting were obtained by Dr. A. E. Murneek of the Mo. Agr. Exp. Sta. Dr. Murneek states (41) that he is inclined to attribute the heavy setting (much heavier than normal for central Missouri) in 1947 to the vigorous condition of the trees following a light crop in 1946. However, it may be noted that the sunshine received during the first 7-day, 14-day and 30-day periods starting with full bloom was 96, 48 and 20 percent, respectively, above normal.

[4]The radiation figures are for Lincoln, Nebr. The data on fruit setting were obtained by Mr. R. H. Moore of the Nebr. Agr. Exp. Sta. He states (40) that the trees from which the fruit-setting records were obtained had been weakened by winter injury; presumably, therefore, setting was somewhat lower than would be expected from normally vigorous trees.

[5]The radiation data are for Twin Falls, Ida., where probably conditions do not closely approach those at Vancouver, Wash.

[6]The radiation figures are for Boston, Mass. The fruit-setting data were obtained by Drs. J. K. Shaw and J. S. Bailey of the Mass. Agr. Exp. Sta. Messrs. Shaw (51) and Bailey (3) both state that fruit setting of Delicious at Amherst, Mass., in 1947 was in line with its usual performance in that area; usually some thinning of the fruit is necessary if satisfactory size is to be obtained.

[7]The radiation figures are for Twin Falls, Ida. The fruit-setting data were obtained by Dr. L. Verner of the Ida. Agr. Exp. Station. Dr. Verner (59) states that the fruit set of Delicious at Fruitland in 1946 is typical for Idaho; it usually sets so heavily that thinning is required to obtain satisfactory size.

[8]The radiation figures are for Boston, Mass. The data on fruit setting were obtained by Dr. A. F. Yeager of the N. H. Agr. Exp. Sta. Dr. Yeager (62) states that in general the Delicious apple sets heavily enough in New Hampshire to bear good crops, but that often yields are not entirely satisfactory because the fruit does not reach good size. He expresses the opinion that in 1947 setting was perhaps a little above the average.

[9]The radiation figures are averages for Boulder, Colo., and Salt Lake City, Utah. The fruit-setting data were obtained by Mr. F. M. Green, Superintendent of the Western Slope Experiment Station. Mr Green (27) states that characteristically the Delicious apple sets fruit so heavily in Colorado that it becomes an alternate bearer.

[10]The radiation figures are for Boston, Mass. The fruit-setting data were obtained by Dr. J. H. Waring of the Univ. of Me. Dr. Waring states (61) that in 1947 Delicious perhaps set a little heavier than usual: however, it often sets so heavily that some thinning is required.

[11]The radiation figures are for Twin Falls, Ida. The fruit-setting data were obtained by Dr. D. V. Fisher of the Dominion Experimental Station, Summerland, B. C. Dr. Fisher states (23) that in the Okonagan Valley of British Columbia the Delicious almost invariably sets so heavily that it requires considerable thinning.

[12]The radiation figures are for Boston, Mass. The fruit-setting data were obtained by Dr. W. H. Griggs of the University of Conn. Mr. H. A. Rollins, of the same institution states (48) that the set on Delicious trees in Connecticut in 1947 was perhaps a little below normal, that usually it is necessary to thin the fruit in order to obtain satisfactory size.

[13]The radiation figures are for Nashville, Tenn. The fruit-setting data were obtained by Mr. T. B. Hagler of the Ala. Agr. Exp. Sta. Mr Hagler states (28) that in 1947 the set on Delicious was below normal, that ordinarily they have to thin this variety heavily.

[14]The radiation figures are for Salt Lake City, Utah. Deviations from the average are not given because of the relatively short period for which radiation data have been obtained at Salt Lake City. The fruit-setting data were obtained by Mr. R. K. Gerber of the Utah Agr. Exp. Station.

[15]The radiation figures are for New Orleans, La.; they are not given for the 30-day period because of gaps in the Weather Bureau record. The fruit-setting data were obtained by Mr. L. R. Farish of the Delta Branch Experiment Station, Stoneville, Miss., Mr. W. S. Anderson and Mr. C. H. Ragland of the Miss. Agr. Exp. Sta. at State College, Miss.

[16]The radiation figures are averages for Twin Falls, Ida., and Davis, Calif. The fruit-setting data were obtained by Mr. E. S. Degman of the U. S. Bureau of Plant Industry, Soils and Agr'l Engineering.

[17]The radiation figures are for Washington, D. C. The fruit-setting data were obtained by Messrs. M. E. Gardner and J. G. Francis of the N. C. Agr. Exp. Station. The two orchards were owned by the same individual, had the same cultural treatments and were otherwise comparable. One, however, was at a higher elevation than the other and hence blossomed later. The mean maximum temperature at the two orchards during their 5-day blossoming season were 66.6°F. and 72.4°F., respectively. Thus the second orchard had more favorable temperature conditions for pollination, as well as more sunshine following pollination. It is a reasonable assumption, however, that on the average radiation in western North Carolina is substantially higher than at Washington, D. C. at any given period during the spring months. Washington is the closest point for which radiation data in 1947 are available. During an earlier 3-year period when radiation records were obtained at Gainesville, Florida, the figures for that station were markedly higher than those for Washington; probably North Carolina presents an intermediate condition.

