Tree-Conditioning The Peach Crop...

A study of the effect of thinning and other practices on size and quality of fruit

By M. J. Dorsey
and
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Tree-Conditioning the Peach Crop

By M. J. DORSEY and R. L. MCMUNN[1]

FROM THE TIME the peach crop actually appears on the tree in the form of fruit buds in midsummer until it is harvested the following July or August, the orchardist can do much to build up the size and quality of the fruit by the attention he gives to the bearing trees. An understanding of the practices that make it possible to influence the size and quality of the crop during the period when it is developing on the tree becomes more important to the grower as the demands of the market become more exacting. The grader can eliminate undesirable fruit but it cannot build up quality.

While the value of many practices has been proved by long experience and carefully controlled experiments, the value of others has remained to be proved, and new and better practices have needed to be developed. To provide further guidance to orchardists in their efforts to improve the peach crop by tree-conditioning it, the investigations reported herein were started at the Illinois Station in 1926.

During the first three years the experiments dealt largely with the time and severity of thinning. While these experiments were under way, it became evident that the success of thinning was influenced by other cultural practices, such as the type and severity of pruning, fertilizer applications, soil cultural practices, and weather. The work was then expanded to include the variables that could be controlled.

Later, tests were made to determine the advantages of delaying harvest in order to secure full benefit of the final swell of the fruit and the improvement in its quality. To give the study additional value, tests were made to find out the relative carrying quality of peaches picked at different degrees of maturity.

REVIEW OF LITERATURE

Just when the idea of thinning fruit first occurred to horticulturists would be difficult to state. Fruit trees, especially peach trees, have always been known to overcrop excessively when all conditions for a set were favorable. Therefore the need for thinning as a means of preventing the breaking of the trees, to say nothing of increasing the size of the fruit, would be obvious to growers after their first experience with overloaded trees. For a long time European horticulturists

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relied upon pruning to do a part of the thinning but this was under the special care given to fruit trees grown in limited numbers in gardens.

In the modern commercial orchard, where there are often extensive plantings of a single variety and it is necessary to put the entire crop into condition, the problem of thinning takes on a different aspect. Since the beginning of the commercial era in this country, as far back as the 1860's, American growers have been concerned with overloaded trees. From their own experiences and observations, practical men have made recommendations for thinning which required some experimental verification.

The idea of conserving the energy of the tree by getting the surplus crop off early has been emphasized by growers and scientists for many years. Flagg (1865) expressed his views on this point before the Illinois State Horticultural Society: "The fruit, if not sufficiently thinned by pruning and shortening in, must be thinned, if you would have the finest, to one on a twig [one fruit on a twig], and that, says Mr. Starr, should be the one nearest the base of the twig." Later Flagg (1867) added: "Thinning the fruit is very important in peach growing, but is praised more than practiced." Huggins (1868) remarked: "Thinning out the fruit when there is a full set, is of great importance. Let all imperfect, and the smallest fruit be taken from the tree, when not larger than a robin's egg, leaving the peaches from five to ten inches apart. . . ." Barry (1869), speaking in general terms, made this comment: "Our apple and peach orchards, and indeed all of our fruit trees, suffer severely from this cause [overbearing] and the importance of thinning, in connection with pruning, cannot be urged too strongly upon cultivators." Brown (1872) said: "I am inclined to think that Dr. Hull pushes thinning to an extreme. . . . That Dr. Hull's system is necessary to the production of market peaches, I have no doubt." The point of view toward thinning in New York in 1896 was stated by Beach (1896) as follows: "Thinning fruit has not generally become established among fruit growers, with the exception that peaches are usually thinned by those who grow this fruit extensively."

Many other early writers and growers also argued the need for thinning, emphasizing that it should be done early before the vitality of the tree was sapped by developing an excess number of seeds. Thus in 1864 a peach grower referring to the development of the seed said (American Pomological Society, 1864): ". . . the whole strength and vigor of the tree is exerted in that direction." Willard (1894), referring to plums, cautioned: "Do not be deceived; it is not the production of the fruit, but the perfection of the pit to perpetuate its species that reduces the vital powers of the plant and often leads to premature death." Gurney (1894) expressed much the same idea, stating that "the great strain upon the vitality of the tree is not in maturing the pulp of the fruit but in maturing the seeds." Goff (1897) said that "thinning fruit is the removal of a part of the fruits to prevent exhaustion of the plant by excessive seed production." Morrill (1899) stated that there are two periods when a tree gets a perceptible check in growth, one at blooming time and the other at pit-forming time, and two years later (1901) he said: "the drain on the peach is while the pit is forming before it hardens."

Some of the more recent writers have also agreed that thinning ought to be done before the vigor of the tree is impaired by excessive seed production. Rees (1919) says, "One of the greatest drains on the vitality of the tree comes from developing the seed." Gould (1923) writes:

> As the development of its pits is an exhaustive process, the limiting of the number of fruits tends to conserve the vitality of the tree. A large portion of the flesh of the peach is water; hence, if the soil is well supplied with moisture the development of the edible portion of the fruit makes a relatively light demand on the strength of the tree.

In line with this point of view is the statement of Burbank, who is quoted by Hall (1926) as saying, " 'It takes just about ten times as much—I'd better say it takes pretty nearly fifty times as much nourishment to make seed and skin as it does meat-fruit pulp.' "

It should be pointed out here, in view of the emphasis some writers have placed on the drain which seed development makes on the tree, that chemical analyses do not support this contention. Dorsey and McMunn (1926) wrote as follows:

> Throughout the entire period of growth the analyses of Bigelow and Gore show that the total solids in the flesh is two to three times greater than that of the stone. At maturity Penny found that the kernel contains more nitrogen and phosphoric acid than either the stone or flesh, and three times more potash than the stone.

More recent analyses (Lott, 1942) show the preponderance of dry matter in the flesh, especially during the third growth period.

The production of a better quality of fruit has long been recognized as another objective in thinning. As early as 1849, Cole (1849) explained the results of thinning as follows:

> In some cases, a tree hangs so full that it is impossible for it to perfect the whole crop; and the consequence of allowing it to remain on will be small, pale, insipid fruit. In many cases if half the crop be taken off while small, the other half would not only be equal to the whole in quantity, but owing to large size, fairness, and superior quality, it would sell for more, perhaps twice as much, in the market.

Somewhat later, Wilder (1871) gave the purpose of thinning as the production of a large crop of good-sized fruits that have quality. Gurney (1894) stated that thinned fruits are much better and handsomer. Goff (1897) said thinning "causes the remaining fruits to grow larger" and guards against overproduction.

A prominent authority of his day, J. H. Hale (1901), recognized thinning as a necessity when he said: "You cannot grow peaches successfully without thinning." Button (1909) noted that the paying results from thinning are size, flavor, and color. A place next to good cultivation in producing excellent qualities of fruit was assigned to thinning by Thomas (1909).

In improving the size and quality of fruit, thinning does not necessarily reduce yield. This is noted by Auchter (1917) and Bailey (1918) when they point out that, since the fruit is to be harvested anyway, it makes no difference in yield that part of it is thinned off while immature, if the remaining fruit grows large enough to make up for what is removed. That thinning brings about this compensation is stated by Peck (1923): "Six or seven hundred fruits may be removed from a mature tree heavily loaded, and still not reduce the number of pounds of fruit which the tree would ultimately bear if unthinned." Green (1910) also points out that thinning need not reduce yield. On the other hand, Moon *et al* (1941) report that thinning before the hardening of the stone reduced the yield 20 percent but increased the average weight of the peaches 40 percent.

Other objectives in thinning have been expressed by a number of writers. Cooch (1906) says that it is economical in that it saves time at picking. Rees (1919) notes that thinning prevents the trees from breaking and affords an opportunity for grading the fruit on the tree.

The main objectives of thinning have been summarized by Gourley (1925) as follows:

> To increase the size, color, and quality of the remaining fruits; to produce a more uniform product; to prevent breakage of limbs and trees from overweight; to bring about more regular bearing; to maintain the vigor of the trees; and to decrease disease and insect injury.

Drew (1926) also emphasized the value of thinning in relieving the load on the tree, preventing breakage, and preserving the vitality of the tree.

Thinning and pruning are also looked upon as a means of keeping the tree producing a hardy crop of buds each season. To illustrate, Morrill (1899) expressed the belief that trees which are thinned as well as pruned "go into the winter strong and full of vitality and capable of wintering live buds and sound wood, while trees that are not controlled in this manner fail." Wickson (1900) said that thinning ". . . joins hands with pruning in preserving the health and future production of the tree."

From this review of literature it can be seen that, at the beginning of commercial horticulture in this country, the need for thinning bearing peach trees was recognized. The importance given to the practice by different writers usually varied with the objectives that they thought were to be gained. However, it remained for some of the more recent writers, such as Chandler (1925) and Gourley and Howlett (1941), to first present a discussion of thinning in a separate chapter in a textbook and thus put this phase of orcharding on a comparable basis with some of the other necessary practices like pruning and fertilization.

TREE-CONDITIONING AND SIZE OF CROP

Whether a peach grower has a bumper crop, a light crop, or an off year is dependent upon many factors which come to a focus in the spring. A single factor, such as the amount of fruit-bud killing, may have had a large part in determining the outcome of the crop one year but may be almost negligible the next season.

Some of the factors that influence the success of the peach crop, such as the amount of thinning and the kind of fertilizer, can be regulated by the grower but other factors may be only partly under his control. Still the better a grower understands how a peach crop is affected by different sets of circumstances, the better prepared he will be to apply his practices intelligently in order to set the stage for the crop. If the spring is late and fruit-bud killing has been heavy, for example, the grower, in conditioning the tree for the crop, will need to know how to adjust his pruning to the number of buds that he estimates will set.

Shoot Growth

In order to relate shoot growth to production and tree-conditioning, the basic structure of the shoot must be understood. As the shoot grows, the fundamental plant unit, the node, is repeated over and over again. Between the nodes are the internodes. At the node three types of specialized structures may arise: leaves, buds, and shoots. Buds are of two kinds, leaf buds and fruit buds. The shoots may be looked upon as an expansion of a leaf bud during the current season.

As the tree responds to its environment, adjustments are evident in the period of time the shoot continues to grow and in its length and complexity. Elongation ceases early in the season in shoots that are not vigorous, but in vigorous shoots elongation may continue until after midsummer. The length a shoot attains and the number of days it grows are thus closely related and both involve an increase in the number of nodes and thus an opportunity for the formation of more fruit buds. The variations in the complexity of nodal development, taking into consideration leaves, buds, and lateral shoots, were found (Dorsey, 1935) to fall for the most part into these five classes:

Class 1, representing the lowest degree of development at the node, includes those nodes which bear a single leaf without the development of either a leaf or fruit bud in the angle between the leaf and the shoot. These blind nodes are of no consequence in fruit-bud production or subsequent growth.

Class 2 consists of nodes with a single leaf and either a leaf bud or a fruit bud centrally located in the leaf axil.

Class 3, like Class 2, has at the node a single leaf but there usually are in addition two or three buds—a leaf bud centrally located and a fruit bud on either one or both sides of it—or more rarely two fruit buds without a leaf bud, or occasionally three fruit buds.

Class 4 has the same fruit- and leaf-bud combinations as Class 3, but it has more than a single leaf at the node. In Class 4, leaves are sometimes formed on only one side of the primary leaf, but a secondary leaf may develop on both sides of the primary. There may even be a fourth leaf formed in the axil of the primary leaf.

Class 5 represents the next possible step in growth complexity—the formation of a lateral in the axil of the primary leaf during the growing season. Classes 4 and 5 occur mostly when the terminal growth is 18 inches or more.

These five classes of nodes describe the kinds of growth response which normally take place on peach shoots. The longer the shoots are up to a certain point, the more nodes there will be and the more opportunity for those classes which include fruit buds. Extremely long shoots may produce only a relatively few fruit buds.

Pruning as related to shoot growth. In order to obtain a more accurate picture of the extent of the bearing surface on the peach tree, the length of all living shoots on four 12-year-old Elberta trees in the Heaton orchard were measured to the nearest quarter-inch at the end of the season in 1931. These shoots were then grouped into classes differing by 2 inches (Table 1).

The trees were making a fairly typical growth. They were in plots set up in 1930 to study the different degrees of pruning in an off year on the size of the crop and fruit the succeeding year. The fertilizer applications were the same for each tree. Trees 2-2 and 2-3 were in the plot given a thinning-out type of pruning—that is, small, well-distributed cuts—in March, 1930 and 1931. At the same time, Trees 3-2 and 3-3 were cut back into one- and two-year-old wood according to the practice of peach growers in southern Illinois. Measurements made in December, 1930, before pruning, showed an average shoot length for the four trees as follows: Tree 2-2, 11.36 inches; Tree 2-3, 9.7 inches; Tree 3-2, 17.51 inches; and Tree 3-3, 19.02 inches (Table 1).

There was a surprisingly large number of shoots less than 2 inches long on the trees given both types of pruning. Ruth (1921) has shown that such short shoots may be very productive of fruit buds per unit of length.

The total number of shoots produced on the four trees varied from 2,270 to 2,983. It is evident, therefore, that some of the shoots must be left without peaches after thinning if the number of fruits per tree is reduced to 1,200, which is considered an adequate load for mature trees. Older and larger trees are likely to produce even more shoots than these four Elberta trees did.

TABLE 1.—LENGTH OF ALL LIVING SHOOTS AT END OF SEASON ON 12-YEAR-OLD ELBERTA PEACH TREES PRUNED IN THE SPRING BY THINNING OUT AND BY CUTTING BACK
(Heaton orchard, 1931)

Shoot length in inches	Shoots of each length on trees pruned by thinning out		Shoots of each length on trees pruned by cutting back	
	Tree 2-2	Tree 2-3	Tree 3-2	Tree 3-3
Below 2	586	712	688	378
2-3¾	1 077	1 046	1 173	850
4-5¾	291	447	525	420
6-7¾	128	208	252	259
8-9¾	73	126	110	167
10-11¾	49	103	69	100
12-13¾	38	59	43	68
14-15¾	15	30	38	50
16-17¾	6	13	29	38
18-19¾	4	4	18	27
20-21¾	1	0	12	25
22-23¾	1	0	9	14
24-25¾	0	1	7	10
26-27¾	1	1	3	6
28-29¾	...	2	0	4
30-31¾	...	2	1	4
32-33¾	...	...	1	4
34-35¾	...	...	1	2
36-37¾	...	...	3	2
38-39¾	...	...	1	2
40-41¾	...	...	...	1
42-43¾	...	...	...	1
44-45¾	...	...	...	1
Total shoots	2 270	2 754	2 983	2 433

Influence of nitrogenous fertilizers. In the spring of 1928 an experiment was started in the Bates orchard to test the relative effectiveness of some of the nitrogenous fertilizers on trees growing on the soil type of that region (silt loam on tight clay and yellow-gray silt loam). The trees selected were uniform in size, vigor of growth, and type of pruning. Previous to 1928 all trees in the experimental block had received annual applications of nitrogenous fertilizers with occasional light applications of manure. The experiment was laid out as a single-row treatment for each of the following fertilizers: cyanamide, ammonium sulfate, and sodium nitrate. Guard rows of trees not receiving fertilizer (check trees) were located between the treated rows. The number of trees used for experimental purposes in each row varied from 10 to 15 (Table 2).

In order to measure the effect of the different fertilizers upon growth, a sufficient number of 2- or 3-year-old limbs ½ to ¾ inch in diameter were chosen from each vertical quarter of the tree to get 25 shoots to measure. The upper half of the tree as well as the lower half was represented, and all the living shoots on the limbs selected were measured until 25 measurements were recorded for each quarter of the tree. By making the choice in this way, the tendency to select shoots of any given length or type was, for the most part, eliminated. When a total of 100 shoots per tree was measured to the nearest ¼

TABLE 2.—SHOOT GROWTH ON ELBERTA PEACH TREES DURING A HEAVY CROP YEAR WHEN DIFFERENT NITROGEN FERTILIZERS WERE APPLIED

(Bates orchard, Centralia, 1929)

Fertilizer treatment and time applied	Number of trees in plot	Number of shoots measured per plot	Number of shoots of each length[a]															Average shoot growth in inches
			1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	
$CaCN_2$, 5 pounds in March	10	981	64	245	226	177	95	53	38	27	20	11	9	9	3	2	2	3.89
$(NH_4)_2\,SO_4$, 3 pounds in March	10	1 000	214	398	153	94	52	32	24	13	11	3	2	2	2	0	0	2.77
$NaNO_3$, 5 pounds in March	10	1 000	10	138	125	127	129	123	124	83	54	37	23	13	9	2	3	5.54
$NaNO_3$, 5 pounds in July	15	1 500	25	341	341	253	175	127	90	48	38	24	13	10	8	2	5	4.29
No treatment	15	1 500	437	766	212	61	15	7	2	0	0	0	0	0	0	0	0	1.99

[a]The shoots were measured to the nearest quarter-inch, then grouped with 1″, 2″, etc., as the midpoints. The same plan was followed in Table 3.

inch by this method, the shoots were grouped into classes differing by 1 inch.

Since cropping was quite erratic from year to year in this orchard on account of the killing of fruit buds, the effect of the fertilizers was determined by the general appearance of the trees and by the length of the shoots rather than by yield.

With the application of greater amounts of nitrogenous fertilizers than had been used before, the foliage of the trees took on a darker shade of green. The leaves on the trees receiving cyanamide and ammonium sulfate were of about the same shade (moderately dark green). The leaves of the trees which had received nitrate of soda were a darker green. Because the trees in the three check rows made slow growth and bore leaves with a yellowish cast, the five west trees in each row were eliminated as check trees and were given 5 pounds of sodium nitrate per tree on July 1, 1929. By late summer this midsummer application had caused the leaves to take on a shade of green similar to that of the trees which had received the spring application of this material. The foliage of the check trees had a yellowish cast characteristic of low-nitrogen trees. Using leaf color as an index, there was no evidence of cross-feeding between rows.

As to shoot growth, applications of either cyanamide, ammonium sulfate, or sodium nitrate caused an increase in length of shoots over those on the check trees; and such an increase in shoot length would mean a potential increase in yield. Because it was a heavy crop year in spite of fruit-bud killing, the shoots tended to be short thruout the orchard generally, but they were typical of orchards with similar trees on a similar soil type. The trees receiving ammonium sulfate tended to form fewer long shoots than those receiving sodium nitrate or cyanamide. The average increase in vigor from all three kinds of fertilizer is shown by an average shoot length of 2.77 to 5.54 inches in the fertilized rows, compared with an average of 1.99 inches in the check rows.

Effect of pruning and nitrate applications. Experiments combining nitrogenous fertilizer applications and different pruning types were set up in the Heaton and McBride orchards in 1930 and 1931. Pruning was done in the spring of 1930, a year when all the fruit buds were winterkilled, and again in the spring of 1931, a year when there was no fruit-bud killing. Shoot measurements were made in December both years.

The trees used at the start were of only medium growth vigor but were under excellent cultural care. At the time the experiment was begun, the McBride trees were 9 years old and the Heaton trees 11 years old. In both orchards the trees had developed a tall spreading top with the bearing shoots fairly short and well toward the end of long rangy scaffold limbs. The length and position of the bearing shoots with reference to the original top spread and the time the crop matured were noted. The check trees were unpruned.

The types of pruning were for the most part repeated in each orchard so that the growth response could be studied under a wider range of conditions. The types used in the combined treatments were as follows:

Very heavy pruning, approaching dehorning, consists of cutting back into the scaffold branches. Limbs as large as 2 to 2¾ inches in diameter were removed on older trees. The lateral spread of the top was reduced by such heavy cutting. The fruit buds left were for the most part on the small branches (Fig. 1). This type of pruning is seldom used in Illinois now except in correcting trees that have been severely winter-injured.

In the *heavy type of pruning,* cuts were made into 2- and 3-year-old branches which were for the most part under 1½ inches in diameter (Fig. 2). The spread and height of the top was reduced to some extent but not so much as in very heavy pruning. More than half of the fruit buds were removed and the crop as a result was borne on lateral branches and what terminal growths were left.

The *medium type of pruning* was comparable in severity to the kind of pruning generally done by growers in this state (Fig. 3). The cuts seldom in-

Fig. 1.—Growth response after very heavy pruning approaching dehorning. A year previous, in the spring, these trees were pruned by making large cuts, such as shown at **a.** A vigorous growth was made the same season (**b**). This year only corrective cuts were made, such as the one shown at **c.** Note how the spread of the tree has been kept. (*Bates orchard*)

Fig. 2.—Heavy pruning leaving a wide tree spread. A large number of bearing shoots have been removed from the trees (*upper picture*). This will greatly reduce the need for thinning later on. A vigorous shoot growth to bear next year's crop is produced after this type of pruning (*lower picture*). (*McBride orchard*)

cluded branches over ¾ inch in diameter. The spread of the top was reduced but little and only about one-fourth to one-third of the fruit buds were cut off in most cases. There was plenty of bearing wood left on the tree but it was thinned out so that the light reached most of the crop.

Thinning out is a light type of pruning practiced for the most part when

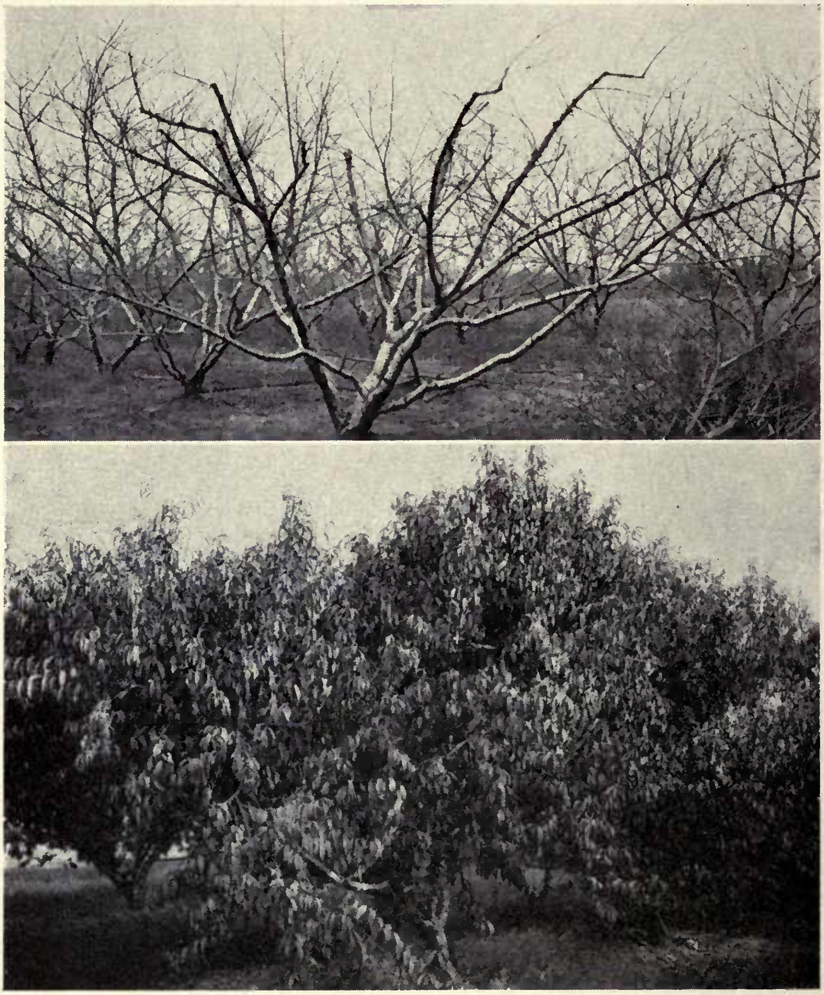

Fig. 3.—Moderately heavy pruning. The trees shown in the upper picture have just been pruned. The tops have been lowered 4 to 5 feet. The scaffold limbs will support the crop and no propping will be necessary. The heavy foliage on these trees after harvest (*lower picture*) shows how much moderate pruning may stimulate shoot growth. The trees are of the same type as shown in Fig. 4 after a thinning-out pruning. (*Heaton orchard*)

the fruit-bud killing has been extensive (Fig. 4). An excess of bearing wood is left (Fig. 5). In this type of pruning there is practically no reduction in the height or spread of the top in a tree type such as shown in Fig. 6, and growers generally find it necessary to make heavier cuts the following year.

The nitrogenous fertilizers applied in the early spring of both years were limited to nitrate of soda and ammonium sulfate in amounts varying from 3 to 5 pounds per tree. The applications were spread evenly on the ground under the trees in an area extending as far as the tips of the branches.

In measuring the shoot growth the same method was followed as in the preceding experiment to study the effect of nitrogenous fertilizers on shoot growth.

