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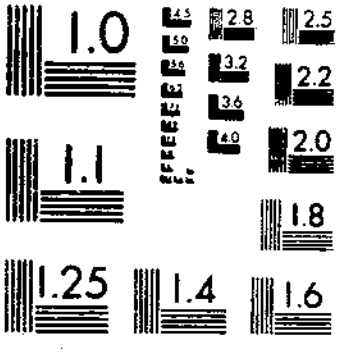
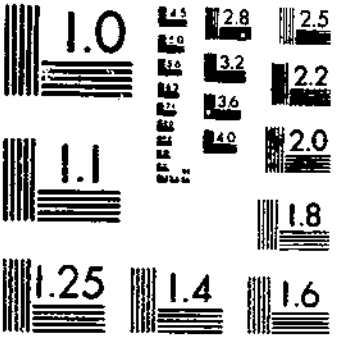


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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

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Evaluation of Indexes of Maturity for Apples [1]

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NEED FOR RETESTING INDEXES OF MATURITY

The stage of maturity at which apples are picked greatly influences their size, color, and storage and dessert qualities. Because of the importance of picking apples at the proper maturity, many investigations to establish indexes for picking have been conducted, but definite, objective indexes have been difficult to establish.

In rather extensive earlier investigations (*28*, *29*) [3] the three most important factors to consider in determining the best time of picking have been given as (1) the changes in the ground color from green toward yellow, (2) the firmness of the fruit as determined by pressure tests, and (3) the way the fruit is holding to the tree, or ease of separation and dropping. The elapsed period from full bloom to maturity also has been suggested as a possibility. Other investigators (*1*, *4*, *5*, *7*, *30*) have suggested the iodine-potassium-iodide test for starch as a maturity index.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 51.

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Various studies have indicated, however, that most of the indexes just mentioned are unreliable. Hesse and Hitz (*19*) found that there was not enough change in ground color or firmness in Grimes Golden and Jonathan apples for these factors to be reliable indexes to maturity. Similar results were obtained by Haller (*11*) for these varieties and Yellow Newtown and by Britton, Fischer, and Palmer (*5*) for Northern Spy and Yellow Newtown. Haller (*11*) also observed that, although dropping may make picking necessary, it may not be an indication of maturity, for there frequently appeared to be no measurable change in case of separation during the harvest period. Various workers (*11, 39, 40*) found the starch test to be unreliable and dependent on factors other than maturity. Phillips (*34*) was the first to study the relation of the time of full bloom to ripening (maturity). He observed that this period was markedly longer in some regions than in others and that it was largely determined by the amount of heat received by the tree. Ellenwood's results (*8*) also indicated considerable variation between seasons in the period from full bloom to harvest.

Changing horticultural practices have also influenced the determination of maturity. The increased planting of red bud sports of many varieties makes it difficult if not impossible to follow the ground-color changes as the fruit approaches maturity. The use of harvest sprays to prevent dropping affects the normal change in case of separation so that the change becomes of no value as an indication of maturity.

Because of the conflicting results relative to indexes of maturity and the changing horticultural practices that influence them, further investigations of the value of maturity indexes were conducted. These formed the basis for the Department's present recommendations for picking (*17*). The present paper gives the data upon which these recommendations were based and the apple-maturity indexes evaluated.

DEFINITION OF TERMS

The terms "maturity" and "ripening" have sometimes been used rather loosely in horticultural literature. In this bulletin, however, the terms are distinguished as done by Haller, Lutz, and Mallison (*15*). "Maturity" and "maturing" refer to those conditions or changes in the fruit on the tree that would influence quality after harvest; "ripeness" and "ripening" refer to those conditions or changes in the fruit that make it suitable for eating. Changes in the fruit after harvest are ripening changes, but such changes may also occur while the fruit is still on the tree and may accompany or follow the maturity changes. This usage of the terms is in accordance with their definitions in standard dictionaries, but not with their horticultural usage, as suggested by Lott (*24*).

Haller and Magness (*17*) distinguished several stages of maturity in apples as follows:

Immaturity.—Apples picked when immature will soften somewhat and may turn yellow when ripened; but the flesh is likely to be tough, the taste sour, the flavor lacking or undesirable, or the storage quality poor because of susceptibility to storage scald, bitter pit, or other disorders associated with immaturity.

Early maturity.—Apples picked at early maturity ripen with only fair dessert quality for the variety, but are reasonably free of disorders associated with

immaturity during storage. The beginning of this maturity period is the earliest time at which picking can begin with satisfactory results.

Optimum maturity.—Apples picked at optimum maturity can be stored with a minimum of storage disorders and ripened with maximum dessert quality for the variety and conditions of growth.

Late maturity.—Apples picked at late maturity are still satisfactory for picking, but they will be somewhat flat in flavor and may show a slight tendency to become mealy and to develop disorders associated with overmaturity.

Overmaturity.—When allowed to remain on the tree until overmature, apples may ripen quickly to a mealy condition, may be flat in taste, or may be subject to internal break-down or decay during storage.

In this bulletin the primary interest is in determination of an index of early maturity, because at the beginning of that period picking may start with the expectation that the fruit will have reasonably good dessert and storage qualities.

MATERIAL AND METHODS

Investigations in which the elapsed time from bloom (full bloom) to maturity (earliest maturity) was determined were started in 1938. In 1938, 1939, and 1940 only four varieties (Williams Early Red, Jonathan, Grimes Golden, and Yellow Newtown (Albemarle Pippin)) were used. In these three seasons Williams Early Red apples were grown on the sandy or sandy loam soil of the Eastern Shore near Salisbury and Berlin, Md. The Jonathan apples were obtained from near Kearneysville (or Martinsburg), W. Va., where they were grown on Hagerstown clay loam, and from Berlin, Md.; the Grimes Golden from near Crozet, Va., Kearneysville, W. Va., and Salisbury and Berlin, Md.; and the Yellow Newtown from near Crozet, Va.

Beginning with 1941, the work was expanded to include additional varieties and similar studies by cooperating workers in widely separated localities. It was intended that the cooperative studies should be continued during several seasons, but war conditions caused the cooperators to drop out after the first or the second season. In 1941 maturity studies were conducted at Beltsville, Md., Geneva, N. Y., Wooster, Ohio, East Lansing, Mich., Urbana, Ill., Wenatchee (and nearby localities), Wash., and Hood River, Oreg. Insofar as they were available, the same varieties were used in all localities to determine the influence of varying climatic and cultural conditions on maturity and particularly on the elapsed time from bloom to maturity. However, only a few of the varieties were available in all localities. In 1942 the studies were continued at the same localities as in 1941, except for Geneva, N. Y., and Urbana, Ill. In 1943 and 1944 apples were not obtained from the Bureau's experimental orchard at Beltsville, Md., but were obtained from four commercial orchards in Virginia and West Virginia. These represented various soil types and elevations. In some instances the fruit was also from trees bearing light or heavy crops. The studies were continued also at Wenatchee, Wash., in 1943. Pertinent data from other studies were included in a few cases.

The date of full bloom of each variety was noted for each orchard from which apples were obtained. This was taken as the day on which about 75 percent of the side blossoms were open; at that time the petals were generally dropping from the center, or king, blossom.

During the harvest period pickings were made at about weekly intervals. At each picking the condition of the fruit was determined as follows: The ground color was determined by comparison with a standard color chart (*28*), and the percentage of the surface covered with red color was estimated. The firmness was determined by means of a pressure tester with a plunger having a 7/16-inch diameter and a 5/16-inch penetration. The amount of dropping of sound fruit was noted, and the ease of separation was measured by counting the number of stems and spurs broken by a standard picking technique. In some instances, particularly with the Jonathan variety, the iodine-potassium-iodide test for starch was made on a median cross section of the apples, and the percentage of the cut surface showing the starch reaction was estimated.

Bushel lots or 100 apples of each picking were placed in storage at 31° to 32° F. until toward the end of the normal storage period for the variety. At this time the lots were removed to 70° for post-storage ripening. After ripening, the apples were inspected for storage disorders and tasted for dessert quality. In some instances dessert quality was determined also on apples ripened at 70° immediately after picking. On the basis of the storage and dessert qualities of the fruit ripened after storage, it was possible to establish the approximate picking date when the fruit was first of satisfactory maturity for picking.

The fruit was judged as having been picked at a satisfactory maturity when it ripened after storage with only fair dessert quality for the variety and was reasonably free of scald[1] and other storage disorders that are associated with immaturity. The fruit was considered to have been picked at optimum maturity when it ripened after storage with maximum dessert quality and a minimum of storage disorders. In some instances pickings were made when the fruit was overmature as shown by mealiness or internal break-down and deterioration in dessert quality.

The apples were rated fair in dessert quality when they ripened with a minimum of characteristic flavor for the variety for satisfactory dessert quality. This condition is given a numerical rating of 0 and degrees of quality above it are given positive values up to +4 for very good and those below it negative values to −3 for very poor to aid in plotting (see fig. 6 and similar figures). In some instances the dessert quality was established by means of a panel of several tasters, but in most instances it was based on one individual's judgment. Since change in dessert quality is usually very gradual and there is no objective and definite measure of dessert quality, it is recognized that there may be considerable error in establishing a time when apples reach a particular degree of maturity when this is based on dessert quality. Some of the variation in the length of time between bloom and maturity is doubtless due to errors in judgment of dessert quality.

[1] In the experimental lots reported on in this bulletin, the apples were judged to be not "reasonably free of scald" and therefore immature if more than 20 percent of the fruit developed scald when ripened after storage. However, scald may be due to factors other than immaturity (such as absence of oiled paper, improper storage, and temperature); therefore, under commercial conditions the presence of more than 20 percent of scald would not necessarily mean that the apples were immature when picked.

With some varieties and under some conditions, the earliest satisfactory maturity may be determined by the storage quality. For example, because Grimes Golden usually attained satisfactory dessert quality before it lost its susceptibility to scald, the earliest satisfactory picking of Grimes Golden was determined primarily by when it became resistant to scald. In contrast, Golden Delicious is not subject to scald, and its earliest satisfactory maturity was based very largely on when it became passable in dessert quality. Although dessert quality of some varieties changed rather distinctly between pickings made a week apart, in other varieties or lots the change was slight and it was frequently difficult to ascertain at just which picking the apples had attained satisfactory dessert quality for the variety. Therefore there may be considerable error or variation in the estimate of picking maturity as made by different investigators or by the same investigator in different seasons.

RESULTS

Evaluation of Maturity Indexes

GROUND COLOR

For ground-color changes to be of value as a maturity index, they should be rather marked as the apples approach maturity and the shade of green to yellow at maturity should be the same under various cultural and climatic conditions. The results do not indicate that ground-color changes comply with these requirements. At earliest maturity the ground color of such varieties as Yellow Newtown and Grimes Golden had hardly changed perceptibly from the darkest shade of green on the color chart. In other varieties the change was too gradual to be of value as a maturity index, and at earliest maturity the shade was not the same in the different seasons or localities. The ground colors of Delicious at different periods after full bloom are shown in figure 1. In most cases Delicious reached earliest maturity about 150 days from full bloom, at which time the ground color of the various lots ranged from about 2 to 3.

During the 7 days preceding earliest maturity the average color of the various lots changed only from 2.5 to 2.6, which is not a significant change and would not be perceptible. The results indicate that the ground color of Delicious will be at least 2 when earliest maturity is reached, but shade 2 is of little or no value as a maturity index, because under some conditions the apples may reach this color long before they are mature. Most of the lots in figure 1 averaged 2 or considerably more at 142 days or less from bloom, but they were still judged immature. The ground color did not become 3 in any instance before 149 days from bloom, when the apples were mature. The results indicate, therefore, that when Delicious apples become as yellow as 3 of the color chart, they are mature and ready to pick, but that in most instances they are mature before they reach this shade of yellow and that they are likely to be overmature by that time.

As Golden Delicious approaches maturity its ground color changes more than that of most other varieties; therefore if ground-color change constitutes a satisfactory maturity index, it should be satisfactory with this variety. The ground colors of this variety at

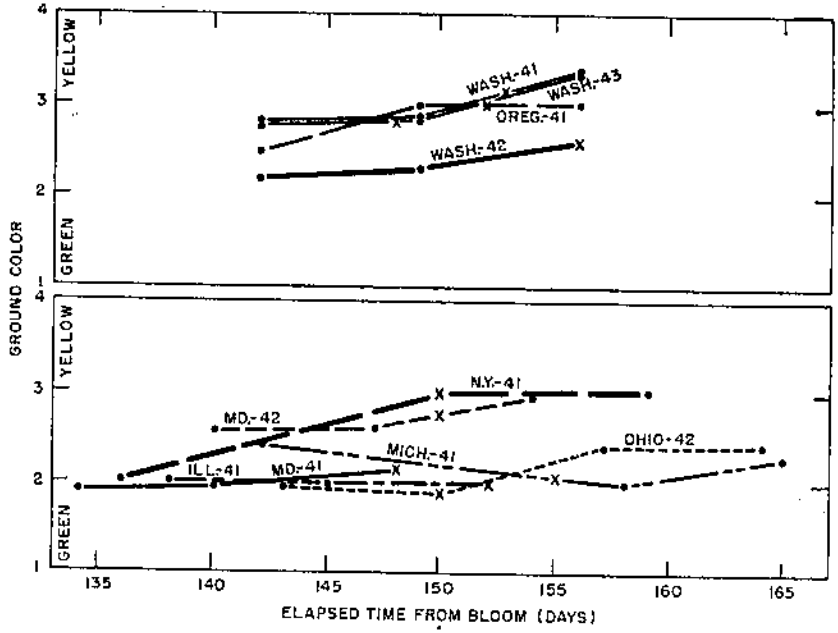

FIGURE 1.—Ground color of maturing Delicious apples from various sources. Number after State name or abbreviation, season; X on curves, earliest time at which apples were considered to be mature.

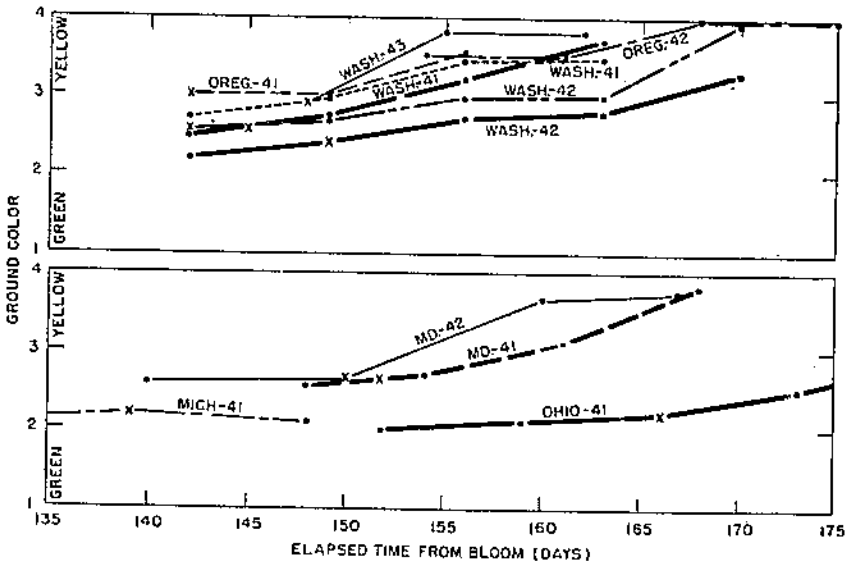

FIGURE 2.—Ground color of maturing Golden Delicious apples from various sources. Number after State name or abbreviation, season; X on curves, earliest time at which apples were considered to be mature.

different periods are shown in figure 2. There was a more distinct change in ground color with time than there was with Delicious. The ground color at earliest maturity ranged from 2.2 for Michigan in 1941 to 3.5 for Oregon in 1942. Generally at earliest maturity the ground color of Golden Delicious was at least 2.5. If this had been used as a minimum standard, however, the apples of this variety at Wooster, Ohio, would not have been picked until at least 170 days from bloom in 1941. In most instances earliest maturity occurred by about 150 days from bloom. In other instances, however, the ground color had changed to 2.5 considerably before the apples were mature.

Similar results were obtained for the other varieties under test.

Apparently factors other than maturity influence ground color, and therefore ground color varies too much at maturity to be of much value as a maturity index.

FIRMNESS AS MEASURED BY PRESSURE TEST

Magness and his associates (*29*) found that the rate of softening varied greatly under different growing conditions and that frequently there was not enough softening before harvest for firmness as measured by the pressure test to be of value as an index of when to start picking apples. Britton, Fisher, and Palmer (*5*), Hesse and Hitz (*19*), and Trout, Tindale, and Huelin (*40*) arrived at similar conclusions. The present investigations confirm these earlier conclusions. The pressure-test readings for 17 lots of Delicious and its bud sports Starking and Richared representing different sources and seasons varied at earliest maturity from 15.5 pounds in Maryland in 1942 to 18.3 pounds in Washington in 1943, a range of 2.8 pounds.

The average rate of softening in these lots between the first and the last picking equaled 0.046 pound per day, and in 4 of the 17 lots there was no softening or a slight increase in firmness. The range in pressure-test readings at earliest maturity is equivalent to the average softening during a period of about 2 months. The softening of Grimes Golden on the tree was much more rapid than that of Delicious and averaged 0.171 pound per day. However, the firmness at earliest maturity also varied more and ranged from 17.0 to 22.8 pounds (table 3). The difference of 5.8 pounds was equivalent to softening over a period of about a month. The softening of Grimes Golden during the maturing period, shown in figure 3, illustrates the great variability in pressure-test readings at maturity. Similar results were obtained with the other varieties.