were obtained are dependable; furthermore, they may be assumed to be applicable to the Grand Rapids and Fremont orchards, 70 and 120 miles distant respectively. Probably the Twin Falls, Idaho, sunlight data do not apply with the same degree of accuracy to Fruitland, Idaho, Summerland, B. C., Pullman, Vancouver, Yakima and Wenatchee, Washington, and Hood River, Oregon, but they are the only ones available for the entire Northwest and use has been made of them. In some instances, where an orchard from which fruit-setting records were obtained was more or less midway between two Weather Bureau pyrheliometer stations, the mean radiation records for the two stations for the days in question were used; thus the figures for Stephenville, Texas, are the averages for New Orleans, Louisiana, and Lincoln, Nebraska. Some of the apparent inconsistencies in the tables are doubtless due to the fact that sunlight conditions at the orchards where the records were obtained deviated considerably from those obtained at the nearest pyrheliometer station.

Data are presented in Tables 4a, 4b and 4c showing the gram-calories of radiation (direct + diffused) received per square centimeter at the U. S. Weather Bureau pyrheliometer stations closest to those where the orchards furnishing the fruit-setting records were located. In general, the figures show a rather high degree of correlation between the percentage of blossoms that set fruit and the amount of sunshine during a 30-day post-blossoming period. The figures for the 14-day and especially the 7-day periods immediately following full bloom show still higher correlations with fruit-setting percentages and, therefore, may be assumed to be especially important in this connection. The average gram-calories of sunlight received at the 16 stations where fruit setting of Delicious was less than 10 but more than 5 percent was 11 percent greater during the 7-day period starting with full bloom than for the 14 where it was less than 5 percent; for the 17 stations where the setting exceeded 10 percent it was 21 percent greater. As might be expected, the records obtained at certain individual stations appear to be exceptions to the general trend. Thus there were 5 locations out of the 14 (Table 4a) where light conditions were very favorable during the week following full bloom and less than 5 percent of the blossoms set fruit. In one of these (Arendtsville, Pennsylvania—Table 2a), however, frost during the blossoming period probably accounted for the low set; in one other (Doniphan, Kansas) the trees had been weakened by previous winter injury. There were only two locations in the 17 where more than 10 percent of the blossoms

set (Austin, Colorado and Storrs, Connecticut) and where sunlight conditions were as low as the *average* for the low-setting group. At only two other stations in the entire country (Lexington, Kentucky and Blue Ridge, Georgia) were the figures approximately as low as they were for the Michigan stations and both of those received applications of relatively toxic fungicides during the critical preblossoming and fruit-setting period (Table 9).

Especially significant for the point under discussion are the figures on amount of radiation received at Pittsfield, Illinois, in 1940 and 1941

TABLE 5—*Yield records of a block of Delicious apple trees in the Eveline Orchard in Charlevoix County, Michigan, for the period 1943-48, as correlated with light immediately following blossoming*

Year	Date of full bloom	Relative amount of bloom	Relative size of crop	Gram-calories of radiation received per square centimeter during 7-day period starting with full bloom
1943	5–30	Heavy	Good	2633
1944	5–23	Light	Light	3410
1945	5–16	Heavy[1]	Fair	2090
1946	5–21	Fair	Fair	2300
1947	6–8	Heavy	Heavy	3022
1948	5–30	Light[1]	Light	4083

[1]The owner states that in 1945 there was some frost injury to the blossoms and that he believes that in 1948 the cropping was somewhat reduced by winter injury to the trees as well as by the heavy cropping the preceding season (16). In both instances light blossoming followed heavy cropping; when blossoming was heavy or fair the cropping—and hence setting—showed a rather close correlation with amount of radiation received during the early part of the fruit setting period

TABLE 6—*Yield records of a block of Delicious apple trees in the Titus Orchard in Grand Traverse County, Michigan, for the period 1945-48, as correlated with light immediately following blossoming*

Year	Date of full bloom	Size of crop in bushels[1]	Gram-calories of radiation received per square centimeter during 7-day period starting with full bloom
1945	5–16	296	2098
1946	5–19	969	2149
1947	6–9	1392	2714
1948	5–24	754	4127

[1]The owner attributes the small 1945 crop, at least in considerable part, to the residual effect of a heavy crop in 1944 and a falling off in the 1948 crop to relatively heavy production in 1947 (56). However, it may be noted that in the seasons 1946 and 1947, when there was no such residual effect of heavy cropping the preceding year, production was correlated with amount of sunlight received during the early part of the fruit setting period.