Length of shoots.—By taking as a base the relatively short shoot growth on the unpruned trees (Table 3, lines 1 and 6) and on the trees pruned by thinning out (lines 11 and 17), contrasts in growth as the result of pruning can be brought out. The medium-heavy type of pruning when used without nitrogen in the Heaton orchard induced adequate growth averaging 10.9 inches in 1930, an off year (line 5);

Fig. 4.—Thinning-out type of pruning. Altho as many as 360 cuts were made on each of the trees shown above, the cuts were small and the tops of the trees were not cut back. On trees of this type the limbs, unless propped, will bend to the ground under the weight of a full crop. Old trees tend to produce short shoots after being pruned in this way. (*Heaton orchard*)

TABLE 3.—SHOOT GROWTH IN TWO ELBERTA ORCHARDS 10 AND 12 YEARS OLD WHEN DIFFERENT PRUNING, NITRATING, AND THINNING TREATMENTS WERE USED, 1930 AND 1931
(120 shoots measured per tree)

Year and line	Row	Number of trees	Spring pruning treatment	Fertilizer treatment	Number of shoots measured	Number of shoots of each length[a] 1"	2"	3"	4"	5"	6"	7"-9"	10"-12"	13"-15"	16"-18"	19"-21"	22"-24"	25" and above	Average shoot growth in inches[b]
Heaton orchard (10 years old)																			
1930 (off year, no thinning)																			
1	1	5	None	None	600	3	34	75	85	67	58	103	64	71	27	11	1	1	7.59
2	1	6	None	None	720	2	54	121	101	66	45	133	79	64	42	13	0	0	7.32
3	2	10	Thinning out	None	1 202	0	4	15	58	94	117	321	230	201	84	41	17	20	10.38
4	3	10	Heavy	None	1 200	0	1	0	0	3	17	79	152	206	175	175	127	265	19.16
5	4	11	Medium	None	1 320	2	16	37	79	97	118	305	212	178	133	84	26	33	10.90
1931 (heavy crop year, 5-inch thinning)																			
6	1	5	None	None	600	98	166	106	47	29	30	62	36	24	1	1	0	0	4.18
7	1	6	Thinning out	$NaNO_2$, 3 lb.	720	22	91	129	106	57	41	88	69	51	36	12	10	8	6.94
8	2	10	Thinning out	$NaNO_3$, 3 lb.	1 200	107	251	165	110	90	76	165	149	69	14	1	2	1	5.55
9	3	10	Heavy	$NaNO_3$, 3 lb.	1 200	44	168	273	157	91	72	122	83	91	46	35	7	11	6.50
10	4	11	Medium	None	1 320	142	321	270	149	79	54	128	105	55	10	6	1	0	4.64
McBride orchard (12 years old)																			
1930 (off year, no thinning)																			
11	1	6	Thinning out	None	720	61	371	212	53	18	3	2	0	0	0	0	0	0	2.46
12	2	6	Thinning out	$(NH_4)_2SO_4$, 5 lb.	720	106	297	194	65	35	13	9	1	0	0	0	0	0	2.60
13	3	6	Heavy	$(NH_4)_2SO_4$, 5 lb.	720	19	128	195	148	93	56	59	10	9	2	1	0	0	4.16
14	4	6	Heavy	None	720	36	104	181	166	94	50	62	15	8	3	1	0	0	4.21
15	5	6	Medium	None	720	33	149	208	154	79	40	43	8	4	2	0	0	0	3.77
16	6	6	Medium	$(NH_4)_2SO_4$, 5 lb.	720	21	104	153	120	106	78	101	32	4	0	1	0	0	4.66
1931 (heavy crop year, 6-inch thinning)																			
17	1	6	Thinning out	$NaNO_3$, 5 lb.	720	49	176	234	146	41	23	35	11	3	2	0	0	0	3.46
18	2	6	Thinning out	$NaNO_3$, 5 lb.	720	29	109	180	130	80	49	70	38	24	8	3	0	0	4.83
19	3	6	Heavy	$NaNO_3$, 5 lb.	720	28	85	139	115	80	36	80	61	44	30	12	3	7	6.39
20	4	6	Heavy	$NaNO_3$, 5 lb.	720	32	144	160	110	67	34	56	51	39	18	8	1	0	5.29
21	5	6	Medium	$NaNO_3$, 5 lb.	720	43	116	134	116	55	38	71	55	36	34	19	3	0	6.01
22	6	6	Medium	$NaNO_3$, 5 lb.	720	36	68	132	105	65	53	79	53	63	45	15	4	2	6.82

[a]See footnote at bottom of Table 2, page 332, for explanation of groupings. [b]Averages were figured before the shoots were grouped into classes.

Fig. 5.—Bearing surface affected by pruning. The trees in the left row, which were pruned lightly, have much more bearing surface than those in the right row, which were pruned heavily. If both rows were thinned so that the fruits were the same distance apart on the shoot, the crop loads would differ in size. (*McBride orchard*)

but in 1931 (line 10), while the shoot growth was adequate, it was reduced to an average of 4.6 inches. The heavy crop probably was an important factor in the lower average for 1931. In the McBride orchard the effect of medium pruning on shoot growth when used with and without nitrogen in 1930, the off year (lines 15 and 16), was about the same as when the trees were given 5 pounds of nitrate of soda in 1931, the heavy crop year (lines 21 and 22).

After the heavy pruning there was some variation in the response in the two orchards. In the Heaton orchard in 1930 shoot growth made an excessive response to the heavy cutting even when nitrogen was not applied (line 4). The following year these same trees bore a heavy crop but still made an excessive growth when this type of pruning was supplemented by 3 pounds of nitrate of soda. In the McBride orchard response to heavy pruning in 1930 was not so pronounced as in the Heaton orchard and there was little difference in the growth between the nitrated trees and those not nitrated. The next year, however, the heavily pruned trees (lines 19 and 20) bore a heavy crop and also produced more longer shoots than they did the previous season.

These experiments illustrate the way in which pruning can be combined with nitrate applications to control shoot growth under practical orchard conditions. The results agree with the findings of

Harmon (1933) under California conditions in showing that the shoots grew longer after heavier pruning.

In general, the leaf color was the deepest green on the more vigorous growth, whether induced by pruning or by fertilizer applications. As in the experiments in the Bates orchard, there was no evidence of cross-feeding between rows.

Lowering the bearing surface.—Growers should note how the bearing area of the tree can be lowered by pruning trees of the type shown in Fig. 4 back to the extent shown in Figs. 1 and 3. In this instance the bearing surface was brought about 5 feet nearer the ground. The

Fig. 6.—Old trees after a thinning-out pruning. These trees have an expansive top, or bearing surface. Compare them with trees given other types of pruning. (*American Fruit Grower's orchard*)

unpruned trees had long scaffold branches that bent down so far that the entire crop was picked from the ground. Some large branches broke under the strain of the bending. Moderately heavy pruning during an off year will correct such high trees which have not been previously cut back and in this way will make both thinning and picking easier and less expensive.

Delaying maturity.—Sometimes growers attempt to delay picking in a part of the orchard by heavier pruning or nitrate applications. The heavy pruning in the McBride orchard combined with 5 pounds of nitrate of soda (Table 3, lines 19 and 20) delayed ripening about 5 days; while with moderately heavy pruning, nitrated trees were delayed only 2 or 3 days. The available soil moisture had much to do with the time harvest was delayed following these combined treatments.

Fruit Buds

Once shoot growth on a tree is made, the amount of bearing surface is determined and the formation of the fruit buds sets the stage for the crop. Of the fruit buds formed on the new shoots, a large percentage may winterkill. Of the buds that survive, another part will be taken off by pruning in the spring, and after bloom the crop will be further reduced during the natural drops. If, after the drops are over, the tree still has more fruit than it is able to mature, further adjustment in the crop load can be made by thinning. This section deals with the way in which tree-conditioning is related to the formation and development of fruit buds.

Quantity of fruit buds produced. While the total number of fruit buds produced by a variety fluctuates greatly year after year, it is generally recognized that during any one year the peach normally produces more fruit buds than are necessary for a crop. In the spring of 1931 the flowers were counted on an average-sized 12-year-old Elberta tree in the Heaton orchard, where no killing of fruit buds had occurred during the winter. The tree was found to have produced over 23,000 flowers. The number of flowers borne by a tree of the Captain Ede variety of the same age and of comparable size was estimated as over 40,000. These numbers may be exceeded by larger trees, but they suggest the amount of excess flowers that have to be dealt with in some instances on large unpruned trees.

Fluctuation in the number of fruit buds produced between varieties and in the same variety from season to season may be expected in view of the variation in the growth that takes place at the node, as was pointed out in the description of the five classes of nodal development (pages 329-330).

Since the number of fruit buds produced is one of the underlying factors determining yield, the fruit-bud level was studied over a period of years in the Foote orchard in early spring. Ten representative shoots were cut from each tree in 16 different fertilizer plots each year. Since there were 14 to 20 record trees in each plot, this made a total of 140 to 200 shoots per plot each year upon which to base the fruit-bud determinations. The sample shoots were terminal twigs cut from all sides of the tree 5 to 8 feet above the ground, since it was thought that these shoots would be the most directly responsive to cultural conditions. Shoots thus selected were each divided into three parts of equal length—*base, middle,* and *tip.* Both the number of nodes and the number of fruit buds for each section were then ascertained and used as a basis for determining the fruit-bud level for the year.

The fruit-bud level of Elberta varied from year to year (Fig. 7), confirming the observation of growers. The number of fruit buds produced on different sections of the shoot also varied from year to year (see also Knowlton and Dorsey, 1927). During those years when the fruit-bud level was low, the proportion of fruit buds produced on the middle section of the shoot tended to be greater than when the fruit-bud level was high. Even during the years when the fewest fruit buds were produced in this orchard, there were enough for a full crop, provided that winterkilling was light and the set was high. These figures are based upon a relatively large count of both nodes and fruit buds.

Since the fruit-bud level varies from year to year, the grower needs to be on his guard to keep the level high by means of cultural practices. This is his best assurance that he will have a full crop, even tho number of fruit buds and the size of the crop are not directly related, because winterkilling must also be taken into consideration.

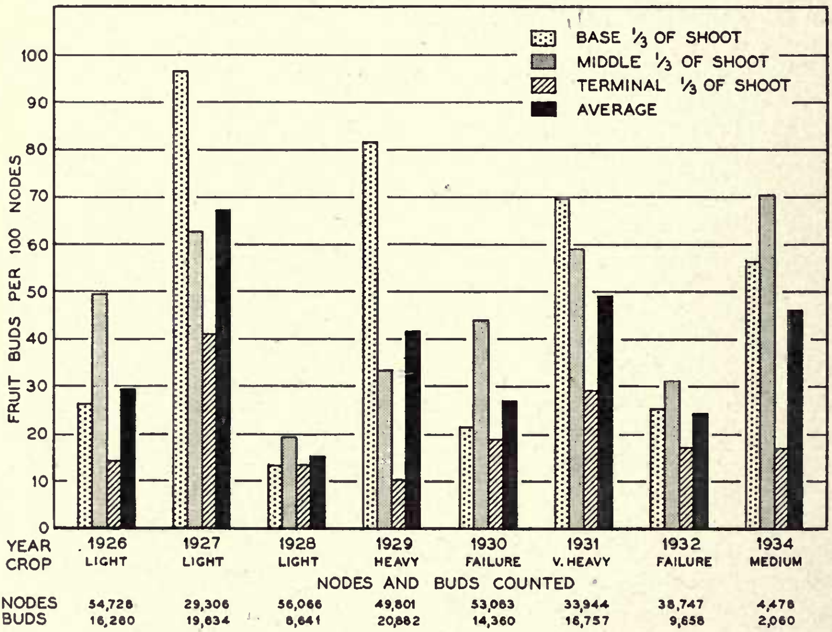

Fig. 7.—Year-to-year variation in the number of fruit buds. The average number of fruit buds on the base, middle, and terminal thirds of 100 nodes on Elberta trees during eight seasons (1926-1932 and 1934) is shown above. During this time even the smallest number of fruit buds produced in 1928 was enough for a full crop. The crop was light in that year because so many of the buds were winterkilled. No counts were made in 1933. (*Based on data taken in Foote orchard and previously reported by McMunn and Dorsey, 1943B.*)

TABLE 4.—WINTER SURVIVAL OF FRUIT BUDS AND EXTENT OF PEACH CROP DURING FIRST 19 CROP YEARS IN AN ELBERTA ORCHARD
(Foote orchard, 1926-1944; trees planted in 1922)

Year	Fruit buds surviving up to full bloom	Extent of the crop	Year	Fruit buds surviving up to full bloom	Extent of the crop
	perct.			*perct.*	
1926	58	Light	1936	95[a]	Failure
1927	81	Light	1937	25	Medium
1928	30	Light	1938	50	Heavy
1929	48	Heavy	1939	0	Failure
1930	0	Failure	1940	100	Heavy
1931	100	Very heavy	1941	0	Failure
1932	91[a]	Failure	1942	25	Medium
1933	0	Failure	1943	15	Light
1934	30	Medium	1944	95	Medium
1935	50	Heavy			

[a]The flowers were killed at full bloom.

Killing of fruit buds. Experience has shown that the loss of a part of the crop from either the killing of the fruit buds during the winter or the killing of the flowers during the late spring freezes may be a blessing in disguise, since thinning later on is greatly reduced or even made unnecessary.

Some investigators have placed the winter survival of fruit buds necessary for a crop as low as 3 to 10 percent of the quantity produced (Chandler, 1908). Ten percent would seem to be a safe margin for the trees of Elberta and 5 percent for Captain Ede, if a sufficiently large proportion of the fruit buds which survive were to set.

The percentage of flowers which set is equally as important as the percentage which survive, as shown by records in the Foote orchard. In 1927 as many as 81 percent of the fruit buds came thru the winter, but there was only a light crop (Table 4). In 1929 only 48 percent of the fruit buds survived the winter, but there nevertheless was a heavy crop that year.

The crop record in the Foote orchard is especially interesting because it shows the relationship between the survival of fruit buds thru the winter or early-spring frosts and the possible need for thinning later in the summer. In this particular orchard, which may be looked upon as typical, in only 5 out of the 17 years did the fruit-bud survival and the set reach a point high enough to make thinning necessary. Because a crop loss would interfere with the experiment, it was deemed inadvisable, under Illinois conditions, to attempt to check the effect of thinning upon either fruit-bud initiation or hardiness, as was reported under New York conditions by Tukey (1939) and by Tukey and Einset (1938). In 1938 a heavy crop followed the loss of as many as 50 percent of the fruit buds. On the other hand, in 1932 and 1936, altho fruit-bud survival was high, the crop was a failure because the flowers were killed by a freeze at full bloom. In 1937 and 1942 medium crops were obtained with a fruit-bud survival as low as 25 percent.

Reduction of fruit buds in pruning. There is always some concern among growers over the possibility of cutting off too many fruit buds when pruning, especially when fruit-bud development is light or winterkilling excessive. Since pruning is a part of tree-conditioning, the reduction of buds from this practice was given some study.

When fruit-bud killing is severe and the number of buds surviving approximates the number necessary for a crop, pruning may be delayed until the set can be determined after the second drop. A light pruning, consisting of cutting out shoots and smaller limbs upon which there are no fruits, can under these conditions take the place of the regular pruning. The reduced number of peaches will be partly counterbalanced by the larger size of the fruit at harvest. In observations made in a number of orchards a fair growth stimulus followed this light type of pruning made late in the season and enough buds were formed for a crop the following year.

In the Foote orchard in 1927 careful counts were made of the number of fruit buds cut off in the moderately heavy type of pruning practiced in this state. In the regular orchard pruning, consisting of moderately large cuts for the most part but including both small and large cuts, 33 percent of the fruit buds were removed in making an average of 521 cuts per tree on each of six 10-year-old Elberta trees. In this same experiment, in making an average of 581 smaller cuts per tree on each of three trees, 52 percent of the fruit buds were cut off. In making moderately heavy pruning cuts on a 5-year-old Elberta tree at the Olney Farm in 1931, 4,965 fruit buds were cut off and 5,724 were left on, which is more than enough for a crop.

The reduction in fruit buds by pruning was also studied in two instances when larger pruning cuts were made. In the Foote orchard in 1927, in making an average of 166 pruning cuts per tree on four trees 10 years old, 42 percent of the fruit buds were cut off.

In the McBride orchard in the spring of 1930 two 8-year-old Elberta trees, similar to that shown in Fig. 4, were pruned very heavily. Even tho all of the fruit buds were winterkilled, they had not shed at the time of pruning. After making bud counts on several representative limbs, it was estimated that the trees bore about 10,000 to 12,000 fruit buds each. The heavy pruning removed 90 percent or more of the fruit buds. Following the heavy spring pruning of 1930, the trees produced a rank growth, many of the shoots forming laterals with few fruit buds per unit of length. Again in the spring of 1931 the two trees were pruned heavily. After this pruning 1,025 flowers were left on one tree and 1,986 flowers on another. For the most part these flowers were on hang wood and not on the vigorous growths of 1930.

These studies of the reduction which may be expected to take place in number of fruit buds as a result of different types of pruning will enable a grower to estimate roughly the number of buds cut off in the type of pruning which seems best suited to the condition of his trees. Since peach growers in Illinois generally prune moderately heavy, they cut off only about one-fourth to one-half of the buds by this practice. It would seem, therefore, that growers need have no concern that they will remove too many buds in pruning if the percentage of fruit buds winterkilled has not been high.

Defoliation as related to fruit-bud initiation. Early spring defoliation caused by leaf curl (*Taphrina deformens*) may result in the formation of very few fruit buds, especially on trees of low vigor. Trees that have been infected with leaf curl but are still in good vigor generally produce enough fruit buds for a crop, sometimes forming them on the later growth. In recent years the most extensive infection from the leaf-curl fungus in Illinois occurred in 1933, but even then the disease reduced the fruit-bud level seriously only in orchards with the severest outbreak.

In Illinois infection from bacterial spot (*Phytomonas pruni*) generally comes too late in the season to affect the formation of fruit buds. Defoliation caused by the disease reaches its height in the middle or late summer. Bacterial spot may, however, interfere with leaf activity to such an extent that the hardiness of the fruit buds and shoots may be affected.

Because leaf curl and bacterial spot potentially affect the size and quality of fruit in the current crop or the formation of fruit buds for the succeeding crop, it is worth while to take measures to hold these diseases in check.

The Drops

The natural dropping of fruit generally reduces the set, or the proportion of the fruit buds apparently undergoing normal development after pollination and fertilization. Therefore the amount of thinning required cannot be definitely foretold until the drops are over. The drops, which are commonly referred to as the first, second, and the third, or June drop (May drop, further south), differ as follows:

First drop. The first drop in the peach comes about two weeks after full bloom in the latitude of Illinois and about three weeks after full bloom in Georgia, according to Harrold (1935). It is composed of flowers in which for various reasons the pistil has failed to develop properly (Fig. 8a); the pistil, or immature fruit, has not grown large enough to fill or break the shuck. In some flowers only the pistil has been killed by freezes and the anther is not injured. Such flowers open and produce normal pollen but they fall soon after bloom. In others, the pistil is suppressed at later stages, which prevents fertilization.

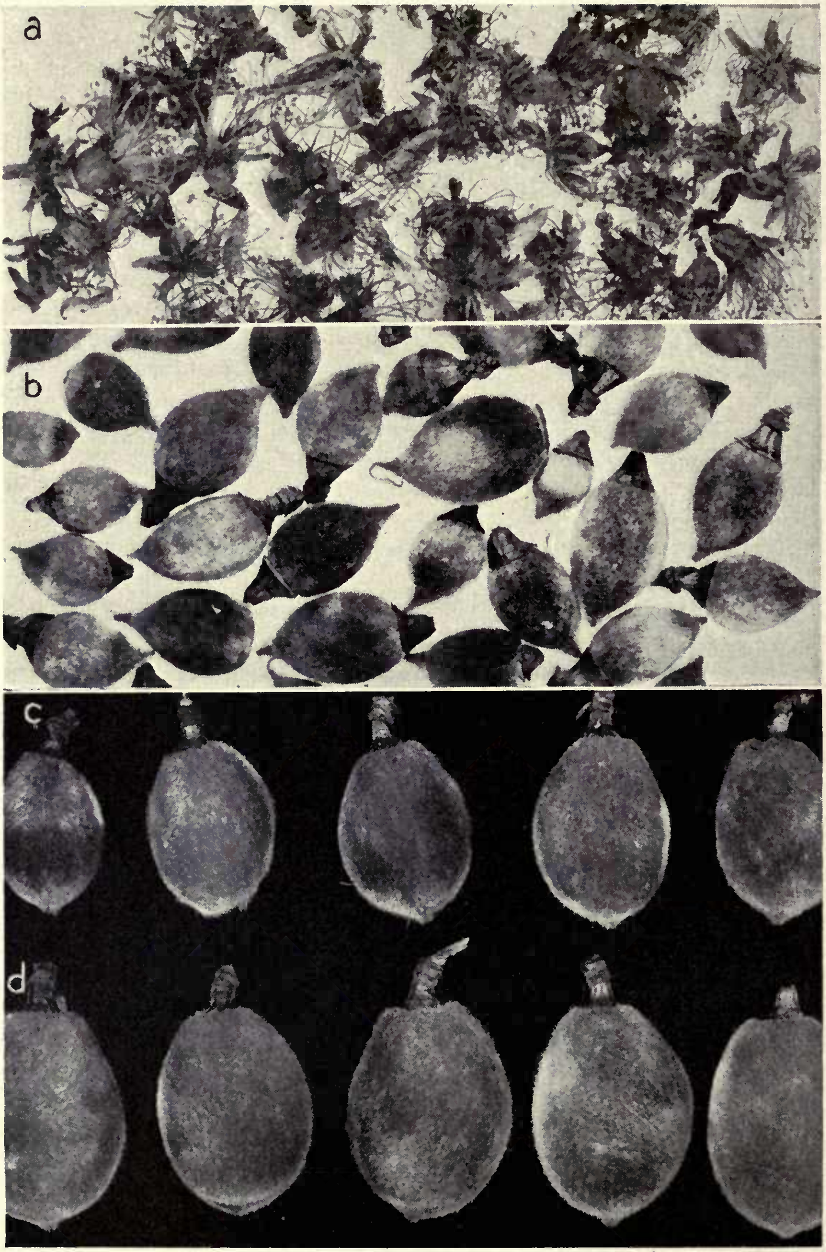

Fig. 8.—Stage of development at the drops. The first drops still have shucks (**a**). From the second drops the shucks have been shed (**b**). Third, or June, drops (**c**) are smaller than peaches remaining on the tree (**d**).

Generally, the first drop in the peach is light and hence inconspicuous as compared with the apple or plum. It should be taken into consideration, however, because it sometimes includes a large proportion of the flowers produced. Winterkilled fruit buds start falling a week or ten days before bloom and are all down by full bloom and are not for that reason included in this drop.

Second drop. This drop is sometimes called the nonpollinated drop, or more properly the nonfertilized drop, since pollination and tube growth can take place without fertilization. The pistils which fall at this drop differ from those which fall at the first drop in these respects: (1) they develop in an apparently normal way up to full bloom or even a few days afterward; (2) they persist longer than flowers of the first drop, the peak of the Elberta drop coming in Illinois during the fifth and sixth weeks after bloom (a few may persist as late as the June drop); (3) for the most part they enlarge and shed the shuck before falling (Fig. 8b).

June drop. The June drop, also known as the third or physiological drop, is made up of larger fruits than the second drop (Fig. 8c) and comes on a week or ten days later. Studies made in Illinois of peaches that have fallen during this drop show that fertilization has taken place because an embryo is present. These findings check with those of Detjen (1926) and Harrold (1935). Altho the June drop is generally the most conspicuous because the peaches are now larger, it may not be the most important one in reducing the crop.

Apparently there is not a distinct gap between the time of the second and third drops in the peach. A distinction might be made based on the presence of an embryo in peaches falling during the third drop rather than on the time they abscise.

To study the time peaches drop when fertilization has not taken place, all flowers on a vigorous Elberta tree growing in a tub were emasculated but not pollinated. Under greenhouse conditions most of these unfertilized pistils grew slowly compared with those in which fertilization had taken place, but the unfertilized pistils persisted until pulled off for special study 50 days after bloom. In this instance the nonpollinated, and hence unfertilized, pistils persisted into the period normally assigned to the June drop. The overlapping of these two drops, as measured by the number of fruits being cut off from day to day, is probably caused by the persistence of the most vigorous fruits of the second drop and the early abscission of the weaker peaches of the June drop.

Relative extent of the drops. A survey made in two Elberta orchards in 1937 showed the relative proportions of the three natural drops. In one orchard the first drop was very light; at the second drop there were 20 to 30 fruits per square yard under the trees; and at the June drop 80 to 120 fruits per square yard. In the second orchard the first drop was also very light; the second drop averaged about 25 fruits per square yard; and the June drop only 8 to 10 fruits per square yard. That same season the first drop was negligible in an orchard planted with Gage; the second drop was heavy; and the June drop was very light.

These differences between the severity of drops may be expected to occur in different orchards, in different varieties, and from year to year. They are determined by the outcome of the competition between the fruits on a tree, which in turn depends on many factors, such as the time the flower opens, the time it is pollinated and fertilized, the genetic constitution of the gametes, the position of the fruits on the tree, and the general nutritional level of the orchard.

Unproductive Shoots

Relatively few shoots on the peach tree fail to form fruit buds; but as a result of winterkilling, natural drops, and thinning, some of the shoots become unproductive by midseason. To get some idea of the proportion of shoots that were actually bearing the crop, a count was made of the bearing and nonbearing shoots on four 5-year-old Elberta trees at the University farm at Olney in July of 1931, a year when there was practically no fruit-bud killing (Table 5).

TABLE 5.—NUMBER OF BEARING AND NONBEARING SHOOTS ON 5-YEAR-OLD ELBERTA TREES THINNED TO 5-INCH AND 10-INCH SPACINGS
(University farm at Olney, 1931)

Thinning distance, inches	Tree	Bearing shoots	Nonbearing shoots	Leaves
10	7-2	422	318	56 202
10	10-2	315	451	44 638
5	9-2	214	259	46 806
5	11-2	295	222	45 876
Total	....	1 246	1 250	......

The trees had been given a moderately heavy spring pruning, which had eliminated about a third of the fruit buds and probably about the same proportion of the shoots. The set was heavy, and thinning was delayed until after the June drop. The thinning crew was instructed to leave only one peach on all bearing shoots less than 10 inches long and to reduce the clusters on longer shoots by thinning off small or defective specimens first and then spacing the remainder about 6 inches apart. In following this procedure some of the shoots could have been completely stripped of peaches if all the peaches were defective.

It was surprising to find that in midsummer after thinning about half the shoots on trees of this age were not bearing peaches. The proportion of nonbearing shoots would be expected to vary greatly from year to year on account of differences in the set, the drops, or the severity of thinning. If, after the tree is pruned, the number of shoots still exceeds the number of peaches that can be sized up, it follows that some of the shoots must be fruitless. The number of nonbearing shoots would be expected to increase somewhat during the summer because of the loss of fruit from storms or accidents. These nonbearing shoots are not parasitic, however, but take part in the general nutrition of the tree, and new shoots grow from them which develop fruit buds for the next year's crop.

Summary

The shoot system of the tree is affected by differences in growth conditions, pruning, fertilizers, fruit-bud killing, and the drops. A count of shoots of all lengths on a tree showed that the total number of shoots was considerably more than the number of peaches adequate for a full crop after thinning. The number and length of shoots, as well as the position of the bearing wood with reference to its height and its spread, varied according to the pruning and nitrate applications used.

Since the production of shoots and buds was shown to be excessive, attention was directed to the extent they were reduced by pruning. Fruit-bud survival affects yield only indirectly, but full crops were not obtained when more than 80 or 90 percent of the total number of buds was killed. After fruit-bud killing, the extent of the crop is determined by the severity of the three drops, and the need for thinning cannot be known for certain until they are over.

Because the number of fruit buds or fruits is greatly reduced as the season progresses, by midseason nearly half the shoots on bearing trees may carry no fruit. This proportion would be expected to vary considerably with seasons and with varieties, but fruit-bud killing, the drops, and thinning all contribute to the complete loss of peaches from a part of the shoots.

In the final analysis, therefore, the shoots produced by the tree can be put into three groups: (1) those removed by pruning, (2) those which are left on the tree but bear no peaches, and (3) those which are productive. Thinning is limited to the productive shoots and is practiced as the final step in tree-conditioning the crop.