EASE OF SEPARATION

For ease of separation of the fruit from the spurs to be of value as an index of maturity, the fruit from adhering tightly when the fruit is immature to separating readily or easily when it is first mature should be definite and the means of measuring the ease of separation should be rather definite. To measure the ease of separation, the apples were picked with an upward twist and pull and the percentage that separated at the abscission layer without breaking either stem or spur was determined. The ease of separation was also usually

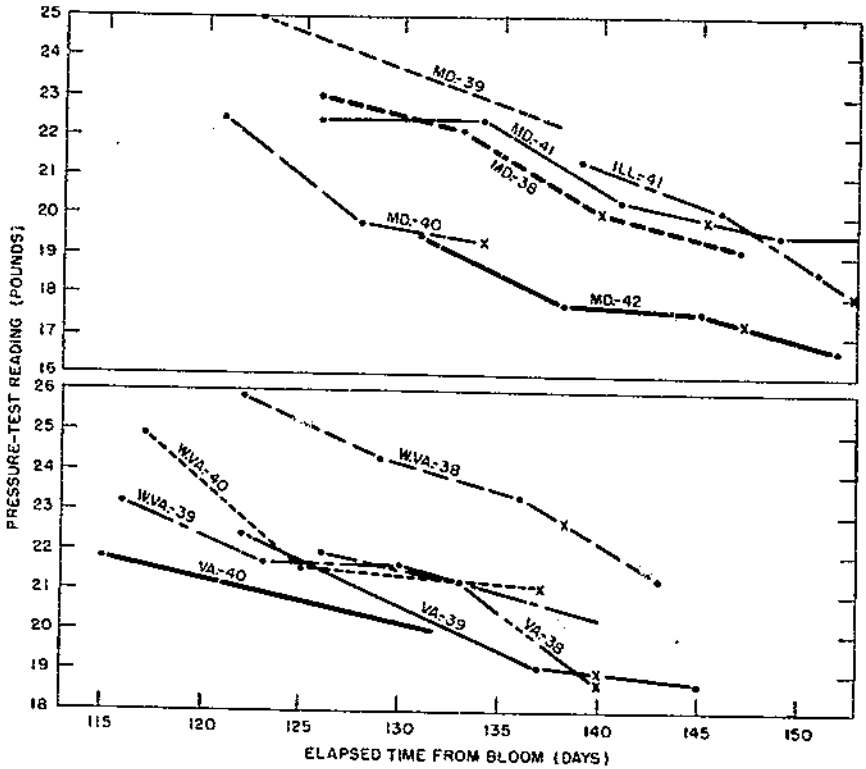

FIGURE 3.—Firmness (as shown by pressure test) of maturing Grimes Golden apples from various sources. Number after State abbreviation, season; × on curves, earliest time at which apples were considered to be mature.

described in general terms such as "adhering tightly" or "separating readily." The amount of dropping of sound fruit was also noted.

No appreciable change in the ease of separation of many varieties during maturation was found (table 1). With Jonathan, for example,

TABLE 1.—*Ease of separation of apples from spurs from the first to the last picking of various varieties of apple*

Variety	Comparisons	Average period between first and last picking	Separation [1]		Difference in ease of separation
			First picking	Last picking	
	Number	*Days*	*Percent*	*Percent*	*Percent*
Jonathan	15	22	84	86	2
Grimes Golden	13	20	88	85	−3
Delicious (and bud sports)	18	17	90	94	4
Golden Delicious	11	21	87	93	6
Yellow Newtown	10	35	85	89	4
Winesap	8	15	80	85	5
Stayman Winesap	7	15	80	89	9
Rome Beauty	4	17	86	93	7
McIntosh	6	16	95	95	0

[1] Percentage of the fruit that separated at the junction of fruit to stem and spur without breaking either the stem or the spur when picked with a standard technique (described p. 7).

the time between the first and last pickings was 22 days but the percentage of apples that separated properly (without breaking stem or spur) increased only from 84 to 86 percent. This slight increase was obviously not significant or of any value as a measure of picking maturity, as in 7 of the 15 comparisons there was no change or a decrease instead of an increase. With Grimes Golden there was an apparent decrease in the average ease of separation at the last pickings, made 20 days after the first pickings, and in only 1 of the 15 comparisons was there an appreciable increase in the ease of separation. Results obtained with the other varieties were similar to those with Jonathan. Although the changes in ease of separation for several varieties were somewhat larger, they were not sufficiently consistent to be of value as maturity indicators. General notes on ease of separation likewise frequently failed to show any marked change in the way the fruit adheres to the spurs.

The amount of dropping of sound fruit is another measure of the ease of separation of the fruit from the spur, but dropping may also be caused by windstorms rather than a change in ease of separation. Abnormally early dropping may be a result of unfavorable climatic conditions such as an early frost or a period of wet weather after a dry spell. Under such conditions the fruit may drop before it reaches a suitable stage of maturity to attain good dessert and storage qualities. Once a tendency to drop starts to develop, dropping is likely to become severe rather quickly; therefore if picking is not started until dropping begins, considerable loss is likely to occur before picking can be completed. Under such circumstances harvest sprays to retard dropping are indicated, but it is questionable whether picking should be much delayed even when such sprays are used. On the other hand, with some varieties and under favorable conditions the fruit may adhere well until it is overmature. Thus, the ease of separation or dropping is not reliable as an index of maturity, because under some conditions dropping may occur prematurely and under other conditions it may not occur until the fruit is overmature.

STARCH TEST

At each picking of certain varieties median cross sections of 10 to 20 apples were dipped in an iodine-potassium-iodide solution and the percentage of the surface that showed the starch reaction was estimated. This test was used particularly with the Jonathan variety, for which it has been recommended as an index of maturity (*1*), but it was also applied to Grimes Golden and Yellow Newtown.

The entire cut surface of Grimes Golden apples usually showed starch at all pickings; therefore the starch test would not be of value as a maturity index for this variety. The starch test was applied to Yellow Newtown fruit from Virginia during three seasons (1938 to 1940). At earliest maturity in 1938 and 1939 there was little or no starch disappearance. In 1940, however, at earliest maturity the starch was gone from 25 to 50 percent of the surface of apples from rather heavily loaded old trees and from 0 to 10 percent of slightly more mature fruit from less heavily loaded young trees.

These results indicate that the starch test would not be a reliable index of maturity for Yellow Newtown. The results are in agreement

with those of Martin and Carne (*31*), who observed that light-crop fruit loses starch later than heavy-crop fruit. They disagree, however, with those of Britton, Fisher, and Palmer (*4*), who suggested the starch test as a maturity index for Yellow Newtown, Northern Spy, and Cox Orange varieties. Their results indicate that Yellow Newtown should be picked when the starch has disappeared from the core region. Approximately this condition prevailed in the Yellow Newtown from Virginia in 1938 and 1939 at about optimum picking maturity. However, in 1940 the apples were in this condition on the heavily loaded trees while the fruit was still distinctly immature.

The range in the percentage of the median-cross-sectional surface of Jonathan apples with starch at earliest maturity is given in figure 4. The results show that the starch test would be unsatisfactory as a maturity index for two reasons: (1) The average percentage of the surface with starch at maturity varied from more than 60 percent to less than 10 percent in different seasons and in apples from different sources; (2) there was great variability in starch among individual fruits of practically the same degree of maturity in a given picking.

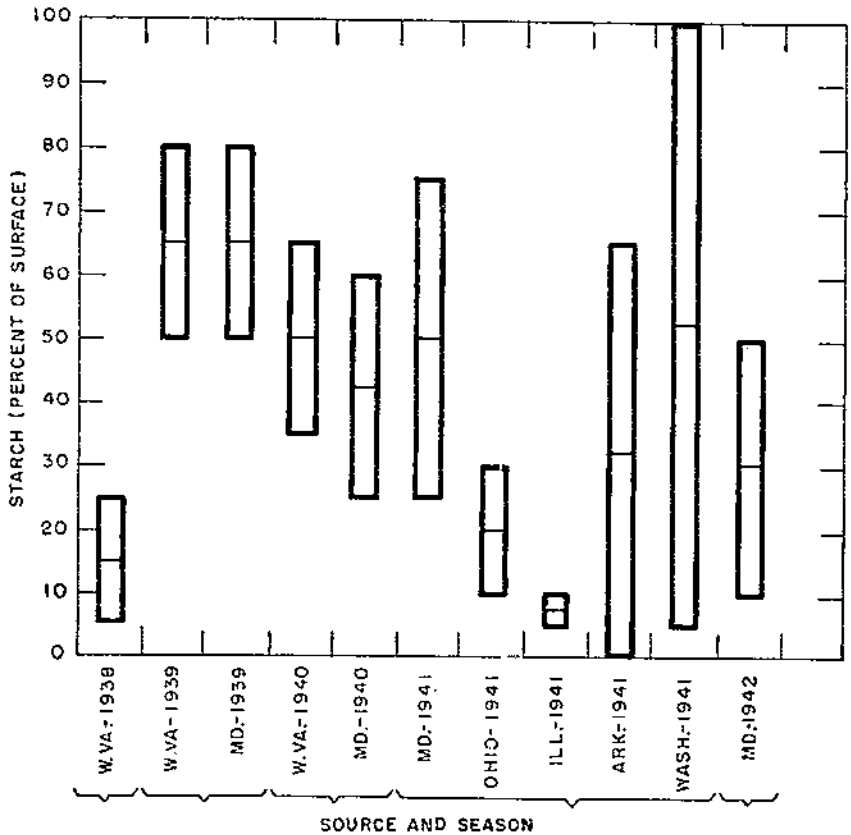

FIGURE 4.—Range in percentage of median-cross-sectional surface of Jonathan apples showing starch at earliest maturity.

The greatest variation among individual apples at earliest maturity was found in Washington in 1941, the starch ranging from 100 percent of the surface to only 5 percent.

The iodine-potassium-iodide test for starch has been suggested as a maturity index for Gravenstein (*22*), McIntosh and Fameuse (*7*), Cox Orange, Northern Spy, and Yellow Newtown (*4, 5*), and Jonathan (*1, 30*). At maturity of Jonathan in Maryland (*1*) the starch was illustrated as present just under the skin, somewhat mottled in the outer flesh, and absent from the core region. A rather similar condition (absence of starch from the core region and half of the cortex) was indicated at maturity of Jonathan in Australia (*30*). On the other hand, Trout, Tindale, and Huelin (*40*) observed that the amount of starch present varied with individual fruits and was dependent on seasonal conditions. In some years they found more starch in the later picked fruit. Tiller (*39*), working with Jonathan, Cox Orange (Cox's Orange Pippin), Delicious, Sturmer, and Statesman, observed that frequently there was little or no change in the starch content during the harvest period and concluded that the starch test was of no value as an index of maturity. Hinton (*20*) reported that in most cases treatments that delayed maturity increased the starch content. Thus, the more mature apples would generally have more starch instead of less starch. The results presented in this bulletin support the conclusions of Trout, Tindale, and Huelin (*40*) and Tiller (*39*) that the iodine test for starch is not a practical test of maturity of Jonathan apples.

ELAPSED TIME FROM BLOOM TO MATURITY

Phillips (*34*) compiled the dates of bloom and of commercial harvest for Yellow Transparent, Ben Davis, and Winesap apples as grown in various parts of the United States. He concluded that the length of the period between full bloom and ripening (harvest) is rather largely determined by the amount of heat received by the tree. He observed that this period was longest on the Pacific coast, shortest on the Atlantic coast, and intermediate in the Central States. However, he reported that the period was longer in the South, where it was warmer, than in the North. He attributed the more rapid maturing in the colder North to greater insolation. The date of ripening (maturity) used by Phillips was the date of harvest as reported by growers; this would undoubtedly represent widely varying degrees of maturity and the actual maturity at harvest was not determined.

Magness and his associates (*29*) determined the number of days from blooming to optimum picking for several varieties in widely different localities. They observed a marked difference in the length of the growing season for the different varieties and in certain cases for the same variety, depending upon where it is grown. Contrary to the results of Phillips (*34*), they found that for varieties with short growing seasons the length of the period from bloom to maturity varied only slightly with geographic location or climatic conditions. They indicated that the shorter period from bloom to picking observed in the northeastern region was probably due to the shorter growing season, which necessitated the picking of the fruit before it reached

proper maturity in order to avoid frost. These results were based on optimum picking dates estimated from detailed data on the condition of the fruit during the harvest period, but no samples were stored and actually optimum maturity may have varied considerably from the dates given.

Ellenwood (*8*) reported the period from bloom to harvest for a number of varieties grown in Ohio for 10 and 30 seasons. He found considerable variation within varieties from season to season. Because these data also are based on harvest dates, when the fruit may or may not have been at proper maturity, the variations between seasons may have been due in part to picking at different degrees of maturity in the different seasons. Similar results have been presented for New York (*42*). For varieties of apples that have a relatively short growing season the time periods from bloom to maturity in New York (*42*) agree fairly well with those given for Ohio (*8*) and other sections (*28*). However, for varieties that have relatively long growing seasons, the time periods given for New York are much shorter than those reported for other sections. It seems likely that these shorter periods were due to the short growing seasons in New York, which necessitated early picking, at an immature stage, of the varieties with long growing seasons in order to avoid frost. Haller (*11*) in a preliminary report on four varieties of apples grown in Maryland, Virginia, and West Virginia showed a more constant elapsed time from bloom to maturity when storage samples were picked at approximately weekly intervals and the dates of earliest and optimum maturity were determined more definitely on the basis of dessert quality and storage response of fruit from the different pickings.

Additional data for the same and other varieties grown in the same and other widely separated localities and presented in this bulletin generally confirm the results given in the preliminary report. Delicious and its red strains were found to require approximately 150 days from bloom to picking before they attain satisfactory dessert and storage qualities when grown on trees bearing a moderate crop in such widely separated parts of the country as Orondo, Wash.; Hood River, Oreg.; Urbana, Ill.; Wooster, Ohio; East Lansing, Mich.; Geneva, N. Y.; Beltsville, Md.; and Kearneysville, Romney, and Paw Paw, W. Va. This period is considerably longer than periods given by Magness and his associates (*29*); they varied from 134 to 153 days and averaged 140 days for various parts of the country including several of the districts just mentioned. It is also longer than the longest period (134 days) given for New York (*42*) and the average (143 days) for 3 seasons for British Columbia (*33*), but it is in good agreement with the average number of days (153) to the first picking for 30 seasons in Ohio (*8*).

Factors Influencing the Bloom-to-Maturity Period

The variations in the length of the period from bloom to maturity might be influenced by various factors such as growing-season temperatures, soil fertility, soil moisture, and size of crop on the tree. If the factor or factors responsible for variations could be determined and evaluated, it might be possible to make allowances for them and thus to predict more accurately the time of maturity from the date of full bloom as has been done with apricots (*2*) and pears (*6*).

TEMPERATURE

Since many physiological reactions in plants are hastened by increased temperatures, it seems reasonable to suppose that relatively high temperatures (up to the optimum) during the growing season or certain parts of it might hasten the maturity of apples as reported by Phillips (*34*). Harley and Masure (*18*) found that the growth rate of Winesap apples was dependent on the evaporating power of the air, which was due largely to air movement, but they observed that high temperatures might tend to reduce the growth rate by increasing evaporation. Tufts (*41*) observed that in three apricot orchards that bloomed simultaneously the total of the heat units (above 35° F.) was greatest in the earliest ripening orchard and lowest in the latest ripening (2 to 3 weeks later) orchard. Baker and Brooks (*2*) also found that relatively high temperatures shortened the period from bloom to maturity of apricots and to a less extent that of prunes. Similar results for apricots and pears were reported by Brooks (*6*). On the other hand, Ryall, Smith, and Pentzer (*36*) found that pears from different sections varied somewhat in the elapsed time from bloom to maturity, but they observed no consistent effect of temperature on the period from bloom to maturity.

It is probable that temperature differences might have a greater influence during certain periods than others. It has been suggested that seasons of exceptionally early bloom are likely to be followed by periods of relatively cool days, in which the fruit would make little or no development. In this connection studies of Lilleland (*23*) on apricots and of Brooks (*6*) on apricots and pears showed that the earliest stages of fruit development were most affected by temperature. On the other hand, temperatures prevailing late in the season just before or during maturation might be expected to influence greatly the rate of maturing. Thus, it appears that it is difficult to determine just when temperature might influence the period from bloom to maturity.

In addition, a precise measure of effective temperatures is difficult to obtain. Temperature-remainder indexes for plants have been based usually on 35° to 45° F., the temperature range below which vital activities are presumed to cease. However, vital activities of harvested apples such as respiration and softening have been shown to take place appreciably even at 32°. Magness and his associates (*29*) showed that temperature affects the rates of respiration and softening of apples very similarly. They found that the rates at 40° are about double those at 32°; at 50° they are less than double those at 40°; at 70° they are at least double those at 50°; and at 80° they are about 10 times those at 32°.

These data probably give the nearest measure of the physiological response of the fruit to temperature differences that are available. They were plotted as shown in figure 5 and a smooth S-shaped curve of physiological indexes of effective temperatures was obtained. These were used with the daily mean temperatures in the orchards or at the nearest United States Weather Bureau station to determine the effective temperatures, or physiological heat units, during the growing seasons in the different districts or localities. The data used for the curve in figure 5 were obtained from fruit held at constant tempera-

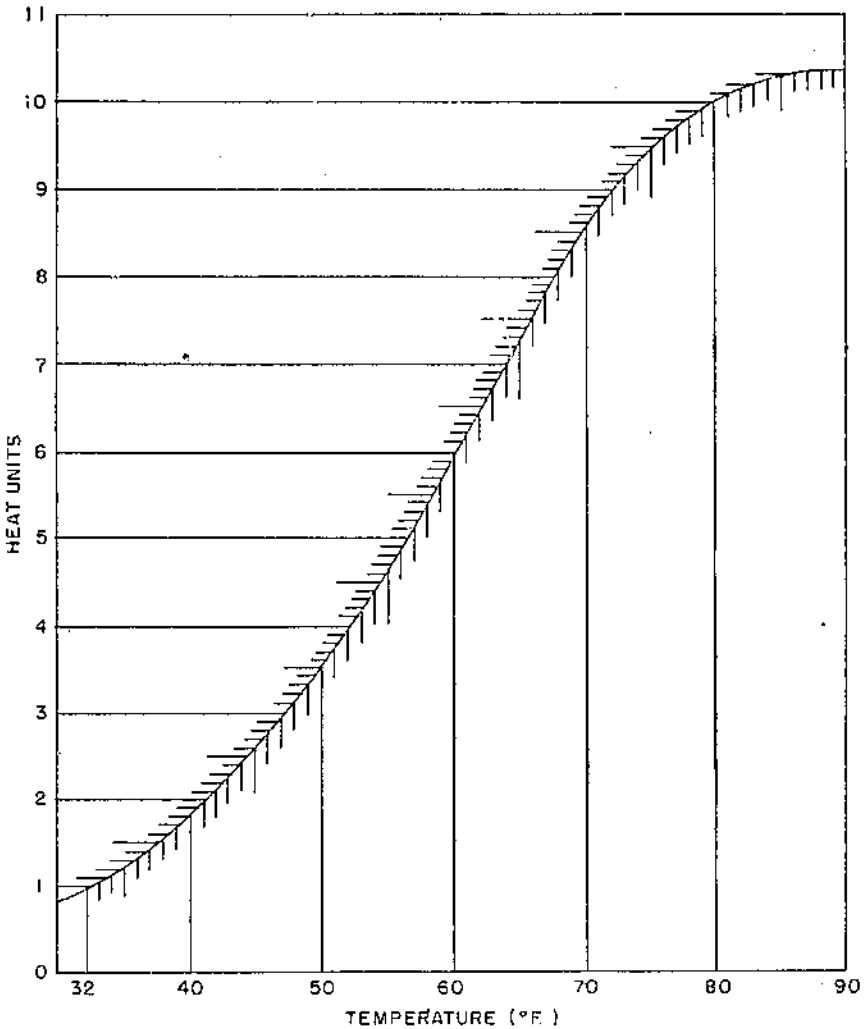

FIGURE 5.—Physiological heat units per day based on respiratory activity of apples at different temperatures.

tures, whereas wide daily fluctuations exist in the mean of outside temperatures. The effect of fluctuating temperatures that average a given temperature may differ considerably from that of a constant temperature of the same magnitude. Furthermore, the mean air temperature would differ greatly from the fruit temperatures and even temperatures of fruit exposed to the sun would differ greatly from those of fruit in the shade. The fact that shaded and exposed fruit mature at approximately the same time is in itself perhaps the best evidence that temperature has little or no appreciable influence on the length of the period from bloom to maturity.

