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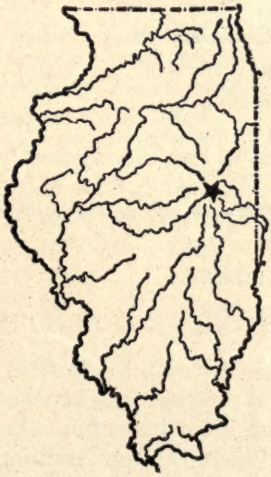
APPLE-BUD SELECTION
APPLE SEEDLINGS FROM SELECTED TREES

By CHARLES S. CRANDALL



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Contents of Bulletin No. 211

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APPLE SEEDLINGS FROM SELECTED TREES

By CHARLES S. CRANDALL, Chief in Plant Breeding in Horticulture

INTRODUCTION

In addition to hybridizing, which stands as the major project in apple breeding as outlined and undertaken by the Department of Horticulture in 1907, two minor projects in selection were entered upon at the same time. These are:

1. Growing apple trees from selected buds to determine whether or not there are differences in value, for purposes of propagation, between large buds and small buds, between buds produced on different parts of the tree, and between buds from different locations on the shoot.
2. Growing apple seedlings from fruits from trees chosen as possessing special merit.

The nature of the plants is such that the projects must of necessity extend over a considerable number of years. Judgment as to the value of a fruit tree is based upon capacity to bear fruit and upon the character of the fruit produced. It follows that trees propagated from selected seeds or from selected buds must become well established in fruit production before conclusions are possible from which answers to the original questions may be formulated.

It is the purpose of this publication to bring together the records thus far made in connection with these minor projects, to present the methods pursued, and to give the status of the trees growing under each of the projects.

APPLE-BUD SELECTION

This project is an attempt to discover and bring out such differences in value, for purposes of propagation, as are commonly supposed to exist between large buds and small buds, between buds from different situations on the same tree, and between buds from different locations on the same shoot. The trees grown under the project are divided into groups designated as series and numbered by thousands to prevent confusing any of them with numbered groups in other projects.

Selection of the buds began in 1908 and additions were made in each of the three years following. The aggregate is fourteen series represented by 5,400 selected buds distributed as shown in Table 1.

TABLE 1.—DISTRIBUTION OF SELECTED BUDS, BY SERIES

Year	Series	Test	No. of buds	No. of varieties
1908	1 000	Size	100	5
	2 000	Location on tree	450	5
	3 000	Location on shoot	320	5
1909	4 000	Location on tree	750	13
	5 000	Location on shoot	430	10
	6 000	Size	220	11
	7 000	Location on tree	290	6
	8 000	Location on shoot	190	6
1910	9 000	Location on tree	840	12
	10 000	Location on shoot	450	11
	11 000	Size	240	12
1911	12 000	Location on tree	530	11
	13 000	Location on shoot	330	11
	14 000	Size	260	13
		Total	5 400	

When one year old, all living trees in the 4,000, 5,000, and 6,000 series, originally represented by 1,400 selected buds, were transferred to the Station farm at Olney and, because of incomplete growth records, are not to be further considered at this time. The two other series selected in 1909, the 7,000 and 8,000 series, differ from all other series in that here, the selected buds, instead of being propagated by grafting in the spring, were budded in August of that year, and as they were dormant until the next spring, the trees rate, as to age, with those selected and propagated in the spring of 1910.

Of the eleven series here considered, three, with 600 selected buds, represent the comparison between large and small buds; four series, with 2,110 buds, represent the test of location on tree; and four, with 1,290 buds, represent the test of location on shoot.

Numbers of buds in the different series varied for two reasons; in some cases the time available for making grafts was limited; in other cases series were incomplete because buds desired were not available. These irregularities occurred mainly in those series including buds from different locations on the tree.

Buds from twenty-one varieties were used, but these varieties did not have equal representation. Five varieties were represented in nearly all series; these were Yellow Transparent, Oldenburg, Winesap, Grimes, and Ben Davis. Other varieties represented in one or more of the series were Jonathan, Fameuse, Minkler, Kinnard, Willow,

Whitney, Rome, Osimoe, Huntsman, Isham, Twenty Ounce, Dominie, Arkansas Black, York Imperial, Cornell, and Sweet Bellflower.

TEST OF SIZE: LARGE BUDS AND SMALL BUDS

The test of size of buds included three series: the 1,000 series of 100 buds, selected in 1908; the 11,000 series of 240 buds, selected in 1910; and the 14,000 series of 260 buds, selected in 1911.