GROWTH OF THE FRUIT

The growth of the peach may be looked upon as starting with the microscopic rudiment in the fruit bud after the rest period is over in December. Since the chief interest in this study is centered about the fruit crop, the details of fruit-bud initiation are omitted. The stage of development reached in Gage by October (Fig. 9a) and in Elberta by February (Fig. 9b) should first be observed to get some idea of the amount of growth that takes place during the winter months. As early

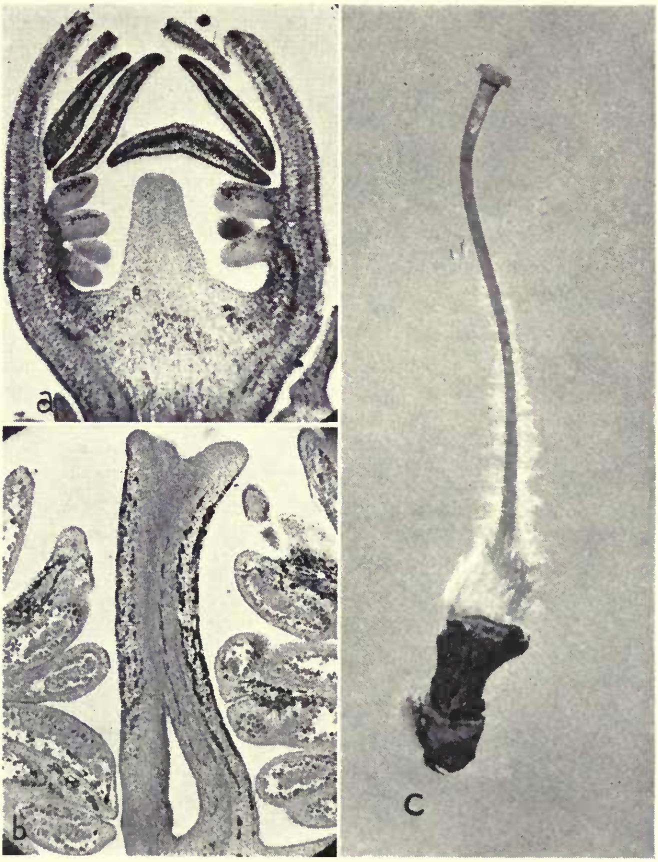

Fig. 9.—Peach pistil at three stages of growth. The pistil at the end of the growing season in October is shown at a, as it appears the following February at b. Note the large amount of growth that has taken place during the winter. The pistil at full bloom is shown at c with the other flower parts cut away. (a *and* b *are magnified 55×,* c *is magnified 6×*)

as full bloom (Fig. 9c) the base of the pistil—that is, the young peach—is quite pubescent. The shedding of the shuck as a result of the rapid growth after fertilization may be looked upon as marking the emergence of the fruit from the bud and the flower.

Growth Periods

Three fairly distinct growth periods are now generally recognized in the fruit of the peach. These were outlined by McElvain (1915), an observing Illinois grower, in the following terms:

If you will notice the peach in growing, it will grow the first month to a size large enough to cover the seed, then the late ones will stand still, apparently, possibly for two months; then a few days or weeks before ripening it begins to grow very fast, and will swell out almost double or treble size.

This sequence of a rapid growth period and then a slow one and another rapid growth period has probably been recognized by practical orchardists for some time, but it took detailed measurements of the growth rate of peaches at frequent intervals during the season to verify these observations. The three growth periods, as defined first by Conners (1919), were verified later by others (Blake, 1925; Dorsey and McMunn, 1927; Lilleland, 1932; and Tukey, 1933A and 1939).

First growth period. Petal fall and the initial stages of hardening of the stone at the tip are generally looked upon as marking the approximate limits of the first growth period. Tukey (1933A) shows that in New York the time from bloom to the time the stone begins to harden at the tip (53 to 55 days) is surprisingly uniform in both the early and late varieties in a single season. The stone of Elberta, however, was found to be hardening at the tip in Illinois in about 42 days in 1926 (Dorsey and McMunn, 1926), but this stage was not reached in this same orchard in 1927 until 64 days after full bloom. It should be noted however (Fig. 10), that in 1927, the first growth period was exceptionally long when dated from petal fall, this being brought about by the cold weather which delayed the early growth of the fruit. However, under normal conditions, the first growth period in Illinois can be considered to include about the first 45 days after full bloom, but will vary from year to year, depending on growing conditions early in the season.

The outstanding developments in the fruit during this period include: (1) fertilization, (2) growth of the stone and seed coats to nearly full size, (3) slower growth in the flesh as compared with that in the third period, (4) shedding the shuck, (5) the three drops, (6) end of division in the flesh cells 30 days or so after bloom (Nightingale *et al,* 1930; Dorsey and Potter, 1932; and Tukey and Einset, 1938).

Second growth period. The external dimensions of the peach do

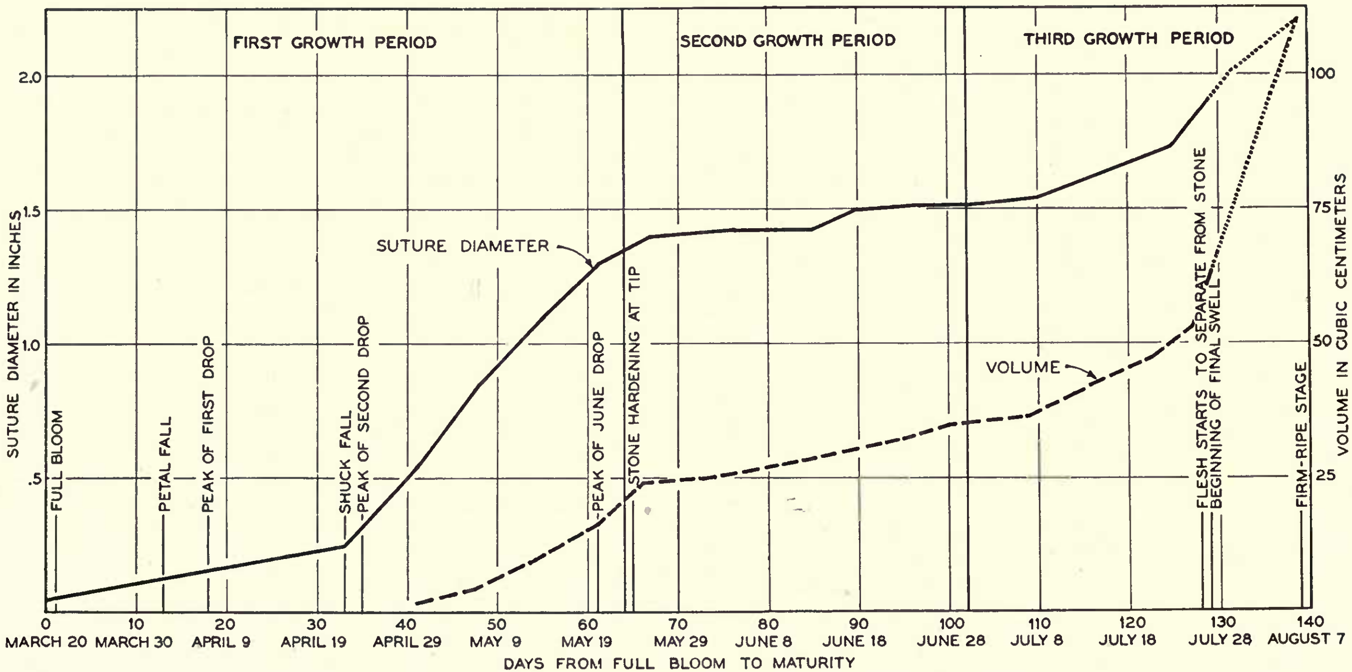

Fig. 10.—Development of the Elberta peach during the three growth periods. The data are for the long season in 1927 when 140 days elapsed between bloom and harvest. Note the striking increase in the size of the fruit both in diameter and volume during the final swell. The fruit was firm ripe on August 8.

not increase so markedly in the second growth period as in the first and third periods; but there is a constant increase in ash content or dry weight during the second period, as brought out by the work of Lott (1931 and 1942).

In Elberta the second period normally extends from about the 45th day after full bloom to about the 70th day afterward, or up to the beginning of the third period. Unlike the first period, the second period differs in length among varieties, being short in the early varieties such as Red Bird (Early Wheeler), Mayflower, Greensboro, and Carman (Conners, 1919; Tukey, 1933A), and even being absent in Sneed and Triumph (Lilleland, 1932). Carman showed a shorter second growth period than Elberta in the measurements made by Dorsey and McMunn (1927) in Illinois.

The distinguishing feature of the second growth period is that it varies with different varieties and is completely absent in some. During the second period occurs (1) hardening of the stone and (2) development of the cotyledons.

Third growth period. This period is characterized by expansion of the flesh of the peach, especially in the cheek diameter. While there are no visible external changes in the stone during this period, the analyses of Lott (1932, 1939, and 1942) show that important chemical changes are taking place in it.

The outstanding features of the third period are: (1) growth of the flesh ending in the final swell (limited to about the last two weeks), the soft-ripe stage and the abscission of the fruit; (2) maturing of the kernel; (3) increase in size of flesh cells; (4) accelerated increase in dry-matter content of the flesh (Lott, 1932 and 1942); (5) greater growth rate in the cheek diameter than in the suture diameter; (6) separation of the flesh from the stone in the freestone varieties; and (7) development of the characteristic flavor and color.

The peach continues to expand as long as it is attached to the stem, even tho the flesh has become soft in the meantime (McMunn, 1933; and Dorsey and McMunn, 1934). It is during the third growth period, and especially during the final swell, that the crop overload taxes the capacity of the tree to the greatest extent.

Manner of Growth

While the growth phases of the peach seem to fall into three fairly distinct periods, as indicated by external measurements, the growth of the fruit as a whole is a continuous process. This will be evident from the following considerations:

1. When the growth of the fruit is measured by volume instead of suture diameter (Fig. 10), the retarded enlargement during the second period seems less pronounced (Dorsey and McMunn, 1927;

and McMunn, 1933). The suture diameter and the length of the fruit measure more than the cheek diameter at first, but the cheek diameter becomes relatively larger at maturity. This relationship varies somewhat in different varieties (Blake, 1925) but in commercial varieties like Elberta or J. H. Hale, the increase in the cheek diameter under good growing conditions is characteristic of the final swell.

2. Even tho the stone reaches its full size about the time it begins to harden at the tip, from that time to maturity it increases in dry weight nearly fivefold, as shown by the analyses of Lott (1932). In other words there are two distinct phases in the growth of the stone—a period of rapid enlargement up to full size, followed by deposition of material in the cells.

3. The different parts of the kernel do not develop simultaneously (Dorsey and McMunn, 1926). It is true that the seed coats enlarge very rapidly as the stone grows and enlarges, but the embryo and cotyledons do not expand until relatively late in the second growth period (Fig. 11). Tukey (1933B) shows that the time that elapses between bloom and embryo growth is remarkably uniform in all varieties, even those which vary as much in blooming time as Greensboro and Chili. The chemical analyses of Lott (1932) check closely with the histological studies. A development similar to that in the peach apparently occurs in the apricot, as shown by the studies of Lilleland (1930 and 1936) and Lilleland and Brown (1936).

From this analysis it will be seen that growth in the peach is really continuous. Development in stone and kernel overlap those in the flesh. There are additional features of growth which show further how the expansion of the fruit is part of a continuous growth process. The first of these is the way in which the cells increase in size.

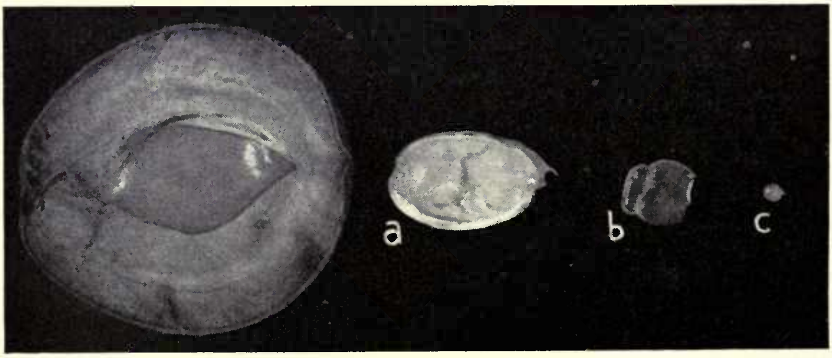

Fig. 11.—Seed parts during middle of second growth period. Note how small the rudimentary cotyledons (**c**) are in relation to the endosperm (**b**) and the seed coats (**a**). The cotyledons will grow and fill the seed coats early in the third growth period. The variety is J. H. Hale; all parts are natural size.

Relation of cell growth to enlargement of fruit. As the peach enlarges, either of two processes can take place: (1) cells increase by dividing continuously thruout the season; or (2) cells formed during the earlier stages of growth expand. In the peach the period of active cell division is stepped up somewhat after fertilization but gradually comes to an end in the epidermal and flesh cells in Elberta about one month after bloom (Addoms *et al,* 1930; Dorsey and Potter, 1932; and Tukey and Einset, 1938). From then on, the peach enlarges, not by the formation of additional cells, but by the second method, the stretching and expansion of the walls of cells previously formed.

The extent of the stretching process in the outer flesh cells of Elberta collected at different times during the season has been determined. At bloom many of the flesh cells are about 12 microns[1] in

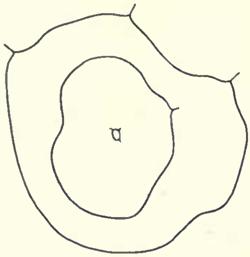

Fig. 12.—Relative size of flesh cells in the peach at different growth stages. The smallest cell represents a flesh cell in the pistil at full bloom; the cell next in size, the same flesh cell at the end of the second growth period; the largest cell, the flesh cell at maturity if the peach sizes up to a diameter of 3 inches.

diameter. At the end of the first growth period when the stone starts to harden at the tip, about 45 days after bloom, the outer flesh cells have increased to 25 to 40 microns in diameter. At maturity in large specimens of Elberta some of the larger flesh cells range from 250 to 270 microns across the greatest diameter. These dimensions are somewhat larger than those given by Ragland (1934) because the larger cells were purposely selected.

As the cell dimensions increase, the volume of the cells naturally increases in proportion. While the cells are irregular in size and it is difficult to determine their volume accurately, the increase in volume can be closely approximated by using the average diameter of a number of measurements (12 microns for the diameter at bloom, 270 microns at maturity). On this basis the volume of some of the larger flesh cells in ripe Elberta peaches observed in these studies was about 11,400 times as large as the volume of the cells in the pistil base at bloom (Fig. 12).

Increase in volume of fruit. In Elberta the pistil at full bloom measures $\frac{3}{32}$ inch in diameter and weighs .1 gram. It would require 226,800 fruits of this size to make a bushel (50 pounds). The pistil

[1]A micron equals .025 inch.

Fig. 13.—Seeds from large and small peaches. The seeds in the top row are from Elberta peaches sized 2¼ inches and larger, those in the bottom row are from Elbertas sized 1¾ inches and less. Altho the larger peaches have larger seeds, the total weight of the seeds in 50 pounds is less than in the same weight of the smaller peaches. The seeds are approximately natural size.

grows rapidly after fertilization so that at shuck fall, two to three weeks after bloom, the suture diameter is about ¼ inch. A typical pistil now weighs about .7 gram and there are about 32,000 pistils in 50 pounds. At the end of the first growth period the diameter has increased to about 1.4 inches and the number in 50 pounds has been reduced to about 960. At the end of the second period when the suture diameter is 1¾ to 2¼ inches, the number in 50 pounds is about 480. At maturity individual fruits of Elberta vary in size from 1¾ to 3 inches or even more.

Growth in diameter from $\frac{3}{32}$ inch at bloom to 3 inches at harvest involves an increase in volume of nearly 33,000 times. This increase in the volume of the whole fruit is even greater in proportion than the increase in the volume of individual cells because many additional cells

TABLE 6.—NUMBER, SURFACE AREA, AND WEIGHT OF FLESH AND OF SEEDS IN 50 POUNDS OF ELBERTA PEACHES OF DIFFERENT SIZES

Size class in inches	Approximate number	Surface area	Weight of flesh	Weight of seeds
		sq. ft.	*lb.*	*lb.*
1¼ to 1½	960	40	40.0	10.0
1½ to 1¾	611	35	43.0	7.0
1¾ to 2	340	26	45.0	5.0
2 to 2¼	250	25	45.5	4.5
2¼ to 2½	195	24	46.7	3.3
2½ to 3¾	140	23	47.0	3.0
2¾ to 3	110	20	47.3	2.7
3 to 3¼	90	17	47.5	2.5

are formed before cell division in the young pistil ceases. Growth, however, involves an enormous increase in the volume of the cell as well as in the volume of the whole fruit.

As the fruit increases in size, the number of peaches in a given weight of course decreases: in 50 pounds there are only about half as many peaches 3 inches in diameter as peaches 2¼ inches in diameter. This inverse relationship between size and number of fruits is shown in Table 6. The figures listed are based upon counts of a large number of bushels of Elberta sized to ¼-inch intervals by orchardists. Other varieties with characteristic differences in shape may vary somewhat from the numbers given.

As the size of the fruit increases, the weight of the flesh increases and the seeds become larger (Fig. 13). At the same time the proportionate weight of the seeds decreases, as does the number of seeds in a given quantity of peaches (Dorsey and McMunn, 1932). When peaches are larger there is also less surface area for a given amount of flesh and the job of peeling is lighter.

Summary

The peach builds up from a tiny rudimentary structure in the bud to a very complex fruit of much greater size at maturity. After fertilization, during the first growth period, enlargement of the seed coats and the stone takes place rapidly and is followed by the growth of the embryo in the second and third periods. As the fruit enlarges, the cells divide and increase in number up to a certain stage. Then the individual cells stretch and enlarge with the growth of the peach.

As the season advances and the peaches increase in size, the number in a given weight decreases rapidly and the weight of flesh increases. Yield can be measured in two ways, either by the size of the fruit or by the number of peaches produced. When the tree cannot size up all the fruit that sets, a grower must at thinning time choose between size and number and adjust the crop to the tree accordingly.

TYPES OF THINNING

In working out a procedure for thinning, horticulturists have tried three types—distance thinning, thinning according to the fruit-leaf ratio, and thinning with the total fruit load in mind. A brief discussion of each type follows.

Distance Thinning

The oldest conception of the way to thin is to space fruits a certain distance apart on the shoot. This is known as distance thinning, a practice still in general use by orchardists. Five-inch thinning, for example, means spacing the fruit as nearly as possible 5 inches apart on the bearing shoots (Fig. 14). In popular writings the way to space fruit in thinning was illustrated by a long, straight shoot before and after it had been thinned. Wickson (1900) gave the following directions for thinning: "The distance between the fruit shall be two and one-half times the diameter desired in the fruit." This would "fix an arbitrary distance of 6 to 8 inches for peaches." About the same time Fulton

Fig. 14.—Thinned and unthinned branch. The branch to the right is from a tree thinned to a 5-inch spacing. Note how much larger the peaches on this branch are than those on the unthinned branch to the left. The branches are from Elberta trees of similar vigor.

(1901) wrote that "a distance of ten inches between fruits seemed to be none too great."

When the thinning investigations at the Illinois Station were started in 1926, the following method of spacing was adapted in thinning experimental trees: In using the 5-inch spacing, for example, the peaches on the longer shoots were thinned so that those remaining were as near 5 inches apart as possible. If there was more than one peach on shoots under 9 inches, all except one were pulled off. On the older wood (2 or 3 years old or older), if the lateral fruiting growths were short (under 3 inches so that the peaches were borne close to the limb), these older growths were also thinned to a 5-inch spacing. In using this method, the distinction between the different thinning distances consisted primarily in the proportion of shorter shoots left with only one peach.

After observing thinning done as described above for the first three seasons both on experimental trees and in commercial orchards, it became evident that this type of thinning, using distance alone as a guide, left a crop excess on the tree. To obtain data that might point out the inherent weakness of distance thinning, it was decided in 1929 to: (1) study the results from distance thinning in a commercial orchard and (2) set up an experiment to compare trees thinned to a 5-inch interval with those thinned to a 10-inch interval. The first part of this study was carried out in the Bates orchard.

Distance thinning in a commercial orchard. A large block of 12-year-old Elberta trees in the Bates orchard had been given the usual 5-inch thinning by an experienced crew. The crop from a representative tree was picked firm ripe at harvest and run over a commercial sizer. In the size group of 1¾ inches or below, there were 262 peaches which weighed 37 pounds; in the 1¾-to-2-inch group, the 1,734 peaches weighed 310 pounds; and in the 2-to-2¼-inch group, there were only 375 peaches which weighed 81 pounds. Altho the crop borne by this tree was about 9 bushels, it was disappointing because so much of the fruit grew no larger than 2 inches in diameter. The orchard had been given excellent care and the trees had been pruned moderately heavy in the spring.

Obviously it is necessary to reduce the crop more in thinning trees like this, with a broad top and many fruiting branches. A load of 2,371 peaches was too large for such a tree to size up properly, at least under the growth conditions of the summer of 1929. Thinning had been delayed so that full advantage could be taken of all the natural drops. In spite of the number of flowers or peaches that fell at the drops, it apparently was easy for the crew to leave an overload on the trees when thinning to a 5-inch interval because an excess of short fruiting branches had been left after pruning.

Comparison of 5- and 10-inch intervals. In the second phase of the 1929 studies an experiment was set up in the McBride orchard using 17-year-old trees (Table 7, lines 1 and 2). Three trees were thinned to a 5-inch interval and three to a 10-inch. Both sets of trees had been making a moderately vigorous growth and each tree was given a 3-pound application of sodium nitrate in the spring. Pruning consisted of making moderately heavy cuts well toward the end of the scaffold branches, an operation which reduced the crop considerably.

That a large excess crop had set on the shoots left after pruning was shown by the fact that it was necessary to pull off many peaches in thinning these two groups of trees. Naturally more peaches were thinned off in the 10-inch than in the 5-inch spacing. Here again trees spaced to the 5-inch interval seemed to have an excess load, a large part of the crop from them sizing in the 2-to-2¼-inch class or below. The trees thinned to the 10-inch interval (line 2) bore a lighter crop, but the fruit could all be picked on the first picking date because it had ripened evenly. With the 5-inch spacing, three pickings were required. Both sets of trees were thinned 64 days after bloom, or near the start of the second growth period (Fig. 10).

From these studies made in 1929 it was apparent that distance thinning needed further study. The results in the Bates orchard emphasized that an overload was a handicap in controlling fruit size. In the McBride orchard the difference in the time of maturity between peaches spaced to the 5-inch interval and those spaced to the 10 inches suggested that a crop excess also affects evenness of ripening.

Another experiment was therefore set up in 1931 at the University farm at Olney (Table 7, lines 3 to 6). Five-year-old Elberta trees which had been given comparable pruning and cultural treatments were used. The orchard had been treated with a spring application of 3 pounds of nitrate of soda per tree. The 5- and 10-inch spacings were

TABLE 7.—SEVERITY OF THINNING: YIELD AND SIZE OF FRUIT FROM ELBERTA TREES THINNED TO 5-INCH AND 10-INCH SPACINGS
(McBride orchard, 1929, and University farm at Olney, 1931)

Orchard	Thinning treatment			Number of trees	Proportion of crop in size classes indicated[a]					Yield per tree	Yield of fruits above 2¼" in diameter
	Spacing	Days after bloom	Fruits thinned off per tree		1¾" and less	1¾"-2"	2"-2¼"	2¼"-2½"	2½"-2¾"		
	in.				*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*lb.*	*perct.*
1. McBride......	5	64	1 063	3	1	19	64	17	0	228	17
2. McBride......	10	64	1 544	3	0	4	40	56	0	195	57
3. Olney........	5	46	1 997	5	0	0	14	66	20	141	86
4. Olney........	10	46	4 340	5	0	1	11	59	28	256	87
5. Olney........	5	60	702	4	0	0	10	80	10	196	89
6. Olney........	10	60	1 205	5	0	0	5	88	8	154	95
7. Olney........	Check	..	.....	5	0	8	60	31	1	243	32

[a]Thruout the experiments reported in this bulletin the peaches were grouped into size classes by means of commercial grading machines.

Fig. 15.—Clustered set in Elberta. Clusters like these should be thinned by removing the smallest peaches until those remaining are far enough apart so that they will not touch when ripe.

compared at two thinning dates, the first one before the June drop and the second one after it.

The 10-inch thinning was much more time-consuming than the 5-inch thinning, as many more fruits had to be taken off. In using either interval, the average number of peaches thinned off before the June drop (46 days after bloom) was much greater than after the June drop (60 days after bloom). That the crop excess in this orchard was sufficient to reduce the size of the fruit considerably if no thinning was done, was shown by the large proportion of the fruit from the check trees in the 2-to-2¼-inch class (60 percent). Apparently this excess was taken care of under the conditions of this experiment by thinning to the 5-inch interval.

In studies of distance thinning made at the Ohio Station, Shoemaker (1934) showed that, after the crop was thinned, only about a third of the peaches were actually spaced according to the distance interval used. Since 20 percent of the fruits were more than 8 inches apart on the limb before thinning, they could not even be spaced according to the 8-inch interval, the largest one used. Only a relatively small percentage of the crop was spaced at a shorter distance than the 4-inch, 6-inch, and 8-inch intervals used.

Shoemaker's studies and those made at the Illinois Station show that thinning by distance alone has the following shortcomings: First, the principle of removing all fruits except those a certain distance apart on the shoot is difficult to apply with accuracy. Actually selecting the spacing distance that will leave the right proportion of the crop on the tree is a difficult problem. No set rule can be applied because the type of shoot growth on a tree is so variable. For example, if many of the fruits are clustered (Fig. 15), a 5-inch thinning may be severe. In the second place, if all the thinning is done at one time by spacing the fruit a certain distance apart, it is not possible to improve the crop by removing the small and imperfect peaches.

The distances of thinning indicated in these experiments are descriptive of the severity of the thinning rather than of the precise distances between the fruits left on the tree.

Thinning According to Fruit-Leaf Ratio

Another approach to the thinning problem has been made thru a study of the relation between size of fruit and number of leaves on the tree.

Review of literature. Some earlier writers were aware that a relationship existed between number of leaves and size of fruit. Thus Hull (1865) says:

> If the tree is showing fruit, they must be so subordinated, by careful pruning, until the fruit shall, by its demand on the tree, prevent the further formation of leaves, except at the extremity of the vertical or leading branches, that each individual leaf shall receive its full share of light, and may add all that a perfectly formed leaf can impart to the development of the fruit. This reduced growth of leaves will, if they be favored during their natural period of growth, do its full share of work in maturing a full crop of large and highly colored fruit. . . .

McAffee (1871) wrote: "The fruit and the seed within are the result of the leaves closest to them—fair, large fruit, if they have a chance to do so. . . ."

Recent experiments dealing specifically with the fruit-leaf ratio in the peach have been reported by Weinberger (1931), Overholser and Claypool (1931), Jones (1931), Weinberger and Cullinan (1932), Kinman (1941), and others.