TABLE 7—*Average gram-calories of radiation received during the 1-week following full bloom in selected areas, calculated on the basis of average date of full bloom. Radiation data are for the nearest U. S. Weather Bureau radiation station or in some instances averages of the records for the two stations on either side of the areas.*

Area	Average date of full bloom	Estimated average gram-calories of radiation received in 7 days starting with full bloom
Great Lakes region:		
Southern Michigan	5–12	2,550
Southern Ontario	5–24	3,125
Ohio Valley:		
Central Ohio	5–8	2,875
Southwestern Illinois	4–26	2,550
Central Indiana	4–30	3,225
Central Kentucky	4–23	2,996
Central Tennessee	4–13	3,056
Southeastern Missouri	4–4	2,950
New England:		
Central Maine	5–25	2,967
Central New Hampshire	5–23	2,917
West Central Massachusetts	5–17	3,850
Central Connecticut	5–14	3,675
Central Nova Scotia	6–2	3,059
Central Atlantic region:		
Northern Delaware	4–16	2,900
Southeastern Pennsylvania	5–1	2,975
Washington, D. C. area	4–25	3,195
Central West Virginia	4–30	3,282
Lower Piedmont	4–10	2,830
Winchester, Virginia	4–26	3,212
Southeast:		
Western North Carolina	4–12	2,875[1]
Central South Carolina	4–8	2,850[1]
East Central Alabama	4–1	3,225
Missouri Valley:		
Central Missouri	4–21	3,175
Southwestern Missouri	4–18	3,100
Northeastern Kansas	4–23	3,150
Northwestern Arkansas	4–13	2,807
Central Nebraska	5–8	3,272
North Central Oklahoma	4–15	3,125
Rocky Mountain area:		
Southwestern Colorado	4–19	3,500
Pacific Northwest:		
Southern Idaho	4–28	3,550
Southeastern Washington	5–10	4,036
Yakima, Washington	4–25	3,264
Wenatchee, Washington	4–27	3,492
Southwestern Washington	4–20	3,494
Hood River Valley, Oregon	4–27	3,712
Rogue River Valley, Oregon	4–27	3,875
Okanagon Valley, B. C.	5–8	4,025
Southwest:		
Southern New Mexico	4–16	3,793

[1]Were one to use the averages for the Washington, D. C., and Gainesville, Fla. records (Gainesville records being available for only 3 years), instead of only the Washington records, the figures for Western North Carolina and Central South Carolina would be 3,500 and 3,150, respectively—figures probably closer to actual conditions.

(Table 4a and 4b) where fruit-setting records were obtained in the same orchard and likewise the 1943-48 yield figures for two Delicious blocks in Michigan (Tables 5 and 6). At Pittsfield in 1940 the gram-calories of radiation received per square centimeter during the 7-day period starting with full bloom were 2,766, a departure of 167 or 5 percent below average; in 1941 they were 3,572, a departure of 644 or 23 percent above average. These differences in radiation were associated with fruit setting percentages of 4.25 and 7.96, respectively. In the two Michigan orchards, after due allowance is made for the residual effects of heavy cropping one year on production the following season and for possible crop reduction due to spring frost and winter injury, there is distinct evidence of the influence of radiation on fruit setting and size of crop.

Attention is called to the fact that Tables 4a, 4b and 4c present figures on the solar radiation *for certain locations* and *for certain years* only, and likewise fruit-setting data for the Delicious apple *for certain locations* and *for certain years* only. Throughout much of the eastern United States blossoming was very late in 1947. The solar radiation figures, therefore for a given location, e.g. East Lansing, Michigan, for 1947, even when accompanied by figures showing departures from the mean, do not present the *average* radiation conditions for those same locations for the average blossoming periods. In Table 7 an attempt is made to indicate the mean solar radiation for 7-day, 14-day and 30-day periods immediately following the *average full-bloom stage for apples* at a number of places where apples are produced in considerable quantities commercially.

FOREIGN EXPERIENCES

As already stated, quantitative data on radiation in other parts of the world are much less complete than for the United States. There are, however, a number of stations for which pyrheliometer records are available and some of them are probably representative of areas from which information on fruit setting in the Delicious apple has been obtained through the cooperation of investigators in certain other countries. Some of the more pertinent data that have been collected will be presented here.

MEXICO

The Delicious apple is not raised extensively in Mexico, but it is grown commercially in a number of orchards in widely separated

places. At Canatlan in the state of Durango at an altitude of approximately 6,000 feet 8- to 15-year-old Delicious trees reached full bloom in 1947 about April 1 (March 25 - April 5 depending on altitude and exposure); an average of 10.2 percent of their blossoms set fruit (13). Canatlan is located at latitude N. 24°32′ and longitude 104°47′ and is characterized by bright sunshine, more or less comparable to the Mesilla Valley area of New Mexico. At Valle de Allen in the state of Chihuahua (approximately 5,000 feet altitude) 8- to 10-year-old Delicious trees reached full bloom March 25, in 1947 and 13.5 percent of their blossoms set fruit. The latitude is N. 26°55′ and the longitude W. 105°. Valle de Allen is likewise characterized by bright sunny weather in early spring. At Zacatlan in the state of Puebla (approximately 6,500 feet altitude) 12-year-old Delicious trees came into full bloom on March 3, 1947. Sixty-five percent of their blossoms set fruit when hand pollinated. Zacatlan is at latitude 19°55′ N. and longitude 89° W. It too is characterized by very bright sunny weather. On the other hand, good setting in the Delicious apple is not universal in Mexico. At Torreon in the state of Coahuila, (latitude N. 26°, longitude 103° W.) the set in the spring of 1947 was only 1.8 percent (57), though in this same orchard a 90-percent set was obtained with hand pollination.

SOUTHERN URUGUAY

In the Rio Negro area of Uruguay (latitude 33° S., longitude 58° W.) where the sky is described as bright and cloudless, the Delicious sets heavily, requiring considerable thinning of fruit in order to obtain satisfactory size. On the other hand, fruit setting is far less satisfactory in the southern Rio de la Plata and Atlantic Coastal areas, where the rainfall is heavy and atmosphere humidity high, there is much cloudiness and the trees grow luxuriantly (4).