Although it is recognized that there is no very sound basis for evaluating effective temperatures and that heat units computed from daily

mean temperatures are rather crude measures of effective temperatures, the physiological heat units for several varieties grown under different temperature conditions due to locality and seasonal differences have been computed. The heat units were computed from the monthly mean temperature. For example, the mean temperature for June might be 70° F. in a certain orchard, and in figure 5 the number of the heat units for 70° is 8.6. Multiplying 8.6 by the number of days in the month gives 258 as the total heat units for that month. In some instances weighted monthly mean temperatures were determined by making area measurements of the chart by means of a planimeter and in other instances by converting the mean temperature for each day into heat units and summing these. Monthly means of heat units as determined by the three methods did not differ appreciably. For fractions of a month such as at the beginning and the end of the season, the mean daily temperatures were converted to heat units and these added.

The physiological heat units for the first 20 or 30 days after full bloom, for approximately the entire growing season, and for the last 20 or 30 days are given in tables 2 to 6 for Jonathan, Grimes Golden, Delicious, Golden Delicious, and Stayman Winesap varieties. The number of days from bloom to maturity given in the tables is to the

TABLE 2.—*Date of full bloom, period from bloom to earliest maturity, physiological heat units,[1] and ground color and firmness (pressure test) at maturity of Jonathan apples grown at various localities and in different seasons*

Season and source	Date of full bloom	Period from bloom to maturity	Physiological heat units at different periods from bloom			Ground color [2]	Pressure-test reading
			0–20 days	0–130 days	110–130 days		
1938		*Days*	*Number*	*Number*	*Number*		*Pounds*
Kearneysville, W. Va.	Apr. 21	140	142	1,135	194	2.5	14.2
1939							
Kearneysville, W. Va.	Apr. 25	120	124	1,122	194	1.7	18.1
Berlin, Md.	do.	134	107	1,003	178	1.7	17.3
1940							
Kearneysville, W. Va.	May 11	132	148	1,030	154	2.4	15.8
Berlin, Md.	do.	130	154	1,122	141	1.7	16.4
1941							
Wenatchee, Wash.	Apr. 20	135	105	967	165	2.6	15.0
Beltsville, Md.	Apr. 25	130	120	1,131	172	1.7	17.4
Wooster, Ohio	May 1	141	100	1,073	171	2.2	15.0
Urbana, Ill.	May 2	135	138	1,103	158	2.4	16.0
East Lansing, Mich.	May 8	145	110	1,020	159	2.3	16.3
1942							
Wenatchee, Wash.	Apr. 23	142	75	894	103	2.6	15.7
Beltsville, Md.	Apr. 25	131	134	1,164	180	2.8	17.7
Wooster, Ohio	Apr. 20	145				2.2	13.5
East Lansing, Mich.	May 3	135	86	972	155	1.5	21.3
1943							
Wenatchee, Wash.	Apr. 27	139	75	743	141	2.3	15.8
Kearneysville, W. Va.	Apr. 30	132	145	1,180	192		
Romney, W. Va.	May 9	130					
1944							
Kearneysville, W. Va.	May 3	127	150	1,183	184		
Romney, W. Va.	do.	128	152	1,008	152		
Paw Paw, W. Va.	May 4	128	153	1,120	155		
Average		134					

[1] A measure of growing-season temperatures as explained on p. 13.
[2] Ground color determined by comparison with standard color chart in which 1 is green and 4 yellow.

TABLE 3.—*Date of full bloom, period from bloom to earliest maturity, physiological heat units,[1] and ground color and firmness (pressure test) at maturity of Grimes Golden apples grown at various localities and in different seasons*

Season and source	Date of full bloom	Period from bloom to maturity	Physiological heat units at different periods from bloom			Ground color[2]	Pressure-test reading	Crop size[3]
			0–20 days	0–140 days	120–140 days			
1938		*Days*	*Number*	*Number*	*Number*		*Pounds*	
Crozet, Va.	Apr. 13	139	125	1,072	178	1.5	18.8	
Salisbury, Md.	Apr. 15	139	131	1,037	191	1.0	20.0	
Kearneysville, W. Va.	Apr. 20	138	133	1,170	177	1.1	22.4	
1939								
Crozet, Va.	Apr. 17	140	104	1,148	177	1.1	18.9	
Berlin, Md.	Apr. 22	[4] 145	111	1,134	172			
Kearneysville, W. Va.	Apr. 25	[4] 145	124	1,216	187			
1940								
Crozet, Va.	May 1	[5] 135	132	1,109	153			
Berlin, Md.	May 9	135	136	1,154	137	1.2	19.3	
Kearneysville, W. Va.	May 10	136	148	1,187	152	1.2	21.1	
1941								
Beltsville, Md.	Apr. 22	145	119	1,216	179	1.3	19.9	
Kearneysville, W. Va.	do	148	120	1,191	189	1.4	22.8	
Urbana, Ill.	May 1	153	135	1,244	183	2.3	17.5	
East Lansing, Mich.	May 7	150	143	1,165	189	1.5	22.6	
1942								
Beltsville, Md.	Apr. 23	147	138	1,261	178	1.8	17.0	
1943								
Kearneysville, W. Va.	Apr. 27	145	131	1,251	179			Light.
Do	do	154	131	1,251	179			Heavy.
Romney, W. Va.	May 1	142						
Paw Paw, W. Va.	May 3	156	148	1,237	153			Do.
Romney, W. Va.	May 9	140						
1944								
Romney, W. Va.	Apr. 29	137	145	1,141	149			
Kearneysville, W. Va.	May 2	134	158	1,294	166			Light.
Do	do	155	158	1,294	166			Heavy.
Romney, W. Va.	do	137	148	1,164	150			Light.
Do	do	157	148	1,164	150			Heavy.
Paw Paw, W. Va.	May 3	157	153	1,203	154			Do.
Average		144						

[1] A measure of growing-season temperatures as explained on p. 13.
[2] Ground color determined by comparison with standard color chart in which 1 is green and 4 yellow.
[3] Crop size usually moderately light to moderately heavy except as noted.
[4] Severe scald developed on apples of last picking at 137 and 139 days from bloom, respectively. Extrapolation of scald curves (fig. 8) indicated sufficient reduction in scald for satisfactory maturity at about 145 days.
[5] Last picking was made at 131 days from bloom but apples picked at that time developed considerable scald. If the apples could have been picked somewhat later (135 days from bloom), they would have been of more satisfactory maturity for storage.

first picking date at which the fruit was considered mature. Pickings were made at approximately weekly intervals, and the period might have differed from that given by several days if pickings had been made somewhat earlier or later. In computing the heat units for the entire season from bloom to earliest maturity about the average number of days to earliest maturity for the variety was used for all lots of a variety regardless of the period given for each lot.

In general the results in tables 2 to 6 do not indicate that a relatively long period from bloom to maturity was associated with low growing-season temperatures during the first 20 or 30 days, the last 20 or 30 days, or the entire growing season. The only exception was the Jonathan variety (table 2); lots of this variety with the longest periods from bloom to maturity (135 to 145 days) generally were grown under con-

TABLE 4.—*Date of full bloom, period from bloom to earliest maturity, and physiological heat units,[1] of Delicious (and its bud sports) apples grown at various localities and in different seasons*

Season and variety	Source	Date of full bloom	Period from bloom to maturity	Physiological heat units at different periods from bloom		
				0–30 days	0–150 days	120–150 days
1941			*Days*	*Number*	*Number*	*Number*
Delicious	Hood River, Oreg	Apr. 14	152	137	992	208
Starking	do	do	152			
Delicious	Orondo, Wash	Apr. 16	153	154	1,070	197
Starking	do	do	149			
Delicious	Beltsville, Md	Apr. 23	148			
Starking	do	do	150	201	1,285	256
Richared	do	do	148			
Delicious	Urbana, Ill	May 1	152	226	1,321	259
Starking	Wooster, Ohio	May 2	146	185	1,279	245
Delicious	East Lansing, Mich	May 8	155	191	1,161	206
Starking	do	May 7	147	188	1,157	206
Delicious	Geneva, N. Y	May 9	150	198	1,218	220
Starking	do	do	150			
1942						
Delicious	Hood River, Oreg	Apr. 10	160	115	972	212
Starking	do	do	160			
Delicious	Orondo, Wash	Apr. 22	156	131	1,025	203
Starking	do	Apr. 21	157	126	1,024	207
Delicious	Beltsville, Md	Apr. 24	150	212	1,337	260
Richared	do	do	147			
Delicious	Wooster, Ohio	Apr. 27	150	101	1,136	223
1943						
Delicious	Orondo, Wash	do	148	143	963	199
Starking	do	Apr. 26	140	139	961	201
Richared	do	Apr. 27	146	143	963	199
Do	Paw Paw, W. Va	May 2	145	225	1,305	218
Delicious	Romney, W. Va	May 9	144			
1944						
Delicious	Kearneysville, W. Va	May 3	147			
Richared	Paw Paw, W. Va	do	143	240	1,264	216
Starking	Romney, W. Va.[2]	May 4	134	217	1,192	198
Do	do.[3]	do	155			
Average			150			

[1] A measure of growing-season temperatures as explained on p. 13.
[2] Light crop.
[3] Heavy crop.

ditions of low numbers of heat units during the first 20 days after bloom, but with no appreciable difference in the amount of heat during the last 20 days. This would indicate that temperatures during the early part of the growing season had more influence on the date of maturation than temperatures during the latter part of the growing season. However, data for the other varieties were not consistent with this. In the case of Grimes Golden apples the three lots requiring the longest period from bloom to maturity were apples grown on trees with very heavy crops. In two of these instances apples were grown also on trees under identical temperature conditions but with lighter crops; in these cases much shorter periods from bloom to maturity were recorded. This indicates that with Grimes Golden the size of the crop may be a more important factor than growing-season temperatures on the period from bloom to maturity. Similar results have been obtained with other varieties (table 7).

The data in tables 2 and 4 to 6 indicate that the amount of heat is lower immediately after bloom and for the entire growing season in

TABLE 5.—*Date of full bloom, period from bloom to earliest maturity, and physiological heat units,[1] of Golden Delicious apples grown at various localities and in different seasons*

Season and source	Date of full bloom	Period from bloom to maturity	Physiological heat units at different periods from bloom			Crop size[2]
			0–30 days	0–150 days	120–150 days	
		Days	*Number*	*Number*	*Number*	
1941						
Hood River, Oreg.	Apr. 10	141	145	999	200	
Cashmere, Wash.	Apr. 22	145	180	1,068	169	
Orondo, Wash.	Apr. 16	145	150	1,066	200	
Beltsville, Md.	Apr. 24	152	204	1,288	354	
Wooster, Ohio	May 2	168	185	1,259	245	
East Lansing, Mich.	May 10	140	204	1,106	190	
1942						
Hood River, Oreg.	Apr. 29	161	117	998	267	
Orondo, Wash.	Apr. 22	149	131	1,025	303	
Beltsville, Md.	Apr. 24	150	212	1,337	290	
Cashmere, Wash.	Apr. 29	142	145	1,051	291	
1943						
Orondo, Wash.	Apr. 27	148	143	964	190	
Kearneysville, W. Va.	May 2	149	229	1,318	223	
Romney, W. Va.	May 11	142	----------	----------	----------	Light.
Do.	do	148	----------	----------	----------	Heavy.
1944						
Kearneysville, W. Va.	May 4	140	251	1,339	239	
Romney, W. Va.	do	144	217	1,192	108	Light.
Do.	do	109	217	1,102	109	Heavy.
Average	----------	140	----------	----------	----------	

[1] A measure of growing-season temperatures as explained on p. 13.
[2] Crop size usually moderately light to moderately heavy except as noted.

the Pacific Northwest than in the other parts of the country. For example, in the case of Delicious and its bud sports the heat units for 30 days after bloom varied from 115 to 154 for Washington and Oregon and from 161 to 240 for the other States and for 150 days after bloom they ranged from 961 to 1,070 for Washington and Oregon and from 1,136 to 1,337 for the other States. Except for Golden Delicious, the cooler conditions particularly during the first part of the growing season in the Northwest were associated generally with longer periods from bloom to maturity. However, other factors in addition to temperature are different in the Northwest; there are more hours of sunshine each day and, because the fruit is grown under irrigation, the soil moisture is maintained at a more nearly optimum condition throughout the growing season.

In 1945 the date of full bloom was unusually early in Maryland, Virginia, and West Virginia—about April 1 to 5. This early bloom was followed by cool weather with frost as late as May 2 or 3. Rainfall was generally above normal, particularly during July and August, and cool weather generally prevailed late in the season. Maturity studies in which the date of actual maturity was determined by means of storage lots of different pickings were not conducted during this very abnormal season, but general observation indicated that maturity was not advanced proportionately with the date of bloom. For example, Grimes Golden picked as late as 165 days from bloom (instead of the normal about 145 days) was still adhering well and the ground color was still green; Golden Delicious and Delicious picked 170 days from bloom (instead of 150 days) were still sour and starchy and had a green

TABLE 6.—*Date of full bloom, period from bloom to earliest maturity, physiological heat units,[1] and ground color and firmness (pressure test) at maturity of Stayman Winesap apples grown at various localities and in different seasons*

Season and source	Date of full bloom	Period from bloom to maturity	Physiological heat units at different periods from bloom			Ground color [2]	Pressure-test reading
			0–30 days	0–160 days	130–160 days		
1941		*Days*	*Number*	*Number*	*Number*		*Pounds*
Wenatchee, Wash	Apr. 16	160	153	1,111	153	2.5	17.6
Wooster, Ohio	May 1	[3] 167	152	1,286	221	1.8	14.8
Urbana, Ill	do	168	226	1,395	230	2.0	15.5
East Lansing, Mich	May 7	[4] 161	186	1,208	186	1.4	19.5
1942							
Wenatchee, Wash	Apr. 21	172	126	1,000	200	1.9	16.8
Beltsville, Md	Apr. 24	160	212	1,384	227	3.9	16.8
Wooster, Ohio	Apr. 30	[5] 160	166	1,135	217	1.3	17.4
1943							
Wenatchee, Wash	Apr. 27	163	143	1,027	190	2.5	17.2
Mount Jackson, Va	Apr. 29	157	216	1,302	174	----------	----------
Kearneysville, W. Va	Apr. 30	160	218	1,309	194	----------	----------
Paw Paw, W. Va	May 3	156	223	1,357	183	----------	----------
Romney, W. Va	May 9	155	----------	----------	----------	----------	----------
1944							
Mount Jackson, Va	Apr. 27	160	237	1,402	226	----------	----------
Kearneysville, W. Va	May 3	160	250	1,397	196	----------	----------
Paw Paw, W. Va	do	162	240	1,322	191	----------	----------
Romney, W. Va	May 4	160	217	1,241	167	----------	----------
Average		161	----------	----------	----------	----------	----------

[1] A measure of growing-season temperatures as explained on p. 13.
[2] Ground color determined by comparison with standard color chart in which 1 is green and 4 yellow.
[3] This picking rated good in dessert quality. Earlier picking did not develop scald so that these apples might have been of satisfactory maturity at a somewhat earlier date.
[4] This picking rated good in dessert quality and no scald developed so that had an earlier picking been made, it might also have been satisfactory.
[5] This picking rated very good in dessert quality so that it is likely an earlier picking would have been satisfactory.

ground color, and the response of these varieties to ripening and storage did not indicate that they were picked at a late stage of maturity.

Although the experimental results do not indicate a distinct relation between temperatures during different parts of the growing season and the rate of maturation, the observation in 1945 and the results with Jonathan and for the Pacific Northwest compared with those for other districts indicate that extremely cold weather, particularly during the first part of the growing season, may delay maturity; it is likely that less extreme cold may delay maturity, but the delay may be masked by other factors.

SIZE OF CROP

As indicated in the previous section, the size of the crop influences the time of maturity. The evidence along this line is shown in table 7.