THE 1,000 SERIES

Buds were selected in groups of ten and, using scions approximately six inches in length, were root-grafted, by the veneer method, on ordinary apple stocks. For the 1,000 series, the numbers 1,001 to 1,010 were given to the grafts made with the ten selected buds of large size, and the numbers 1,011 to 1,020 to the grafts made with the selected buds of small size, all from the same Yellow Transparent tree. This plan of numbering was also used for the varieties Oldenburg, Ben Davis, Winesap, and Grimes. There were then 100 grafts in this series as made up in February, 1908.

In selecting for large size, terminal buds from central terminal shoots on bearing trees were chosen, because these, in most varieties, were the largest to be found on the trees. With Grimes, however, the terminal buds of terminal shoots were quite small, many of them protruding but little from the concavity formed by the enlargement of the tip of the shoot. Short lateral shoots just below the terminal shoots were, in most cases, crowned with large, well-developed terminal buds, and these were the buds selected in this variety. It occasionally happened in other varieties that on vigorous terminal shoots the apical bud was undeveloped, the food supply having been appropriated by an adjacent bud in an upper axil. In such cases the large lateral bud was the one selected. The small buds were, in most cases, lateral buds from short interior branches, but with Grimes, terminal buds of interior branches were selected as being smaller than the laterals on these branches, or on other branches elsewhere on the tree. When a lateral bud was selected, the shoot was cut back to this bud so that in all grafts the chosen bud was at the distal end of the scion. The scions were tied with raffia, the unions waxed with alcoholic plastic, and the grafts stored in moist sphagnum until the series was complete; they were then transferred to sand, where they remained until planted in the field, May 12, 1908. Table 2 shows the averages for length and diameter of shoot, and the number of buds; and, for buds, the averages for length and diameter, and also the length of scion and the number of buds on scion used.

At the time of planting the grafts (May 12), the selected buds appeared to be in good condition, but when checked over twenty-four

TABLE 2.—TEST OF SIZE OF BUDS: MEASUREMENTS OF SELECTIONS OF 1908

Variety	Size of buds	Serial numbers	Shoot					Bud		Scion	
			Average length (cm.)	Average diameter (mm.)			Average No. of buds	Average length (mm.)	Average width (mm.)	Average length (cm.)	Average No. of buds
				Basal	Middle	Distal					
Yellow Transparent...	Largest	1001-1010	36.0	6.7	4.0	3.6	18	6.4	4.6	16.5	9
	Smallest	1011-1020	17.5	5.0	2.7	2.5	12	4.8	3.2	15.0	11
Oldenburg.....	Largest	1021-1030	12.0	6.3	4.1	4.6	17	5.5	4.4	13.5	10
	Smallest	1031-1040	26.0	5.2	3.5	3.4	18	1.8	1.9	14.8	9
Grimes.....	Largest	1041-1050	16.0	4.4	3.0	2.8	10	6.7	4.4	15.6	9
	Smallest	1051-1060	14.8	3.8	2.5	2.1	9	3.9	3.2	14.8	9
Winesap.....	Largest	1061-1070	23.2	6.6	4.5	4.5	28	6.4	4.6	16.2	15
	Smallest	1071-1080	23.0	3.9	2.5	2.5	19	4.6	3.3	16.2	13
Ben Davis	Largest	1081-1090	29.8	6.0	4.0	4.7	20	6.2	4.7	16.8	13
	Smallest	1091-1100	30.8	5.5	3.5	3.5	21	2.8	2.4	15.7	10

days later it was found that eleven of the buds had not started or had started and immediately died. These failures were fairly well distributed. Six were in lots of large buds and five in lots of small buds. The buds that were growing on June 6 exhibited all degrees of vigor. Some were strong, others so weak that their early death was foreseen. When the plants were taken up for winter storage (November 3), 77 were living; most of them were fairly vigorous, but a few were small and weak. Of the 23 failures, 12 were of small buds and 11 of large buds. The greatest loss in any one lot was five of the small buds of Winesap, and next to this was the loss of four of the large buds of Ben Davis. One lot, the small buds of Oldenburg, came thru this first season with the full complement of ten. During 1909 six of the weak trees died, so that at the close of this second season the losses totaled 29. In the spring of 1910 the remaining 71 trees of this series were planted in orchard. Four more trees died during this third season. More serious losses occurred during the first winter in orchard. Of the 17 trees recorded as dead in the fall of 1911, some had not started in the spring and some had made a feeble effort at growth and then died. Thus 50 percent of the buds included in this series dropped out during the first three years. The 50 trees remaining are established, and altho exhibiting differences in vigor, should reach maturity unless lost thru accident.