THE ARGENTINE

One of the leading apple-producing areas in the Argentine is the Mendoza district (latitude 34° S., longitude 68° W.), about 150 miles northwest of Santiago, Chile, and comparable to Central Alabama in the United States. Fruit setting in this variety in 1947 at Mendoza averaged 12.4 percent (43). On the basis of radiation data by Kimball (36) sunlight conditions during the blossoming period in the west central part of the Argentine may be assumed as probably resembling those of Boston, Massachusetts, or Nashville, Tennessee, during their blossoming seasons.

ANGOL, CHILE

Mr. D. S. Bullock (11), Superintendent of an agricultural school at Angol, Chile, for about 25 years, has had the Delicious apple under commercial cultivation and furnishes the following information: Angol is about 300 miles south of Santiago, Chile, latitude 38° S. comparable to Washington in the northern hemisphere, longitude 73° W. and almost due south of New York City; the elevation is 200 feet. Seldom does the temperature fall below 26° F. in the winter or exceed 90° F. in the summer; nights are cool; there are about a dozen frosts each winter. The area is characterized by relatively bright sunshine and little cloudiness. It is unique in that both the apple and citrus fruits grow and produce equally well. The Delicious apple sets abundantly and is a heavy producer.

FRANCE

Records (54) obtained on the Delicious apple in the spring of 1947 at Angers, France (latitude 47°30′ N., latitude 1° W.) indicated a set of 6.0 percent; at La fitte-sur-Lot in southwestern France a set of 7.7 percent. Mr. Suissa (54) describes both sections as characteristically having bright sunny weather during the apple blossoming period. M. Chevalier (12) reports that in the vicinity of Versailles, France, the Delicious apple characteristically sets fruit so heavily that considerable thinning is required. Kimball (35) gives 1.16 gram-calories per minute (estimated as about 3,500 gram-calories per square centimeter during the 7-day period following full bloom) as the average solar radiation for Paris, France, for the month of April when the apple blossoms—approximately that of Twin Falls, Idaho, and 15 percent higher than mid-May at East Lansing, Michigan, when the trees usually come into blossom there.

GERMANY

Fruit setting of the Delicious apple at the Cologne Research Station in Germany in the spring of 1947 was 5.5 percent (54). Minimum and maximum temperatures during the blossoming season were 39° F. and 70° F., respectively. Weather was described as sunny. Cologne is at latitude 51° N. and longitude 7° E.

POLAND

At the agricultural experiment station at Skierniewice, Poland, about 50 miles southwest of Warsaw (latitude 52° N., about that of Central Labrador, longitude 21° E.) the Delicious apple is described

by S. A. Pieniazek (46) as growing reasonably well, blossoming freely and setting fruit abundantly, though because of relatively cool summers its fruits are small. Dr. J. Matusewicz of the Institut Hydrologique et Meteorologique de Pologne (38) at Warsaw gives the mean solar radiation for May, when the Delicious blossoms in that part of Poland, as 13,300 gram-calories per square centimeter. This is 21 percent higher than the average for East Lansing, Michigan.

SWEDEN

Alnarp in southern Sweden, is located at about 56° N. latitude and 13° E. longitude. Its latitude approaches that of Juneau, Alaska, far north of what we in the United States think of as apple-producing districts. Yet Dr. Emil Johansson, Director of the Horticultural Research Station located there reports (33) that the Delicious apple grows well (though it is not extensively grown), sets fruit abundantly, and bears moderately heavy crops. Growing season temperatures are comparatively low—the means for June, July, and August being 59.2°, 64.6° and 63.5° F., compared with 66.4°, 70.8° and 65.8° F. for East Lansing, Michigan, and 64.8°, 73.9° and 73.8° F. for Yakima, Washington. However, Dr. Johansson describes the weather as characteristically bright and sunny. He states that the trees reach the full-bloom stage between May 20 and June 5. If the average full-bloom stage may be assumed as May 28, data on radiation supplied by C. J. Ostman, Meteorologist for the Stockholm Meteorologiska Hydrologiska Institut (44), give the average gram-calories of sunlight received per square centimeter for the 7-day period starting with full bloom as 3,218; this is comparable to the average for the blossoming season of Delicious in the New England States and but slightly below that of the Pacific Northwest; it is 20 percent above that for East Lansing, Michigan.

UNION OF SOUTH AFRICA

According to M. W. Black, Chief of the Department of Agriculture and Forestry of the Union of South Africa (5), the Cold Bokkeveld area of the Ceres district (latitude 33° S., longitude 19° E.) is one of the best adapted in South Africa to apple culture. The Delicious apple is grown there commercially, though not extensively; it grows well, sets fruit abundantly and bears moderately heavy crops. The weather during the blossoming period in October is described by Mr. Black as bright and sunny; the percentage of possible sunshine is comparable

to that at Boise, Idaho. The gram-calories of radiation received during October per square centimeter per day averages 541, measured by a Michelson–Buttner Actinometer, a different instrument than that used by the U. S. Weather Bureau. Mr. Black writes (5): "In Elgin, another important growing center, the general complaint amongst growers is that Delicious is a more straggly blossomer and does not set as heavily. . . . Especially the later blossoms set very poorly. The summer and fall climate of Elgin is duller, cooler and more humid than the Cold Bokkeveld, where the yields of Delicious are generally better."