When the ratio of leaves to fruit is low, carbohydrates elaborated are insufficient, the fruit is smaller, and the accumulation of elaborated material is less. The lower concentration of elaborated material delays the time when the fruit can be picked and ripened with satisfactory aroma and dessert quality. The apples from light-crop trees were of potentially satisfactory dessert quality 5 to 10 days or even more earlier than apples from heavy-crop trees. They also averaged larger

TABLE 7.—*Effect of size of crop on number of days from bloom to maturity*

Variety	Source	Season	Period from bloom to maturity in case of—	
			Heavy crop	Light crop
			Days	*Days*
Grimes Golden	Kearneysville, W. Va.	1943	154	145
Do	do	1944	155	134
Do	Romney, W. Va.	1944	157	137
Golden Delicious	do	1943	148	142
Do	do	1944	160	144
Starking	do	1944	155	134
Winesap	Mount Jackson, Va.	1943	169	162
York Imperial	do	1943	167	153
Do	Paw Paw, W. Va.	1943	169	150
Do	do	1944	170	153
Average			161	145

and, particularly in Golden Delicious, became yellow sooner. This is in agreement with the results of Haller and Magness (*16*) and Martin and Carne (*31*) with apples and of Palmer (*32*) with plums and peaches.

RAINFALL AND SOIL MOISTURE

Under conditions of deficient soil moisture the efficiency or functioning of the leaves is interfered with (*26*); and, when a drought is severe or of long duration, the effect is somewhat similar to that of a heavy crop in that fruit development and maturity are retarded (*14*). With ample soil moisture throughout the growing season, the fruit tends to be large but has a low concentration of solids and is subject both to break-down, which is associated with overmaturity, and to scald, which is associated with immaturity. In the experiments reported in this bulletin soil moisture was not controlled. However, there were differences in the amount of rainfall during the growing season in the different years and at the different localities (table 8). In West Virginia the 1943 and 1944 growing seasons were characterized by deficient rainfall, with totals from May through September of only 10.5 and 12.2 inches at Kearneysville. Although records were not available for all localities, rainfall probably did not differ greatly in the three orchards in West Virginia. The effect of rainfall would depend not only on the amount but also on the distribution throughout the season and the retention by the soil. In 1943 the drought was particularly severe late in the season, whereas in 1944 it was most severe early in the season. The three localities in West Virginia from which apples were obtained differed greatly in soil type. At Paw Paw the soil was a shallow shale loam in which the trees soon suffer from deficient rainfall. At Romney the soil is a deep porous chert loam that is very retentive of moisture and in which the trees suffered least from lack of rain. At Kearneysville the soil is a moderately deep Hagerstown loam intermediate in moisture retention.

Variation in soil type or availability of soil moisture due to soil type did not seem to influence consistently the time from bloom to maturity. For example, Jonathan varied only from 127 to 132 in the

TABLE 8.—*Rainfall during growing season at U. S. Weather Bureau Station nearest to sources of apples* [1]

Locality	Season	Rainfall during—					
		May	June	July	August	September	Total
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Charlottesville, Va. (near Crozet, Va.)	1938	2.95	4.79	10.52	2.84	3.73	24.83
	1939	1.31	4.11	6.16	4.15	.91	16.64
	1940	4.08	3.94	6.73	6.63	1.50	22.94
Salisbury, Md. (near Berlin, Md.)	1938	3.15	5.30	9.75	2.45	8.78	29.43
	1939	.80	2.85	7.65	4.72	4.05	20.07
Martinsburg, W. Va.	1938	4.07	2.56	5.48	3.03	3.97	19.60
	1939	.96	8.46	3.51	1.65	3.52	18.10
	1940	4.89	1.28	4.90	4.22	3.71	19.00
Kearneysville, W. Va.	1941	2.23	4.80	2.07	3.38	1.40	13.97
	1943	4.08	1.00	3.25	.98	.56	10.47
	1944	1.31	1.91	3.64	1.68	5.18	12.22
Urbana, Ill.	1941	3.91	6.19	3.27	3.61	4.91	21.92
College Park, Md. (near Beltsville, Md.)	1941	1.48	6.39	6.82	2.75	.24	17.68
	1942	4.07	5.45	5.10	9.15	2.63	26.40
Romney, W. Va.	1943	2.85	1.96	-------	2.18	1.36	8.35+
Great Cacapon, W. Va. (near Paw Paw, W. Va.)	1944	2.68	2.12	2.15	1.70	2.68	11.33
East Lansing, Mich.	1941	3.28	3.70	.80	2.86	2.96	13.60
	1942	5.25	4.48	4.33	2.36	2.16	18.58
Wooster, Ohio	1941	3.00	3.95	5.70	3.72	2.90	19.43
	1942	3.94	3.20	2.05	1.38	3.11	14.69
Geneva, N. Y.	1941	.90	3.87	4.08	2.06	1.74	13.25
Luray, Va.[2] (near Mount Jackson, Va.)	1943	4.71	2.70	2.70	1.45	.57	12.13
	1944	3.20	2.46	1.81	2.90	4.91	15.28

[1] Orchards around Wenatchee, Wash., and Hood River, Oreg., are almost entirely dependent on irrigation for moisture during the growing season. Under these conditions soil moisture is usually ample.
[2] The orchard near Mount Jackson, Va., from which the apples were obtained supplemented the rainfall with irrigation during dry periods.

number of days from bloom to maturity in the two seasons and three localities and Winesap and Stayman Winesap from 155 to 162 days with no consistent relation to locality. However, apples from these three sources differed in other respects. Scald was more prevalent in susceptible varieties from Kearneysville than in those from the other sources. The principal differences, however, were in the apples from near Romney, which usually had a distinctly smoother finish, seemed to grow larger when the crops were of similar size, and seemed to be less highly flavored. Whether these differences are due to available soil moisture or to other causes is not apparent.

Any effect of soil moisture on time of maturity should show up under extreme conditions of rainfall. Among the seasons of very heavy rainfall was 1942, Beltsville (College Park), Md. (26.5 inches), and among those of very light was 1943, Kearneysville, W. Va. (10.5 inches). The average number of days from bloom to maturity for seven varieties at Beltsville in 1942 (wet season) was 154 days compared with 151 days for the same varieties at Kearneysville in 1943 (dry season). These results indicate that heavy rainfall slightly delayed maturation particularly of varieties susceptible to scald, which was severe in later picking of some varieties in the wet season (see fig. 8). Apples grown at Urbana, Ill., in 1941 were also subject to scald later than usual (see figs. 8 and 12), and the rainfall was fairly heavy in that season and locality. In general, however, the results do not indicate any very marked or consistent effect of soil moisture or rainfall on the time of maturation.

OTHER FACTORS

Other factors such as soil fertility, soil type, and elevation might influence the length of time from bloom to maturity. Apples for these investigations were obtained from moderately vigorous trees grown with the standard fertilizer practice for the particular orchard from which they were obtained. The soil types in the various orchards varied greatly in natural fertility and texture. The orchards also differed in elevation. These factors, however, are confounded so that if differences in time of maturity occurred, it would be impossible to determine which factor was responsible. In general, the period from bloom to maturity was fairly constant regardless of rather wide differences in soil and climatic factors.

Maturity Indexes for Different Varieties

As pointed out earlier, the first picking that was considered to be of satisfactory maturity was determined on the basis of the dessert quality and the storage response of different pickings. Because of the large number of lots of some varieties and the number of observations made on each lot, it is not feasible to present the detailed data by which picking maturity was established. A discussion of some of the factors considered is presented for each variety.

DELICIOUS, STARKING, AND RICHARED

Delicious or its red bud sports were used as available and are grouped together herein since these results, as well as those of Ellenwood (*9*), indicate that the bud sports do not differ from the regular variety in time of maturing.

The sources of the various lots of Delicious and its bud sports, with the dates of full bloom and the elapsed time to earliest maturity, are shown in table 4. The dates of bloom varied from April 14 to May 9, a range of 25 days. The dates of maturity varied from September 12 to October 10, a range of 28 days. In about 59 percent of the cases these apples were considered mature when picked between 147 and 152 days from bloom (a range of 5 days). Out of the 29 lots there were only 3 that varied greatly from this range. These were the Starking grown near Romney, W. Va., in 1944, in which the fruit came from light-crop trees and matured very early, and the Delicious and Starking grown at Hood River, Oreg., in 1942, in which the fruit matured very late.

Lots of Delicious, Starking, or Richared were held in cold storage usually until the last half of February or first half of March when they were removed for ripening and inspection. Practically no internal break-down was found in any of the lots after this period of storage. In most lots there was no decay or only insignificant amounts. In the few lots in which decay occurred there was no indication that it was associated with the time of picking except in Delicious grown at Geneva, N. Y., in 1941, the third picking of which had appreciably more decay than earlier pickings. Break down and decay therefore were not considered in establishing picking maturity.

Storage scald was very variable in its occurrence. Delicious and Starking in many instances did not develop any scald during storage

even though picked about 140 days from bloom or earlier. The most severe scald occurred on Delicious and Starking grown near Wenatchee, Wash., in 1942. About 90 percent of these apples scalded during storage when picked 142 and 143 days from bloom. When less than 20 percent of the fruit shows scald, the scald is usually mild and not of serious commercial consequence. Scald development on Delicious and Starking grown in Washington in 1942 decreased with delay in picking, but scald did not become less than 20 percent unless the fruit was picked more than 156 days from bloom. Although these lots were of satisfactory dessert quality when picked 150 days from bloom, they were not considered mature until 156 or 157 days from bloom, because of their susceptibility to scald when picked earlier. The only other lots in which scald exceeded 20 percent when picked more than 150 days from bloom were Delicious and Starking at Hood River, Oreg., and Delicious at Orondo, Wash., in 1941. Picking of these lots had to be 153 days or more from bloom before less than 20 percent of the fruit scalded in storage. However, these were rated as mature by the local cooperators when picked 149 days from bloom—a rating that seems questionable in view of the susceptibility to scald.

In most other lots storage scald was much less severe and their time of maturity was established largely on the basis of dessert quality. The dessert quality of the different pickings of Delicious, Starking, and Richared from different sources and in different seasons is shown in figure 6. There was generally a distinct rise in dessert quality as picking was delayed, but there was a decline in some of the late pickings. When the fruit ripened to fair dessert quality (designated as 0 on the chart), it was considered satisfactory for picking. Most lots picked 140 days from bloom failed to develop fair or satisfactory dessert quality. At 145 days from bloom about half of the lots picked were unsatisfactory. Delicious and its bud sports picked 150 days from bloom were nearly always of fair or better dessert quality. In 19 lots picked at this time the quality of the fruit was fair or better, whereas in only 4 was it unsatisfactory. Thus, both dessert quality and resistance to storage scald of most lots of Delicious apples would have been satisfactory at the localities and in the season tested if picking had started about 150 days from bloom.

The lots in which satisfactory maturity was not attained up to 150 days from bloom were Delicious and Starking grown in Washington in 1942 in which scald was rather severe until after 155 days from bloom, and Delicious and Starking grown in Oregon in 1942 in which satisfactory dessert quality was not attained until after 160 days from bloom. There was no indication that Starking apples differed from regular Delicious in their resistance to scald or in dessert quality when picked the same number of days from bloom.

Although Delicious apples were of satisfactory maturity 145 days from bloom in some cases (about 50 percent), it was not until about 150 days from bloom that one could be reasonably sure that Delicious would be mature in most instances. Optimum maturity from the standpoint of dessert quality frequently occurred at about 155 days from bloom. There was some tendency for dessert quality to decrease in pickings made as late as 160 days from bloom. An increased tendency of the fruit to drop was sometimes apparent between 155 and 160 days from bloom. The results agree well with those of Ellenwood (*8*),

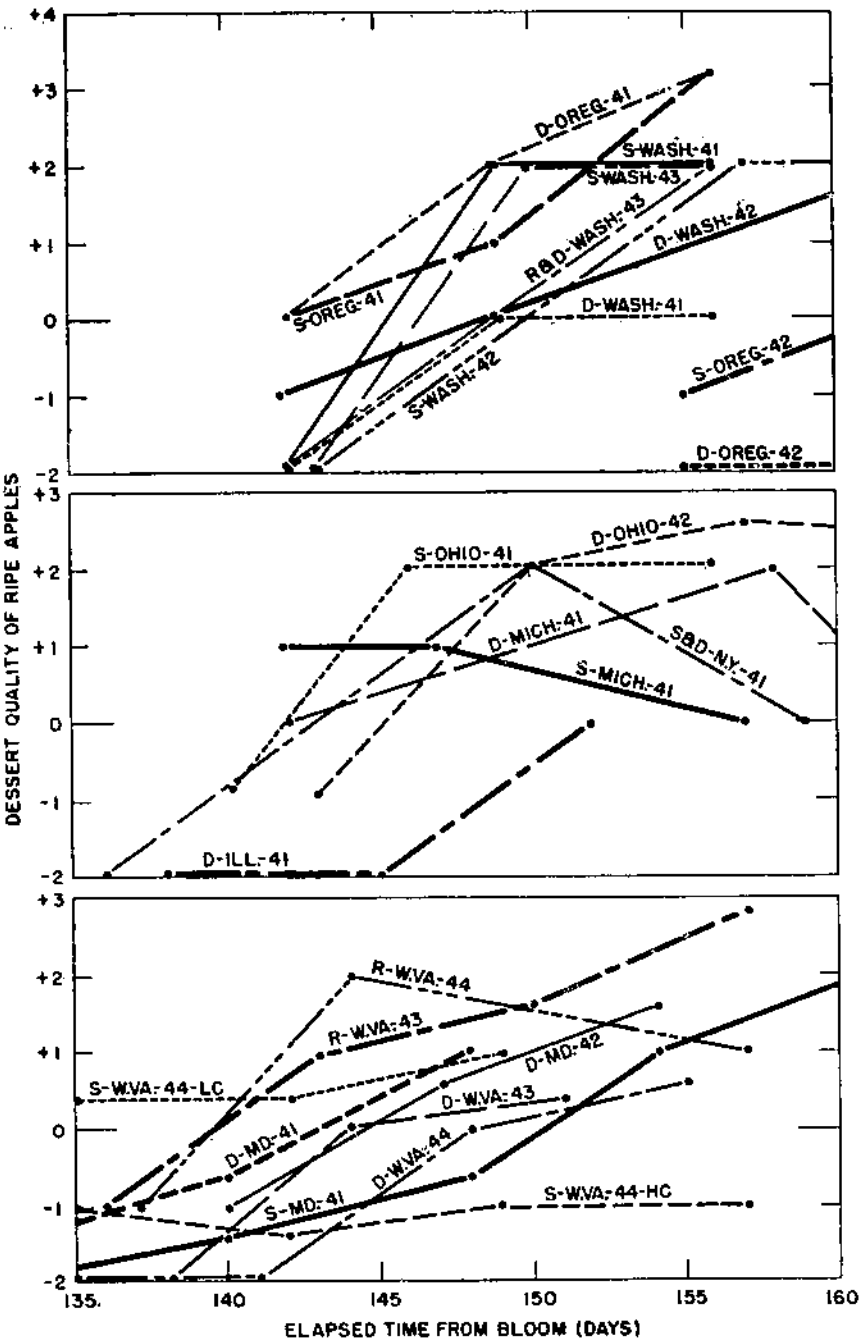

FIGURE 6.—Dessert quality of Delicious (D), Starking (S), and Richared (R) apples from various sources in relation to days from bloom to picking. Number after State name or abbreviation, season; LC, light crop; HC, heavy crop; 0, dessert quality fair or passable; + and — numbers, quality ratings above and below passable.

who found the average time (for 30 seasons) from bloom to first picking of Delicious to be 153 days. Under the short growing season in New York, Tukey (*42*) reported a much shorter period, averaging only 132 days during 4 seasons. Magness and his associates (*29*) also gave a shorter period from bloom to what they thought represented optimum maturity (140 days) in Delicious grown in 9 different localities or seasons.

As shown in figure 1 and discussed earlier, the ground color of Delicious at maturity varied from about 2 to 3 of the color chart. This did not constitute a satisfactory index of maturity. At earliest maturity the pressure-test readings ranged from 15.5 to 18.3 pounds, and, as pointed out previously, the pressure test did not give a satisfactory index of maturity. Magness, Diehl, and Haller (*28*) suggested that Delicious apples should be picked before the pressure-test reading becomes less than 16 pounds; otherwise the fruit is likely to be too soft for satisfactory storage. In general, the present results are in agreement with this in that most lots were of satisfactory maturity before the reading became less than 16 pounds.

GOLDEN DELICIOUS

Because Golden Delicious apples are very resistant to storage scald, the scald that developed in a few instances on early pickings was slight and of no commercial consequence. Under most conditions of these tests little or no decay developed during storage. When appreciable amounts of decay were found, there was no apparent effect of picking maturity on the percentages. No internal break-down developed in any of the lots. Susceptibility to these storage disorders, therefore, was of no value in establishing the time of maturity. Golden Delicious is very subject to shriveling during storage. It has been the general opinion that immature apples shrivel more rapidly during storage than well-matured ones (*28*). On the other hand, Magness and Diehl (*27*), Hinton (*21*), and Pieniazek (*35*) found that transpiration and wilting during storage were not significantly affected by time of picking or that they might increase as maturity of the fruit increased. In the investigations reported herein, however, there was no evidence that wilting of Golden Delicious apples was influenced by picking maturity; therefore, shriveling was also of no value in establishing the time of maturity.

The sources of the various lots of Golden Delicious apples, the dates of full bloom, and the elapsed time to earliest maturity are shown in table 5. The date of bloom ranged from April 16 to May 16, and the date of earliest maturity extended over an even longer period (September 4 to October 20). The number of days from bloom to maturity also varied considerably (140 to 169 days). The average number of days from bloom to maturity was 149 days, and in most cases it was between 142 and 150 days.