In these experiments the number of leaves per fruit were varied from 10 to 100 by thinning and pruning. Because of shoot growth and loss of fruit, some further attention was necessary during the summer to keep the fruit-leaf ratio constant. The bearing area under study was generally set off from the rest of the tree by ringing.[1]

A few illustrations will give some idea of the results from these studies of thinning according to the fruit-leaf ratio. In Weinberger's

[1]Ringing consists of cutting out a ring of bark as deep as the cambium and of varying widths up to about ½ inch. This procedure was outlined for the first studies with the apple by Haller and Magness (1925). It is supposed to prevent the translocation of carbohydrates downward in the bark past the ring but at the same time it permits the movement of water and mineral substances upward thru the xylem (sap wood) past the ring.

report (1931), Elberta peaches showed a definite increase in size as the leaf area per fruit increased. In this instance the upper limit was 75 leaves per fruit. Chemical analyses showed that fruit grown with only 5 leaves had 5.4 percent sugar, whereas fruit grown with 10 leaves per fruit had 7.6 percent sugar. The percentage of sugar ran somewhat higher with a larger leaf number.

In the analysis of the fruit-leaf ratio reported by Overholser and Claypool (1931), Elberta peaches were thinned on June 15 to ratios varying from 35 to 125 leaves per fruit, both in a ringed and an unringed series. At harvest, while the color and time of maturity of the fruit in the two series were nearly the same, the ringed series showed greater variation in fruit size. In both series the percentage of sucrose in the fruit increased as the number of leaves per fruit increased.

The experiment reported by Jones (1931) furnished data on the relationship between fruit size, leaf number, and soil moisture. The setup included a study of the size of the fruit in relation to leaf number per fruit in plots which were irrigated, mulched, in "average" condition, and also in a "dry" condition. A ratio of 15, 30, 45, 60, and 90 leaves to a fruit was set up in each plot for the variety Georgia Belle. As in the other experiments, size of fruit in each plot increased as the leaf numbers increased. Also with a given leaf number, fruit size and quality varied in the different plots according to the amount of soil moisture.

The results of the studies of Weinberger and Cullinan (1932) with fruit-leaf ratios agree with the other studies in showing that on ringed branches fruit size, seed size, and dry weight of fruit increased with the larger leaf numbers which, in this instance, ran 10, 20, 30, 40, 60, and 80 leaves per fruit. The production of fruit buds on the ringed branches also varied directly with the number of leaves per fruit. The extremes were 7 fruit buds per 100 nodes on ringed branches with 10 leaves per fruit to 56 fruit buds per 100 nodes when the leaf number per fruit was stepped up to 60.

The results of studies made by Kinman (1941) show that as the leaf area per fruit is increased on ringed branches of irrigated trees, the amount of red on the fruit is decreased. This is shown by the following figures: with 10 leaves per fruit, 45 percent of the surface was solid red; with 60 leaves per fruit, 17 percent was solid red.

Illinois studies. In 1929 in the Illinois studies, all leaves were first counted on a large Elberta tree in the Bates orchard. This tree had been given the regular orchard type of pruning and bore about 1,300 peaches that season. On September 1 it retained 65,797 leaves and 2,467 were on the ground—68,264 in all. Again in 1931 the leaves were counted on four 5-year-old Elberta trees in the thinning plots at the University farm at Olney (Table 5). Unfortunately, after these trees were thinned and the leaves counted, there was some loss of fruit in midsummer as a result of spray injury, which made it impossible to maintain the fruit-leaf relationship until maturity. At the time of thinning, however, a crop load of 1,000 to 1,200 peaches was left per tree. These trees bore 44,000 to 56,000 leaves each, giving a fruit-leaf ratio of 1 to 40 or 1 to 50. This number approximates the middle values of the experiments noted above.

Practical value of fruit-leaf ratio. In making use of the fruit-leaf ratio as a further check or guide to the severity of thinning under practical conditions, a grower should thin a tree or a part of the tree as seems most desirable from past experience. By determining the number of leaves and then dividing it by the total number of fruit left after thinning, he can use the fruit-leaf ratio to check distance thinning. In the actual practice of thinning, however, the principle of the fruit-leaf ratio, like that of distance, is somewhat difficult to apply with certainty because the fruit-leaf ratio established at thinning time is later changed during the build-up in leaf number from summer growth.

Thinning According to Total Load

Thinning in order to adjust the crop to a load that the tree will be able to size up has been discussed for many years. Thus Starr (1872) said: "When the fruit has been thinned out, or more correctly speaking when it has been proportioned to the capacity of the tree, the results have been precisely similar to those produced under the same treatment for the vine." Flagg (1872) reports, "Dr. Hull's idea is about five hundred peaches to a full grown tree."

A similar approach to thinning was advocated in California in 1922 by Weldon (1922) who recommended a thinning schedule which took into consideration the age of the tree, the distance between trees, the size of the fruit desired, and the approximate tonnage expected per acre. Thus, for a yield of 5 tons an acre from trees spaced 20 feet apart, 624 peaches per tree were recommended for a crop of 2¼-inch fruits and 324 peaches for a crop of 2¾-inch fruits. Figuring by the same method, Weldon gives the approximate crop load for a yield of 1 to 10 tons an acre for the 2¼-, 2½-, and 2¾-inch sizes. These recommendations are, of course, for irrigated orchards in which the supply of soil moisture can be regulated more closely than under Illinois conditions.

As some of the limitations in applying the principles of distance and fruit-leaf ratio for thinning became apparent, the following recommendations were made to Illinois peach growers in 1931 (Dorsey and McMunn, 1931A and 1931B): ". . . select a typical tree in the orchard for a standard. This tree should be thinned with reference to the total crop to be left." Thinning according to the total crop load has also been recommended in New York by Tukey and Einset (1938) and by Tukey (1939) and in Arkansas by Cooper (1942).

It would not be difficult to adjust the crop in an orchard to the desired limits if the growing conditions of a season could be foretold. Since this cannot be done and seasons vary greatly, it would probably be best to thin the crop to the most desirable limits for the drier seasons. Then, if the season does not turn out dry but favorable for sizing up fruit, the peaches will grow to a larger size and in this way tend to make up the same yield as would have been obtained had a larger number of peaches been left on the tree. After the size of the load for the drier seasons is computed, it may be desirable to leave about 100 extra fruits on the tree in order to allow for possible loss later from oriental fruit moth, wind, hail, or accident.

Summary

A comparison was made of three methods of adjusting the crop to the tree—distance thinning, thinning by the fruit-leaf ratio, and thinning according to the total load.

Detailed measurements of distance thinning, together with general results obtained in using it under commercial conditions, showed that the principle on which it is based is difficult to apply, and that in using it growers tend to leave an overload on a tree when there are a large number of short fruiting branches.

The principle of the fruit-leaf ratio is difficult to apply because, after the thinning is done, the leaf number increases with the summer growth.

Thinning according to the total load was found to be the best method to use under Illinois conditions. With this method a grower can take full advantage of what he knows about the productivity of his orchard and the type of trees in it.

Thinning to such an extent that most of the crop may reasonably be expected to size up to a 2¼-inch minimum during the drier seasons may seem severe. The resulting increase in the size of the fruit may be expected, however, to make up for the decrease in number.

It is an advantage to a grower to understand each of the three thinning methods so that he can supplement one with the others.

GROWTH RESPONSE TO THINNING

When part of an excess crop is removed by thinning, how soon and to what extent is the lighter load reflected in the enlargement of the peaches which remain on the tree? Since this question is basic to an understanding of the thinning problem as well as to an interpretation of the data on thinning, a series of experiments was set up to study the response to thinning under different conditions.

The measure of response was based upon the growth rate after thinning and the size of the fruit at maturity. Other factors such as

Fig. 16.—Sizer used in thinning experiments. The slots widen out uniformly from the top to the bottom of the grader. The peaches that are 1¾ inches or less in diameter drop out first and are caught in the box below. The peaches measuring 1¾ to 2 inches fall out next and are caught in another box. They are followed in turn by the other sizes, each ¼ inch larger than the preceding one. Only the peaches measuring 2¾ to 3 inches in diameter reach the bottom.

quality, color, and chemical composition are also affected by thinning, but size was selected primarily because it could be determined most easily under orchard conditions. Size was measured by means of a caliper or a grader with slots gradually increasing in width (Fig. 16).

Thinning at Different Times

In 1927 an experiment was carried out in the Foote orchard to study the growth response to thinning done at different times during the season. The trees selected for the study were carrying what seemed to be an excess crop. A series of trees were each thinned to a 6-inch spacing at different times starting at shuck fall, which because of the cold spring was 41 days after bloom, and continuing at weekly intervals thereafter until harvest time.

The average number of fruits removed per tree in the first thinning was 949 from Elberta, 2,001 from Captain Ede, and 788 from Carman (Table 8). The average number removed per tree decreased considerably at the later thinning dates, especially after the June drop. The effect of thinning at each date was determined by getting the average weight, volume, and suture diameter of a random sample of 50 to 100 peaches per tree. Since no fruit was removed from the check trees, all peaches on small limbs were measured in order to reduce the possibility of selecting only peaches of a certain size. The plan of this experiment was such that the growth rate of the fruit could be compared for three varieties on thinned and unthinned trees. Comparisons of thinned trees were made before and after thinning at different dates thruout the season up to and including harvest. (See Dorsey and McMunn, 1927, for further details.)

On the Elberta and Carman trees the effect obtained from thinning was not reflected in an increase in the average diameter of the fruit until about two weeks before harvest; the Captain Ede fruit showed no increase from thinning (Table 8). During the early part of the season there apparently was not a large enough overload to retard the growth of the fruit. In experiments at the Ohio Station (Shoemaker, 1934) the set was much heavier than in this instance. Accordingly in the Ohio experiments early thinning (46 days after bloom) was more effective than late thinning (76 days after bloom). It would seem, therefore, that early thinning would be most effective when the set is exceptionally heavy.

Thinning Tree Units of Different Sizes

In order to obtain data on the relation between individual peaches on the tree, a series of experiments was set up to study the effect of thinning tree units of different sizes. The units selected were: half trees, large limbs, and small limbs.

Half tree. In 1929 five 14-year-old Elberta trees in the Perrine orchard near Centralia were matched for uniformity of size and crop load. Even tho the trees had been given the regular orchard thinning after the June drop, an average of 226 peaches were removed from each half tree in spacing the fruit 5 inches apart on August 20, one week before the first picking. Thinning to this extent left an average of 448 peaches on the thinned side of the tree and 709 on the unthinned side. The season was unusually dry, no rain having fallen from the middle of July until after harvest. Under these conditions the fruit continued to enlarge during the final swell at about the same rate on the thinned and unthinned sides of the trees (Dorsey and McMunn, 1934). The thinned peaches were somewhat larger, however, because the smaller peaches were pulled off when the second thinning was done.

Large limb. In 1926 in the Foote orchard four 9-year-old trees of

TABLE 8.—TIME OF THINNING: GROWTH OF FRUIT ON 10-YEAR-OLD TREES THINNED AT DIFFERENT TIMES (WHOLE-TREE TEST)
(Foote orchard, 1927: full bloom on March 20, harvest started on August 8; fruit thinned to 6-inch intervals; 100 fruits per tree measured up to June 3 and from then on, 50 fruits per tree)

Elberta

Days after full bloom that thinning was done	Number of trees	Average number of fruits thinned off per tree	Average suture diameter of fruit in inches														Average number of fruits in 50 pounds	Yield per tree in pounds
			Apr. 30	May 7	May 14	May 20	May 26	June 4	June 13	June 18	June 25	June 30	July 8	July 23	July 29	Aug. 6		
41	6	949	.59	.85	1.11	1.35	1.40	1.47	1.47	1.50	1.53	1.53	1.57	1.74	2.04	2.26	181.5	136
47	6	1 029	...	.84	1.14	1.34	1.42	1.48	1.48	1.49	1.51	1.52	1.56	1.71	2.01	2.23	209.0	168
54	6	844	...	...	1.12	1.36	1.41	1.48	1.49	1.51	1.53	1.56	1.65	1.74	2.04	2.29	206.5	117
61	6	867	...	...	1.09	1.32	1.41	1.47	1.47	1.51	1.52	1.55	1.60	1.76	2.06	2.31	190.5	116
66	6	610	...	...	1.06	1.31	1.42	1.43	1.48	1.51	1.53	1.55	1.60	1.77	2.15	2.29	192.5	128
73	6	511	...	...	1.10	....	1.36	1.44	1.47	1.49	1.50	1.52	1.68	1.70	2.04	2.26	204.5	137
82	6	378	...	...	1.10	....	....	....	1.46	1.47	1.49	1.51	1.52	1.72	2.03	2.12	210.0	129
95	4	211	...	...	1.11	....	....	....	1.49	1.47	1.48	1.51	1.55	1.71	2.03	2.23	225.0	157
100	4	307	...	...	1.09	....	....	....	1.49	1.47	....	1.52	1.56	1.69	2.03	2.26	217.5	156
109	4	310	...	...	1.09	....	....	....	....	1.47	....	1.51	1.56	1.70	2.02	2.25	229.0	158
115	2	269	...	...	1.12	....	....	....	....	1.47	....	1.52	1.57	1.76	2.07	2.26	199.0	189
122	2	271	...	...	1.12	....	....	....	....	1.49	....	1.52	1.57	1.73	2.08	2.31	196.5	125
128	2	326	...	...	1.12	....	....	....	....	1.49	....	1.51	1.55	1.65	2.08	2.25	195.5	161
No treatment	6	0	.55	.80	1.03	1.03	1.39	1.43	1.46	1.47	1.48	1.50	1.55	1.69	1.97	2.18	225.5	227

Captain Ede

Days after full bloom that thinning was done	Number of trees	Average number of fruits thinned off per tree	Average suture diameter of fruit in inches															Average number of fruits in 50 pounds	Yield per tree in pounds
			Apr. 28	May 4	May 13	May 21	May 25	June 2	June 9	June 16	June 24	June 28	July 7	July 12	July 18	July 27	Aug. 2		
39	4	2 001	.49	.72	1.05	1.26	1.35	1.35	1.40	1.40	1.42	1.44	1.47	1.50	1.65	1.94	2.08	229	289
75	4	1 104	...	.69	1.01	1.21	1.27	1.34	1.38	1.38	1.39	1.41	1.45	1.46	1.59	1.86	2.01	192	207
53	4	1 680	...	...	.96	1.26	1.31	1.36	1.40	1.42	1.44	1.47	1.49	1.53	1.67	1.98	2.10	199	162
58	4	453	...	...	.93	1.20	1.32	1.40	1.40	1.42	1.44	1.47	1.49	1.54	1.63	1.96	2.14	197	93
65	4	552	...	...	.98	1.25	1.36	1.39	1.41	1.42	1.46	1.46	1.52	1.55	1.69	1.98	2.13	200	175
72	4	533	...	...	.95	....	....	1.37	1.39	1.41	1.43	1.44	1.48	1.50	1.68	1.90	2.09	227	255
81	4	477	...	...	1.03	....	1.36	1.38	1.40	1.41	1.44	1.45	1.50	1.54	1.69	1.91	2.07	216	210
87	4	691	...	...	1.00	....	....	....	....	1.42	1.43	1.44	1.48	1.52	1.63	1.94	2.04	231	297
94	4	508	...	...	1.01	....	....	....	....	1.38	1.42	1.43	1.45	1.47	1.62	1.87	2.04	246	202
100	2	351	...	...	1.01	....	....	....	....	1.39	1.44	1.43	1.47	1.48	1.64	1.92	2.07	210	194
No treatment	4	0	.48	.69	.90	1.20	1.28	1.35	1.39	1.40	1.42	1.44	1.48	1.52	1.65	1.92	2.10	208	168

TABLE 8.—GROWTH OF FRUIT ON 10-YEAR-OLD TREES THINNED AT DIFFERENT TIMES—*Concluded*

Days after full bloom that thinning was done	Number of trees	Average number of fruits thinned off per tree	Average suture diameter of fruit in inches													Average number of fruits in 50 pounds	Yield per tree in pounds
Carman																	
			Apr. 27	May 4	May 11	May 17	May 24	June 1	June 9	June 15	June 24	June 27	July 6	July 11	July 18		
38	4	788	.47	.67	1.04	1.21	1.38	1.45	1.47	1.52	1.60	1.62	1.88	1.99	2.12	277	152
44	4	631	...	.67	1.05	1.19	1.36	1.38	1.48	1.51	1.57	1.63	1.82	1.99	2.25	224	143
52	4	436	...	...	1.06	1.21	1.40	1.43	1.42	1.41	1.49	1.52	1.87	1.90	2.31	217	107
58	4	322	...	...	1.04	1.21	1.37	1.46	1.47	1.51	1.58	1.53	1.85	1.94	2.38	236	128
64	4	306	...	...	1.05	1.20	1.38	1.46	1.46	1.48	1.58	1.61	1.83	1.96	2.29	236	94
72	4	423	...	...	1.00	....	1.37	1.44	1.50	1.52	1.58	1.60	1.87	1.90	2.41	226	98
80	4	538	...	...	1.03	....	....	1.43	1.49	1.46	1.57	1.52	1.85	1.91	2.27	255	146
86	4	650	...	...	1.02	....	....	....	1.43	1.46	1.52	1.54	1.74	1.91	2.20	257	138
93	4	601	...	...	1.01	....	....	....	....	1.41	1.48	1.50	1.64	1.83	2.14	239	118
No treatment	1	...	.43	.72	1.01	1.16	1.31	1.34	1.42	1.42	1.49	1.52	1.56	1.78	1.99	337	188

TABLE 9.—GROWTH OF PEACHES ON LARGE LIMBS OF THE SAME TREE, EACH LIMB THINNED AT A DIFFERENT TIME
(Foote orchard, 1926: trees 10 years old, harvest started on August 16, final picking done on August 24; about 100 fruits measured on each limb)

Time thinned	Number of fruits thinned off	Number of fruits left on	Average suture diameter in inches								
Elberta											
			May 10	June 1	June 12	June 21	June 29	July 7	July 12	July 27	Aug. 7
Full bloom, April 16	....	....	.41	1.40	1.54	1.56	1.58	1.58	1.61	1.74	1.86
After shuck fall, May 14	1 005	787	....	1.38	1.52	1.52	1.53	1.56	1.57	1.73	1.86
After the June drop, May 25	557	752	....	1.25	1.47	1.53	1.53	1.56	1.55	1.72	1.82
Stone hardening, May 31	562	534	....	1.32	1.42	1.51	1.52	1.54	1.55	1.72	1.85
Second growth period, June 5	159	384	....	....	1.48	1.51	1.53	1.56	1.57	1.72	1.90
Second growth period, June 11	120	221	....	....	....	1.47	1.51	1.53	1.55	1.72	1.91
Not thinned (check limbs)	....	....	....	....	....	1.47	1.47	1.49	1.53	1.72	1.92
Captain Ede											
			May 25	June 12	June 21	June 29	July 7	July 12	July 28	Aug. 8	
Full bloom, April 16	....	....	1.11	1.42	1.40	1.42	1.47	1.50	1.62	1.83	
After shuck fall, May 14	1 386	917	1.08	1.36	1.38	1.40	1.44	1.49	1.62	1.83	
After the June drop, May 25	1 296	1 195	1.03	1.38	1.36	1.39	1.44	1.49	1.61	1.82	
Stone hardening, May 31	917	733	....	1.35	1.35	1.38	1.42	1.45	1.57	1.81	
Second growth period, June 5	474	463	....	1.32	1.34	1.37	1.40	1.44	1.57	1.80	
Second growth period, June 11	142	271	....	....	1.36	1.41	1.42	1.44	1.57	1.80	
Not thinned (check limbs)	....	....	....	....	1.36	1.36	1.38	1.43	1.57	1.72	

Captain Ede and four of Elberta were carefully selected as to size, crop load, and vigor. One large limb on each tree was thinned to a 6-inch spacing on a different date between full bloom and well into the second growth period. The remaining limbs on each tree were left unthinned as checks (Table 9). At the intervals given, the suture diameter of about 100 peaches was measured on each limb. An index of the severity of thinning at each date may be obtained by figuring the proportion of peaches pulled off to those left on.

The removal of blossoms or fruit to the extent indicated in spacing to the 6-inch interval was not immediately reflected in the average rate of growth of the peaches on the thinned limbs (Table 9). The crop on the check limbs, which presumably was considerably heavier than that on the thinned limbs, grew at about the same pace until the time of the last measurements, which were made on August 7, 9 days before the first fruit from these trees was picked firm ripe. There is some possibility that a cross-transfer of nutrients, as well as of water, from one limb to another enabled the tree to function as a unit and thus somewhat obscured the effect of local thinning.

Small limb. In the tests with half trees in the Perrine orchard in 1929, five small limbs bearing 6 to 7 peaches each were chosen on each of the five check trees. These were 14-year-old Elberta trees. Picking was delayed until the fruit became soft ripe. On each of these 25 limbs all but two of the peaches were pulled off on August 13, 14 days before harvest. The cheek diameter of each of the two remaining peaches was measured at two-day intervals until they were picked. Under the drouth conditions prevailing, the two peaches thus relieved of competition did not show a sudden increase in cheek diameter over the other fruit.

Effect of Picking Largest and Ripest Fruit

In 1929 a study was made of the way in which the picking of the largest and ripest fruit affects the growth of peaches left on the tree. This practice, known as "topping" or "bugging," is in general use, especially when the trees are bearing heavily. The experiment was set up in the Perrine orchard in this way: On five check trees the entire crop was left until the fruit had reached the soft-ripe stage. The growth rate of the fruit on these trees was determined by measuring the cheek diameter of approximately 150 tagged peaches per tree every other day during the last 30 days before the fruit was picked. Picking started August 29. The growth rate of these peaches is shown by the averages of the diameter measurements taken on the dates shown at the top of page 372.

In spite of the extremely dry condition of the soil of this orchard in 1929, the fruit increased more than 20 percent in volume in the last

Date	Diameter measurement cm.	Date	Diameter measurement cm.
July 30	4.3	August 17	5.2
August 3	4.5	August 19	5.3
August 5	4.5	August 21	5.3
August 7	4.6	August 23	5.4
August 9	4.7	August 25	5.5
August 11	4.9	August 27	5.6
August 13	5.0	August 29	5.7
August 15	5.1		

12 days before harvest, when the crop load averaged 1,470 peaches per tree.

On August 16 the five experimental trees in the adjacent row, which bore a comparable crop, were topped when firm ripe, an average of 540 peaches being picked per tree. One hundred peaches from this lot were selected at random for measuring, and the cheek diameter of these at the time averaged 5.1 cm., which, it will be noted, was the average size of the fruit on the adjacent trees as measured on August 15. The next picking from the topped trees was made on August 20, at which time an average of 480 peaches per tree were pulled off. The average cheek diameter of these peaches was 5.1 cm., which was slightly less than the peaches on the check trees on either August 19 or 21. The last fruit from the topped trees was picked on August 26, when an average of 355 peaches per tree were harvested. The cheek diameter of these was 5.4 cm., which was slightly less than that of the fruit on the check trees.

It will be seen from this study that, compared with the growth rate of the fruit on the check trees, the crop left on the experimental trees after topping did not make a sudden increase in growth. In fact, within the crop limits of this experiment, the fruit on the two sets of trees seemed to increase during the last few days of the final swell at about the same rate. The objective in topping (removing the largest and most advanced peaches) was actually accomplished, however, as is shown by the fact that the average cheek diameter of the fruit removed at the different dates was almost the same.

Reducing Doubles to Singles

In 1933 an experiment was set up to study the release obtained when a fruit was thinned after it had been in the closest possible relationship with another fruit—that is, one of a pair borne at the same node. During some seasons there are doubles at a large proportion of the nodes on shoots of medium vigor (Dorsey, 1935). Fortunately tho, unless the set is heavy, two peaches do not set at many of the nodes.

In this study a total of 200 shoots with two peaches at a single node were selected on 7-year-old Elberta trees at the Olney farm. These

TABLE 10.—GROWTH OF DOUBLE PEACHES AND OF SINGLE PEACHES OF PAIRS FROM WHICH ONE FRUIT WAS REMOVED

(University farm at Olney, 1933: first picking on August 18; measurements started with an average of 200 double peaches and 100 single peaches)

Date measured	Average cheek diameter of peaches					
	No pruning		Moderate pruning		Heavy pruning	
	Doubles	Singles	Doubles	Singles	Doubles	Singles
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
June 19	28.6	29.5	31.2	31.5	32.0	32.9
June 29	29.3	30.2	32.2	32.7	33.1	33.7
July 10	30.9	32.2	33.7	34.5	35.0	36.6
July 20	32.5	34.2	37.1	37.9	37.7	39.1
July 31	36.0	38.2	41.4	43.6	41.9	43.6
August 10	41.9	44.4	48.2	49.2	48.5	51.8
August 18	45.2	47.2	51.5	52.3	53.0	55.7

shoots were paired on the basis of length and vigor and divided into two series: one in which both peaches were left on and the other in which one of the peaches was removed. The growth rate in each series was measured at approximately 10-day intervals starting June 19, which was 72 days after bloom and 60 days before the first picking date (August 18). Measurements were made of the two series on trees which had been given no pruning, moderate pruning, and heavy pruning the year before (Table 10). Four pounds of nitrate of soda was applied to each tree in April. Since the five trees selected were not thinned they were heavily loaded.

Measurements showed that the released single peaches increased in size only slightly more than the doubles. Both single and double peaches tended to become larger as the severity of pruning was increased. Since the trees selected for the study were heavily loaded, the single peach, after being released from competition with the other one, was still subject to strong competition from the rest of the crop for both food substances and water. Under these conditions the effect obtained by removing one of the doubles was not markedly reflected in the average diameter of the peach left on.

Thinning Different Parts of the Shoot

Since the number of fruit buds produced on different sections of the shoot was found to vary from year to year, and also because certain varieties tend to set fruit in clusters on the basal part of the shoot (Fig. 15, page 361), the relation between the size of fruit on the basal and terminal halves of the shoot after thinning was studied.

Sixty bearing shoots were numbered serially on each of four Greensboro trees and on each of two trees of Lemon Free. As far as possible, shoots were selected whose length in inches measured a multiple of 5. The shoots from each variety were divided into groups. On

June 9 all fruit was stripped from the basal half of one group and from the terminal half of the other group. In Lemon Free a third, or check, group was made up of shoots on both halves of which the fruits were left after they were thinned to 5-inch intervals. The fruits left on either the terminal or the basal half of the shoot were thinned on the basis of 1 to each 5 inches of total shoot length. The remaining shoots were then thinned to 5-inch intervals. A tagged shoot was eliminated if for any reason some of the fruit was lost.