PALESTINE

According to S. Friedman (24), of the Jewish Fruit Growers' Association of Jagur, Palestine, the apple is grown alongside the plum, olive, fig, orange, and banana in Palestine. The trees grow well, blossom abundantly and set fruit very heavily, so heavily that very heavy thinning of fruit is required. Records supplied by Messrs. S. Friedman and D. Brocki (10) indicated fruit setting percentages in 1947 of 13.6 percent for Delicious, 53 percent for Winter Pearmain and 38 percent for Winter Banana. Mean yearly temperature is given as 67.4° F., absolute maximum as 110° F., absolute minimum as 36° F.; average annual precipitation is 20.8 inches; average relative humidity is 78 percent. In general, Messrs. Friedman and Brocki liken the climate to that of San Bernardino, California, or Pima County, Arizona. Dr. D. Ashbel, Director of the Division of Meteorology of the Hebrew University at Rehovot (39), gives the average daily gram-calories of sunlight received per square centimeter during March as 512 and during April as 599. From these figures it may be estimated that the average total for the last week in March, the week following full bloom, is approximately 3,800 gram-calories per square centimeter; this figure is comparable to those sections in the United States having the most solar radiation (Table 6).

AUSTRALIA

Speaking for the Stanthorpe area of Queensland, Australia, (latitude 28° S., longitude 152° E., altitude about 3,000 feet), W. A. T. Summerville (53) reports that in 1937 17.7 percent of Delicious flowers set and matured fruit where the trees were planted in solid blocks with no provision for cross pollination; set was 21.9 percent where Jonathan was used as a pollinator. In general, the setting is good and cropping is heavy with this variety, but not much thinning is necessary. Dr.

Summerville characterizes the area as one of intense sunshine. Dr. C. G. Savage (49), Chief of the Division of Horticulture for the Department of Agriculture of New South Wales, reports for the Orange area fruit setting percentages of 20 to 25 for the 1940 season.

TASMANIA

The observations of P. H. Thomas (55) of the Department of Agriculture of Tasmania are pertinent in this connection. He states: "My observations, which extend over a period of 38 years in this State, are that the 'set' of pome and drupe fruits has generally been heavier when a period of a week or 10 days' sunshine occurred during the blossoming and post blossom period. This has been very noticeable amongst certain varieties such as Delicious and Delicious sports, Cox's Orange Pippin and Scarlet Pearmain—which appear to be more affected by uncongenial climatic conditions than other varieties. If such blossoming and setting conditions are followed by a normal season, heavy crops which often necessitate severe thinning result."

FOREIGN EXPERIENCE IN GENERAL

The data on fruit setting and cropping in the Delicious apple in many parts of the world that have been presented indicate clearly that those areas where the percentage of blossoms that set and develop fruits is high are in general characterized by relatively bright sunshine during the fruit setting period. At least it is substantially more than characterizes the Great Lakes area in the United States where setting is characteristically light.

FRUIT SETTING AS RELATED TO APPLICATION OF FUNGICIDES

High sunlight intensity or low sunlight intensity, as the case may be, during any particular period or at any particular place, is likely to be associated with certain other differences in environment. If there is relatively much solar radiation there is likely to be relatively low atmospheric humidity and little rainfall; conversely if there is much precipitation and the humidity is high, there will be less solar radiation. Unfortunately, the climatological data usually recorded do not make possible accurate quantitative comparisons of humidity for the fruit-setting periods for the locations for which fruit setting data are presented in this article.

Correlated with both solar radiation and atmospheric humidity is another environmental factor or complex affecting apple tree performance just preceding, during and just following blossoming that appears to be of much importance in this connection. Where there is considerable precipitation and particularly where atmospheric humidity is relatively high during this period, the apple is subject to attack of the scab fungus and repeated applications of fungicides are required. In many apple-growing sections of the United States three or four such applications have come to be standard practice (the so-called "pre-pink", "pink", "calyx" and "first cover" applications). In many instances, especially when the weather is cool and the season is long drawn out, one or two additional applications may be made. On the other hand, few or no fungicidal applications are made in those areas where sunshine is brighter, humidity lower and scab control is not much of a problem. Different fungicides are in use. Bordeaux mixture or some other copper-containing material was at one time commonly used; more recently sulfur in one form or another has largely supplanted copper. Sulfur is commonly applied in the form of "liquid lime-sulfur", "dry lime-sulfur" or "wettable sulfur". The first two materials consist principally of various sulfides and sulfates of calcium together with certain inert materials. The sulfur of "wettable sulfur" is carried largely as metallic or elemental sulfur along with certain wetting agents and adhesives. The sulfides and sulfates are more active chemically than elemental sulfur and, consequently, the various "lime-sulfurs" are more caustic, more likely to be toxic to host plant as well as to fungi. Because of this toxic effect on the plant that has come to be well recognized the "lime-sulfurs" have been gradually giving way to the less injurious "wettable sulfurs" in recent years. Still more recently other fungicides, such as fermate (ferric-dimethyl-dithiocarbamate), have been used at least experimentally, with the objectives both of improved scab control and reduced injury to the host plant.