Dessert quality was of primary importance in establishing maturity in the Golden Delicious variety. It was somewhat variable among the different lots, but in general it showed a gradual increase with delay in picking (fig. 7). Golden Delicious apples picked about 140 days from bloom were of unsatisfactory dessert quality in 6 cases and fair in 2 in which the fruit was from light-crop trees. At 145 days

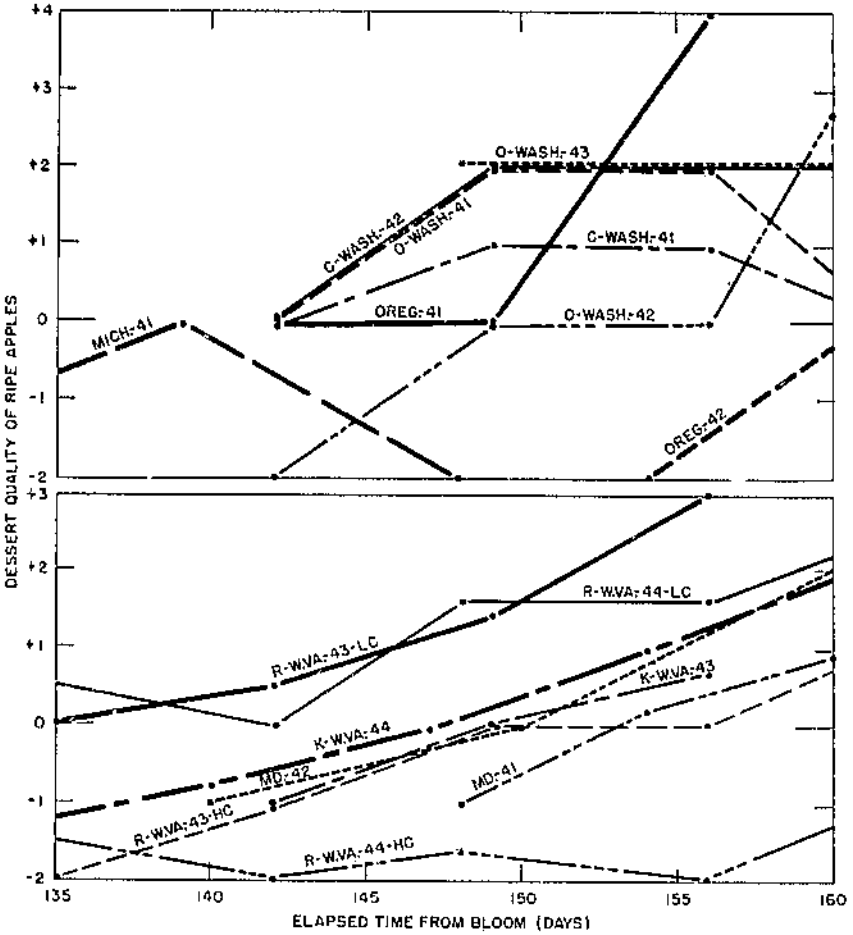

FIGURE 7.—Dessert quality of Golden Delicious apples from various sources in relation to days from bloom to picking. C, Cashmere; O, Orondo; K, Kearneysville; R, Romney; number after State abbreviation, season; LC, light crop; HC, heavy crop; 0, dessert quality fair or passable; + and — numbers, quality ratings above and below passable.

from bloom the quality was fair or better in about half of the lots. By 150 days from bloom most pickings (12) were of fair or better quality and only 2 were unsatisfactory. However, in one other instance (Oregon, 1942) the first picking was not made until 154 days from bloom, at which time the quality was poor (—2) and did not become satisfactory until 161 days. In another instance (Michigan, 1941) the last picking was made 148 days from bloom, at which time the quality was poor, apparently because of overmaturity.

The influence of leaf area per apple, or of crop size, is shown by the lots obtained from near Romney, W. Va., in 1943 and 1944 when fruit was picked from adjacent trees bearing heavy and light crops. In 1943 the fruit from the light-crop trees developed fair dessert quality and was of nearly satisfactory maturity in the first picking made 135

days from bloom, whereas the fruit from the heavy-crop tree did not develop fair dessert quality until 2 weeks later, 149 days from bloom. In 1944 the effect of crop size was even greater as the light-crop fruit developed fair quality when picked 134 days from bloom, whereas the heavy-crop fruit failed to ripen with fair dessert quality until picked about 170 days from bloom.

These results indicate that Golden Delicious apples from trees bearing moderate crops will generally be of satisfactory maturity from the standpoint of dessert quality if picked 150 days after full bloom and of optimum maturity if picked 155 to 160 days from bloom. Picking might start a week to 10 days earlier on light-crop trees, but it should be delayed a week to 10 days on trees bearing heavy crops. Apples picked during these periods will usually have developed desirable yellow color as well as desirable dessert quality. Ellenwood (*8*) reported a considerably longer period from bloom to first picking, averaging 163 days for 10 seasons, whereas Tukey (*42*) gave an appreciably shorter average, 138 days for 3 seasons.

The ground color of the different pickings of Golden Delicious are shown in figure 2. At earliest maturity the average ground color varied from 2.2 to 3.5 of the color chart and, as discussed earlier, did not constitute a satisfactory index of maturity.

The average pressure-test readings of the various lots of Golden Delicious at earliest maturity varied from 14.0 to 17.0 pounds. As with other varieties, this range was too great in relation to the rate of softening to be of value as an index of maturity.

GRIMES GOLDEN

The sources of the Grimes Golden lots, with the dates of full bloom and the elapsed time to earliest maturity, are shown in table 3. The dates of full bloom occurred between April 13 and May 10, a period of nearly a month, while earliest maturity varied more than a month, from August 30 to October 7. The elapsed time from bloom to maturity averaged 144 days, with most lots falling between 135 and 145 days. Excessively long periods from bloom to maturity were due usually to heavy-crop conditions.

The storage season for Grimes Golden is usually relatively short and most of the apples are marketed by Thanksgiving or Christmas. The experimental lots, therefore, were usually removed from storage in the latter part of November, December, or the first part of January. When removed from storage at this time and ripened at room temperature (70° F.) there usually was no decay or break-down or the amounts were insignificant. Scald, however, usually was very severe in the early pickings and diminished with increased picking maturity as shown in figure 8. In addition to lots for which data are presented in figure 8, Grimes Golden were obtained from 3 different sources in West Virginia in 1944. No appreciable scald developed in any of these lots, and the data are not plotted. As shown in figure 8, there was less than 20 percent scalded in all instances except 1 when the Grimes Golden apples were picked as late as 150 days from bloom. In pickings made 145 days from bloom there was less than 20 percent scalded in a large proportion of the cases, 17 cases with less than 20 percent scalded as against 4 with more than 20 percent scalded. From

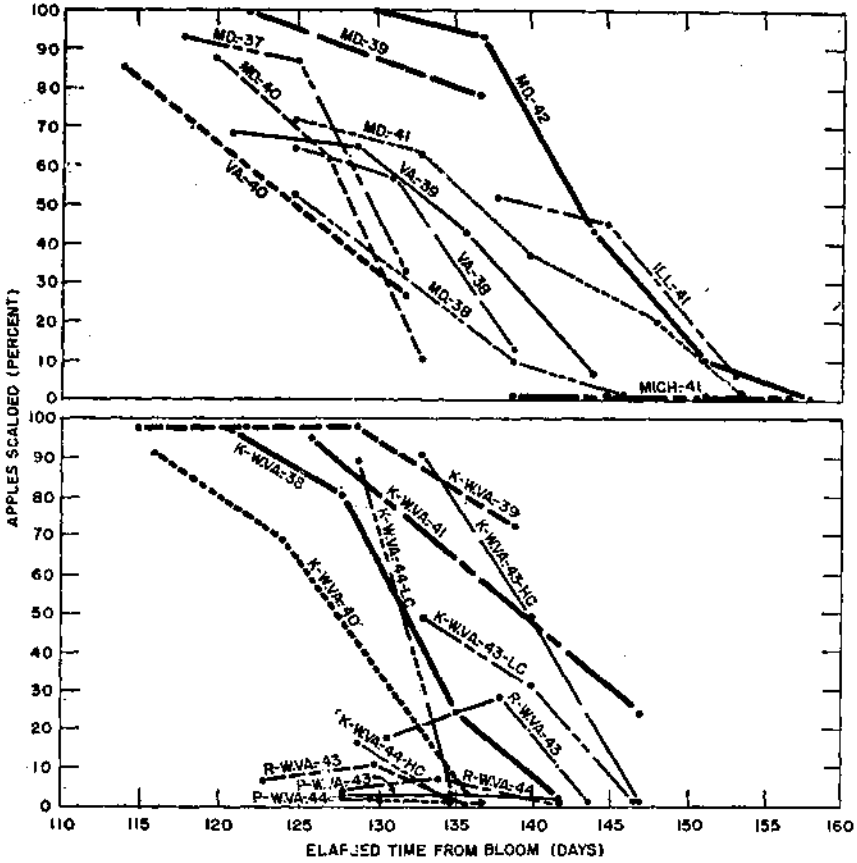

FIGURE 8.—Scald development during storage on Grimes Golden apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season; LC, light crop; HC, heavy crop.

the standpoint of susceptibility to scald, therefore, Grimes Golden apples were usually mature by 145 days from bloom. Pickings made 140 days from bloom were reasonably free of scald in only about 50 percent of the cases. In 2 instances (Maryland, 1939, and West Virginia, 1939), when the last pickings were made 137 and 139 days from bloom, a high percentage of the apples were still subject to scald (fig. 8). From the shape of the curves it seems likely that these apples would have had satisfactory resistance to scald if they had been picked about 145 days from bloom.

In most cases Grimes Golden apples ripened with at least fair (0) dessert quality when picked as late as 140 days from bloom. As shown in figure 9, there were 17 instances in which at least fair dessert quality was attained when the fruit was picked 140 days from bloom or earlier and 7 cases in which dessert quality was less than fair. In 5 of these 7 cases the trees were bearing very heavy loads of fruit and most of it did not attain good commercial size. The size of the Michigan 1941 fruits (78 to 96 gm.) seems to indicate that it also came from a heavily loaded tree or trees. The Illinois apples, however, were of good size

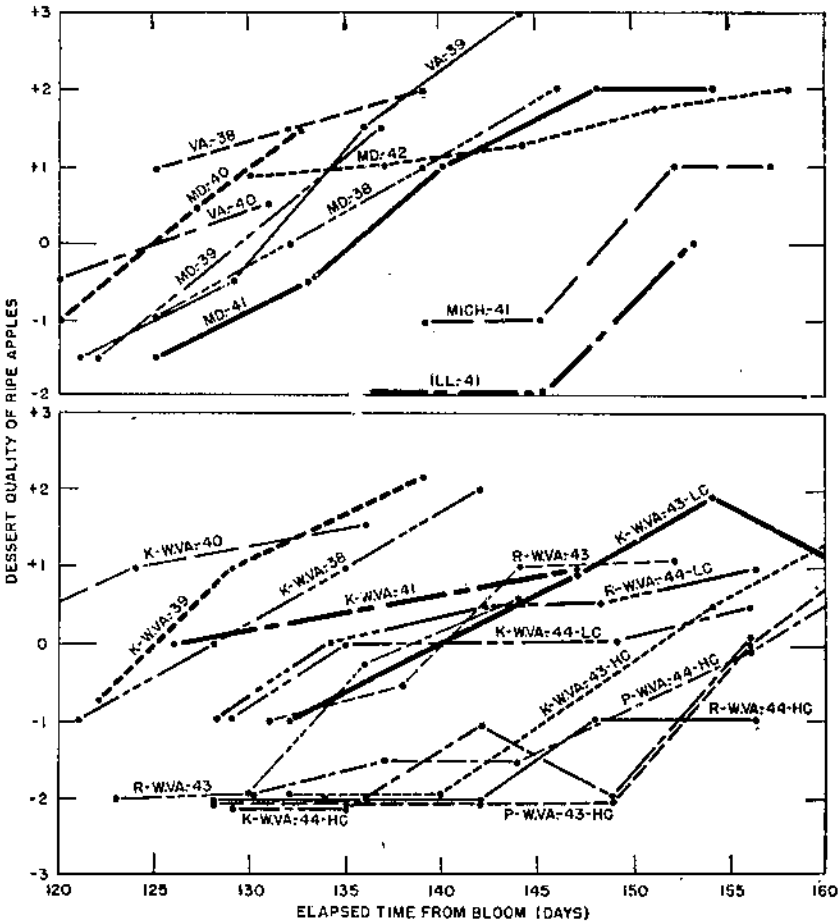

FIGURE 9.—Dessert quality of Grimes Golden apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season; LC, light crop; HC, heavy crop; 0, dessert quality fair or passable; + and — numbers, quality ratings above and below passable.

(average about 125 to 140 gm.). The investigator at Illinois may have had a higher standard of dessert quality than the investigators at the other localities. However, from the standpoint of both dessert quality and susceptibility to scald, the Illinois Grimes Golden apples were late in reaching picking maturity. In general, the results indicate that from the standpoint of potential dessert quality, Grimes Golden apples were of satisfactory maturity 140 days from bloom and often earlier provided they were grown on trees bearing moderate to light crops, but that they may require 145 days from bloom to mature sufficiently to be reasonably resistant to storage scald. Delay in picking would also permit the fruit to increase in size and tend to advance the yellowing somewhat. These results are in fair agreement with those of Ellenwood (*8*), who reported an average of 147 days from bloom to first picking for 30 seasons. Magness and his associates (*29*)

recorded a shorter period, averaging 140 days from bloom to optimum maturity for 10 localities or seasons, and Tukey (*42*) reported an even shorter average, only 134 days, for 2 seasons.

The average pressure-test readings for Grimes Golden apples at the different pickings are shown in figure 3. The average firmness at earliest maturity ranged from 17.0 to 22.8 pounds and, as pointed out earlier, this range was too great in relation to the rate of softening to be of much use as an index of maturity. At the time of earliest maturity there was usually no appreciable change in ground color from the darkest green of the color chart; so this also was of no value as an index of maturity.

JONATHAN

In commercial practice Jonathan apples are usually marketed by the Christmas holidays, although some may be held somewhat later. The experimental lots were removed from cold storage for ripening and inspection between the first of December and the middle of January. Jonathan apples are more subject to storage disorders associated with overmaturity such as Jonathan spot and internal break-down than to disorders associated with immaturity such as storage scald. In the experimental lots no decay of commercial importance developed during storage or poststorage ripening and in only a few instances was there an appreciable amount of internal break-down, storage scald, soft scald, or Jonathan spot. The determination of the first picking with satisfactory maturity therefore depended largely on estimation of the dessert quality of the ripened fruits. These results are plotted in figure 10. The sources of the fruit, the dates of full bloom, and the elapsed time to earliest maturity are shown in table 2. Most of the lots (13 out of 20) attained maturity between 128 and 135 days from bloom. However, there were a number of instances in which maturity was not attained until 140 to 145 days. In all cases the apples grown in the southern Appalachian region (Va., Md., and W. Va.) were ripened with satisfactory (fair) dessert quality (designated as 0 on chart) when picked as late as 130 days from bloom, but usually the quality was below fair when they were picked 125 days from bloom. Optimum dessert quality was sometimes attained about 135 days from bloom. On the other hand, a few lots grown in other localities did not ripen with fair dessert quality unless picked later. One season's results in Illinois indicated that earliest maturity was only slightly later since the first picking, at 133 days from bloom, was satisfactory and optimum maturity was attained at about 145 days. The first pickings in Michigan were not made until 135 days or more from bloom. In 1942 the first picking was of satisfactory maturity, and the results indicated that picking at 130 days would probably also have been satisfactory. However, in 1941 satisfactory dessert quality was not attained until about 142 days. Results for Washington indicated earliest maturity at 142 days in 1942, 136 days in 1943, and earlier than the first picking at 135 days in 1941. These results seem to indicate too great a seasonal spread in the time of maturity from standpoint of dessert quality for days from bloom to be of value as a maturity index of Jonathan in Washington.

The results in the southern Appalachian region are relatively uniform in this respect. Although Jonathan apples grown in West Virginia in 1938 were of satisfactory dessert quality by 130 days, the

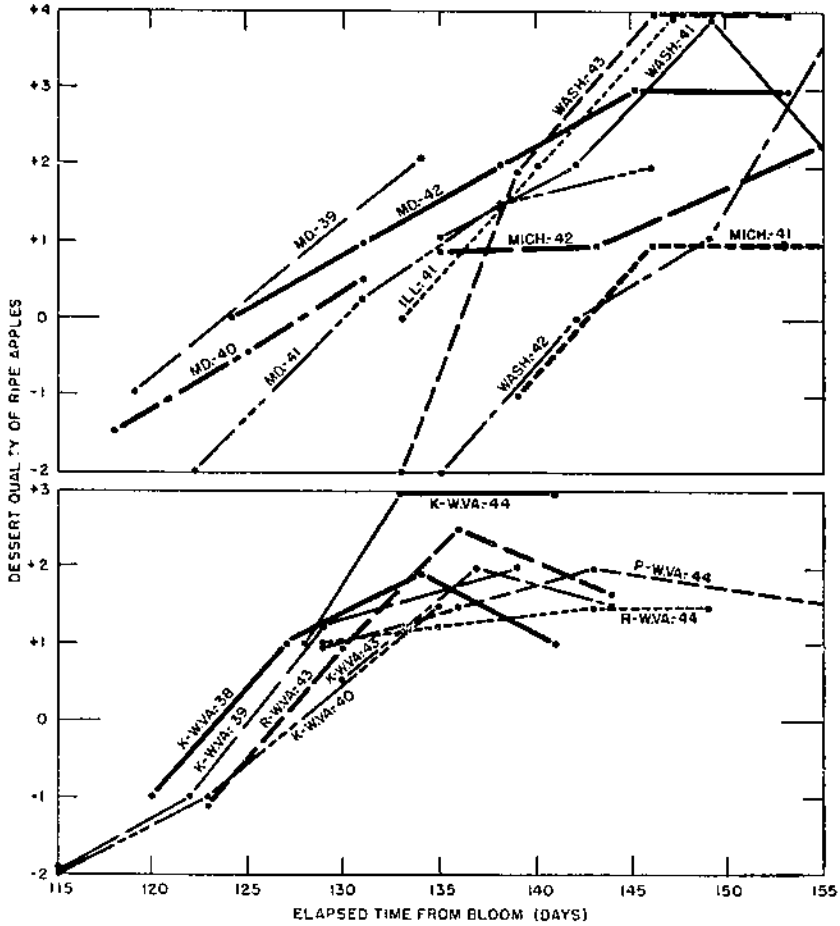

FIGURE 10.—Dessert quality of Jonathan apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season; 0, dessert quality fair or passable; + and − numbers, quality ratings above and below passable.

apples were subject to scald when picked at this time and did not become resistant until about 140 days. This was the only instance in which the fruit was still subject to scald after reaching fair dessert quality. Jonathan spot indicated overmaturity in late pickings in Washington in 1941, and dropping was severe in late pickings in West Virginia in 1944.