The peaches taken from the terminal part of each shoot during thinning on June 9, 52 days after bloom, averaged higher in volume than those taken from the basal section: 8.61 cc. versus 8.31 cc. on Greensboro and 9.3 cc. versus 8.5 cc. on Lemon Free (Table 11). On the Greensboro trees more fruit was thinned from the terminal than from the basal half of the shoot, a total of 571 fruits being taken from the terminal half and only 381 from the basal half. In Lemon Free the reverse was true, a total of only 141 peaches being removed from the terminal half of the shoots and 229 from the basal half. At the start of the experiment with Lemon Free, the average size of the peaches thinned off was less than that of the peaches left on either the terminal or the basal part of the shoot.

As the season advanced, the fruit on the basal half of the shoot enlarged more rapidly than that on the terminal part and was larger at harvest. In adjusting the crop load, therefore, it would be well to leave somewhat more of the crop on the base than on the ends of the shoots.

Drawing Power of Peaches on Defoliated Shoots

In 1931 an experiment was set up to study how peaches on defoliated shoots draw upon the food supply of the tree as a whole. This study was prompted by observations that large fruits sometimes develop on badly defoliated trees and that solitary peaches on the inner bearing area sometimes grow to a large size even tho borne on shoots devoid of leaves.

The Sunbeam trees selected for this study carried a heavy crop after the June drop was over. In order to reduce competition on the experimental shoots, the entire tree was thinned to a 5-inch spacing. Paired shoots of 1930 growth were selected. These paired shoots were of approximately the same length, bore about the same number of peaches, and arose not more than 3 inches apart on the same branch. On one of each pair the current season's growth and all the leaves were cut off. So far as possible, the peaches were left in relatively the same position on each pair of shoots. On the defoliated shoots the distance to the nearest leaf from the fruit closest to the base, as measured along the shoot, averaged 12.7 inches.

TABLE 11.—GROWTH OF PEACHES ON TERMINAL AND BASAL HALVES OF SHOOTS WHEN FRUIT WAS STRIPPED FROM THE OTHER HALF
(University orchard, Urbana, 1931: fruit on the thinned half was spaced at 5-inch intervals)

Number of shoots measured	Average length of shoot	Part of shoot left with fruit	Total number of fruits removed from stripped halves	Average volume of fruits from stripped halves, June 11	Total number of fruits removed in thinning	Average suture diameter of fruit left on shoots							Number of fruits measured
						July 9	July 28	Aug. 1	Aug. 21	Sept. 4	Sept. 8	Sept. 16	
Greensboro													
	in.			*cc.*		*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	
120.............	23.83	Terminal half	381	8.31	190	35.79	47.78	48.96	.....	.....	.....	.....	507
120.............	23.75	Basal half	571	8.61	134	35.74	48.95	50.33	.....	.....	.....	.....	518
Lemon Free													
39.............	25.90	Terminal half	229	8.50	64	30.18	.....	.....	38.62	45.41	46.55	47.18	199
39.............	23.95	Basal half	141	9.30	71	29.62	.....	.....	38.10	45.64	47.20	49.22	191
39.............	25.62	Entire shoot	...	....	210	30.45	.....	.....	39.23	46.52	47.62	49.29	199

The peaches on the defoliated shoots continued to enlarge during the two-month period but at a lower rate than those on the shoots with leaves, according to data from 40 pairs of shoots (Table 12). The crop of this variety, Sunbeam, could have been picked at the firm-ripe stage on August 8, but the peaches were left on as long as they would hold. It is rather surprising to note that, either because the fruit fell off or because it was broken off in measuring, more fruit was left on the stripped shoots than on the untreated shoots at the last measuring date, August 17. On the defoliated shoots 61 peaches were still attached, but only 16 remained on the other shoots.

TABLE 12.—SIZE OF PEACHES ON SHOOTS STRIPPED OF ALL CURRENT GROWTH AND LEAVES, AND ON UNTREATED PAIRED SHOOTS

(University orchard at Urbana, 1931, 6-year-old Sunbeam trees: averages for 40 paired shoots with an average length of 22.2 inches)

Dates measurements were taken	Stripped shoots		Untreated shoots	
	Average suture diameter of fruit	Number of fruits at each date	Average suture diameter of fruit	Number of fruits at each date
	mm.		*mm.*	
June 15	26.5	103	26.6	103
June 27	27.5	100	28.0	98
July 8	29.3	90	29.6	98
July 16	33.0	90	33.2	97
July 24	35.7	90	37.8	97
July 31	38.9	90	41.7	97
August 5	41.4	90	44.7	96
August 8[a]	42.7	89	46.6	95
August 12	45.1	80	47.1	55
August 14	46.2	75	47.7	36
August 17	46.9	61	47.4	16

[a]Fruit was firm ripe on August 8.

The fact that there was only a relatively slight difference in size between the peaches grown on the check shoots and those on the stripped shoots shows that when a peach is isolated from the leaves it continues to enlarge by drawing upon the food supply stored locally in the tree or upon that built up by the nearest leaves. Since the peach itself contains chlorophyll, it may be assumed that some food substances are built up from that source.

Summary

During the years of these studies of the growth response of the peach to thinning, the set of fruit in these orchards was not in general exceptionally heavy. Under these conditions no immediate or marked increase occurred in the enlargement of the peaches left on the trees after thinning. Even in the closest possible relationship—doubles at the same node—the response was relatively slight and gradual when one of the peaches was pulled off.

WHAT DETERMINES BEST TIME TO THIN

During the development of commercial peach growing in this country there has been considerable difference of opinion as to the best time to thin the crop.[1] Recommendations made have extended well into the third growth period, but most recommendations are for the period after the June drop before or soon after the stone begins to harden. It has been emphasized over and over again that early thinning makes possible more economical tree performance. This would seem to be supported by chemical analyses, which show that more and more food substances are required by the fruit as it develops (Bigelow and Gore, 1905; Lott, 1932, 1933, 1939, and 1942; and Lott and Ashley, 1935). If thinning done early in the season is more effective, the question naturally comes up as to whether this gain is offset by the risk and increased cost involved in adjusting the crop to the tree before the natural drops are over. In other words, what are the important factors to be considered in determining the best time to thin? From the standpoint of the grower, the important factors would be the cost, risk, and relative effectiveness of thinning at different times.

When Is the Most Economical Time to Thin?

To be at all accurate, cost figures for thinning peaches would have to be based upon extensive studies of the time required under a wide range of conditions. Growers are familiar with such variables as the extent of the set, variety, tree type or age, speed of workers, working conditions, and stage of development of the fruit, and know how difficult it would be to obtain worth-while cost figures. Therefore, while many observations have been made of the conditions under which thinning has to be done in this state, and some time records have been obtained, it seems best to point out only certain inherent factors which contribute to the cost of thinning peaches early in the season.

In the first place, there are the largest number of fruits on the tree at bloom, the number decreasing from then onward and becoming more or less stabilized after the drops are over. In the second place, it is more difficult to thin during the early part of the season soon after bloom because the peaches, besides being still numerous, are small and difficult to find among the leaves.

Even tho there are more peaches on the tree at bloom, the leaves are small at this time and the flowers are conspicuous. For this reason

[1]Different opinions as to the best time to thin will be found in the following references: Bridgeman (1863), Strenzel (1883), Gurney (1894), Goff (1897), Morrill (1901), Hale (1903), Kyle (1905), Funk (1907), Thomas (1909), Green (1910), Friday (1914), Rees (1919), Gould (1923), Peck (1923), Fraser (1924), Gourley (1925), Drew (1926), and Dorsey (1937, 1938, and 1940).

there has been increased interest in the last few years in thinning at bloom. The excess flowers are easy to remove at this stage, since they can simply be brushed off. The experiments of Weinberger (1941 and 1944) indicate that bloom-thinning can be done economically under Georgia conditions. He rightfully points out, however, that "where there is material danger of frost damage after thinning this method would involve risk of serious reduction of the crop."

Since bloom thinning takes full advantage of the earliest possible crop reduction, it will be watched with interest by peach growers in the northern states. For the present, however, it seems safest to wait until the June drop is over before thinning in Illinois.

When Is There Least Risk From Thinning?

There is always some risk in carrying a peach crop thru the summer. Sometimes windstorms or hail knock off or injure enough fruit to reduce an excess crop to about the right proportions and thus save the expense of thinning. The summer loss of peaches from all causes in the University orchard at Urbana in 1931 with the variety Waterloo is shown by the following figures, which are the averages of records taken on 19 trees. Starting before the June drop was over, the following numbers of peaches were lost: June 29, 271; July 3, 7; July 6, 3; July 10, 3; July 17, 11; July 21, 4; July 24, 11; July 28, 40; and July 31, 69. In the same orchard the average loss from three trees of June Elberta was 24 peaches, from four trees of Sea Eagle, 38, and from three thinned trees of the variety Martha between June 30 and September 16 the drop was slight. Then during a storm the drops from three Martha trees were 126, 129, and 395 respectively.

There is also the possibility of a drop occurring after the June drop. Two of these late drops have taken place in southern Illinois, one happening about 1910 and the other in 1927. In the late drop about 1910 all the fruit fell in some orchards. In 1927 the late drop reduced a thinned crop to a light crop in many southern Illinois orchards, and in some cases the crop on unthinned trees was reduced to such an extent that thinning was unnecessary.

Because of the possibility of losses late in the season, growers are sometimes reluctant to thin peaches until the crop has become stabilized on the tree. Later thinning reduces this risk somewhat.

When Is Thinning Most Effective?

Because of the increased cost of thinning early and the risk involved in carrying the crop thru the season, growers tend to thin as late as practical. Much depends, therefore, upon whether the effectiveness of thinning varies at different times during the season. This point seemed sufficiently important, in view of the many variables involved, to be given experimental analysis. Accordingly a number of experiments were set up in which the time of thinning was the principal variable. Before drawing conclusions as to the best time to thin, the relative effectiveness of the different times should be considered in the light of fruit size and thinning cost. There will then be a basis for evaluating the best time for thinning under orchard conditions.

Base from which to date time of thinning. After going over the literature it was apparent that there was need for some definite reference point upon which to base the time of thinning. Terms such as "early" and "late" in referring to thinning time are not specific. One grower spoke of bloom thinning as "early," whereas Shoemaker (1933 and 1934) considered thinning as late as 46 days after bloom as early thinning. In the Delaware experiments thinning done at the time of the June drop was considered early and that done when the pits were hardening was considered late (Close, 1902). In New Jersey, Farley (1923) considered as early thinning that done 44 days after bloom and as late thinning that done 71 days after bloom. Knowlton and Hoffman (1928) designated as early thinning, that done when the pits began to harden, and as late thinning that done about one month before harvest. Weinberger (1941), working with early varieties, made comparisons between thinning done as early as bloom and that done as late as the beginning of the final swell.

There are a number of stages at which physiological development in the fruit is clearly marked, such as at full bloom, the June drop, or the hardening of the stone at the tip. Any of these stages could be used as a reference point from which to date the time of thinning. In fact, it may be desirable to use more than one such point, since in observations made by Blake (1930) in New Jersey on a single variety, Elberta, the time between bloom and harvest was found to vary from 123 to 144 days.

Of all the reference points, however, full bloom is the most convenient to use. For this reason thinning time was given as so many days after full bloom at the outset of the Illinois experiments (Dorsey and McMunn, 1926). Tukey (1939), however, emphasized thinning with reference to the stage of development of the fruit. Because of the variations from season to season between time of bloom and time of maturity, some inaccuracy must be expected no matter what reference point is used.

General procedure in experiments. Most of the plots for the experiments made at this Station on time of thinning were set up in commercial orchards under carefully chosen conditions as to variety, uniformity of trees, pruning, spray treatment, and cultural care. Distance thinning was used on the experimental trees in most cases with slight modifications where it seemed necessary to bring the total crop load within the proper limits. Where the trees were thinned during bloom, a single flower was left on all shoots less than 10 inches long. On the old wood where the fruit laterals were less than 3 inches long, the fruits on the laterals were spaced along the limb according to the interval used on the rest of the tree. The effect of thinning at different times was determined by weighing or sizing the entire crop from each plot at harvest. The percent of the crop in the different sizes (Fig. 17) has been used as a basis for comparing one treatment with another. This method of analysis was adopted after considerable discussion because the results of the thinning treatments of most interest to the peach grower are those influencing size of fruit.

Bloom thinning. In Illinois there has been some interest in thinning peaches as early as bloom, especially with the variety J. H. Hale; but only a few attempts have been made to thin in full bloom those varieties that set as many fruits as Elberta or Captain Ede. To obtain experimental evidence of the amount of response that the tree gives when the excess fruit is thinned off at bloom, experiments were set up in which bloom thinning was compared with thinning at later dates under comparable conditions.

The first studies of crop adjustment at bloom were made on individual limb tests in 1926. In this experiment with Elberta and Captain Ede scaffold limbs on 9-year-old trees were thinned at bloom, after shuck fall, after the June drop, at stone hardening, and at two points in the second growth period. Thinning time in this instance therefore covers the period from bloom into the second growth period, the time during which thinning is usually done (Table 9).

Since, in the experiment with individual limbs, thinning done early in the season was not reflected in larger fruit, another experiment to study bloom thinning was set up in 1933 on the University farm at Olney. In this experiment five Elberta trees 7 years old were thinned while in full bloom.[1] Forty-six percent of the fruit buds had been winterkilled and those left had been further reduced by spring pruning (line 9 of Table 15 on page 390).

The average number of peaches harvested from the trees thinned at bloom was 811 (216 pounds); from trees in the next row thinned 40 days later, it was 1,079 (238 pounds) (Table 15, line 11). Measured by an increase in fruit size, bloom thinning was slightly better than thinning either 40 or 70 days after bloom when the type of pruning was the same (Table 15, lines 11 and 13). That there was difficulty in regulating the total load is shown by the lower yield when thinning was done as early as bloom.

[1]The thinning was done with the assistance of L. T. Clark, in charge of vocational agriculture at the Olney high school, and his class.

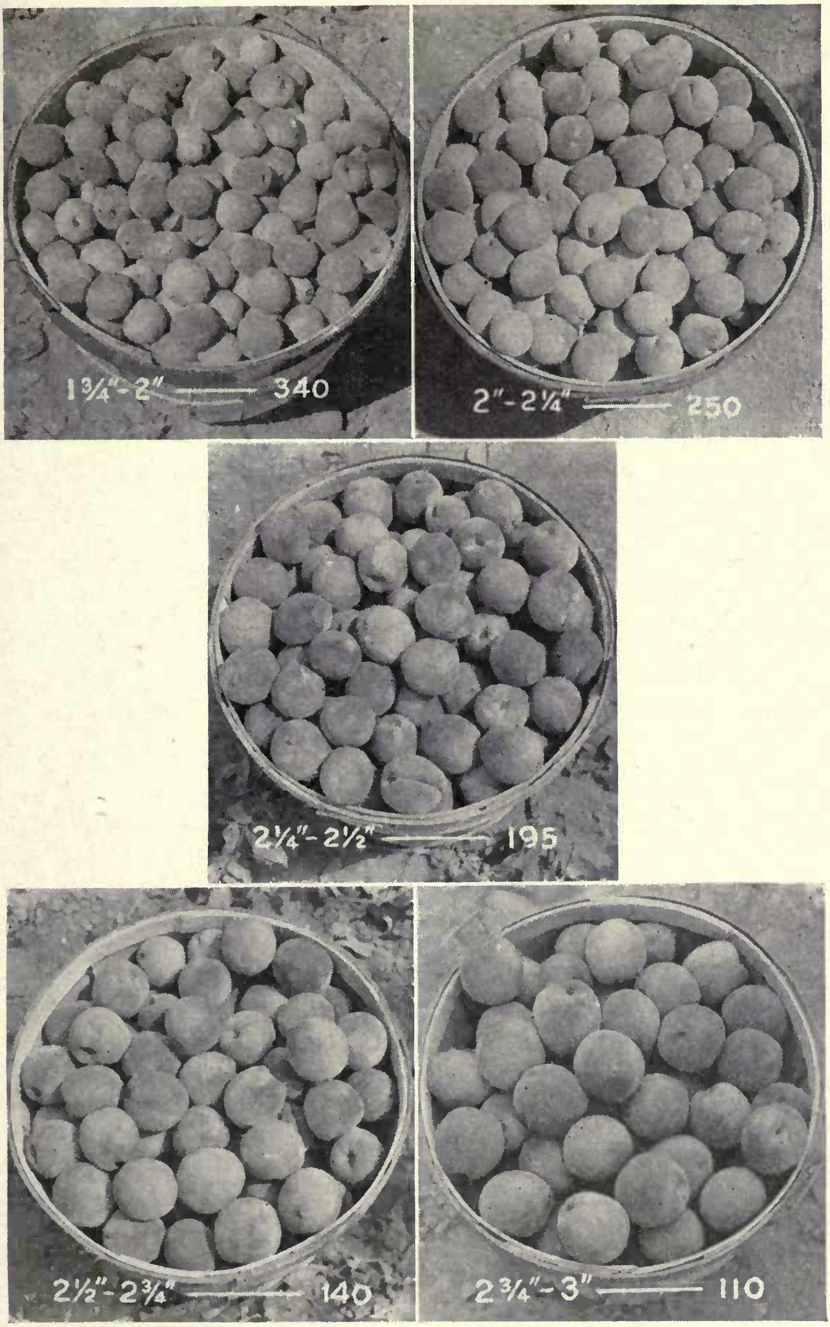

Fig. 17.—Numbers of peaches of different sizes in a bushel

In an attempt to make allowance for the drops, Weinberger (1941) proceeded as follows when thinning in Georgia: "At bloom thinning, the blossoms were left 3 inches apart; at later thinnings 4; then 5; and finally after the May drop 6-inch spacings were used." In Weinberger's experiment with Early Rose, the time of thinning had little effect upon size of fruit even when the crop load was light, as in 1939, because of a heavy drop.

Thinning after bloom. As in the preceding experiments, the number of peaches thinned off at each date is used to describe the severity of the thinning treatment; and the amount of the crop in each size group and the total yield are used as a means of showing the relative effectiveness of thinning done at different times. The location of the orchard, the variety and age of tree, and the vigor of growth are shown in Table 13 for each experiment. Pruning was moderately heavy in each experiment except Experiment 11, in which it was heavy.

Experiment 1.—In the Bates orchard thinning 7-year-old trees of Red Bird (Early Wheeler) before the June drop in two series, one 37 days after bloom and the other 52 days after bloom, reduced the yield considerably. Part of the reduction in yield in the crop thinned 37 days after bloom was caused by the fact that, since the thinner could not tell which peaches were going to drop, he left fruit which fell at the June drop. All the fruit produced on the experimental trees in this orchard was relatively small even on the thinned trees, but a large proportion of the crop from the unthinned, or check, trees was in the smaller sizes, which are difficult to dispose of.

Large peaches are especially desirable in Red Bird. It is one of the earliest maturing commercial varieties and goes on the market at a time when Illinois peaches must compete with the large peaches from the southern crop. To get as large fruit as possible, it would seem a good plan to thin the Red Bird trees early, that is, before the June drop. In thinning early, tho, it will be necessary to make some allowance for the additional fruit loss which may be expected at the June drop.

Experiment 2.—The crop in this experiment was not run over a sizer. The number of peaches removed in thinning 12-year-old trees was not excessive but apparently was enough to cut the yield slightly. Contrary to what usually occurs, more peaches were thinned off at the latest thinning than at the first one. The relatively small yield from the trees thinned early, before the June drop, should again be noted.

Experiment 3.—Thinning the Alton variety as late as 57 days after bloom did not reduce the yield and resulted in slightly larger fruit.

Experiment 4.—Thinning 22-year-old Slappy trees 74 days after bloom, even when removing only 211 peaches per tree, was apparently inadvisable because these trees could size up all the fruit which had set.

TABLE 13.—SUMMARY OF TIME-OF-THINNING EXPERIMENTS: YIELD AND SIZE OF PEACHES FROM TREES THINNED TO 5-INCH INTERVALS AT DIFFERENT TIMES AFTER BLOOM, 1928, 1929, AND 1935

Days after bloom that thinning was done	Number of trees	Age of trees in years	Average number of fruits thinned off per tree	Pounds of fruit in size classes indicated					Yield of fruit per tree in pounds
				1¾" and less	1¾"-2"	2"-2¼"	2¼"-2½"	2½"-2¾"	
Experiment 1: medium-vigorous Red Bird, Bates orchard, 1928									
37...........	5	7	827	2	65	57	4	0	128
52...........	4	7	913	8	111	46	1	0	166
No treatment..	4	7	0	27	157	37	1	0	222
Experiment 2: medium-vigorous Carman, Foote orchard, 1928									
41...........	10	12	459	..	..	..	..	..	139
54...........	10	12	623	..	..	..	..	..	184
62...........	10	12	513	..	..	..	..	..	194
No treatment..	10	12	0	..	..	..	..	..	230
Experiment 3: medium-vigorous Alton, Schoembs orchard, 1928									
57...........	3	7	444	7	54	50	3	0	114
No treatment..	2	7	0	3	75	27	2	0	107
Experiment 4: medium-vigorous Slappy, Hardin orchard, 1928									
74...........	5	22	211	34	102	12	0	0	148
No treatment..	2	22	0	58	139	10	0	0	207
Experiment 5: medium-vigorous Belle, Corzine orchard, 1928									
39...........	5	6	372	2	43	131	15	0	191
56...........	5	6	361	2	49	117	13	0	181
73...........	4	6	159	3	46	115	9	0	173
No treatment..	4	6	0	7	93	104	2	0	206
Experiment 6: vigorous Belle, McBride orchard, 1928									
39...........	5	7	589	1	49	186	14	0	250
59...........	5	7	633	1	53	172	14	0	240
75...........	5	7	431	1	52	151	27	0	231
No treatment..	5	7	0	3	80	148	19	0	250
Experiment 7: vigorous Elberta, Cobb and Waterbury orchard, 1928									
76...........	2	5	183	0	13	66	52	0	131
No treatment..	1	5	0	10	71	88	5	0	174
Experiment 8: vigorous Elberta, Endicott orchard, 1928									
41...........	5	7	559	0	2	74	196	71	343
61...........	5	7	756	0	1	31	210	101	343
77...........	5	7	583	0	2	43	150	84	279
No treatment..	5	7	0	0	16	164	184	27	391
Experiment 9: vigorous Elberta, Foote orchard, 1928					2" and less	Over 2"			
44...........	10	5	489	..	7	131	..	..	138
60...........	10	5	301	..	20	100	..	..	120
90...........	10	5	312	..	20	108	..	..	128
No treatment..	10	5	0	..	39	135	..	..	174

(Table is concluded on next page)

TABLE 13.—YIELD AND SIZE OF FRUIT FROM PEACH TREES THINNED AT DIFFERENT TIMES AFTER BLOOM—*Concluded*

Days after bloom that thinning was done	Number of trees	Age of trees in years	Average number of fruits thinned off per tree	Pounds of fruit in size classes indicated					Yield of fruit per tree in pounds
				1¾" and less	1¾"-2"	2"-2¼"	2¼"-2½"	2½"-2¾"	
Experiment 10: medium-vigorous Elberta, Bates orchard, 1928									
36............	7	11	853	..	12	138	153	..	303
52............	7	11	618	..	17	142	113	..	272
68............	7	11	597	..	10	100	136	..	246
No treatment..	5	11	0	..	35	138	135	..	308
Experiment 11: vigorous Elberta, Simpson and Landenberger orchard, 1928						2¼" and less	2¼"-2¾"	2¾" and over	Yield of fruit per tree in pounds
38............	10	11	226	..	..	24	155	32	211
57............	12	11	202	..	..	17	144	35	196
84............	11	11	306	..	..	90	174	21	285
No treatment..	12	11	0	..	..	70	191	26	287
Experiment 12: medium-vigorous Elberta, Endicott orchard, 1929				1¾" and less	1¾"-2"	2"-2¼"	2¼"-2½"	2½" and over	Yield of fruit per tree in pounds
64............	9	8	860	1	10	100	167	12	290
87............	9	8	786	0	15	121	121	5	262
108...........	10	8	593	0	20	125	116	5	266
No treatment..	9	8	0	4	81	227	96	1	409
Experiment 13: medium-vigorous Gage, University orchard at Urbana, 1935[a]						2¼" and less	2¼"-2½"	2½" and over	Yield of fruit per tree in pounds
64............	7	8	704	..	..	9	172	76	257
71............	7	8	551	..	..	7	155	59	221
79............	6	8	567	..	..	7	156	57	220
85............	7	8	424	..	..	9	165	68	242
96............	7	8	495	..	..	6	137	64	207
107...........	6	8	449	..	..	4	118	92	214
118...........	6	8	355	..	..	8	109	53	170
No treatment..	7	8	0	..	..	14	164	67	245

[a]In Experiment 13 the crop was thinned by adjusting it to 1,000 to 1,200 peaches per tree instead of spacing the fruit to 5-inch intervals.

Experiment 5.—In this experiment with 6-year-old Belle trees in the Crozine orchard, thinning was done 39 days, 56 days, and 73 days after bloom. The crop load was not excessive, as will be seen from the relatively small number of peaches thinned off. Thinning was effective, however, even when done as late as 73 days after bloom, as indicated by the fact that the unthinned, or check, trees bore a larger proportion of peaches in the 1¾-to-2-inch class than the thinned trees did. The fruits from trees thinned at different dates did not show a marked variation in size.

Experiment 6.—This experiment repeated Experiment 5 in another orchard except that the set and crop load were slightly heavier; the thinning dates were approximately the same. The average number of peaches thinned off per tree in spacing to the 5-inch interval was rather large even in the last thinning, altho it was then considerably less than in the first two thinnings. This last thinning was desirable but not especially urgent, as shown by only a slight decrease in the quantity of fruit in the 1¾-to-2-inch class in the thinned over the unthinned trees. Thinning did, however, cause some increase in the size of the peaches even when done as late as 75 days after bloom.

Experiments 7 thru 13.—With the exception of Experiment 13 in which Gage was used, all the remaining experiments were carried out with Elberta, each in a different orchard. The age of the trees varied from 5 to 11 years and the thinning time from 36 days to 118 days after bloom. Various types of trees were selected and the crop load, as indicated by the number of peaches pulled off in thinning, was in most cases much too heavy.

On the 5-year-old trees in *Experiment 7,* the set was too heavy, and response to thinning is indicated by the fact that the thinned trees bore more fruit of the larger sizes. The removal of an average of only 183 peaches per tree as late as 76 days after bloom resulted in an increase of about a bushel of fruit per tree in the 2¼-to-2½-inch class. The total yield of the thinned trees was less than that of the unthinned trees for the most part, because the small and injured fruit was eliminated in thinning.

In 1928 the set on the 7-year-old Elberta trees in the Endicott orchard in *Experiment 8* was heavy, and the crop load at thinning time was excessive, not having been materially reduced by the drops. That thinning was necessary is shown by the large proportion of fruit from the check trees in the small sizes. A 5-inch spacing was effective in this orchard at the last thinning as late as 77 days after bloom. The total yield was cut somewhat by the last thinning, but the yield of fruit measuring over 2¼ inches was larger than from the check trees, which bore a large quantity of fruit in the 2-to-2¼-inch class.