The injurious effects of most fungicides have generally been thought of as limited to fruit russeting and leaf yellowing, burning or premature defoliation. More recently, however, other toxic influences have been recognized. One of the more important of these toxic influences is interference with photosynthesis even when there is no visible injury to the leaf. Heinicke (32) has demonstrated that in the case of the apple the leaf's photosynthetic efficiency is reduced by as much as 25 percent by an application of summer strength lime-sulfur—and this

refers to that portion of the leaf surface that shows no apparent injury in the form of burning or spotting.

Dutton (19), Groves (26), Young (63) and Rasmussen, Toenjes and Strong (47) have shown how these combined influences of burning, stunting and finally reducing the photosynthetic activity of the leaves have resulted in reduced yields. Groves (26) has stated that part of this reduction in the case of the apple is due to reducing fruit set, though quantitative data on how much of it is due to that factor and how much to reduced fruit bud formation are not given.

Kienholtz and Childs in Oregon (34a) have demonstrated a marked reduction in fruit setting and a corresponding reduction in yield in the case of the Anjou pear, following the use of wettable sulfur for the control of scab. There were not similar reductions in yields when fermate or copper phosphate-lime-bentonite were used as fungicides.

Cooperators in various parts of the United States and Canada furnishing the data on fruit setting in the Delicious, presented in Tables 1-4c, were in many instances able to supply the exact spraying schedules employed in the orchards in question. In Table 8 these data are arranged in groups in which 1) no fungicides at all were used and groups in which 2) mildly toxic or 3) more strongly toxic materials were used. It is realized that each group may include one or more records that in reality belong more properly in one of the other groups. Thus, for instance, there might be a difference of opinion as to whether the Orono, Maine, record should be placed in the mildly toxic or strongly toxic group in view of the fact that the orchard received one lime-sulfur application. The division lines had to be drawn somewhere and they were more or less arbitrarily drawn between no fungicide and fungicides in the one instance and one application or less of lime-sulfur and two or more in the second instance *before* the so-called "10-day" application.

It will be noted that in general the highest percentage setting was obtained where no fungicides were applied. The difference between the two groups receiving fungicides, the one less and the other more toxic, is not great. Closer examination, however, reveals some significant differences. The Michigan lower-than-average fruit-setting figures in particular, appearing in the less toxic fungicide group, were associated with relatively low temperatures and low solar radiation immediately following full bloom; the higher-than-average fruit setting figures for Tennessee, Alabama and North Carolina, appearing in the

TABLE 8—*Fruit setting of Delicious apple in various sections, as related to the application of fungicides*

Location	Per-cent set	7-day total day-degrees above 42°F.	7-day gram-calories radia-tion re-ceived	Early season applications of fungicides			
				Prepink	Pink	Petal-fall	10-day
Vancouver, Wash...	10.6	188	3,472	none	none	none	none
Yakima, Wash.....	6.6	239	3,170	none	none	none	none
Wenatchee, Wash...	6.72	255	4,238	none	none	none	none
Pullman, Wash.....	8.12	222	3,396	none	none	none	none
Fruitland, Ida.....	11.9	238	3,922	none	none	none	none
Mesilla, N. Mex....	10.2	270	4,045	none	none	none	none
Hood River, Ore....	7.3	156	3,575	none	none	none	none
Summerland, B. C..	16.7	.....	4,111	none	none	none	none
Brushy Mt., N. C..	33.8	222	2,862	none	none	none	L.S. 2½ gal. to 100
Clemson, S. C.....	8.5	260	3,897	none	none	none	none
Austin, Colo.....	14.8	159	2,847	none	none	none	none
Average.....	12.3	221	3,948				
Storrs, Conn.....	16.8	225	2,922	W.S. 8 lb. to 100	W.S. 10 lb. to 100	W.S. 6 lb. to 100	W.S. 5 lb. to 100
Pittsfield, Ill. '40...	4.25	215	2,766	W.S.	W.S.	W.S.	W.S.
Pittsfield, Ill. '41...	7.96	261	3,572	W.S.	W.S.	W.S.	W.S.
Durham, N. H.....	12.9	208	3,399	W.S.	W.S.	W.S.	W.S.
Stephenville, Tex...	5.0	230	3,286	.....	W.S. 6 lb. to 100	W.S. 6 lb. to 100	W.S. 6 lb. to 100
Orono, Me.....	16.6	194	3,209	W.S.	W.S.	L.S.	W.S.
Kentville, N. Sco...	6.6	184	3,092	Bord.	W.S.	W.S.	W.S.
Columbia, Mo.....	10.4	187	4,912	L.S. 1 gal. to 50	W.S.	W.S.	W.S.
Amherst, Mass.....	11.7	227	3,629	W.S. 4 lb. to 100 + Fermate ½ lb.	W.S. 4 lb. to 100 + Fermate ½ lb.	Fermate ½ lb. to 100 gal.	W.S. 4 lb. to 100 + ½ lb. Fermate
Lincoln, Nebr.....	10.8	222	3,650	B-341 3 lb. to 100	.....	B-341 3 lb. to 100	.....
Mt. Grove, Mo.....	4.0	205	3,905	.....	Puratized 1 pt. to 100	Puratized 1 pt. to 100	W.S. 4 lb. to 100 + Fermate 2 lb.
Holly Springs, Miss.	5.0	205	2,843	.....	W.S	W.S.	W.S.
East Lansing, Mich.	4.3	135	2,248	W.S.	W.S.	L.S.	W.S.
Grand Rapids, Mich.	4.2	136	2,248	W.S.	W.S.	L.S.	W.S.
Average.....	8.6	202	3,263				
Blairsville, Ga.....	4.2	221	2,477	.....	L.S. 1½ gal. to 100	L.S. 1½ gal. to 100	.....
Wooster, O.....	1.13	212	2,621	L.S. 1¼ gal. to 100	L.S. 1 gal. to 100	L.S. 12½ lb. to 100	Fermate
Knoxville, Tenn....	8.3	238	3,142	L.S. 3 gal. to 100	L.S. 3 gal. to 100	W.S.	W.S. 12½ lb. to 100
Kentucky.....	2.9	7	2,447	L.S. 2 gal. to 100	L.S. 2 gal. to 100	W.S.	W.S.
Fayetteville, Ark...	7.0	.....	2,702	.....	L.S. 1½ gal. to 100	L.S. 1 gal. to 100	Bord.
Lafayette, Ind.....	6.3	238	3,063	L.S. 2 gal. to 100	L.S. 2 gal. to 100	W.S. 8 lb. to 100 gal.	L.S. ½ gal. + 8 lb. W.S.
Brushy Mt., N. C..	19.4	202	3,207	L.S. 2½ gal. to 100	L.S. 2½ gal. to 100	L.S. 2½ gal. to 100	L.S. 2½ gal. to 100
Auburn, Ala.....	17.7	195	3,067	.....	1¼ gal to 100	L.S. 1¼ gal. to 100	L.S. 1¼ gal. to 100
Average.....	7.4	187	2,841				