In general, the results indicate that Jonathan apples increase rapidly in dessert quality during the maturing time and will usually be of satisfactory maturity from the standpoint of dessert quality by 130 days from bloom, with optimum maturity at about 135 to 140 days. This is much less than the average of 151 days to first picking as given by Ellenwood (*8*) for Ohio and somewhat less than the average (for 11 localities or seasons) of 144 days to optimum maturity as given by Magness and his associates (*29*), but it conforms with the average of 134 days as given by Tukey (*42*) for 3 seasons in New York.

The ground color of Jonathan varied from 1.5 to 2.8 of the color chart at earliest maturity (table 2). As with the other varieties this range is too large for ground color to be used as a maturity index. Similarly pressure-test readings ranged from 13.5 to 21.3 pounds, with no consistent relation of firmness to maturity of Jonathan.

McINTOSH

Limited results were obtained with McIntosh apples (table 9). Storage lots of McIntosh were removed from storage during December or early in January. No scald and little or no decay developed during storage. Some shriveling developed in the apples grown in New York, but the amount was reduced by delay in picking. Slight core browning (low-temperature injury) was found in a large proportion of the apples grown in Washington. There was some tendency for this to decrease with delay in picking. Dessert quality was an important consideration in establishing maturity. In all instances earliest maturity was attained at the picking made nearest to 135 days from bloom (table 9). The results indicate that the period during which McIntosh can be picked with satisfactory maturity is rather limited, as in some instances pickings made a few days after 140 days from bloom were considered somewhat overmature.

TABLE 9.—*Date of full bloom, period from bloom to earliest maturity, and ground color and firmness (pressure test) at maturity of 5 varieties of apples grown in various localities and in different seasons*

Variety, season, and source	Date of full bloom	Period from bloom to maturity	Ground color [1]	Pressure-test reading
McIntosh:				
1941		*Days*		*Pounds*
Wenatchee, Wash.	Apr. 16	133	1.2	15.5
East Lansing, Mich.	May 6	137	2.0	13.4
Geneva, N. Y.	May 8	134	2.0	14.7
1942				
Wenatchee, Wash.	Apr. 19	132	1.9	16.9
Wooster, Ohio	Apr. 28	135	3.5	13.1
East Lansing, Mich.	May 1	136	2.1	16.8
1943				
Wenatchee, Wash.	Apr. 25	135	2.0	16.2
Average		135		
Rome Beauty:				
1941				
Wenatchee, Wash.	Apr. 19	165	2.9	19.6
1942				
Wenatchee, Wash.	Apr. 26	167	2.1	18.4
Beltsville, Md.	Apr. 27	165	2.2	17.0
Wooster, Ohio	Apr. 30	165	1.4	17.8
1943				
Wenatchee, Wash.	do	162	2.5	19.0
Kearneysville, W. Va.	May 4	155		
Paw Paw, W. Va.	May 7	160		
Romney, W. Va.	May 12	150		
1944				
Kearneysville, W. Va.	May 5	160		
Paw Paw, W. Va.	do	160		
Romney, W. Va.	May 6	155		
Average		160		

TABLE 9.—*Date of full bloom, period from bloom to earliest maturity, and ground color and firmness (pressure test) at maturity of 5 varieties of apples grown in various localities and in different seasons*—Continued

Variety, season, and source	Date of full bloom	Period from bloom to maturity	Ground color [1]	Pressure-test reading
		Days		*Pounds*
Winesap:				
1941				
Wenatchee, Wash.	Apr. 19	165	2.9	20.2
Beltsville, Md.	Apr. 22	165	2.1	23.0
Urbana, Ill.	May 1	162	2.0	21.0
East Lansing, Mich.	May 7	160	2.2	22.6
1943				
Beltsville, Md.	Apr. 24	160	2.7	20.4
Wenatchee, Wash.	Apr. 25	165	3.3	22.6
East Lansing, Mich.	May 2	166	1.9	26.4
1945				
Wenatchee, Wash.	Apr. 28	165	3.0	21.2
Mount Jackson, Va.[2]	do	162		
Do.[3]	do	169		
Kearneysville, W. Va.	do	160		
Paw Paw, W. Va.	May 2	157		
Romney, W. Va.	May 9	155		
1944				
Mount Jackson, Va.	Apr. 28	164		
Kearneysville, W. Va.	May 3	155		
Paw Paw, W. Va.	do	155		
Romney, W. Va.	May 4	155		
Average		161		
Yellow Newtown:				
1938				
Crozet, Va.	Apr. 13	140	1.0	21.5
1939				
Crozet, Va.	Apr. 17	160	1.2	21.8
1940				
Crozet, Va.	May 2	150	1.1	20.2
1941				
Hood River, Oreg.	Apr. 17	165	2.0	
Crozet, Va.	Apr. 18	150	1.0	21.5
Wenatchee, Wash.	Apr. 23	152	1.1	19.2
1942				
Crozet, Va.	Apr. 18	165	1.2	21.0
Hood River, Oreg.	Apr. 24	164	2.0	
Wenatchee, Wash.	Apr. 25	161	1.2	19.2
1943				
Wenatchee, Wash.	Apr. 28	160	1.5	21.0
Average		158		
York Imperial:				
1941				
Beltsville, Md.	Apr. 25	160		
1942				
Beltsville, Md.	do	163		
1943				
Mount Jackson, Va.[2]	Apr. 30	153		
Do.[3]	do	167		
Kearneysville, W. Va.[2]	May 3	158		
Paw Paw, W. Va.[2]	May 4	150		
Do.[3]	do	169		
Romney, W. Va.[2]	do	162		
1944				
Kearneysville, W. Va.	do	160		
Romney, W. Va.	do	160		
Paw Paw, W. Va.[2]	May 5	153		
Do.[3]	do	170		
Average		160		

[1] Ground color determined by comparison with standard color chart in which 1 is green and 4 yellow.
[2] Light crop.
[3] Heavy crop.

On the basis of these results earliest maturity in McIntosh occurs between 130 and 135 days from bloom, with optimum maturity between 135 and 140 days. This is in good agreement with 132 days, the average number of days from full bloom to first picking, given by Ellenwood (*8*) for a period of 30 seasons. Tukey (*42*) gave a somewhat shorter average, 127 days, for 5 seasons, and Palmer (*33*) stated that about 130 days from bloom is usually sufficient to bring McIntosh to satisfactory picking maturity.

On the other hand, Smock (*37*) stated that days from bloom is of little value as a maturity index for McIntosh in New York, since in 1945 McIntosh required 154 days to mature instead of the 127 days recommended by Tukey. The 1945 season in the East was unusual in that there was an extremely early bloom followed by a very cool season. Under these conditions the period from bloom to maturity was apparently lengthened, as pointed out earlier (p. 18), but not usually as much as indicated by Smock for McIntosh. Under more or less normal climatic and cultural conditions, the elapsed time from bloom to maturity seems to be rather constant and a satisfactory index of maturity.

As shown in table 9, the ground color and pressure-test readings varied too greatly at maturity to be of value.

ROME BEAUTY

Rome Beauty is a fairly late storage variety (storage season to April) that is very susceptible to scald if immature when picked, but that becomes mealy when overmature or overripe. The experimental samples were removed from storage for ripening and inspection during March, when there was generally little or no decay or break-down.

The results for Rome Beauty (table 9 and fig. 11) do not indicate any very definite period from bloom to maturity. In only two instances were the apples very susceptible to scald when packed in oiled paper. In these cases (Washington, 1942, and Maryland, 1942) scald was very severe in pickings made 155 days from bloom or earlier and did not become less than 20 percent until picking was delayed until 165 to 170 days.

There were six other cases in which pickings were made at 155 days or earlier and in which the fruit developed 10 percent or less of scald when picked at this time. In this connection Palmer (*33*) stated that a period of 160 days from bloom seems to be necessary to render the Rome Beauty resistant to scald. The 1942 season in the southern Appalachian region apparently was favorable for scald development as Grimes Golden also developed scald in 1942 in later pickings than in 1943 or 1944 (fig. 8). In seasons favorable to scald susceptibility, picking of varieties that are not normally scald-resistant should be considerably delayed. This is of little value, however, as there seems to be no reliable or accurate measure of the climatic factors favorable to scald, although in general it seems to be associated with wet weather before harvest.

From the standpoint of dessert quality also the results are rather variable as shown in figure 11. A dessert-quality rating of fair (designated as 0 on chart) when apples are ripened has been used as a

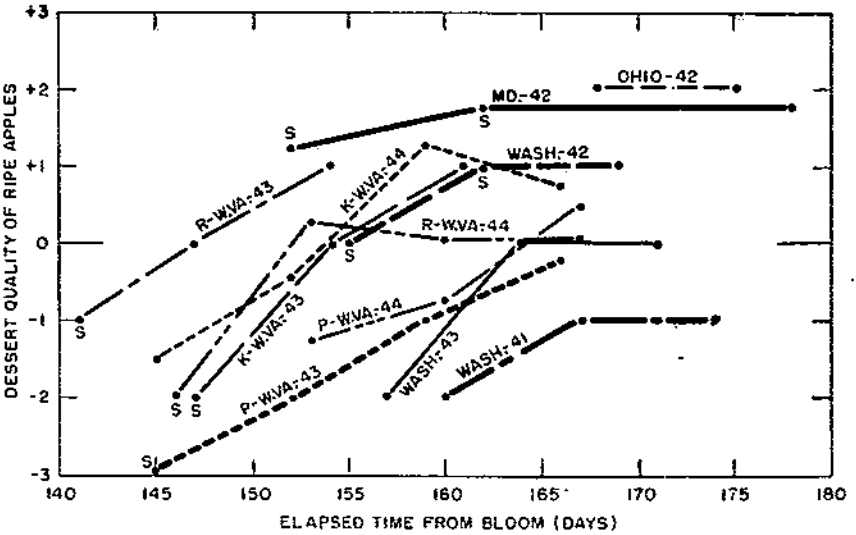

FIGURE 11.—Dessert quality of Rome Beauty apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State name or abbreviation, season; S, appreciable scald developed on apples picked at that time; 0, dessert quality fair or passable; + and — numbers, quality ratings above and below passable.

standard that they should reach before they could be considered mature. In the case of Rome Beauty, which is a rather poor-quality variety, the optimum dessert quality attained frequently was not much above this minimum standard. In one instance the last picking, as late as 174 days from bloom, failed to develop fair quality. On the other hand, in one instance fair quality was attained as early as 147 days from bloom. With this variety it may be that a somewhat lower standard of poor to fair (−1) might be used to establish maturity. With such a standard practically all lots were passable when picked as late as 160 days, and in about a third of the instances this standard had been attained and the lots were resistant to scald when picked 150 days from bloom.

In general, it seems safe to assume that under favorable growing conditions Rome Beauty will attain satisfactory potential dessert quality and will be reasonably resistant to storage scald when picked 160 days from bloom, but that more nearly optimum maturity would be between 165 and 175 days from bloom. Ellenwood (*8*) reported an average of 167 days from bloom to first picking for 30 seasons in Ohio, with a range of 155 to 178 days. Tukey (*42*) reported a much shorter average, 140 days to picking, for 6 seasons in New York. These final results indicate somewhat later picking for this variety than reported earlier (*17*).

STAYMAN WINESAP

Stayman Winesap is a variety suitable for moderately long storage, and the experimental lots were removed from storage for ripening and inspection about the middle of March. This variety is very susceptible to storage scald when picked too early and rather subject

to internal break-down when picking is delayed. These factors, therefore, as well as dessert quality, were considered in establishing the period of satisfactory maturity. Decay was not a factor as little or no decay developed in the experimental lots; and, in the few instances when decay was found, it showed no relation to time of picking. The sources of the apples for these investigations, the dates of bloom, and the elapsed time until the apples were considered mature are shown in table 6.

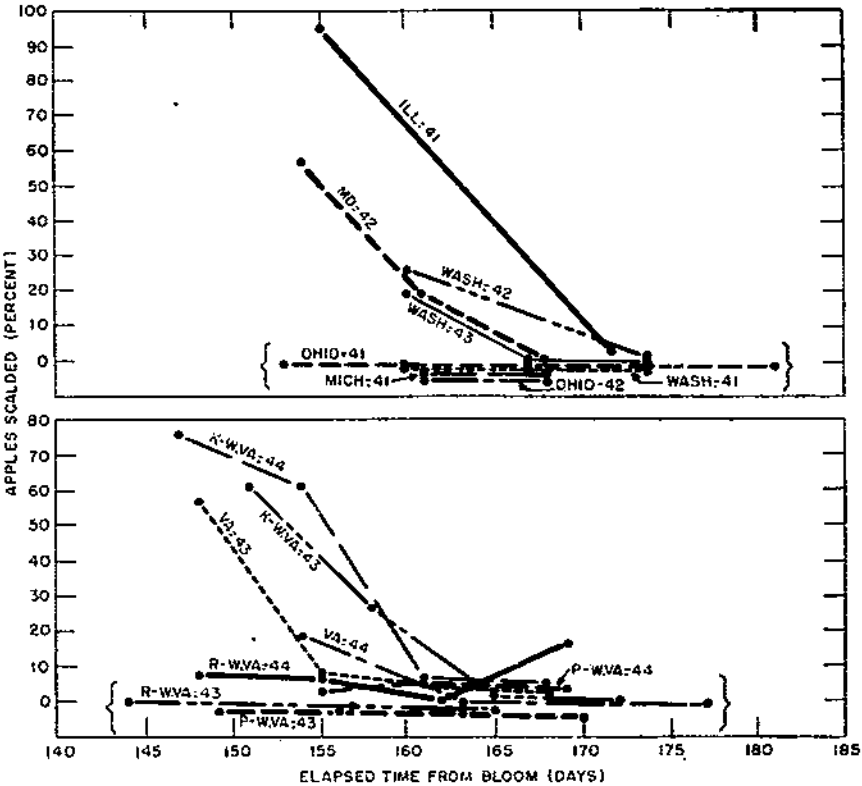

FIGURE 12.—Scald development during storage on Stayman Winesap apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State name or abbreviation, season.

The Stayman Winesap apples showed great variability in their susceptibility to scald, depending on source and seasonal conditions as shown in figure 12. In some instances no scald developed even on pickings made as early as 150 days from bloom, whereas in one case (Illinois, 1941) it required about 170 days to reduce scald to insignificant amounts. In most cases when early pickings were susceptible to scald, the percentage was reduced to about 20 or less when picking was made as late as 160 days from bloom.

The development of internal break-down during storage in relation to the elapsed time from bloom to picking is shown in figure 13 for those lots in which break-down occurred. Additional lots that showed

no break-down in storage were Stayman Winesap grown in Michigan in 1941 and picked as late as 168 days from bloom, Illinois in 1941 and picked as late as 172 days from bloom, Ohio in 1941 and picked as late as 181 days from bloom, Ohio in 1942 and picked as late as 168 days from bloom, Washington in 1942 and picked as late as 174 days from bloom, and Washington in 1943 and picked as late as 174 days from bloom. Susceptibility to break-down varied greatly; in several instances no break-down developed in lots picked after 170 days from bloom, whereas in one case (Maryland, 1942) over 10 per-

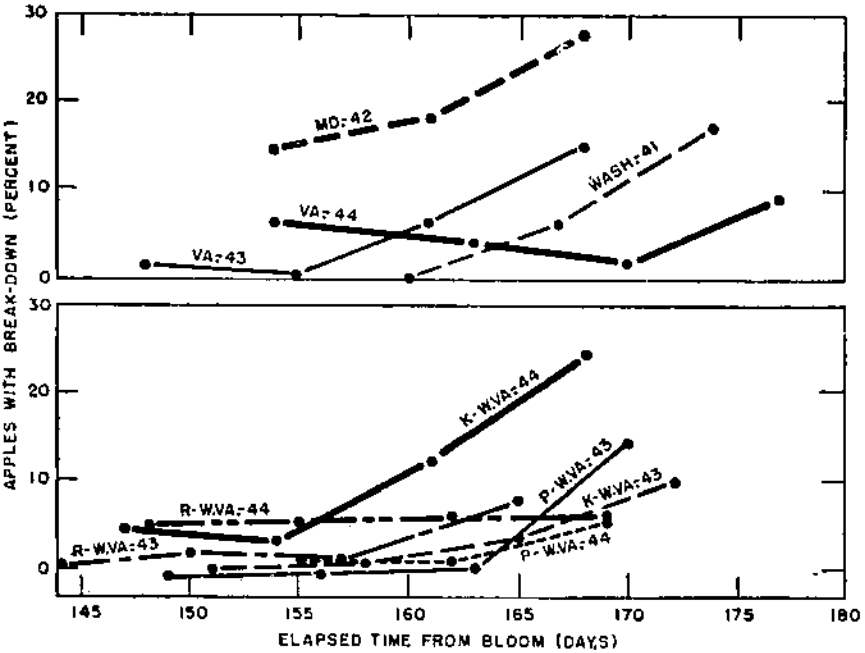

FIGURE 13.—Internal break-down development during storage in Stayman Winesap apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season.

cent was found in apples picked as early as 155 days from bloom. In general, break-down was relatively slight in pickings made 160 days from bloom or earlier.

The results for scald and break-down seem to indicate a relatively narrow interval for satisfactory picking of this variety, as the tendency was for scald to become severe when pickings were earlier than 160 days from bloom and for break-down to become a factor when pickings were made later than 160 days from bloom. In one instance (Maryland, 1942) there was no satisfactory period for picking as appreciable break-down developed in pickings that were still rather subject to scald.