In *Experiment 9,* on account of the relatively light excess on 5-year-old trees, the crop apparently could have matured successfully on most of the trees without thinning. The fruit was sized to a 2-inch minimum. More fruit above 2 inches in diameter was produced by the check trees than by the thinned trees. The 39 pounds of fruit from the check trees in the 1¾-to-2-inch class, compared with the 7 to 20 pounds from the thinned trees, indicates that thinning was not necessary in this instance, the crop load on these trees being about right for the maximum yield without much reduction in size of fruit. The trees thinned at the last date (90 days after bloom) produced fruit that was distributed in the different size classes in about the same way as that from trees thinned at 60 days after bloom.

The trees in the Bates orchard were in excellent condition in 1928 at the time *Experiment 10* was laid out. A careful survey of the plot showed that the set before the drops occurred was somewhat too heavy for the tree to size up during a dry summer. Therefore it was decided to start the thinning experiments at 44 days after bloom and before the drops.

In thinning to a 5-inch spacing, an average of 853 peaches were removed per tree at the first thinning; the number decreased to 597 per tree at the last thinning date, 68 days after bloom. At harvest the grader was set to size the larger peaches to a 2¼-inch minimum; the smaller fruits were divided into two classes. Thinning was unnecessary in this instance, as shown by the proportion of the crop from the thinned and the check trees in the different size classes.

Experiment 11, set up in the Simpson-Landenberger orchard, was planned to test the effectiveness of thinning at different times during the season on trees on which heavy pruning had limited the fruits to about the right number to be sized up. The peaches were thinned to break up the clusters and in general to correct the distribution of the crop on the bearing wood.

Under the conditions prevailing in 1928 even this light type of thinning was not necessary. The crop from the unthinned check trees was distributed in the different size classes in about the same way as the crop from the thinned trees. That all trees were in excellent condition and the right type of pruning done is shown by the large size of the fruit even tho the yield per tree was relatively low.

Experiment 12, carried out in the Endicott orchard with 8-year-old Elberta trees in excellent condition, was set up to study the length of the period after the June drop during which thinning might be done effectively. The large number of peaches thinned off per tree at each date and the heavy yields indicate that the set in this orchard was heavy. The number of trees used in each treatment was large enough to give a fairly reliable index of the effect of thinning.

This experiment showed that, unless trees of this type are thinned when they carry a fruit load of over 8 bushels per tree, they cannot size the crop up to the desired commercial limit of 2¼ inches. As judged by fewer fruits in the larger size classes, thinning done at 87 days and at 108 days after bloom was less effective than that done at 64 days after bloom because the fruits to be removed were left on the trees too long. Thinning even as late as 108 days after bloom did have some effect in sizing up the crop, as shown by the larger proportion of fruit in the 2¼-to-2½-inch class or above compared with the fruit from the check trees.

Experiment 13 was carried out in 1935 in a block of 8-year-old Gage trees in the University orchard at Urbana. Even tho the fruit buds had been reduced 40 to 50 percent by killing temperatures just before bloom, most of these buds had been destroyed on the terminal half of the shoots. The buds on the basal half were still clustered, a condition peculiar to this variety. Since the crop in this experiment was clustered more than in any other experiment, it was decided to thin according to the total load instead of using the 5-inch spacing as in the other experiments.

In thinning, an attempt was made to leave 1,000 to 1,200 peaches per tree by removing the smallest and injured specimens and those on the weakest shoots. The first thinning date was delayed until 64 days after bloom because a heavy post-June drop was anticipated as a result of much rainfall in May. This drop occurred later than was anticipated (Dorsey and McMunn, 1935). The last thinning date was 118 days after bloom and only 31 days before the first picking.

The large proportion of the crop measuring more than 2¼ inches on the check trees as well as the thinned trees shows that thinning was not particularly effective. Since the crop load, even tho clustered at the base of the shoots, was not excessive, there was no need to reduce it except to break up the clusters by removing the smallest peaches. The thinning treatment applied was about equally effective during the entire period of 64 to 118 days after bloom, as shown by the distribution of the fruit in the different size classes.

Experiment 14.—In 1937 the set was heavy enough on twenty 9-year-old Gage trees in the University orchard at Urbana to attempt a more detailed study of the effect of a crop excess in reducing fruit size. The trees used in this experiment had set about twice as many peaches per tree as seemed necessary for a crop, as will be seen from the number thinned off compared with the number harvested (Table 14).

In an attempt to reduce to a minimum the effect of variations in soil and fertility and bring the different treatments into the closest relationship possible, a complete series of tests was made on each tree. Scaffold limbs were selected at random on each of the twenty trees. Some of these limbs were left untreated as checks; others were thinned to as near the same crop load as possible on the following dates: June 8 to 12, July 1 to 2, and July 19 to 21. In selecting the limbs for the different treatments, the trees were divided into quarters according to the four directions of the compass; there was, for example, a southeast and a northwest quarter. Care was taken to place a treatment in each quarter-section of the tree about the same number of times. This could be done easily with Gage because the scaffold limbs come out from the trunk typically in a horizontal direction.

In evaluating the results of this experiment it should be understood that the first thinning was done during the June drop and the last one during the first part of the third growth period. (The three growth periods in Elberta are shown diagrammatically in Fig. 10, page 352.) The fruit was picked firm ripe at two intervals about one week apart.

TABLE 14.—TIME OF THINNING: YIELD AND SIZE OF GAGE PEACHES FROM SCAFFOLD LIMBS ON THE SAME TREE THINNED AT DIFFERENT TIMES, 1937 (EXPERIMENT 14, URBANA)
(Full bloom on April 29; picking started on September 15)

Days after bloom that thinning was done	Number of limbs[a]	Total number of fruits thinned off	Distribution of crop in size classes indicated: 1½"-2" Number	1½"-2" Percent	2"-2½" Number	2"-2½" Percent	2½"-2¾" Number	2½"-2¾" Percent	Total number of fruits harvested
42	23	7 689	457	7.55	3 328	55.01	2 265	37.44	6 050
63	27	4 930	651	10.74	3 673	60.61	1 736	28.65	6 060
82	25	4 554	857	15.19	3 265	57.87	1 520	26.94	5 642
No thinning	26	0	3 815	39.79	4 928	51.41	843	8.79	9 586

Statistical analysis of data[b]

Comparisons made	F value for the size class: 1½"-2"	2"-2½"	2½"-2¾"	Least significant value of F: 5-percent level	1-percent level
Thinning treatment with check	100.24[c]	1.98	44.40[c]	4.02	7.12
Three thinning treatments with each other	3.82[d]	2.12	6.76[c]	3.17	5.01
June thinning treatment with two July treatments	5.65[d]	3.46	13.43[c]	4.02	7.12
Two July treatments with each other	1.98	.77	.08	4.04	7.12

[a]The amounts of bearing surface included in each thinning treatment and in the check are comparable. The limbs varied somewhat in size. [b]The data for the determination of the **F** value is based on the percentage of the number of peaches which fell in the size class. [c]Highly significant. [d]Significant.

The results show: (1) a slight decrease in the number of fruits in the 2½-to-2¾-inch class on the branches thinned later than 42 days after bloom, and (2) proportionately less of the smaller fruit on the thinned limbs than on the unthinned check limbs.[1] The total yield of fruit measuring less than 2 inches in diameter was larger from the check limbs than from the thinned limbs, but the yield of fruit more than 2½ inches in diameter was considerably less on the check limbs. It is rather surprising that the size of the fruit was not reduced more than it was by the presence of the excess crop when thinning was not done until as late as 63 days and 82 days after bloom.

[1]The significance of the differences resulting from the different treatments was found by analysis of variance to be as follows (Table 14): (1) When the thinning treatments are compared with the check there is a highly significant difference between treatments in both the smallest and the largest size classes. (2) When the three thinning treatments are compared with each other, there is still a significant difference between them. (3) This difference between the thinning treatments is due to the difference between the June thinning and the two July thinning treatments. (4) There was no significant difference between the two July thinning treatments. This lack of significant difference shows that thinning was effective as late as 82 days after bloom. There was about the same percentage of the crop in the 2-to-2½-inch size classes in all cases; consequently the difference between treatments and the check occurred primarily in the larger and smaller size classes.

Summary

Since the number of peaches on a tree is markedly reduced during the three drops, the question of the best time to thin narrows down to this: is it necessary, considering the cost, risk, and relative effectiveness, to thin before the end of the June drop?

In setting up experiments to answer this question, the response of the tree to thinning at different times was determined in two ways: (1) by comparing the increase in diameter of peaches from thinned and unthinned trees; and (2) by comparing the percentage of the crop from both series in the different size classes. The number of peaches pulled off plus the yield at harvest shows the crop level under which the experiments were carried out. The set was not so heavy as it was in the Ohio experiments reported by Shoemaker (1934).

From these experiments under Illinois conditions it may be concluded that it is not necessary to thin Elberta until after the June drop. It may be advisable to thin some of the earlier varieties such as Red Bird sooner than this because they normally set heavy crops and tend to produce small peaches during their relatively short growing season.

Delaying thinning until after the June drop in Elberta minimizes the risk of reducing the crop too much before it is possible to determine which peaches will fall naturally. In most of these experiments the average number of fruits removed in thinning decreased markedly after the June drop. This means that with later thinning there was a saving of cost, which might be expected to partly counterbalance the slightly larger size attained by the peaches thinned before the June drop.

COMBINATION CULTURAL TREATMENTS

The object of this series of experiments was to produce a wide range of conditions under which to study the relationship between tree growth and fruit size. Since tree growth in Elberta is very vigorous in many orchards in southern Illinois, the question whether a tree making vigorous growth would size up its crop to the desired commercial minimum, about 2¼ inches in diameter, without being thinned has frequently been asked. To answer this and similar questions, experiments were carried out under some of the extremes in growth vigor induced by various pruning treatments and nitrate applications.

The first combination experiment was set up in 1929 in the Bates orchard near Centralia. Similar experiments were carried out during the seasons of 1931 and 1933 at other places in the state. The treatments that were varied and those held constant in each experiment are shown in Table 15.

TABLE 15.—COMBINATION CULTURAL TREATMENTS: YIELD AND SIZE OF ELBERTA PEACHES FROM TREES GIVEN COMBINATIONS OF DIFFERENT FERTILIZER, PRUNING, AND THINNING TREATMENTS, 1929, 1931, AND 1933

Line	Number of trees	Nitrate treatment	Pruning treatment	Thinning treatment			Percent of crop in size classes indicated					Yield per tree in pounds
				Spacing, inches	Days after bloom	Fruits thinned off per tree	1¾" and less	1¾"-2"	2"-2¼"	2¼"-2½"	2½"-2¾"	
Experiment 1: 12-year-old trees, Bates orchard, 1929												
1	4	$CaNO_3$, 3 lb.	Heavy	5	62	412	1	31	65	3	0	160
2	4	$CaNO_3$, 3 lb.	Moderate	5	62	504	1	44	54	1	0	178
3	4	$CaNO_2$, 3 lb.	Heavy	5	83	422	2	49	46	4	0	167
4	4	$CaNO_2$, 3 lb.	Moderate	5	83	520	3	62	36	0	0	182
5	4	$CaNO_3$, 3 lb.	Heavy	5	102	440	5	72	23	0	0	188
6	4	$CaNO_3$, 3 lb.	Moderate	5	102	486	5	70	26	0	0	200
7	4	$CaNO_3$, 3 lb.	Heavy	Check	..	0	14	75	11	0	0	281
8	4	$CaNO_3$, 3 lb.	Moderate	Check	..	0	14	62	25	0	0	265
Experiment 2: 7-year-old trees, University farm at Olney, 1933												
9	5	$NaNO_3$, 4 lb.	Medium	10	At bloom	6 000[a]	.7	11.5	47.7	37.6	2.5	216
10	4	$NaNO_3$, 4 lb.	Heavy	10	40	210	.2	2.7	24.1	61.4	11.7	165
11	5	$NaNO_3$, 4 lb.	Medium	10	40	879	3.5	31.7	56.4	8.4	.1	238
12	11	$NaNO_3$, 4 lb.	Heavy	10	70	176	.5	5.0	34.7	49.3	10.5	146
13	12	$NaNO_3$, 4 lb.	Medium	10	70	632	.6	11.7	45.7	37.9	4.2	291
14	11	$NaNO_3$, 4 lb.	Thinning out	10	70	665	1.4	22.3	51.0	24.5	.9	258
15	11	$NaNO_3$, 4 lb.	None	10	70	733	1.5	25.5	61.1	11.9	0	321
16	3	$NaNO_3$, 4 lb.	Medium	10	88	729	6.3	40.0	42.8	10.7	.2	227
17	9	$NaNO_3$, 4 lb.	Medium	10	114	395	3.5	26.5	57.7	12.1	.1	159
18	2	$NaNO_3$, 4 lb.	Heavy	Check	..	0	.8	9.6	40.9	40.9	7.9	197
19	8	$NaNO_3$, 4 lb.	Medium	Check	..	0	6.0	35.5	38.1	18.5	1.9	266
20	3	$NaNO_3$, 4 lb.	Thinning out	Check	..	0	6.9	46.7	45.9	.5	0	394
21	3	$NaNO_3$, 4 lb.	None	Check	..	0	9.3	61.9	28.5	.2	0	343

[a]This is an estimate.

(Table is concluded on next page)

TABLE 15.—YIELD AND SIZE OF PEACHES FROM TREES GIVEN COMBINATIONS OF DIFFERENT TREATMENTS—*Concluded*

Line	Number of trees	Nitrate treatment	Pruning treatment	Thinning treatment			Percent of crop in size classes indicated					Yield per tree in pounds
				Spacing, inches	Days after bloom	Fruits thinned off per tree	1¾″ and less	1¾″-2″	2″-2¼″	2¼″-2½″	2½″-2¾″	
Experiment 3: 13-year-old trees, Heaton orchard, 1931												
22	5	$NaNO_3$, 3 lb.	Medium	Check	..	0	45.9	47.9	6.2	0	0	374
23	2	None	None	Check	..	0	2.6	23.9	47.2	26.0	.3	388
24	3	None	None	6	59	661	.1	12.2	48.3	35.5	3.3	263
25	4	None	Heavy	6	59	1 253	4.5	23.1	54.9	16.2	1.3	339
26	10	$NaNO_3$, 3 lb.	Thinned out	6	59	884	3.4	24.5	54.8	17.3	0	269
27	5	$NaNO_3$, 3 lb.	Heavy	6	59	1 033	1.9	23.0	60.7	14.4	0	238
28	10	None	Medium	6	60	495	.7	6.3	34.7	49.8	8.5	209
29	3	$NaNO_3$, 3 lb.	Heavy	Check	..	0	21.8	48.4	25.7	3.3	.8	378
Experiment 4: 9-year-old trees, McBride orchard, 1931												
30	1	$NaNO_3$, 10 lb.	Dehorned, '31	6	..	0	0	.1	7.9	44.1	47.4	152
31	1	$NaNO_3$, 10 lb.	Dehorned, '31	6	61	120	0	0	0	4.9	95.0	103
32	4	$NaNO_2$, 10 lb.	Medium	6	61	...	0	.1	9.8	58.4	31.6	267
33	6	$NaNO_3$, 5 lb.	Thinning out	6	61	1 259	.2	7.4	44.7	40.9	6.6	437
34	6	$NaNO_3$, 5 lb.	Thinning out	6	61	1 063	0	4.1	38.4	48.1	9.2	383
35	6	$NaNO_3$, 5 lb.	Heavy	6	61	1 311	0	1.6	32.7	58.7	5.4	296
36	5	$NaNO_3$, 5 lb.	Heavy	6	61	1 121	0	1.8	28.5	64.1	3.4	336
37	5	$NaNO_3$, 5 lb.	Medium	6	61	...	0	2.7	39.8	55.1	2.2	326
38	6	$NaNO_3$, 10 lb.	Medium	6	61	...	0	2.0	35.6	59.4	2.8	298
39	1	$NaNO_3$, 5 lb.	Heavy	Check	..	0	.5	8.9	35.8	53.7	.1	380
40	1	$NaNO_3$, 5 lb.	Medium	Check	..	0	1.9	36.0	52.6	9.5	0	422
41	1	$NaNO_3$, 10 lb.	Medium	Check	..	0	7.3	57.5	27.6	7.6	0	341

Experiment 1.—The experiment in the Bates orchard was set up in 1929 with 12-year-old Elberta trees which had been given a heavy pruning in the spring of 1928 (see Figs. 1 to 6 for pruning types). The crop in 1929 was borne on the vigorous shoots that resulted from the heavy cutting; some of these shoots were 2 to 3 feet long. For the 1929 pruning, the trees were divided into two main groups, one group being pruned heavily in the spring and the other moderately heavily. The vigor of the summer growth of 1929 was correlated with the pruning treatment given in the spring, the more severely pruned trees showing more vigor. Both groups of trees were then divided into a series spaced 5 inches apart, some were thinned at 62 days after bloom, others at 83 days, and still others at 102 days. With thinning severity and nitrate application held constant, pruning type and the time of thinning were thus under test.

The first thing of note in this experiment is the relatively small size of all the fruit borne by these trees in 1929. Most of the crop was 2 to 2¼ inches in diameter or less. The failure of the trees to size up the fruit was due primarily to the dry summer. Under the conditions which prevailed, neither the fertilizer applications nor the pruning and thinning treatments made it possible for these trees to produce fruit of the desired market size, 2¼ inches or above, and the total yield was low.

Since the June drop was over at the time of the first thinning, the number of peaches thinned off at the three different dates was fairly constant, but the effectiveness of thinning, as measured by fruit size, tended to decrease at 83 days after bloom and still more at the 102-day period. When the trees were pruned heavily and then thinned, the average yield was cut slightly.

It will be seen from this experiment that a dry summer presents the grower with a handicap to sizing up the crop, which may not be completely overcome by pruning, nitrate applications, and thinning combined. Since these trees were in excellent vigor, the calcium nitrate was not added until June 1. The application was delayed because it was made to stimulate the fruit to greater growth rather than to influence the set. Under the weather conditions which prevailed, the nitrate was not effective in sizing up the fruit.

The results of this experiment should be viewed in the light of the studies which have been made of the bearing which soil moisture has upon size of fruit. The following experiments include a wide range of conditions, and for that reason give a better idea of the relative importance of soil moisture as a factor in determining fruit size.

Hendrickson and Veihmeyer (1934) worked in irrigated plots in California where the soil moisture could be controlled. Under the different treatments the percent of the crop above 2⅜ inches in diameter was as follows: Plot 2, in which the soil moisture was maintained above the wilting point thruout the year, had 71 percent of the fruit above 2⅜ inches in diameter; Plot B, in which the trees were allowed to "extract the soil moisture in the top 6 feet to approximately the permanent wilting percentage before the supply was replenished," had 58 percent; Plot C, irrigated like Plot A up to July 1 but not after that date, had 15 per cent; and Plot D, which was not irrigated during the growing season, produced no fruit in this size.

The influence of soil moisture on the growth or enlargement of Elberta peaches on 21-year-old trees was studied by Cullinan and Weinberger (1932) in Maryland. The trees were growing in a sandy loam soil which had a water-holding capacity of about 15 percent in the upper 3 feet and a wilting percentage of 6 percent in the same area. Four weeks after bloom the root zone of each tree in one lot was covered with a waterproof covering 40 feet wide. This covering kept further moisture from entering the surface of the soil.

The size of the fruit obtained from the four selected trees on this dry plot was compared with the size of the fruit from two trees on a normal plot to which water was applied to supplement the rainfall when the wilting point was reached. The increase in volume of fruit was found to be "closely associated with the soil moisture content." The difference between the two plots became more pronounced during the third growth period, at which time the soil moisture in the dry plot was below the wilting point. The trees in both plots were thinned to a 1-to-40 fruit-leaf ratio. At the end of the season the fruit had reached the following sizes: dry plot, 2 inches in diameter; normal plot, 2¼ inches in diameter. The three growth periods for the fruit of Elberta occurred in both plots despite the difference in size finally attained by the fruit.

Jones (1931) carried out experiments with soil moisture in the sand-hill region of North Carolina with trees growing in coarse Norfolk sand, which is quite homogeneous to a depth of four feet or so. Of the treatments set up by Jones the three which follow are of interest here: an irrigated plot, a dry plot covered with mulch paper, and an "average orchard condition" plot. The soil moisture was determined in each plot at depths of 1, 2, 3, and 4 feet. In each plot fruit size was studied on ringed limbs with a variable fruit-leaf ratio. This setup permitted a comparison of fruit size in relation to both soil moisture and fruit-leaf ratio.

Briefly stated, Jones's study showed that fruit size is related to both soil moisture and leaf number. For example, in the irrigated plot the fruit grown on limbs with the lowest fruit-leaf ratio (15 leaves per fruit) was larger than the fruit grown in the dry plot on limbs with the highest ratio (90 leaves per fruit). The length of time the stomata were open was also roughly related to soil moisture, the stomata being open longer in the irrigated plot and the plot in average orchard condition than in the dry one. Soil moisture and leaf number both were thus shown to affect fruit size in this experiment.

During the last part of the third growth period in 1929 the conditions in the Bates orchard approached those in the dry plots referred to in the experiments above. Under these conditions there was a more pronounced decrease in the effectiveness of thinning with the advance of the season than there was under normal conditions. This experiment emphasizes the necessity of looking ahead to the possibility of a dry summer when the crop adjustment is made at thinning time.

Experiment 2.—This experiment with Elberta was set up in 1931 as a repetition of the preceding one. With the exception of a few replants, the trees in the orchard at the Olney farm were 7 years old at the time and in good vigor. A spring application of 4 pounds of $NaNO_3$ resulted in a dark-green foliage generally, especially on the heavily pruned trees. The summer growth in general, however, was closely related to the severity of pruning, which followed the types described on pages 334-337. There was an excess of bearing wood in the trees given the thinning-out type of pruning, but this was partly corrected by severe thinning.

The general level of the fruit size in this crop was considerably larger than that in the Bates experiment made during the dry season of 1929. The heavy pruning, together with thinning, reduced the yield even tho the size of the fruit was increased. The increase in the size of the fruit with different combinations of treatment shows how it is possible to regulate size. For example, with heavy pruning (Table 15, line 10), 73 percent of the crop measured 2¼ inches or above; whereas with moderate pruning (line 11), only 8.5 percent of the crop was this large. From the check trees, which were neither pruned nor thinned (line 21), 61.9 percent of the crop was in the 1¾-to-2-inch class.

As would be expected, the time of maturity varied greatly as a result of the different combinations of treatment. Harvest started on August 18 on the check trees and those which had been lightly pruned. The heavy pruning delayed maturity for about 8 days.

Thinning was done at bloom and as late as 114 days afterward, the 40-day thinning being done just before the June drop. The effect of the time of thinning can be studied on all trees that received a moderately heavy pruning (Table 15, lines 9, 11, 13, 16, 17, and 19). Thinning became less and less effective the later it was done after 70 days following bloom. The number of peaches thinned off at any one date was roughly related to the severity of pruning, the number being less where the pruning had been more severe.

The influence of pruning alone can be seen in the check trees, since these were not thinned and the nitrate treatment remained the same. Heavy pruning sized up the crop so that 40 percent of it fell in the

2¼-to-2½-inch class. When the trees were not pruned, as much as 61 percent of the crop was in the 1¾-to-2-inch class.

Experiments 3 and 4.—These duplicate experiments with Elberta were carried out in different orchards in 1931. Pruning and nitrate applications were varied but thinning distance and time of thinning, which followed the June drop, were not varied. On account of the severity of some of the treatments—dehorning, for example—the number of trees tested was limited. Results of the two experiments show how it is possible to regulate the size of the fruit by varying pruning and nitrating.

In *Experiment 3* the unthinned trees showed the disastrous effects of an extreme overload upon fruit size (Table 15, lines 22 and 23). Of these two rows, the spring nitrated trees actually bore smaller peaches than the trees not nitrated because nitrate treatment produced a heavier set. Thinning partially corrected the overload in trees that were neither pruned nor nitrated, but the yield was reduced (line 24). Heavy pruning without nitrogen but with thinning did not size up a large enough percent of the crop to the 2¼-inch level because the crop load left was still too heavy (line 25). When the trees were nitrated but pruned lightly (given the thinning-out type of pruning), size of fruit was not increased much because the load was still too heavy (line 26). With this same tree type the situation was not corrected by heavy pruning (line 27). Thinning 60 days after bloom without nitrogen but with medium pruning (line 28) resulted in larger fruit than when nitrating and heavy pruning were carried out without thinning (line 29) mainly because nitrating and heavy pruning produced an excess crop. The crop on the thinned trees (line 28) was

Fig. 18.—Tree-run fruit from thinned trees. The fruits are uniform because thinning has allowed them to round out evenly and they have been carefully picked when firm ripe. (*Heaton orchard, 1931: Table 15, line 28, page 391.*)

harvested at one picking and the fruits were remarkably uniform in size and shape (Fig. 18).

In *Experiment 4* the contrasts in fruit size were of much the same nature as in Experiment 3. The dehorning type of pruning cut the yield but greatly increased the size of the fruit. The next combination treatment, 10 pounds of nitrate of soda in the spring and medium pruning, produced results showing a similar trend (Table 15, line 32). In the next five combinations (lines 33 to 37) pruning was varied and all the other treatments were kept constant. The number of peaches thinned off shows that the set was heavy on these trees. The change in the size trend with different types of pruning, altho not pronounced, favors heavy pruning altho it reduced yield somewhat. Size was fairly satisfactory in the tests reported at lines 37 and 38, altho the difference between a 5- and a 10-pound application of sodium nitrate was not striking. Small fruits, such as those from the unthinned check trees, are difficult to dispose of because the market prefers larger peaches.

These tests again demonstrate that the size of the crop has much to do with the size of the fruit, as was found to be the case by Gardner, Marshall, and Hootman (1928) in Michigan.

Summary

In Experiment 1 of this series of cultural tests, soil moisture was a dominant factor in controlling size of fruit, and thinning became less effective in determining size when it was done as late as about 83 days after bloom. In Experiment 2, with a more favorable season and younger trees, the number of peaches that had to be taken off in thinning and the ultimate size of the fruit were markedly influenced by heavy pruning, but the yield was reduced. In Experiment 3 the unthinned trees bore very small fruit even when nitrated or when given a medium-heavy pruning, thus showing that an excess crop tends to reduce the size of the fruit. Finally in Experiment 4 it was shown that the fruit was much smaller on pruned and nitrated trees when thinning was omitted.