more toxic fungicide group, were associated with relatively high temperatures and high solar radiation immediately following full bloom. Obviously the data in Table 8 do not completely separate out from all other factors the influence of fungicides on fruit setting; they nevertheless point to a definite influence that fungicides seem to have. Perhaps the most significant figures in the table relating to influence of fungicide on fruit setting are those for the two orchards at Brushy Mountain, North Carolina, in 1947. It is true that they were at different elevations and blossomed several days apart, but they were exposed to essentially the same effective (above 42° F.) temperatures and to the same solar radiation immediately following full bloom; the one, however, received no fungicide, while the other received applications of one of the more toxic fungicides.

More significant data on the influence of kind of fungicide on fruit setting in the Delicious apple (also McIntosh) are presented in Table 9. They show results obtained in 1948 from applications of several materials made on the same days to trees in different plots in each of three orchards in Michigan. The materials used were Bordeaux mixture,

TABLE 9—*Relation of fungicidal applications, tree vigor, temperature and sunlight intensity to fruit setting of the Delicious apple in three Michigan orchards in 1948, compared with that of the McIntosh*

Relative tree vigor	Date of full bloom	Mean maximum temperatures during the 5-day blossoming period	Gram-calories radiation received during 7-days starting with full bloom	Fungicide applied at pre-pink, pink, calyx and first cover stages	Percent blossoms setting fruit
At East Lansing—Delicious					
Medium	5–14	65.8°F.	2,954	Fermate	1.9
				Wettable sulfur	.3
At Grand Rapids—Delicious					
Very vigorous	5–18	68.7°F.	3,720	Fermate	4.1
				Wettable sulfur	.52
Medium	5–18	68.7°F.	3,720	Bordeaux	6.7
				Wettable sulfur	6.6
Very weak	5–18	68.7°F.	3,720	Bordeaux	1.1
				Wettable sulfur	.75
At Fremont—Delicious					
Medium	5–20	66.8°F.	3,915	Bordeaux	5.1
				Fermate	5.0
				Wettable sulfur	2.2
At Grand Rapids—McIntosh					
Very vigorous	5–18	68.7°F.	3,720	Bordeaux	4.5
				Wettable sulfur	3.8

wettable sulfur and fermate. Bordeaux and fermate are generally regarded as relatively non-toxic and wettable sulfur as mildly toxic to foliage. In the orchard where all three materials were used fruit setting was about the same in the bordeaux- and fermate-sprayed plots and about twice as great as in the sulfur-sprayed plot. At East Lansing, where only fermate and wettable sulfur were compared a much better set was obtained with fermate; the same was true at Grand Rapids in the block of vigorous top grafts. In the blocks at Grand Rapids where bordeaux mixture and wettable sulfur were compared, setting in the sulfur-sprayed plots was less, though not strikingly so, than in the bordeaux-sprayed plot. The one comparison of bordeaux mixture with wettable sulfur in the McIntosh variety likewise indicated a toxic influence on the part of the sulfur.

DISCUSSION

Much of the data presented in the preceding pages on fruit setting in the Delicious apple, as influenced by environmental conditions, point to the week, 10 days or two weeks immediately following the full bloom stage as being *the* critical period in this process. Emphasis is lent to this conclusion by the data presented in Table 10 on spur leaf development. Within a week after full bloom all of the leaves on the smaller spurs have attained their full size and that also holds for three-fourths of those on the large spurs. A few of the younger leaves continue to expand for another week or two, but spur leaves are present right at the start to synthesize materials used in fruit setting; furthermore it appears that fruit setting depends largely upon their proper functioning. It therefore follows that relatively high temperature and abundant sunlight contribute to, and conversely low temperature and cloudiness interfere with, the process. Unfortunately, these are factors that vary greatly from place to place and season to season; moreover, they are beyond control.