The dessert quality of the Stayman Winesap apples is shown in figure 14. The results indicate that in general the apples ripened with fair dessert quality (designated as 0 on chart) when the fruit

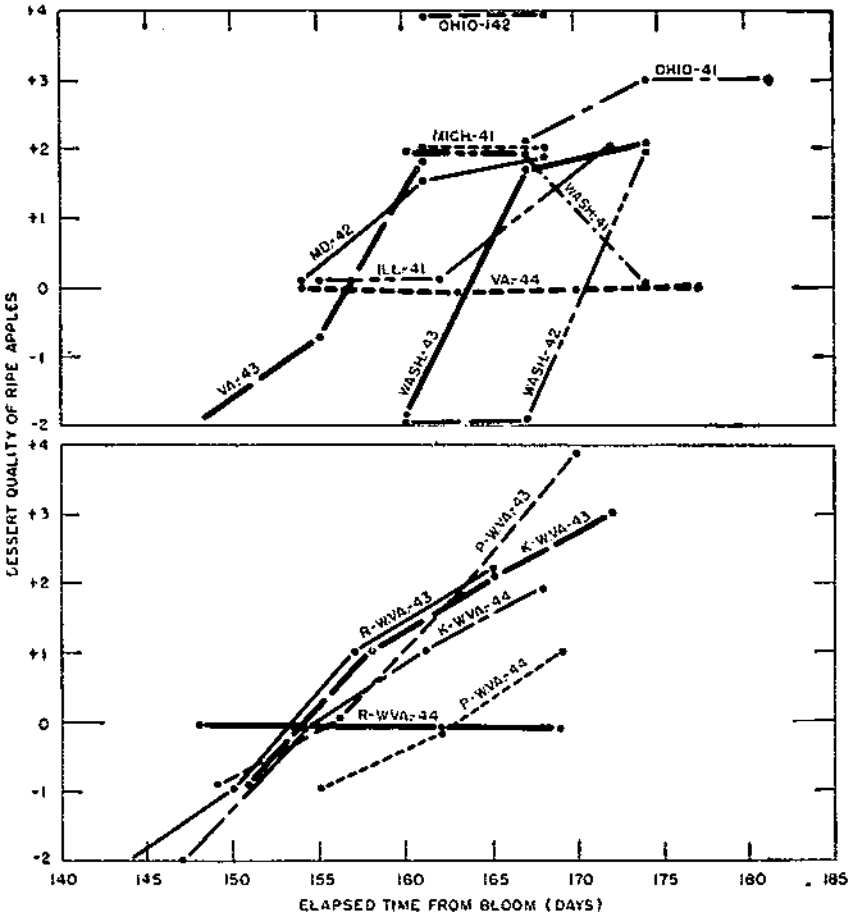

FIGURE 14.—Dessert quality of Stayman Winesap apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State name or abbreviation, season; 0, dessert quality fair or passable; + and —numbers, quality ratings above and below passable.

was picked about 155 days from bloom. However, there were a few exceptions to this, notably apples grown in Washington in 1942 and 1943, when about 170 and 165 days, respectively, were required. In these cases there was no evidence of internal break-down in storage of late-picked fruit, so that pickings could have been delayed with no adverse effects. On the other hand, the Washington Stayman Winesap apples were becoming overmature, as shown by increasing break-down and lower dessert quality, when picked later than 165 days from bloom in 1941.

In general, the results indicate that Stayman Winesap apples should be picked about 160 days from bloom. If picking is much earlier than this, there is danger of severe scald development during storage even when the fruit is packed with oiled paper; and if picking is much later, there is danger of severe break-down development during

storage. Ellenwood (*S*) gave an average of 168 days from bloom to first picking for 30 seasons in Ohio.

WINESAP

Apples of the Winesap variety are suitable for long storage. The test lots were removed from storage for ripening and inspection between the middle of March and the middle of May. No appreciable amount of decay or break-down was found in any of the lots. Winesap apples are moderately subject to storage scald. However, appreciable scald developed in early pickings in only two instances. These were

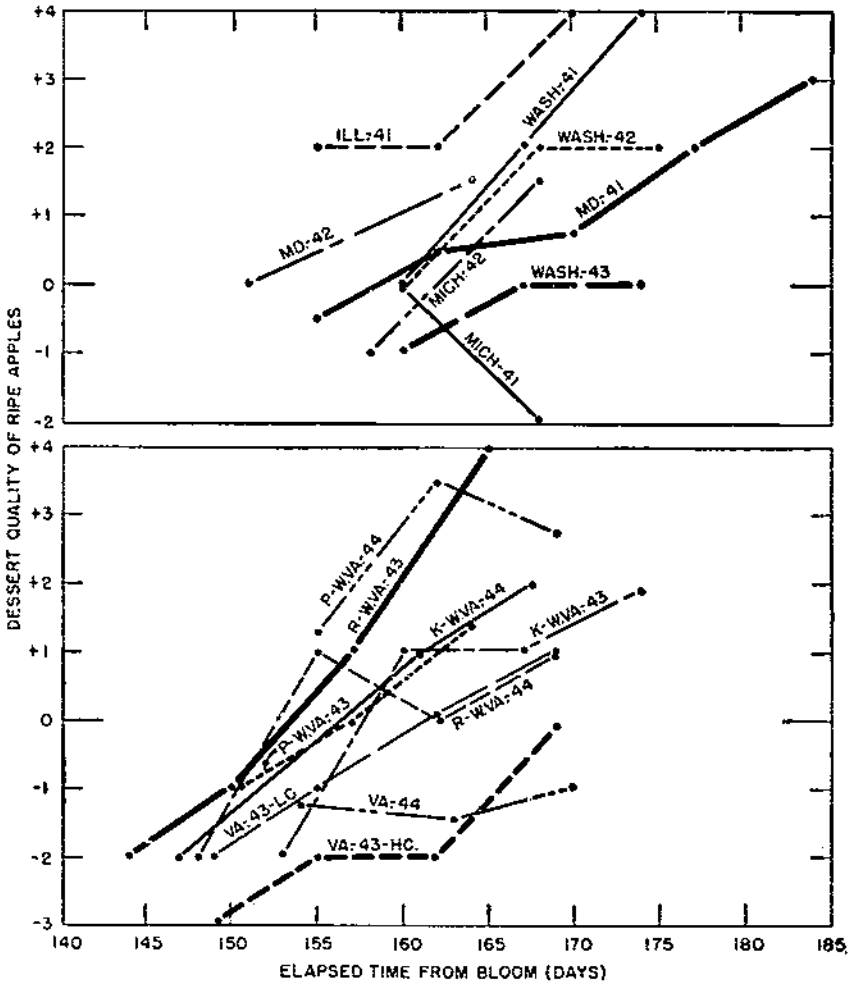

FIGURE 15.—Dessert quality of Winesap apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season; LC, light crop; HC, heavy crop; 0, dessert quality fair or passable; + and — numbers, quality ratings above and below passable.

in the first pickings (155 days from bloom) at Beltsville, Md., and Urbana, Ill., in 1941. Time of maturity, therefore, was established primarily by the dessert quality of apples when ripened (fig. 15). In most cases the apples developed fair dessert quality when picked between 155 and 165 days from bloom. Table 9 shows the sources of the fruit and the number of days from bloom to earliest maturity. The average number of days from bloom to maturity was 161 days, and in nearly all cases apples picked by 165 days from bloom were found to be mature. However, in some cases severe drop occurred by 170 days from bloom, so that unless drop-preventing sprays are used it might not be safe to start picking this variety as late as 165 days from bloom. As with other varieties the length of the growing period necessary to attain satisfactory potential dessert quality was influenced considerably by size of the crop.

In general, the results indicate that picking of Winesap apples should not start until 160 days from bloom and that if dropping can be controlled optimum picking would be between 165 and 175 days. The results given by Magness and his associates (*29*) indicate a shorter average period, 157 days, and a range of 140 to 168 days to optimum maturity. However, the only instances where the period was less than 150 days were in Massachusetts and New York, where the growing season is usually too short to permit full maturity of varieties requiring a long growing period.

YELLOW NEWTOWN (ALBEMARLE PIPPIN)

The Yellow Newtown variety is grown most extensively in California, Oregon, and southern Virginia. It is a long-storage variety of good dessert quality and with only a slight tendency to scald. As grown in the Pacific Coast States, it is a winter apple and one of the last varieties to be picked. In Virginia the tendency has been to treat it as a late-fall variety with commercial picking frequently starting the latter part of August when the fruit is small, green, and of mediocre potential dessert quality. When an export market was available, this variety was extensively shipped to England, where a small green apple was accepted. An additional reason for picking early is that the fruit sometimes develops a skin spotting (reddening around the lenticels) when left on the tree until late. This spotting is considered a defect by the inspection service and reduces the grade of the fruit.

The dessert quality of the different pickings of Yellow Newtown when ripened is shown in figure 16. The number of days from bloom to harvest at which the fruit attained fair (0) dessert quality when ripened ranged from 141 days (Virginia, 1940) to 171 days (Virginia, 1942). However, the chart indicates that, with one exception, the fruit reached fair quality by about 160 days or earlier. This is in general agreement with the results of Palmer (*33*), who stated that the Yellow Newtown seems to require a growing period of at least 160 days in order to develop high quality.

For apples grown in Virginia in 1940, there was no very satisfactory picking maturity. The 1940 season in this orchard was characterized about the middle of August by heavy and frequent rains that caused premature yellowing and dropping of many of the leaves. These weather conditions made the fruit very subject to core browning, which amounted to 40 to 50 percent, when the apples were picked 130 days

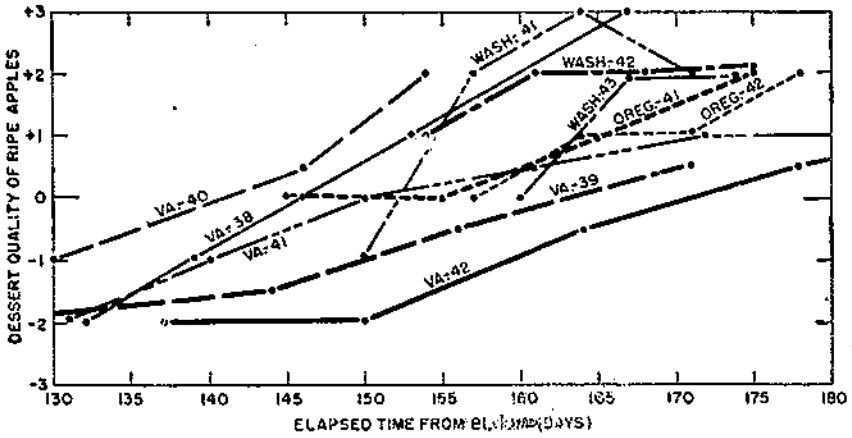

FIGURE 16.—Dessert quality of Yellow Newtown apples from various sources in relation to days from bloom to picking. Number after State abbreviation, season; 0, dessert quality fair or passable; + and − numbers, quality ratings above and below passable.

from bloom. The core browning decreased with delay in picking to insignificant amounts by 154 days from bloom. However, by this time dropping was rather severe and earlier picking was apparently necessary. Even in the picking made 146 days from bloom appreciable dropping had occurred, so that to save the crop harvesting should have started considerably earlier than this. Even when picked at 146 days 21 percent of the apples developed core browning in storage. There seems to be no maturity index that would anticipate a premature drop due to abnormal weather conditions when the fruit is not of satisfactory maturity from the standpoint of dessert and keeping qualities.

Fair (0) dessert quality was attained in early pickings of the apples grown in Virginia in 1938 (fig. 16), but in this instance scald developed in the early pickings and did not decrease to insignificant amounts until about 150 days from bloom to picking.

The sources of the various lots of Yellow Newtown apples, with the date of full bloom and the elapsed time until they were first considered mature, are shown in table 9. These data indicate that the period from bloom to maturity varied from about 150 to 165 days, which would indicate that the time to harvest could not be determined by this index of maturity closer than within a period of about 2 weeks. Actually this period might be considerably shortened, as in those instances when harvest might have started about 150 days from bloom it would have been desirable to delay it until 155 days (except for Virginia, 1940). In those instances (Oregon, 1941 and 1942) in which 164 to 165 days is given as the time of earliest maturity, this is the time indicated by the investigator who conducted the tests in Oregon. However, at 160 days or earlier he rated the dessert quality as fair, which was the standard on which maturity was based in other localities. Yellow Newtown apples grown in Virginia in 1942 also required 165 days from bloom to become mature. In this instance the apples were picked from trees bearing a somewhat heavy crop of small apples that did not ripen with satisfactory quality when picked earlier than 165 days from bloom. Apparently heavy-crop conditions de-

layed maturity in this instance as with other varieties. In general, therefore, it seems that picking of Yellow Newtowns should not start until at least 155 days from bloom and preferably 160 days from bloom. Optimum maturity is likely to occur between 160 and 175 days from bloom, but dropping is likely to become severe after 170 days.

The pressure test at earliest maturity was fairly constant but varied from 19.2 to 21.8 pounds, a range of 2.6 pounds (table 9). The ground color usually had not changed appreciably from the darkest green of the color chart and so could not be used as an index to the time of earliest maturity.

YORK IMPERIAL

York Imperial apples are suitable for moderately long storage. They are firm-fleshed and not subject to break-down, but they are susceptible to storage scald (*25*). The experimental samples were removed from cold storage for ripening and inspection during March. Practically no break-down developed in any of the lots. Decay was also generally of no practical significance except in 1942 and to some extent in 1941. Time of picking had no apparent effect on the percentage of decay so that it was not a factor in establishing the time of maturity. Appreciable scald developed in early pickings in only three instances (Maryland, 1941 and 1942, and Romney, W. Va., 1944). Except in fruit grown in Maryland in 1942, scald did not develop when the fruit was picked as late as 160 days from bloom and not much later than this even in 1942.

In other cases the primary factor used to establish the time of maturity was dessert quality (fig. 17). In a few instances, satisfactory

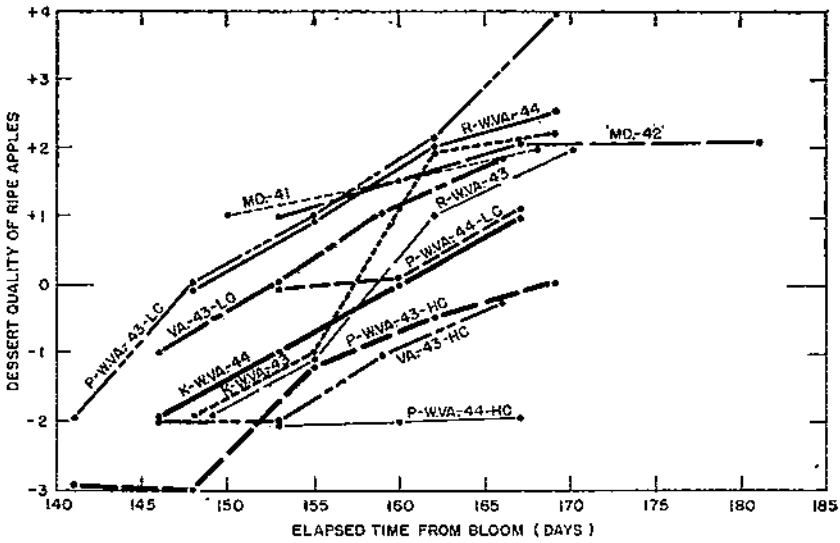

FIGURE 17.—Dessert quality of York Imperial apples from various sources in relation to days from bloom to picking. K, Kearneysville; P, Paw Paw; R, Romney; number after State abbreviation, season; LC, light crop; HC, heavy crop; 0, dessert quality fair or passable; + and − numbers, quality ratings above and below passable.

dessert quality was attained in the apples picked about 150 days from bloom. In these instances, however, the fruit was subject to scald even when packed in oiled paper and so was not ready for picking. At 155 days from bloom the fruit ripened with satisfactory dessert quality in about half of the cases, particularly when the fruit was picked from light-crop trees. By 160 days from bloom, most of the lots were of satisfactory dessert quality and free of scald. The lots still of unsatisfactory dessert quality were from trees bearing very heavy crops. The sources of the various lots and the number of days from bloom to maturity are shown in table 9. The results indicate that picking of York Imperial apples should not begin before 155 to 160 days on trees bearing light to moderate crops and should be even later on trees bearing heavy crops.

OTHER VARIETIES

Williams Early Red.—Williams Early Red is a summer apple usually harvested just after Yellow Transparent. It is rather subject to bitter pit when overgrown or picked too early and to internal breakdown when left on the tree too long. Apples of this variety were obtained from the Eastern Shore of Maryland in 1938, 1939, and 1940. The data were presented in earlier reports (*11, 13*). In four of five instances the fruit was judged to be mature at 70 days from bloom and in the other case at about 80 days. This variety blooms and matures rather unevenly. The trees may have fruits that are full eating ripe and at the same time others that are firm and of good picking maturity.

Baldwin.—The Baldwin variety is grown principally in the Northeastern States, where it is a late-fall variety. It is rather susceptible to bitter pit and to storage scald, both of which are more severe in early pickings. In 1941, pickings of this variety grown in Michigan were made 145, 152, and 160 days from bloom. No bitter pit or scald was observed on any of the fruit. The apples were small and did not develop satisfactory dessert quality. However, they were judged to be mature 155 days from bloom. This is somewhat less than the average of 161 days to earliest picking for 30 seasons in Ohio (*8*), but it is considerably more than the 145 days to optimum maturity for 8 localities or seasons as given by Magness and his associates (*29*). Tukey (*42*) indicated an even shorter season (135 days) for 4 seasons in New York. It would seem, therefore, that the results for Baldwin are too inconsistent to establish the length of the period from bloom to maturity with any degree of accuracy.

Cortland.—Cortland is a variety of the McIntosh type that is usually picked later. Pickings of Cortland grown in New York in 1941 were made 125, 134, and 141 days from bloom. Because considerable scald and shrivel developed on apples of the first picking, they were judged to be immature. Only 12 percent of the apples in the second picking developed slight scald and the dessert quality was good; therefore, this picking (at 134 days) was considered mature. For 3 seasons in the same locality, Tukey (*42*) gave a somewhat shorter period from bloom to picking (125 to 130 days), whereas Ellenwood (*8*) gave a longer period of 133 to 155 (average 144) days to the first picking for 10 seasons in Ohio. These results for Cortland are too conflicting to establish a definite period from bloom to maturity.

Kendall.—Kendall is another variety of the McIntosh type, but it has better keeping quality than McIntosh or Cortland. In 1941 pickings of this variety as grown at Geneva, N. Y., were made 124, 136, and 144 days from bloom. Apples of the first picking were definitely immature, as the flesh was green, the fruit shriveled badly, and the dessert quality was poor. Apples of the last picking were definitely overmature, as the fruit was too soft for satisfactory storage. These results indicate that about 135 days should elapse from bloom to maturity. However, results for one season only are not sufficient to establish the period from bloom to maturity.