In these experiments unthinned trees generally produced too many small peaches, and this tendency was not corrected altogether by either pruning or nitrate applications. As judged by yield and fruit size, the results show that under Illinois conditions it would be best to follow the practice of pruning moderately heavily and continuing the nitrate applications to such extent as the situation seems to demand. Thinning should be used to supplement these two treatments whenever the set is heavy enough to justify it.

THE FINAL SWELL

Peach growers often refer to the last two weeks or so in the growth of the peach, or the last part of the third growth period, as the final swell. This term is quite descriptive because during this time the fruit seems to make a final spurt in growth as it ripens. Since the fruit continues to enlarge as long as it hangs on the tree, it will be seen that the stage of maturity at which it is harvested bears a direct relation to yield.

Increase in Size of Fruit

In 1934 in the Heaton orchard a study was made of the increase in size of Elberta during the final swell. In this experiment on August 15, two days after the first picking, over 1,200 peaches on 11-year-old trees were carefully selected to match the ground color of the peaches being picked at the time. These peaches while still on the tree were tagged with serial numbers. The tagged peaches were about equally distributed between six trees which had been thinned to a 6-inch spacing after the June drop. The suture diameter of all the tagged peaches on the trees was measured on the following dates, when some of the peaches were picked in this way: August 15, every fourth fruit; August 17, every third fruit; August 20, every other fruit; and finally on August 22, the remainder.

Such measurements showed how much the peaches in this orchard enlarged after the first fruit had been picked. On August 15, when the first tagged peaches were picked, the average suture diameter was 2.28 inches; 7 days later, at the fourth picking date, the average diameter had increased to 2.45 inches. This was an increase in volume from an average of 102.8 cc. on August 15 to 127.9 cc. on August 22, or a gain in volume of 24.4 percent. As a result of this growth, the proportion of the crop 2¼ inches or more in diameter had increased from 47.8 percent at the beginning of the experiment to 93.7 percent at the end (Table 16 and McMunn and Dorsey, 1934A).

Coe (1933) reported that fruit increased in volume 42 percent from the first to the third picking. Other studies of maturity have been made by Addoms *et al* (1930), Morris (1932), Fisher and Britton (1940), Blake *et al* (1931), and Lott (1942). Since the peaches in the Heaton orchard increased in size so strikingly during the final swell in 1934, it seemed advisable to repeat the measurements during another season. To this end the following measurements were made in 1941 in the orchard of J. E. Venerable and Sons near Cobden.[1]

At the start, 217 peaches on an Elberta tree and 250 peaches on a

[1]The measurements in this orchard were made by O. K. Loomis and Son of Anna, Illinois.

J. H. Hale tree were numbered consecutively. The two trees, thinned to a 6-to-8-inch spacing after the June drop, were growing in good soil and were in excellent vigor. The peaches tagged for measuring were on the sides of moderately low trees and could be reached from the ground without a ladder.

During the first two weeks of August the weather was considered dry by local peach growers. The official rainfall at Anna 5 miles away was as follows: August 12, .79 inch; August 13, 1.98 inches; August 19, 2.78 inches; and August 24, 2.16 inches. No records were taken in the Venerable orchard, but a heavy rain fell there on August 19. Elberta was topped on August 18 and J. H. Hale on the following day. The remainder of the crop of both varieties was picked on August 24, altho the fruit of J. H. Hale could have been left on 4 or 5 days longer.

There was a constant increase in the diameter or volume of the fruit of both varieties during the 16-day period from August 8 to harvest on August 24 (Table 17). The average volume of the fruit, figured as the volume of a sphere from the average diameter, increased 48 percent in Elberta and 47 percent in J. H. Hale. In fact, Elberta increased in volume 23 percent after the first picking date on August 18 and J. H. Hale, 16 percent after the first picking date a day later.

Ripening Changes

The rapid increase in the size of the fruit that takes place during the final swell must be viewed in the light of the ripening changes. How

TABLE 16.—SUMMARY OF CHARACTERISTIC CHANGES IN ELBERTA PEACHES DURING FINAL SWELL
(Heaton orchard, 1934)

Characteristic	First picking (August 15)	Second picking (August 17)	Third picking (August 20)	Final picking (August 22)
Average suture diameter, inches	2.28	2.34	2.40	2.45
Volume per peach, cc.	102.8	111.5	119.8	127.9
Gain in volume after August 15, percent	0	7.9	16.5	24.4
Fruit 2¼ inches or more in diameter, percent	47.8	70.9	84.9	93.7
Quality	Poor	Poor to fair	Fair to good	Good to very good
Background color[a]	Yellow green	Light yellow-green	Light greenish yellow	Pale greenish yellow
Average area of peach covered by blush, percent	0-10	10-25	25-50	50 and more
Pressure test of these peaches, pounds	9-11	8-10	7-9	6-8
Typical pressure test of Elberta at comparable stage of maturity, pounds	10-12	8-10	7-8	5-7
Maximum shipping radius, approximate miles	1 500	1 500	1 000	500
Consumer acceptance	Low	Fair	Good	Highest

[a]These descriptions of color follow the Ridgway color standards and nomenclature. On August 13, when picking began, the peaches were emerald green.

TABLE 17.—CHANGES IN SIZE AND RIPENESS OF ELBERTA AND J. H. HALE PEACHES DURING FINAL SWELL
(Venerable orchard, 1941: Elberta first picked on August 18, J. H. Hale, on August 19)

Date in August	Elberta				J. H. Hale			
	Average size			Average of 8 random pressure tests	Average size			Average of 8 random pressure tests
	Number of peaches measured	Cheek diameter	Volume		Number of peaches measured	Cheek diameter	Volume	
		cm.	*cc.*	*lb.*		*cm.*	*cc.*	*lb.*
8	217	4.95	63.5	10.5	250	5.07	68.4	....
9	215	5.01	65.8	11.7	250	5.10	69.5	....
11	213	5.13	70.7	12.6	250	5.22	74.5	11.3
12	210	5.18	72.8	10.6	250	5.24	75.3	10.4
13	210	5.23	74.9	10.7	249	5.30	78.0	8.7
14	209	5.31	78.4	9.9	247	5.37	81.1	10.1
15	208	5.42	83.4	9.5	247	5.45	84.8	9.2
16	207	5.50	87.1	8.1	228	5.52	88.1	8.6
18	206	5.65	94.4	10.5	228	5.62	92.9	8.5
19	204	5.76	100.1	5.8	221	5.70	97.0	7.0
20	199	5.82	103.2	6.3	217	5.74	99.0	7.7
21	198	5.86	105.4	7.0	214	5.80	102.2	6.4
22	197	5.94	109.7	4.9	212	5.87	105.9	....
23	194	6.03	114.8	6.3	211	5.96	110.8	5.4
24	187	6.17	123.0	5.4	210	6.04	115.4	5.6

long can picking be delayed in order to take greater advantage of the increase in yield thus built up by the rapid expansion of the fruit? In an attempt to answer this question, studies were made of the ripening of the peaches picked in the Heaton orchard on each of the four picking dates, beginning on August 15, 1934.

As the ripening process proceeded in the different lots, the quality was rated from Poor, in those picked August 15, to Good or Very Good in those picked on August 22 (Table 16). The background color in the meantime changed from a yellowish-green cast on August 15 to a light yellow green on the 17th, a light greenish yellow on the 20th to a pale greenish yellow on the 22d, to use the descriptive terms in the Ridgeway color standards.

The proportion of the surface covered by blush increased from 5 percent at the first picking to 50 percent or more on August 22, a very important improvement as far as market acceptance is concerned. In fact, general consumer acceptance, which was rated Low at the time harvesting was started, gradually rose to Fair on August 19, to Good on August 20, and to the highest rating as the peaches became more mature at the end of the experiment. As ripening proceeded, however, the firmness of the fruit, as measured by the Blake tester,[1] gradually

[1]In this study wherever pressure readings are referred to, it is understood that they have been measured by the instrument with the 5/16-inch plunger, as described by Blake (1929). A number of other devices have been used to measure the firmness of the flesh in different kinds of fruit, but none of these was available for this study.

decreased from 9 to 11 pounds at the start of the experiment on August 15 to 6 to 8 pounds at the last picking date on August 22. Accompanying these changes, the distance that the peaches could be shipped decreased from an estimated 1,500 miles at the first picking to 500 miles at the last date.

The full significance of the ripening process in the peach is not apparent from the size, color, or firmness of the flesh alone. Changes in the composition of the fruit take place at the same time as the external changes and are equally important. The changes that take place within the kernel, seed, and flesh of Hale Haven during ripening have been followed by Lott at the Illinois Station (1942). He found that the amount of sucrose, the principal sugar in the peach, increases rapidly during the final swell. In fact, two-thirds of the entire sugar content of the peach is built up in about the last two weeks before harvest.

Summary

Measurements made during the last two weeks or so before harvest showed that peaches continue to increase in size as long as they remain on the tree. Elberta peaches increased about 25 percent in volume after picking had started. In the Heaton orchard only 48 percent of the fruit was 2¼ inches or more in diameter at the first experimental picking; two days later, 70 percent of the crop had reached this size; and at the last picking, when the fruit had reached the tree-ripe stage, 94 percent of it was 2¼ inches or more in diameter. A grower can take advantage of most of this increase in size by picking at the firm-ripe stage or later.

The ripening changes that take place with the increase in size during the final swell are: (1) a change in background color from a greenish cast to an orange-yellow at full maturity; (2) an increase in the amount of blush or overcolor; and (3) an increase in quality but a loss in firmness.

SHIPPING AND STORAGE QUALITIES AS RELATED TO TIME OF PICKING

High yield and better eating quality are, of course, only part of the concern of the orchardist in deciding at what stage of maturity to harvest peaches. Carrying quality in shipment and holding capacity in storage are important considerations in causing the grower to pick the crop before the fruit has attained its best qualities for eating. Whether so much sacrifice of yield and quality is necessary in order to get the product to consumers without undue loss is a question of sufficient importance to deserve further study. There is little need to point out to the peach grower the advantage there would be in making use of the final swell if it were found that riper peaches could be marketed successfully.

Shipping Tests

In view of the findings from the studies on size increase and ripening changes during the final swell, arrangements were made in 1938 to study the significance of these changes in commercial shipments. These studies were conducted in cooperation with Purdue University.[1]

In this experiment Elberta peaches were picked at the following stages of maturity: (1) Green ripe, or immature, testing 10 to 12 pounds by the Blake tester. In this lot the background still retained a distinct greenish cast. This lot was selected to match the degree of maturity of the earliest commercial picking of Elberta in this state. (2) Firm ripe, testing 7 to 8 pounds; this lot had a more pronounced yellow cast to the background. (3) Tree ripe, testing 3 to 5 pounds; some of these were softening and the final swell was nearly complete but most of the peaches were within 2 to 3 days of the soft-ripe stage.

Bushel baskets of carefully selected peaches of each of the stages of maturity described were shipped to Buffalo, New York. The car was cooled for 7 hours and 22 minutes before it was despatched—which brought the temperature down below 50° F. in the center of the ventilated baskets. A temperature of about 45° F. was reached in the ventilated baskets at about the 12th hour in transit, at which time baskets with regular liners stood at about 50° F. These temperatures were low enough to hold brown rot in check (Brooks and Cooley, 1921) but did not retard the ripening process in the fruit as much as desired. The shipment was in transit to Buffalo 51 hours. Within 6 hours after arrival, sample baskets of peaches from all three lots were returned by uniced express to Purdue University and to the University of Illinois for further observation and study.

The first lot was still hard and green when the fruit reached Urbana on August 18, a week after being picked. What ripening had taken place was uneven, one pressure reading being 3.5 pounds and one 13.5 pounds, the average of 24 peaches being 8.2 pounds. The second lot had softened considerably, 24 pressure tests averaging 2.3 pounds on August 18. The third lot, testing 3 to 5 pounds at the start, averaged only 1.5 pounds for 24 measurements in the return shipment.

When Fawcett examined the shipments in Buffalo, he reported[2] that the third lot was "in very fine condition for immediate consumption." This shipment, it will be recalled, was precooled fruit picked tree ripe.

[1]For a complete report of these studies, see Heinton and Fawcett (1939).

[2]This was reported in a personal letter from C. L. Burkholder of Purdue University, August 16, 1938.

The second lot of peaches reached Buffalo in excellent condition and had plenty of reserve for handling in the trade in the usual manner. The first lot stood the shipment both ways with "only a few specimens bruised," but it was very low in quality and still unpalatable. It is easily understood, therefore, why fruit picked green like the first lot would be preferred by some shippers even tho consumer acceptance would be low.

It will be clear from this shipping test that, if peaches are precooled and handled properly, they can be placed upon distant markets after being picked tree ripe. These studies therefore bear out what Dunlap wrote as far back as 1867: "I find fruit packed when ripe will carry just as well, if properly packed, as that picked before it is ripe." They also confirm other studies made at the Station, on the basis of which it was concluded that "fruit harvested as much as seven days later than is normally done in Illinois will hold up in transit" (McMunn and Dorsey, 1934A). The market can be entirely relieved of peaches as green as the first lot if more attention is paid to selecting riper peaches in picking. The results from this shipping test of precooled peaches are in line with the first studies of Powell in 1904 (reported by Stubenrauch and Dennis, 1911), which were continued by Lloyd and Newell (1929 and 1930), Allen and McKinnon (1935), Heinton and Fawcett (1939), and others.

Storage Tests

Since it was demonstrated that riper peaches could be shipped successfully, further tests were made to see how peaches of different stages of maturity would behave in storage.

Experiments over many years have shown that 32° F. is the best storage temperature for peaches (Powell and Fulton, 1903; Gore, 1911; Haller and Harding, 1939; Fisher and Britton, 1940; and others). The significance of this temperature as a base level in handling peaches will be best understood from the studies which have been made with respiration rate as an index of physiological activity in fruit held at different temperatures. For instance, Gore (1911) found that the respiration rate "increased 1.89-3.01 times for each 10° (F.) rise in temperature." This conclusion was based upon 49 sets of determinations with 40 different kinds of fruit. The delay in the ripening process in the peach was found by Haller and Harding (1939) to be about as follows: "One day at 70° F. is about equivalent to 2 days at 60°, 4 at 50°, 8 at 40°, or 16 at 32°." This general relation between temperature level and length of time fruit may be kept in storage is in line with the earlier studies of Powell and Fulton (1903), Dorsey (1907), Gore (1911), and others.

Besides determining the extent to which ripening of fruit will be retarded in storage and the storage life of the fruit, which varies from 2 to 4 weeks, there are two other ways in which temperature acts upon peaches that are held after picking. First the quality of the fruit is noticeably lower in peaches held in storage and ripened at temperatures between 36° and 50° F. than in peaches ripened at temperatures above 70° F., according to the observations of Haller and Harding (1939) and others. The abnormal ripening at the lower temperature range is described as a breakdown, or the development of mealiness. Even in precooled cars, where an attempt is made to keep the temperature below 36° F., it actually falls between 36° and 50° F. for a considerable part of the time the peaches are in transit. Second, but of equal importance, is the finding that holding fruit at a temperature of 75° F. for as much as two or three days after picking controlled, or at least reduced, the development of mealiness, or wooliness, later on (Davies, Boyes, and DeVilliers, 1937; Haller and Harding, 1939; and Fisher and Britton, 1940). Here again most peach growers do not take advantage of their opportunity to let the peaches remain at the higher temperatures before storing them. They usually store peaches as quickly as possible after they are picked.

With the above research as a guide, further experiments were set up to test the holding capacity of peaches at different temperatures when picked at different stages of maturity. The studies were made with Elberta and Gage, and data were collected on loss of weight and the ripening rate.

Loss in weight in storage as related to temperature. The following variables were included in the setup in the loss-of-weight tests: (1) stage of maturity of fruit—green ripe, firm ripe, or tree ripe; (2) temperatures varying from 37° to 90° F.; and (3) time in storage.

The storage temperatures were maintained in six chambers 3 feet by 3 feet by 4 feet built in a larger cold storage room, the base temperature of which was 37° F. The temperature in the individual chambers was maintained above that of the larger room by the heat from electric light bulbs under thermostatic control. No record was made of the humidity in the individual chambers, altho the relative humidity in the larger room varied from 65 to 85 percent, depending upon the time of year and the material in the storage. It is probable, therefore, that the humidity in the individual chambers varied inversely with the temperature. Unfortunately a chamber at 32° F., the temperature almost universally recommended for storing peaches, was not available. For this reason the lot of peaches to be kept at 37° F. was put in the large storage room. Here the peaches were more exposed to air movement and perhaps a lower humidity than in the individual chambers.

The weight loss was about the same in the lots of peaches picked at different degrees of maturity and stored at different temperatures up to the 90° F. level (Table 18). At 90° F. the green fruit lost weight most rapidly. At the lower temperatures the loss in weight was slight at first with peaches picked at all stages of maturity and there was no noticeable withering until well toward the end of the experiment. At temperatures above 70° F., however, shriveling was pronounced within a few days in the fruit picked at all stages of maturity but it made the green peaches the most unattractive.

As would be expected, on account of the increased transpiration and respiration rates at the higher temperatures, the fruit not only lost weight more rapidly but rots developed as well. Contrary to this general

TABLE 18.—LOSS OF WEIGHT IN STORED PEACHES WHEN HARVESTED AT THREE DEGREES OF RIPENESS AND KEPT AT DIFFERENT TEMPERATURES, 1938

Elberta peaches from University farm at Olney: 20 fruits in each sample, weight on August 11 = 100

Storage temperature	Stage of maturity	Percent weight of stored fruit was of original weight at picking time				
		Aug. 13	Aug. 16	Aug. 19	Aug. 22	Aug. 25
37° F.	Green ripe	97	96	95	91	90
	Firm ripe	97	96	94	91	90
	Tree ripe	98	96	95	92	91
40° F.	Green ripe	98	98	96	95	95
	Firm ripe	97	97	96	95	94
	Tree ripe	98	98	97	96	94
50° F.	Green ripe	97	97	96	94	94
	Firm ripe	98	98	96	94	94
	Tree ripe	100	98	96	95	94
60° F.	Green ripe	98	96	92	88	87
	Firm ripe	97	94	91	88	86
	Tree ripe	96	95	92	89	88
70° F.	Green ripe	96	94	92	87	85
	Firm ripe	96	94	91	86	85
	Tree ripe	97	94	90	86	Rotted
80° F.	Green ripe	96	92	87	82	76
	Firm ripe	96	90	87	82	Rotted
	Tree ripe	97	94	89	83	Rotted
90° F.	Green ripe	84	75	67	61	Rotted
	Firm ripe	95	89	85	74	Rotted
	Tree ripe	94	91	82	72	Rotted

Gage peaches from University orchard at Urbana: 15 fruits in each sample, weight on August 24 = 100

Storage temperature	Stage of maturity	Aug. 27	Aug. 30	Sept. 2	Sept. 6	Sept. 9
37° F.	Green ripe	94.1	92.1	90.2	86.3	84.3
	Firm ripe	94.5	90.9	90.9	87.2	84.5
	Tree ripe	96.2	92.4	90.5	88.7	83.0
40° F.	Green ripe	98.0	96.0	96.0	94.0	90.0
	Firm ripe	98.2	94.5	94.5	92.7	89.0
	Tree ripe	98.3	96.6	95.0	93.3	91.6
50° F.	Green ripe	95.9	91.7	91.7	89.5	85.4
	Firm ripe	96.2	94.3	92.4	90.5	86.8
	Tree ripe	96.5	93.0	91.2	89.5	87.7
60° F.	Green ripe	92.1	88.2	86.2	83.1	78.4
	Firm ripe	94.4	88.8	85.2	79.6	74.0
	Tree ripe	94.5	90.0	87.3	85.4	80.0
70° F.	Green ripe	93.2	88.6	86.4	77.2	72.7
	Firm ripe	93.4	90.1	86.8	81.9	75.4
	Tree ripe	94.3	90.5	88.6	83.0	75.4
80° F.	Green ripe	91.7	85.4	81.2	70.8	Rotted
	Firm ripe	92.0	86.0	82.0	68.0	Rotted
	Tree ripe	92.7	87.2	81.8	74.5	Rotted
90° F.	Green ripe	89.4	78.7	68.1	53.2	Rotted
	Firm ripe	90.0	82.0	70.0	52.0	Rotted
	Tree ripe	88.0	84.1	79.3	63.1	Rotted

TABLE 19.—LOSS OF FIRMNESS IN STORED PEACHES WHEN HARVESTED AT THREE DEGREES OF RIPENESS AND KEPT AT DIFFERENT TEMPERATURES, 1938

Storage temperature	Stage of maturity	Blake pressure reading in pounds					
		Elberta peaches from University farm at Olney: harvested and stored on August 11, 20 fruits in each sample					
		Aug. 11	Aug. 13	Aug. 16	Aug. 19	Aug. 22	Aug. 25
37° F......	Green ripe..............	10.6	11.2	10.3	11.1	10.7	10.9
	Firm ripe...............	8.8	7.2	5.6	4.9	2.9	3.5
	Tree ripe...............	5.7	6.5	4.3	3.6	2.4	2.6
40° F......	Green ripe..............	10.6	11.0	9.0	9.7	7.9	7.1
	Firm ripe...............	8.8	7.3	4.3	4.4	2.8	2.8
	Tree ripe...............	5.7	5.6	2.5	2.3	1.7	1.7
50° F......	Green ripe..............	10.6	10.7	6.7	6.3	2.5	2.6
	Firm ripe...............	8.8	6.1	2.9	2.4	1.4	1.4
	Tree ripe...............	5.7	3.0	1.7	1.9	1.3	.9
60° F......	Green ripe..............	10.6	10.8	3.5	2.4	1.4	1.1
	Firm ripe...............	8.8	5.5	1.6	1.7	1.0	1.0
	Tree ripe...............	5.7	3.3	1.6	1.1	.9	.9
70° F......	Green ripe..............	10.6	9.7	2.8	1.8	1.0	.9
	Firm ripe...............	8.8	4.0	1.2	1.0	.9	.8
	Tree ripe...............	5.7	2.4	.9	1.1	.5	Rotted
80° F......	Green ripe..............	10.6	7.3	2.1	1.5	.9	.6
	Firm ripe...............	8.8	4.0	1.1	.9	.7	Rotted
	Tree ripe...............	5.7	2.1	1.0	.9	1.7	Rotted
90° F......	Green ripe..............	10.6	7.1	1.6	1.6	.9	Rotted
	Firm ripe...............	8.8	2.9	1.1	.9	.5	Rotted
	Tree ripe...............	5.7	1.0	.9	Rotted	.5	Rotted
		Gage peaches from University orchard at Urbana: harvested and stored on August 24, 15 fruits in each sample					
		Aug. 24	Aug. 27	Aug. 30	Sept. 2	Sept. 6	Sept. 9
37° F......	Green ripe..............	...	8.9	9.2	7.6	6.7	3.7
	Firm ripe...............	...	8.4	8.4	7.2	2.9	3.4
	Tree ripe...............	...	5.3	4.0	3.6	1.6	1.0
40° F......	Green ripe..............	...	9.2	8.6	8.1	4.6	2.5
	Firm ripe...............	...	8.2	6.4	6.5	2.4	2.1
	Tree ripe...............	...	4.5	3.9	2.8	1.5	1.1
50° F......	Green ripe..............	...	9.9	7.0	3.3	2.2	1.6
	Firm ripe...............	...	6.6	2.9	2.3	1.6	1.1
	Tree ripe...............	...	3.5	1.6	1.5	1.0	.6
60° F......	Green ripe..............	...	7.8	3.3	1.8	1.4	1.1
	Firm ripe...............	...	5.0	1.9	1.2	1.0	.9
	Tree ripe...............	...	2.6	1.2	1.1	.9	.7
70° F......	Green ripe..............	...	6.1	2.7	1.3	.9	.7
	Firm ripe...............	...	3.2	1.6	1.2	.9	Rotted
	Tree ripe...............	...	1.6	.9	1.0	.6	Rotted
80° F......	Green ripe..............	...	4.6	2.3	1.5	.9	Rotted
	Firm ripe...............	...	2.9	1.6	1.1	.8	Rotted
	Tree ripe...............	...	2.1	.9	1.0	.5	Rotted
90° F......	Green ripe..............	...	3.8	1.7	1.3	.8	Rotted
	Firm ripe...............	...	2.9	1.4	1.1	.7	Rotted
	Tree ripe...............	...	1.6	1.0	1.1	.5	Rotted

tendency, the fruit stored at 37° F. lost weight somewhat more rapidly than the fruit stored at 40° and at 50° F., but the fruit kept at 37° F. was stored in the large room, where it was more exposed. It should be noted that Davies, Boyes, and DeVilliers (1937) found wooliness, or mealiness, develops to a greater degree at 34° and 37° F. than at 32° F. The loss of weight at the 40°- and 50°-F. levels after 14 days was practically the same as at the 5-day interval at 60° and 70° F.

The main finding of this study is that there is only a relatively slight difference in loss of weight between lots picked at different stages of maturity when they are stored at the same temperature. The temperature of the storage influenced loss of weight more than did the stage of maturity.

Ripening rate as related to temperature. Six lots of each sample were placed in each chamber at the start of the experiment. When a lot was taken out at the different dates to determine the weight loss, the pressure reading was also obtained for each fruit in the sample. Averages of 20 Elberta peaches and 15 Gage peaches were thus obtained at the different weighing dates for each degree of maturity at each temperature level.

The fruit picked at different stages of maturity ripened very differently at the several temperatures as shown by the pressure tests in Table 19. The green ripe fruit held up well for the period of the experiment, when stored at 37° and 40° F. At about 50° F., however, even the green ripe lots softened considerably within about one week. As would be expected, the fruit picked at all stages of maturity softened in a few days when held at 60° F. or above. At 70° to 80° F. the fruit matured rapidly and the difference in keeping quality between the lots picked at different stages of ripeness became less pronounced than at the lower temperatures. It should be noted, however, that the tree ripe fruit held up better at 37° F. than the green ripe at 60° F.

The findings of this experiment thus agree with practical experience: the more immature the fruit is, the better carrying quality it has; but even green fruit tends to soften rapidly at high temperatures. If, therefore, peaches are picked riper, it is necessary to pay more attention to holding them at lower temperatures during both shipment and storage.

Summary

The shipping tests made in cooperation with Purdue University showed that tree-ripened Elberta peaches can be shipped to distant markets when packed in bushel baskets if the cars are precooled and the temperature is kept at the proper level during transit.

The storage tests showed that peaches picked at different stages of maturity—that is, green ripe, firm ripe or tree ripe—lose weight at about the same rate at different temperatures, but that the riper peaches soften more rapidly at all temperatures. While the riper peaches soften more rapidly in storage, they are of better quality than peaches picked immature.