Fully as important in many instances is the presence of more or less toxic spray materials. The evidence indicates that the toxic effect of some of them on the process of fruit setting is greater than the retarding effect of unusually cool and cloudy weather. This is a factor largely under the control of the producer. He may not be able to get along without fungicidal applications just before and during the fruit-setting period, but he can and should use only materials with the least harmful influence on the photosynthetic processes of the plant con-

TABLE 10—*Development of spur leaves on the Delicious apple at East Lansing, Michigan, in the spring of 1947. The trees were in full bloom on May 27.*

Spur No.	Leaf No. (from base to apex of spur)	June 7		June 12		June 16		June 19	
		Width cm.	Length cm.	Width cm.	Length cm.	Width cm.	Length cm.	Width cm.	Length cm.
1	A	1.2	1.8						
	B	1.8	3.4						
	C	2.1	4.3						
	D	2.1	5.0						
2	A	.9	1.8						
	B	.9	2.5						
	C	1.8	3.7						
	D	2.5	5.0						
	E	1.8	5.0	2.1	5.6				
3	A	1.8	2.8						
	B	2.5	4.3						
	C	3.1	5.9	3.1	6.2				
	D	3.4	7.5						
	E	3.1	7.8						
	F	2.1	5.9	2.1	7.5	2.8	7.5		
4	A	1.8	2.5						
	B	2.1	4.0						
	C	2.5	5.3	2.8	5.3				
	D	2.8	6.2	2.8	6.5				
	E	2.5	6.2	2.5	6.5	2.8	6.5	2.8	6.8
	F	1.2	4.0	2.5	5.9	2.5	6.5	2.8	6.5
5	A	2.5	4.0						
	B	3.7	6.5						
	C	3.4	6.8						
	D	3.7	8.4						
	E	2.1	6.2	2.5	7.5				
	F	1.2	3.4	2.5	5.9	2.8	6.8	3.1	6.8
6	A	2.5	2.1						
	B	2.5	5.0						
	C	2.5	5.9						
	D	3.1	6.5	3.1	6.8				
	E	3.1	7.1	3.4	7.1				
	F	2.1	5.9	3.4	6.8	3.4	7.1		
	G	1.2	3.7	2.8	6.2	3.1	7.1	3.1	7.5
7	A	2.1	3.1	2.5	3.1				
	B	2.5	4.3						
	C	2.8	5.9						
	D	2.8	6.2						
	E	3.1	6.5						
	F	2.8	7.1	3.4	7.8	3.4	8.1		
	G	1.8	5.3	3.1	7.5	4.0	7.5		
8	A	2.1	3.4						
	B	2.5	5.6						
	C	3.4	6.8						
	D	3.7	8.1						
	E	3.1	8.1	3.4	8.1				
	F	1.8	4.3	3.1	5.9	3.4	6.2	3.7	6.5
	G	.9	2.5	1.8	5.3	2.5	5.6	2.5	6.2
9	A	1.8	1.8						
	B	2.1	3.7						
	C	3.1	5.3						
	D	3.1	5.6						
	E	3.7	6.8						
	F	3.7	6.8	3.7	7.5				
	G	1.5	5.0	2.5	6.8	2.8	7.1	3.1	7.1
	H	1.2	3.7	2.8	6.5	3.4	7.5		

sistent with effective control of the diseases prevalent at that period. The ideal fungicide, one that is highly toxic to the fungi and at the same time completely non-toxic to the host plant, is yet to be found. In the meantime, however, through selection of the best materials that

are available and timeliness of application the producer can do much to improve the chances of his trees setting a good crop. This is especially important in sections, such as Michigan, that are relatively cloudy and cool during the fruit setting period and with varieties, such as the Delicious, that are particularly sensitive to unfavorable influences at that stage in their seasonal life history.

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Staff Members of Research Stations and Other Individuals in Foreign Countries:

Mr. S. S. Colin, Director General for Agriculture, San Jacinto, D. F., Mexico.

Sr. E. J. Torres, Department of Agriculture, Torreon, Coahuila, Mexico.

Sr. Manuel Munoz Castillo, San Juan de Letran, Mexico, D. F.

Dr. Dante Bianchi, Horticulturist, University of Trabajo, San Carlos, Uruguay.

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Dr. Emil Johanssen, Horticultural Research Station, Alnarp Station, Sweden.

Mr. C. S. Richardson, New Zealand Department of Agriculture, Nelson, New Zealand.

Prof. S. A. Pieniazek, Warsaw Central College of Agriculture, Skierniewice, Poland.

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Dr. W. T. Summerville of the Department of Agriculture, Brisbane, Queensland.

Mr. P. H. Thomas, Department of Agriculture, Hobart, Tasmania.

Mr. N. J. Adamson of the Department of Agriculture, Nelson, New Zealand.

Dr. M. W. Black, Pomologist of the Western Province Research Station, Stellenbosch, Union of South Africa.

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