Northern Spy.—Northern Spy is only slightly susceptible to scald (*25*), but it is subject to bitter pit when picked early. Three pickings of this variety grown in Michigan were made during each of two seasons. The results for both seasons indicated that early maturity of the variety occurred about 160 days from bloom. Under the short growing seasons in New York, Tukey (*42*) gave a much shorter period from bloom to picking, averaging 143 days for five seasons. Magness (*25*) suggested an intermediate period of 145 to 155 days from bloom.

Rhode Island Greening.—The Rhode Island Greening variety is very susceptible to storage scald when picked too early. Three pickings of this variety were made in Michigan in 1941. Fruit of the first picking, at 137 days from bloom, did not develop scald, but it was of unsatisfactory dessert quality because of its immaturity. The third picking, at 148 days from bloom, became mealy and had poor dessert quality because of overmaturity. The results indicated satisfactory maturity at about 142 days from bloom for this season and locality. During eight seasons in New York (*42*) the period from bloom to picking varied from 131 to 138 days and averaged 135. Magness (*25*) suggested 135 to 145 days for this variety.

Esopus Spitzenburg.—Four pickings of a red bud sport of Esopus Spitzenburg were made during each of two seasons at Hood River, Oreg. The results for both seasons indicated that pickings made about 155 days from bloom were of satisfactory maturity, with optimum maturity at about 160 to 165 days.

Canada Red (*Steele Red*).—Two pickings of Canada Red were made in Michigan during each of two seasons. The results were not very conclusive, but they indicated a period of about 160 days from bloom to early maturity during both seasons.

DISCUSSION

Various indexes of maturity that have been suggested or recommended for use with apples were studied with a number of commercially important varieties under various seasonal and cultural conditions. Maturity indexes such as ground color, firmness, ease of separation, and starch test were found to be of little practical value. Main reliance was placed on the elapsed time from bloom. This too was found to vary considerably. The size of the crop was the principal factor that caused variations in the elapsed time to maturity.

On the basis of these results figure 18 was prepared to summarize the general recommendations for the 11 varieties for which sufficient evidence has been obtained to establish picking maturity with reason-

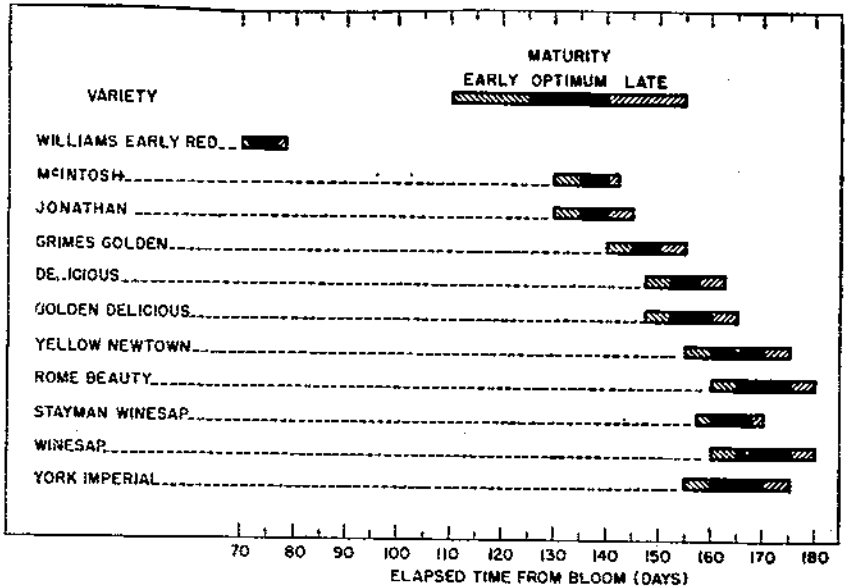

FIGURE 18.—Days elapsing from bloom to maturity. For meaning of different parts of bars, see text (below).

able certainty. Early maturity is the period during which picking might start under conditions that favor early maturity (such as a light crop) but during which the fruit may still be immature (possibly subject to scald or of unsatisfactory dessert quality) under conditions that might delay maturity. Optimum maturity is the period during which the apples are most likely to be in satisfactory condition for picking from the standpoint of both storage and dessert qualities. Late maturity is a period during which picking may be satisfactory under some conditions but during which excessive dropping or overmaturity may occur under other conditions. Thus, the first and the last part of each bar represent periods of questionable maturity, whereas the middle part of each bar represents the period when picking maturity is most likely to be satisfactory and optimum maturity is most likely to occur. Similar charts based on these results have been presented previously (*13*, *17*). As a result of further study of the data some of the periods of maturity have been changed somewhat from the earlier presentations, as shown in figure 18. The principal changes consist in making all periods 4 or 5 days earlier for Jonathan and making all periods 5 days later for Winesap and 10 days later for Rome Beauty; more limited changes were made for a few of the other varieties.

When the crop is light, the leaf-to-fruit ratio relatively high, and the elaborated material ample, the concentration of carbohydrates in the fruit as well as its size tends to increase. This advances the time at which satisfactory potential dessert quality is attained and thus may hasten maturity. Conversely, trees bearing heavy crops have inadequate elaborated food for the development of the fruit. Apples on such trees not only are small, but have a low concentration of carbo-

hydrates and are relatively late to develop satisfactory dessert quality. However, when small, poorly developed fruit results from inadequate leaf area, drought conditions, or both, it usually is much less subject to storage scald than fruit from light-crop trees with ample soil moisture. With varieties that are not particularly susceptible to scald, picking earlier from trees bearing light crops than from those bearing heavy crops would be desirable.

However, in the rush of picking operations it might not be practical to go over a block of a variety more than once in order to pick scattered light-crop trees or to leave scattered heavy-crop trees for a later picking. In some cases the crop may be generally light or generally heavy depending on whether it is the off or the on year. When the crop is generally heavy the period from bloom to harvest should be in the later part of the ranges indicated in figure 18. Here again practical consideration may influence the time of picking as it may be necessary to start picking a heavy crop relatively early in order to get the crop picked before frost or excessive dropping occurs or to reach a later variety in the proper time.

When apples are picked from light- and heavy-crop trees at the same time, it would be desirable to separate the fruits of early and late maturity for subsequent handling. To some extent this could be done on the basis of size. However, it is not a simple size relation, as the largest apples from heavy-crop trees were frequently as large as, or larger than, the smallest ones from the light-crop trees. It was observed that, even if the apples were of the same size and picked at the same time, those from light-crop trees were of distinctly better dessert quality than those from heavy-crop trees. This is in agreement with the results of Martin and Carne (*31*), who observed that fruit from light-crop trees differed from fruit of the same size from heavy-crop trees. They observed that disorders such as bitter pit, water core, Jonathan spot, soft scald, storage scald, and break-down have higher incidence in fruit from light-crop trees than in that from heavy-crop trees and stated that heavy- and light-crop fruit should be stored and marketed separately.

The apples used in the investigations reported herein did not show such marked differences in storage quality, because most of the disorders mentioned by Martin and Carne (*31*) did not develop in the varieties used. However, other investigators have observed that large apples (presumably from light-crop trees) are more subject to these disorders. These results indicate that apples from light-crop trees may be subject to disorders associated with both immaturity (bitter pit, scald) and overmaturity (water core, Jonathan spot, and break-down). Picking of light-crop trees should therefore not be advanced so that it is done with varieties that are particularly susceptible to bitter pit or scald (such as Baldwin and Grimes Golden), but it should be advanced so that it is done with varieties that are not very susceptible to immaturity disorders but are susceptible to Jonathan spot, water core, and break-down (such as Jonathan and Delicious). Varieties that are subject to disorders associated with both immaturity and overmaturity (such as Stayman Winesap, Rome Beauty, and Arkansas, or Black Twig) will have a very short harvest season of satisfactory maturity when grown on light-crop trees.

Large size in apples may result primarily from either of two growing factors. These are a light crop (high leaf-to-fruit ratio) or ample soil moisture. Large size due to a light crop results in apples that are high in percentage of solids and of superior dessert quality (*16*). Large size due to ample soil moisture throughout the growing season results in apples that are low in percentage of solids and of relatively poor dessert quality (*14*). Large apples from either cause are more subject to scald and to internal break-down, and those of many varieties will have a relatively short period of satisfactory maturity.

Even if the crops are moderate, the period of satisfactory maturity may be rather short. From this standpoint it is undesirable for an orchard to be planted largely to one variety or to several varieties that have the same maturity period, as this makes it necessary to extend the harvest season into periods of unsatisfactory maturity. When this is necessary apples picked when of questionable maturity should be kept separate from those picked during the optimum period; and, since they are likely to have poor storage capacity, they should be marketed first. Apples picked late if marketed early should be of good dessert quality and if stored for a short period only should be relatively free of storage disorders. Although it may be possible to avoid scald on early-picked fruit by marketing it early, such fruit is likely to have poor dessert quality that may adversely affect the subsequent market demand for apples. From the standpoint of dessert quality, it would generally be better to extend picking into the late maturity period than into the early maturity period.

Development of red color usually does not take place until the apples approach maturity and continues throughout the maturity periods. Although the amount of red color is not a reliable index of maturity, it frequently influences the time of picking, as picking may be delayed until color development is satisfactory. With some of the red bud sports satisfactory color may appear before the apples are mature from the standpoint of dessert and storage qualities and the tendency is to pick the red strains of a variety too early. These results, as well as those of others (*9*), indicate that most of the red sports do not mature earlier than the regular varieties and therefore picking of the red sports should not start any earlier than the time indicated for the regular varieties.

Delay in picking may be desirable also from the standpoint of ground-color changes, or yellow-color development. Although ground-color changes have not been consistent enough or rapid enough to serve as an index of maturity, they are important from the standpoint of appearance, particularly with yellow varieties such as Golden Delicious. With Grimes Golden and Yellow Newtown the yellowing during the early part of the harvest seasons was not of much practical value as there was relatively little change from the green color of immaturity. This retention of the green color seems to be particularly pronounced under conditions of high nitrogen fertility and with heavy crops.

A nearly uniform increase in volume of apples throughout the harvest season has been reported (*20*). During the 1938 to 1940 seasons circumference measurements were made at intervals during the

picking season. These were converted to volume and are shown in table 10. These results show a growth rate of about 1 percent per day for the early-fall varieties Jonathan and Grimes Golden and about 0.5 percent for the late variety Yellow Newtown. Thus, an additional benefit from late picking would be an appreciable increase in the volume of the crop. However, as picking is delayed the risk of losing crop volume by dropping becomes greater. As long as the daily percentage increase in volume due to growth is greater than the daily percentage drop there would be a net increase in crop volume

TABLE 10.—*Increase in volume of apples of 3 varieties from an early to a late picking in different localities and seasons*

[Volume computed from circumference measurements]

Variety	Source	Season	First picking		Last picking		Difference			Increase in volume per day
			Period from bloom	Volume	Period from bloom	Volume	Days	Volume		
			Days	*Cc.*	*Days*	*Cc.*		*Cc.*	*Percent*	*Percent*
Jonathan	Martinsburg, W. Va.	1938	127	125	141	143	14	18	14.4	1.0
	Kearneysville, W. Va.	1939	129	149	139	165	10	16	10.7	1.1
	Berlin, Md	1939	119	139	131	166	15	27	19.4	1.3
	Kearneysville, W. Va.	1940	123	136	135	154	12	18	13.2	1.1
	Berlin, Md	1940	118	104	131	120	13	16	15.4	1.2
Average			123	131	136	150	13	19	14.6	1.1
Grimes Golden	Kearneysville, W. Va.	1938	128	118 131	142	131 146	14	13 15	11.0 11.5	.8
	Salisbury, Md	1938	132	169 163	146	196 189	14	27 26	16.0 16.0	1.1
	Crozet, Va	1938	132	159 183	139	201 194	7	12 11	6.3 6.0	.9
	do	1939	129	124	144	145	15	21	16.9	1.1
	Kearneysville, W. Va.	1939	129	156 133	139	169 145	10	13 13	8.3 9.8	.9
	Berlin, Md	1939	122	101	137	125	15	24	23.8	1.6
	Crozet, Va	1940	114	139	131	170	17	31	22.3	1.3
	Kearneysville, W. Va.	1940	124	142	136	160	12	18	12.7	1.1
	Berlin, Md	1940	120	129	133	151	13	22	17.1	1.3
Average			127	144	139	163	12	19	13.7	1.1
Yellow Newtown	Crozet, Va	1938	140	141	167	165	21	24	17.0	.8
	do	1939	156	159	171	162	15	12	8.0	.5
	do	1940	146	139	154	145	8	6	4.3	.5
Average			149	143	164	157	15	14	9.7	.6

so that 0.5 to 1 percent of dropping per day may occur without loss of volume.

The use of harvest sprays to retard dropping makes it possible to obtain the benefits of late picking with less danger of serious crop reduction due to dropping. However, the use of these sprays makes it possible and increases the likelihood that the apples may be left on the tree until overmature. In addition to the possibility of the fruit being left on the tree until overmature there is some indication that these sprays may hasten maturation and ripening particularly with early varieties. With six fall and winter varieties (Jonathan, Delicious, Starking, Rome Beauty, Stayman Winesap, and York Imperial) Haller (*12*) found no direct effect of α-naphthaleneacetic acid

sprays on the maturity and storage quality of the apples. Gerhardt and Allmendinger (*10*) also found no advance in the maturity of Delicious and Winesap apples when they were picked during the regular harvest season, but they observed increased maturity and ripening of Delicious as a direct effect of the spray when picking was delayed until far past the normal harvest season of the variety. Batjer and Moon (*3*) found a direct effect of the sprays in hastening the ripening of early varieties (Close, Williams, and Duchess of Oldenburg), but they confirmed the results of Haller and of Gerhardt and Allmendinger with later varieties (Summer Rambo, Jonathan, Delicious, and Rome Beauty) picked during the normal harvest period. Further evidence that ripening of early varieties is advanced by the sprays was presented by Smock and Gross (*38*) for Oldenburg (Duchess), Wealthy, and McIntosh.

Marketing of poor-quality, immature fruit tends to lower the demand for and price of later shipped fruit. Consequently some States, at the request of the fruit industry, enforce maturity standards for some fruits, particularly citrus. This has been done also with the Delicious apple in Washington, the number of days from bloom being used as the primary measure of picking maturity. To maintain the position of apples in competition with other fruits and to justify advertising programs for apples, it may be desirable to establish and enforce maturity standards so that the fruit is not marketed with poor quality due to immaturity. To do this, it is necessary to have reasonably reliable standards that do not unduly delay the picking of fruit of satisfactory maturity and that do not permit the picking of fruit of unsatisfactory dessert and storage qualities.

Although the number of days from bloom has apparently been reasonably satisfactory as applied to Delicious in Washington, it does not seem to be sufficiently accurate for general application to all varieties. Certainly, allowance would need to be made for size of crop and possibly other factors such as growing-season temperatures. Before this can be done, additional studies are needed to establish more definitely the relation of size of crop to maturity and the possible relation of temperature to time of maturity. Additional studies are also needed with many varieties for which the elapsed time from bloom to maturity has not been well established. In such studies maturity should be established on the basis of storage response and dessert quality of ripened samples picked throughout the harvest season and not simply on the date of commercial harvest.

Prevailing temperatures during the growing season have been shown to influence materially the growth and time of maturity of certain stone fruits. It is rather surprising, therefore, to be unable to find any appreciable effect of temperature on the time of maturity of apples of most varieties. However, there were indications that rather large differences particularly during the early part of the season caused differences in the time of maturity. This effect was observed in the 1945 season when the elapsed time from bloom to maturity was apparently unusually long after an extremely early and cold spring. It seems likely that the effect of smaller temperature differences may be obscured or counterbalanced by some other factors so that the effects cannot be measured by the somewhat coarse methods usually employed.

SUMMARY AND CONCLUSIONS

A study of the value of various indexes to maturity of apples was made by measuring for different pickings the ground color, firmness, ease of separation, the starch pattern, and time from bloom of a number of commercially important varieties as grown under various cultural and climatic conditions. Samples of each picking were held in storage at 31° to 32° F. until near the end of their usual storage period and subsequently ripened. The maturity of the fruit at the different pickings was established on the basis of the storage response and dessert quality of the ripened fruit, with particular emphasis on determining the length of the period from full bloom until the earliest time at which the fruit could be considered mature.

Changes in ground color did not constitute a satisfactory index to maturity, as the changes were too gradual and apples of a variety did not attain the same color at earliest maturity under different seasonal and cultural conditions. Similarly firmness as measured by the pressure test was found to be unreliable.

Factors other than maturity frequently influence the ease of separation of the fruit from the spur, so that dropping may occur before satisfactory maturity is attained. The measure used to determine ease of separation did not show an appreciable or consistent change in ease of separation with maturity. A tendency to dropping may make picking necessary, but it is not a reliable index to maturity. Premature dropping should be controlled by harvest-drop sprays so that the fruit can be harvested during the periods of satisfactory maturity. Harvest-drop sprays should not be used to extend harvest beyond the period of satisfactory maturity.

The starch pattern in median cross sections of apples was found to vary greatly at maturity of Jonathan and was not a reliable index to maturity for this variety. Limited results for Grimes Golden and Yellow Newtown indicated that it could not be used with these varieties.

The elapsed time from full bloom to maturity was found to be fairly constant for each variety under widely different cultural and climatic conditions and constituted the most reliable index to maturity. The data indicated that the length of the period from bloom to maturity was not influenced by growing-season temperatures except possibly in case of Jonathan for which the period was shortened by high temperatures during the early part of the growing season. Observation during one season in which an unusually early bloom was followed by a relatively cool growing season indicated that the time from bloom to maturity was lengthened by these unusual conditions. Apparently temperature has less effect on the development and time of maturation of apples than might be expected from results reported for other types of fruit.

The period from bloom to maturity was shortened, particularly from the standpoint of attaining satisfactory dessert quality, when the crop was relatively light (high leaf area per apple) and was lengthened if the crop was relatively heavy.

There was some indication that heavy rainfall or ample soil moisture, particularly late in the season, may delay the time at which the

fruit becomes resistant to storage scald and thus increase the period from bloom to maturity with scald-susceptible varieties.

There was no evidence that other factors such as elevation or soil type had any direct effect on the length of time from bloom to maturity.

On the basis of these investigations recommendations are made as to the most satisfactory elapsed time from bloom to different stages of picking maturity for 11 of the varieties studied.

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