SOFT SUTURE

Peach growers are sometimes confronted with a condition at harvest which has become generally known as "soft suture." This trouble arises from the fact that the peach tends to ripen at one side of the suture line considerably in advance of the rest of the fruit (Fig. 19). This part of the peach then becomes overripe, or soft, while the rest of the fruit is often still too green to market. Soft suture is more serious some seasons than others.

Studies to determine, if possible, how this difficulty might be corrected were begun in 1931 as part of the tree-conditioning investigations. The studies centered around the normal variation in ripening between different parts of a peach, the cause of soft suture, and the growth conditions under which it occurs.

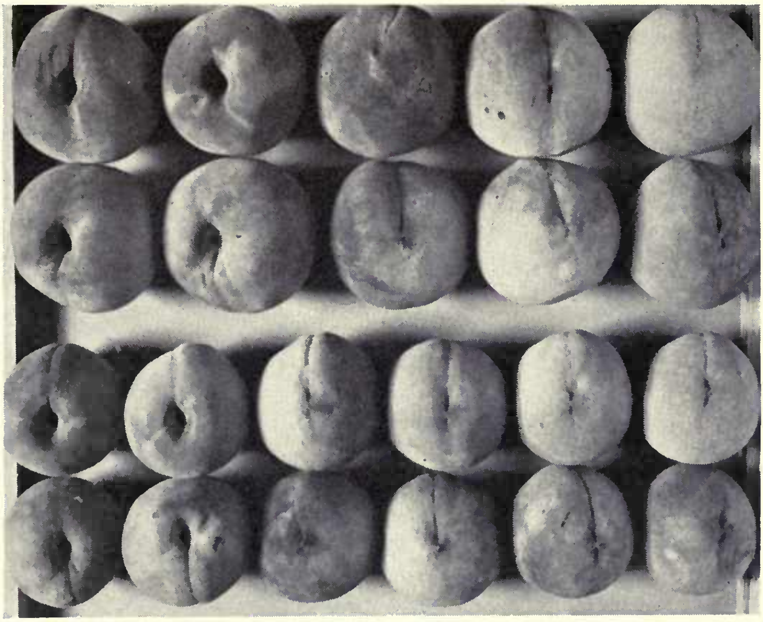

Fig. 19.—Differential ripening. Peaches appear bulged or swollen at one side of the suture line. This swollen area has ripened sooner than the rest of the peach and it will soften first. The two upper rows of fruit are J. H. Hale, the two lower rows Elberta.

Normal Ripening Variations in a Peach

Studies of the normal variation in the degree of ripeness at different positions on a peach were made with peaches picked firm ripe when the average pressure reading made with the Blake tester was between 5 and 7 pounds. The difference in the amount of ripening, or softening, between the two halves was determined by taking plunger tests on each cheek perpendicular to a plane thru the suture.

In most of the crop the Blake pressure tests showed that the differ-

TABLE 20.—RANGE IN DEGREE OF RIPENESS ON OPPOSITE HALVES OF PEACHES OF DIFFERENT VARIETIES AS SHOWN BY BLAKE PRESSURE READINGS

(Readings were made perpendicular to suture diameter in approximate center of cheek; peaches from University orchard, Urbana, 1931)

Range in pressure reading between halves	Number of fruits showing pressure range indicated			
	South Haven	Delicious	Elberta	Sunbeam
lb.				
0	21	24	12	25
.5	38	31	18	20
1.0	37	23	15	12
1.5	26	16	15	2
2.0	19	10	7	1
2.5	5	7	3	0
3.0	2	4	3	0
3.5	2	2	1	0
4.0	0	3	0	0
4.5	0	0	0	0
5.0	1	0	0	0
5.5	0	0	1	0
Total fruits	151	120	75	60

ence in ripeness between the two halves at any one time was only slight, ranging from 0 to 1.5 pounds of pressure after the fruit had been picked at the firm-ripe stage (Table 20). The rest of the peaches showed a difference of 2 to 5.5 pounds of pressure between the halves, only two fruits showing a difference of more than 4 pounds. These measurements are in line with the findings of Lott (1931) and Willison (1940).

After the cheek pressure tests were summarized, the question came up as to what the difference in ripeness between the two cheeks and the area along the suture line might be. The answer has an important bearing not only on soft suture but also on the order in which the parts of a peach ripen. Accordingly in 1938 plunger readings were made in four positions on the peach. As viewed when one faces the suture line with the stem end of the peach down, the positions were as follows: Position 1, ¼ to ⅜ inch from the suture line on the riper side in the approximate center of the suture area; Position 2, at the same distance from the suture line on the other side; Position 3, at the center of the cheek on the same half as Position 1; and Position 4,

TABLE 21.—DEGREE OF RIPENESS OF DIFFERENT VARIETIES OF PEACHES AT FOUR POSITIONS

Variety	Number of fruits measured	Blake pressure reading in pounds			
		Position 1	Position 2	Position 3	Position 4
Elberta, firm ripe[a]	50	4.0	5.1	5.7	6.0
Elberta, green ripe[a]	50	7.4	8.0	8.7	8.9
Sunglow	84	2.5	3.0	3.5	4.0
Valiant	86	3.6	4.0	4.3	4.7
Vedette	63	2.2	2.5	2.9	3.1

[a]Both groups of Elberta were picked the same day.

directly opposite Position 3. Positions 3 and 4, it will be seen, corresponded with the place where the first plunger tests were made. In taking the reading at each position, an attempt was made to place the plunger midway between the tip of the fruit and the stem end.

These pressure readings showed that the peach matured most rapidly at Position 1; next at Position 2, at the other side of the suture line; and then at Positions 3 and 4 in turn (Table 21). Observations showed that the greenest part of the peach was between Positions 2 and 4. The pressure tests check with practical experience with soft suture. Since the peach ripens sooner at one side of the suture line, it is likely to soften there two or three days before the rest of the peach is ready to be picked.

Cause of Soft Suture

Is there a basis in early development of the fruit? The suture begins to form in the rudimentary peach pistil. During the winter the folded borders of the young pistil touch (Fig. 20). Later the edges grow together, forming the suture line, which extends the entire length of the pistil.

Fig. 20.—Formation of the suture. This cross-section of the immature pistil in February shows how the folded edges come together to form the suture. The cells at the juncture will later grow together. (*Magnified 75×*)

It has been pointed out by Péchoutre (1902) that in the stone fruits two ovules start to grow but that one of the two is typically suppressed. Ragland (1934) studied this point in the peach varieties Muir and Phillips Cling and found that the "nonfunctional ovule aborted before fertilization." In the variety Halehaven, Lott (1939 and 1942) states that "at full bloom the two ovules were of the same size, with the exception of an occasional ovary in which one ovule was slightly smaller. Seven days later, one ovule was noticeably thicker than the other and slightly longer. . . . " In Phillips Cling, Ragland (1934) found that "at full bloom, one ovule is often smaller than the other, but no other difference can be detected. This condition prevails with the difference increasing slightly for 10-12 days; then the smaller ovule aborts."

Sometimes both seeds develop in the peach. Bradbury (1929) found that two ovules start growth in the sour cherry but ordinarily one degenerated at about the time of full bloom. Tukey (1933A) describes a similar situation in the sweet cherry in which he shows that the nonfunctional ovule is suppressed "just prior to full bloom." On the other hand, the situation is somewhat different in the plum. Here it was found (Dorsey, 1919) that the extent of development in the suppressed ovule varied considerably, being early in some species or varieties and later in others. One ovule in the plum was generally suppressed, however, as it is in the peach.

Tukey (1936) presented an interpretation of the early growth stages of the peach which is in line with the findings at the Illinois Station. He showed that in fruits like the peach or plum, in which the pistil consists of a single carpel, the side of the carpel to which the seed is attached not only grows faster but is more advanced physiologically and thus matures earlier.

When the young pistil of Elberta was examined at the Illinois Station it was found that the two sides may vary in size or in degree of development even before the appearance of the growing point in which the megaspore develops. Likewise, the megaspore may be formed earlier on one side of the pistil than on the other. Differences in the time the megaspore appears may be reflected in the rate or extent of development in the embryo sac. In a few instances the embryo sac is fully formed in both of the ovules. An even development of the two ovules up to full bloom does not necessarily mean that two seeds will be produced; this happens only if both ovules are fertilized. Even when both ovules are fertilized, one of them will be suppressed if it is fertilized so much later than the other that it is not able to compete with it.

After it was found that one side of the pistil usually develops more rapidly than the other, the next problem was to discover whether this physiological advancement takes place more frequently on the right side of the suture line or on the left. A bushel of Gage peaches selected at random was separated into these three classes, the fruit being viewed from the suture side with the stem end down: (1) peaches riper at the left of the suture line, (2) those riper at the right of the suture line, and (3) those with approximately equal development on both sides. There were 87 peaches in Group 1, 82 in Group 2, and only 5 in Group 3.

When the stones of these peaches were opened (Fig. 21), the seed was found attached sometimes at the left of the suture line and sometimes at the right. The fruit had ripened first on the side where the seed was attached. In the five peaches which had apparently ripened evenly on both sides of the suture line, there was also a single seed; more refinement in measuring the ripeness of the two halves would have placed these peaches in either Group 1 or 2. Theoretically, if both seeds develop, the halves of the peach should ripen at the same time. If peaches with double seeds could be developed by breeding, soft suture might be eliminated. In one of the selections produced at the Illinois Station from a cross of Hale × Gage, one-fourth of the stones had two seeds in them.

Is soft suture increased by position of fruit? That part of the peach which is exposed to the sun tends to ripen more rapidly than the rest of the peach. When the suture area is exposed to the sun, the

Fig. 21.—Left and right seed attachment. When the stones were split open, the seeds in the upper row were found to be attached to the left half and those in the lower row to the right half. The peach ripens sooner on the side of the suture where the seed is attached. Stones are natural size.

chances that soft suture will develop are increased. If the suture area naturally tends to face the sun, the difficulty from soft suture might be partly explained in this way.

When peaches are examined on the tree, the position of the suture area with regard to the direct rays of the sun at noon is found to be extremely variable. This can even be seen in the few peaches shown in Fig. 15. Not only is there variation in the position of the fruit on the shoot but the shoots themselves point in many different directions and in a random fashion as the whole tree is viewed. Fruit that is on the north side of the tree or in the interior or underparts has some natural protection from the sun. On the other hand, if the fruit is in the top of the tree, where it is more exposed, the direct rays of the sun may cause the suture area to ripen faster even tho it does not directly face the sun. When the limbs droop on overloaded trees, some of the peaches that were formerly shaded will be exposed and some of the exposed peaches may become shaded.

Thus even if the peach grew at the node in such a way that the suture area would face the sun directly, there would be other conditions that would prevent exposure to the sun.

The pistil arises in a central position from the growing point of the fruit bud and is nearly parallel to the shoot when the fruit bud is in the dormant state. In dormant fruit buds of the Class-2 or Class-3 nodal pattern, it was found that the direction of the suture diameter was extremely variable in relation to the shoot, the diameter seeming to point at random (Fig. 22). There is, therefore, no fixed relation be-

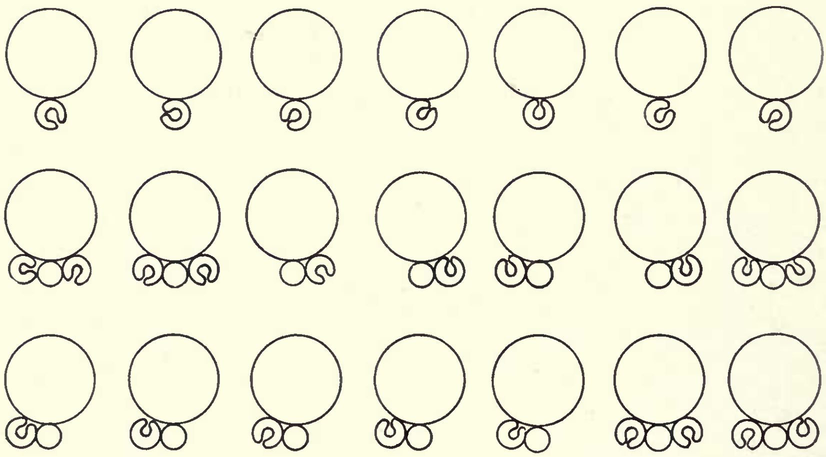

Fig. 22.—Position of suture of peach pistils in relation to shoot. The peach pistils shown above are Class-2 and Class-3 nodes on Elberta trees. The different classes of nodes are defined on pages 329-330.

tween the direction that the suture faces and the growth pattern of the shoot.

From this analysis it can be seen that the basis for soft suture must lie in the early growth stage of the fruit, and that the condition results from the fact that usually only one of the two ovules develops, the growth stimulus that comes from fertilization and seed development thus being more or less localized on one side of the pistil, or young fruit.

Growth Conditions Favoring Soft Suture

In 1937, a year when soft suture was particularly troublesome, observations were made in a number of Elberta orchards in an attempt to determine the conditions under which soft suture was most severe.

Soft suture was found to be most pronounced on slow-growing, overloaded trees. A deficiency of soil moisture, as indicated by the wilting or folding of the leaves in midday, was apparent in most orchards where soft suture was most pronounced. This condition was generally present on lightly pruned low-nitrogen trees which were making a short shoot growth.

On some heavily loaded trees the entire crop sometimes became soft while the ground color of the fruit still had a distinctly green cast. On many such trees a large number of fruits dropped without even completing the final swell. Peaches on such trees were of very low quality. There was a noticeable pick-up in the firmness of the fruit on overloaded trees during the night or when placed in storage.

The peaches softened most on the riper side of the suture in midday or early afternoon, when the temperature was highest and the demand for soil moisture was greatest. The air temperature during the ripening period of Elberta in Illinois is often above 90° F. for considerable periods when the moisture supply is low. The temperature of the fruit exposed to the sun may be considerably above the level of the air temperature. Lloyd and Newell (1930), however, report that during the day peaches were 2 to 4 degrees below the air temperature at the 72° to 85° F. level. On the other hand, Brooks and Fisher (1926) found a difference of 10 to 16 degrees between the exposed and shaded sides of the same apple and a temperature in the apple as much as 25 degrees above the air temperature. The actual temperature of the peach during ripening needs further study, but it can be seen how the fruit will tend to soften rapidly at this time because the temperature is high. Even green fruit softens quickly when held in storage at temperatures above 80° F.

On overloaded trees soft suture was still further accentuated because in many fruits on such trees only the riper area along the suture line seemed to undergo the final swell. It puffed up, making a ridge which matured and softened much in advance of the rest of the peach.

This area seemed to have a greater pull on the limited water and food supply than the rest of the peach.

When the foliage was poor or when there was severe defoliation from spray injury or bacterial spot, soft suture was more severe than on normal trees. Again the food supply for each fruit was decreased, this time because the efficiency of the leaves for manufacturing food was decreased and the rest of the peach had to compete with the riper area along the suture for the limited food supply.

From this survey in 1937 it was found that there was very little soft suture in orchards where the trees were making a good growth, especially when they were nitrated and thinned. Under these conditions the other part of the fruit was not brought into such sharp competition with the advanced suture area, especially if the soil was deep and the moisture content high enough so that maturity was delayed a few days.

Summary

The fundamental basis for soft suture lies in the early growth and development of the peach. The differences in ripening between the two sides of the peach are related to seed attachment and the stimulus which comes to the peach from that source.

The most practical means of reducing soft suture is to keep the trees in good vigor by pruning, nitrate applications, and thinning. When soft suture is troublesome, picking the fruit early in the morning is advised, especially during those seasons when the moisture deficiency is greatest. To lessen the danger from soft suture it would be advisable for a grower to thin his peaches even as late as a month before harvest if for any reason the crop excess has not been previously reduced.

GENERAL SUMMARY AND CONCLUSIONS

This project was initiated with the object of studying how to condition the peach crop while it is still on the tree. Primary attention was directed to analyzing the effect of an excess crop upon size of fruit. Effort was also made to find the most effective and most practical time for growers to reduce this excess so that they may have some assurance of getting the desired size of fruit at picking time.

In studying the relation between shoot growth and the extent of the crop, it was found that the peach tree responds to growth conditions thru variations in the complexity of the development at the node, in length of shoot, and in number of shoots produced. Nitrogenous fertilizers affected the bearing area of the tree primarily by increasing the number and length of shoots. Pruning can be used to control the spread of the top and the height of the bearing surface above the ground.

A tree normally produces fruit buds far in excess of the number of peaches necessary for a crop. The quantity of fruit buds may be reduced both by winterkilling and by pruning. In the moderately heavy type of pruning in common use in Illinois, about a fourth to a half of the fruit buds are cut off. In the Foote orchard, which is typical of the Elberta plantings in southern Illinois, fruit-bud killing during the winter resulted in a complete crop loss four times in nineteen years. Freezes during bloom caused two crop losses in this orchard during the same period. After the loss of fruit buds from low temperatures, the set is finally determined by the severity of the three drops. During nineteen years five crops in the Foote orchard needed thinning after the drops were over.

Studies of the peach from bloom to maturity show that while growth occurs in three distinct phases, it is continuous, the fruit enlarging as long as it remains attached to the shoot. First the cells divide, increasing in both size and number up to the time the peach is ½ to ⅝ inch in diameter. After cell division stops, growth takes place thru the enlargement of the cells of the flesh. As a result of the enlargement, the cells in a mature 3-inch peach are, it is estimated, as much as 10,000 times as large in volume as those in the pistil at bloom.

When adjusting the crop to the tree, it must be kept in mind that a given yield may consist of either a large number of small peaches or a small number of large peaches. When the crop is properly adjusted, there will be fewer peaches to pick and fewer will be needed to make a bushel. Also, the proportion of flesh will be greater and the proportion of stone less in a given weight of large peaches than in the same weight of small peaches.

Of the three methods of thinning—distance thinning, thinning according to the fruit-leaf ratio, and thinning according to the total load—the last method is recommended because it is most adaptable to practical orchard conditions. It is suggested, however, that the total crop load to be left on the tree after thinning be checked by the two other methods also.

The degree to which a tree responds to thinning was determined by measuring the suture diameter of a selected fruit sample from the tree at different times during the summer or by computing the percentage of the crop in the different size classes at harvest.

Experiments showed that in Illinois, with the crop load limited as it is by pruning and the drops, it is not necessary to thin until after the June drop. The response in the growth rate of peaches left on the tree after thinning was neither immediate nor pronounced. The effect of an excess crop load became most acute during the final swell.

In the combination treatments, nitrate applications, the type of pruning, and the severity and time of thinning were varied. Results showed that a fruit overload cannot be corrected by any of the cultural combinations that were tried. Thinning is therefore a necessary supplement to nitrate applications, pruning, and soil moisture in regulating fruit size. The smaller fruit obtained during dry seasons indicates that a deficiency of soil moisture ranks with an excess crop load in its effectiveness in reducing fruit size.

As a basis for recommendations on picking, studies were made of the amount of enlargement and the ripening changes that take place in the peach during the final swell. Peaches left on the tree increased in volume about 25 percent after the earliest picking date observed. In the Heaton orchard at the first picking only 48 percent of the crop was over 2¼ inches in diameter. After the fruit was allowed to become tree ripe eight days later, 94 percent of it measured over 2¼ inches.

Tests showed that peaches picked green ripe, firm ripe, and tree ripe lost weight in storage at about the same rate and that peaches picked tree ripe could be successfully shipped to distant markets in precooled cars.

Soft suture, a condition related to seed attachment, is in part corrected by thinning. Orchard observation showed soft suture to be most severe on overloaded trees when the moisture supply was deficient and the temperature was high.

RECOMMENDATIONS

Thinning the Crop

In thinning peaches, it is recommended that the crop be reduced to a certain load. This has been found to be more accurate than distance thinning, which sometimes leaves too large a load on the tree and sometimes too small a load. The following general procedure has been recommended since 1931 as a way to thin the crop to the desired load:

1. Wait until the severity of the June drop can be forecast. The proportion of peaches which are falling behind in size or are assuming a yellowish cast is a good index to the probable drop. Also the peaches that will fall naturally at the June drop can be pulled off easily several days before they would otherwise drop.

2. After appraising the extent of the June drop, take full advantage of what is known about the bearing capacity of the orchard, especially the yield and size of fruit which has normally been obtained, and decide what should be the yield per tree for the variety under present conditions. Trees planted 25 feet apart each way should, for example, average 5 bushels apiece when the orchard is in full production.

3. Estimate as nearly as possible the size that the fruit of the variety in question may be expected to reach year after year with a crop load of 5 bushels per tree. Suppose, for example, the size of fruit should fall mostly within the 2¼-to-2½-inch class. Turn to Table 6, page 357, and note that Elberta peaches of this size run about 250 per bushel (Fig. 17).

4. Multiply the estimated yield per tree in bushels (5 in this instance) by 250 to get the approximate number of peaches which should be left on the tree after thinning (1,250).

5. With a total load of 1,250 peaches in mind, select a typical tree to thin that is conveniently located so that the crew can observe it frequently. Have the crew study the appearance of the tree both before and after it is thinned.

6. Distribute the peaches on the type tree uniformly thruout the bearing surface, leaving them as far apart as seems necessary to give a total load of 1,250 fruits. In so far as practical, reduce the crop by removing small or injured fruit. The small peaches to be removed can best be recognized if a dozen of the largest peaches and a dozen of the smallest are first selected and compared. Lay the largest on the ground in a row side by side and the smallest in another row so that they can be compared at a glance. After the type tree has been thinned, have the crew make an accurate count of the number of peaches left, in order that the necessary corrections can be made in later thinning.

7. Mark the type tree and bring workmen back to it if they have difficulty in adjusting their work to the pattern set. The approximate distance between the peaches left on the type tree might even be measured and remembered. All trees will not, of course, be thinned exactly as the type tree is; the goal is to leave the largest and most nearly perfect peaches evenly distributed thruout the bearing surface. To accomplish this goal, some trees or parts of trees will have to be thinned lightly and some heavily. It is important to focus attention upon the crop left on the tree rather than on the number of peaches pulled off.

8. After thinning several trees, compare them with the type tree by counting the fruits, or by measuring the distance between the fruits, or by determining the number of leaves per fruit.

9. The heavier the set is, the sooner the excess crop should be removed once the June drop is over. This is true irrespective of the method used in thinning.

10. If the set is not heavy in the entire orchard and general thinning is not necessary, the crop should be evened up by thinning certain trees or parts of trees where the set is too heavy. This will increase the proportion of peaches that reach the commercial sizes at harvest. It should be recognized, however, that while thinning will raise the general size level of the fruit in an orchard, it does not do away with the differences between peaches on the same tree.

(*Note on 1944 thinning experience.* Because of the labor shortage and the heavy bloom during the spring of 1944, peach growers were particularly interested in reducing the cost of thinning. Special interest centered around brush-thinning at bloom and limb-tapping after the June drop. As matters stand now, these two methods hold considerable promise as ways of reducing the cost of thinning; and when growers have more experience with them and a wider understanding of the hazards of an overload, greater progress in tree-conditioning the crop can be expected.)

Picking the Fruit

Under normal conditions that part of the final swell during which peaches are ripe enough to pick lasts not more than 5 to 10 days. The picking period in the Heaton orchard was 6 days and that in the Venerable orchard, 7 days. Harvesting operations during this short period may be delayed by rainy weather, a shortage of labor, or a falling off in the demand for peaches. For these reasons a grower who has a large orchard is tempted to start picking as early as possible in order to extend the use of labor and equipment over as long a period as possible and keep the crop from becoming over-ripe before it is picked. If picking is started too early, however, full advantage will not be gained from tree-conditioning the crop since the fruit will not have had time to attain its full size and its best quality.

Altho the spread in the time peaches ripen may be as much as two to three weeks in Illinois, the peaches in a given area are ready for market at about the same time because most commercial orchards are made up of Elberta. In an attempt to distribute the time of harvest locally, growers have planted some varieties which ripen later or earlier than Elberta. The possibility that time of ripening might be controlled by cultural practices is shown by the fact that, in the greatest extremes in treatment set up in the combination cultural experiments, maturity was delayed about one week on trees given both heavy pruning and heavy nitrate applications.

In order to take as much advantage of the gain in size as he can without allowing the peach to become too soft, a grower will need to watch the oncoming maturity closely. There is no single index of maturity which can be used with finality in deciding when to start picking, but experienced growers rely on color, firmness, size, and shape to identify the most advanced peaches on a tree.

For the bushel-basket pack, Elberta should not be picked until the background color has a yellowish cast and the peach is "rounded up" as a result of the increase in the cheek diameter. This is the firm-ripe stage referred to in the shipping tests, in which the flesh is firm, free from the stone, and is orange-yellow in color. When peaches picked at the firm-ripe stage are held at the right temperature in transit or storage, they soften gradually and develop good color and high quality.

If tree-ripened peaches are desired, the crop should be left on the tree 2 to 5 days beyond the firm-ripe stage in order that larger peaches of higher quality may be obtained. This delay in picking will allow the blush to increase in amount and intensity, the flesh will become less firm and take on a deeper orange-yellow, and the stone will separate from the flesh more readily. At the same time the cheek diameter will increase still more. Peaches picked tree ripe are ready for immediate use and can be got to market in good condition if shipped in precooled cars and handled carefully.

For the approximate relation between (1) the extent of the final swell with crop loads of different sizes and (2) the picking stage and the size of fruit with each crop load see Table 22.

One fact cannot be ignored in considering at what stage of maturity to pick peaches: namely, that the judgment of the orchardist at this point will largely determine the readiness with which the consumer will accept the crop when it is put on the retail market. From the consumer's decision to buy or not to buy, there is no appeal; and on it depends the profitableness of the market which orchardists can build up or maintain. Because the quality of peaches depends finally on the stage of maturity at which they are picked, it is important that the picking crew get clear orders and that these orders once understood be carefully followed out.

TABLE 22.—APPROXIMATE SIZE OF PEACHES IN DIFFERENT CROP LOADS WHEN PICKED AT THREE STAGES OF MATURITY[a]

Number of peaches per tree	Approximate size of fruit when picked at stage indicated		
	Green ripe	Firm ripe	Tree ripe
	inches	*inches*	*inches*
3 000	1½–1¾	1¾–1⅞	1⅞–2
2 000	1¾–2	2–2⅛	2⅛–2¼
1 500	2–2¼	2–2½	2¼–2½
1 250	2¼–2½	2¼–2¾	2½–2¾
1 000	2¼–2½	2½–2¾	2¾–3
750	2½–2¾	2½–3	2¾–3¼
500	2½–2¾	2¾–3¼	3–3¼

[a]The approximate number of peaches of different sizes in 50 pounds is given in Table 6, page 357.

If the grower is to reap full advantage from riper picking—that is, picking after the firm-ripe stage now advised for basket or tub shipments—some other kind of package than the kinds now in use is needed for shipping, because the riper fruit must have more protection. Efforts to devise a new kind of package should certainly be encouraged, since the demand for peaches will be increased if they can be put on the market at a riper stage than is now customary.

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