Of the trees lost, a few were destroyed by rabbits or were broken down by storms, but the chief cause of loss appeared to have been weakness or want of vitality, whether in the buds chosen, in the scion, or in the stock, it was not possible to determine. In considering distribution of the losses, there is nothing to suggest a superior vitality on the part of large buds; in fact, the number of failures of large buds was two greater than the number from small buds. For three varieties the losses were equally divided between large and small buds, for one variety the loss for small buds was greater, and for another the loss for large buds was greater. Trees living in 1915 were divided as follows: Yellow Transparent, one from large bud and one from small; Grimes and Ben Davis, six each from large and small; Winesap, six large and four small; Oldenburg, five large and nine small.

Growth of Trees in Relation to Size of Buds from which Propagated

The basis of comparison of trees is vigor as indicated by growth increment. For the first two years the leader and branches were measured and the total was recorded for each tree, but as the trees increased in size this procedure became impracticable. In the third year (1910) growth of leader only was recorded, and in succeeding years measurements of height and spread only were recorded. This change destroys the uniformity of the record, but does not in any way interfere with the comparison it is desired to make between the two groups of trees,

those from large buds and those from small, in the matter of growth.

At no time during the eight years of this experiment did there appear any striking differences between the groups of trees from large buds and those from small buds. There were and still are marked differences between individuals in the same group, but the summation of growth records for the different groups shows that they closely approximated thruout. Bringing the averages of growth together, in tabular form, by years, and for the last five years considering total height only, they are as shown in Table 3.

TABLE 3.—COMPARISON OF GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: 1,000 SERIES

Variety	Size of bud	No. of trees	Average of growth (inches)							
			1908	1909	1910	1911	1912	1913	1914	1915
Yellow Transparent...	Large	1	21	11	11	37	40	53	74	92
	Small	1	17	6	9	42	50	60	72	93
Oldenburg	Large	5	15	26	11	46	49	63	70	92
	Small	9	11	20	12	37	45	58	72	93
Grimes.....	Large	6	19	20	9	42	51	64	80	102
	Small	6	21	16	8	38	47	53	64	90
Winesap	Large	6	28	17	9	46	55	70	88	116
	Small	4	21	10	11	46	56	72	89	113
Ben Davis	Large	6	28	19	9	43	52	64	78	98
	Small	6	20	21	7	46	56	69	84	109

NOTE.—Total growth is given for 1908 and 1909, for 1910 growth of leader only, and for each succeeding year total height of tree.

There is nothing in these figures, nor was there anything to be derived from inspection of the trees in orchard, to suggest the existence of any marked difference between large buds and small buds in their value for purposes of propagation. The approximation of the growth curves of the classes here under consideration is, perhaps, more clearly indicated in the accompanying graphs platted from the measurements given (Figs. 1 to 6). The number of plants is small and therefore the basis for conclusions is less reliable than if the number were greater. However, careful study of the trees from year to year strengthens the belief that an increase in the number of trees would tend towards nearer coincidence of the lines rather than towards their greater separation.

With Yellow Transparent, only one tree of which remained in each of the two groups, the tree from large bud was in advance of the tree from small bud in the three early years. In the fourth year it fell behind the tree from small bud and remained in this position for the two following years. In the seventh year it again took the lead by a narrow margin, but the last year it again fell slightly behind. Oldenburg, of which there were five trees from large buds and nine from

small buds, except for a slight advantage on the part of trees from small buds in the third year, showed a greater average growth of the trees from large buds than of those from small buds thru the sixth year. In the seventh year trees from small buds gained a slight advantage over those from large buds and this was maintained thru the eighth year. Grimes, with six trees in each group, showed a slightly better average growth by trees from large buds than by trees from small buds. With Winesap, having six trees from large buds and four from small buds, the trees from small buds had a slight advantage from the third to the seventh year and in the eighth year dropped slightly below the trees from large buds, but the lines thruout are so nearly parallel that neither group can be regarded as superior to the other. Ben Davis trees, with six in each group, showed a slight advantage on the part of those from small buds.

Combining the varieties and platting the average growth of the 24 trees from large buds with that of the 26 from small buds, there appears such close coincidence in the lines as to indicate no appreciable difference in value between large buds and small buds for purposes of propagation. A large bud may make a stronger initial growth than a small one, but the supply of nutrients in either bud will be quickly exhausted; then, which takes precedence in growth will depend, not upon the original size of the bud, but upon which has the larger store of reserve food materials in adjacent parts, or which is the better supplied from the stock upon which it is grafted, subject, of course, to other factors which may influence the availability of the reserve food supply.

Individual trees from large buds and from small buds for each of the three varieties Ben Davis, Grimes, and Winesap are shown in Figs. 7 to 12, which are from photographs made in July, 1915. Close proximity of trees in some cases restricted positions and interfered with absolutely uniform camera distance. This resulted in some slight inaccuracies in relative size, and for this reason height of tree as measured October 13, 1915, accompanies each plate.

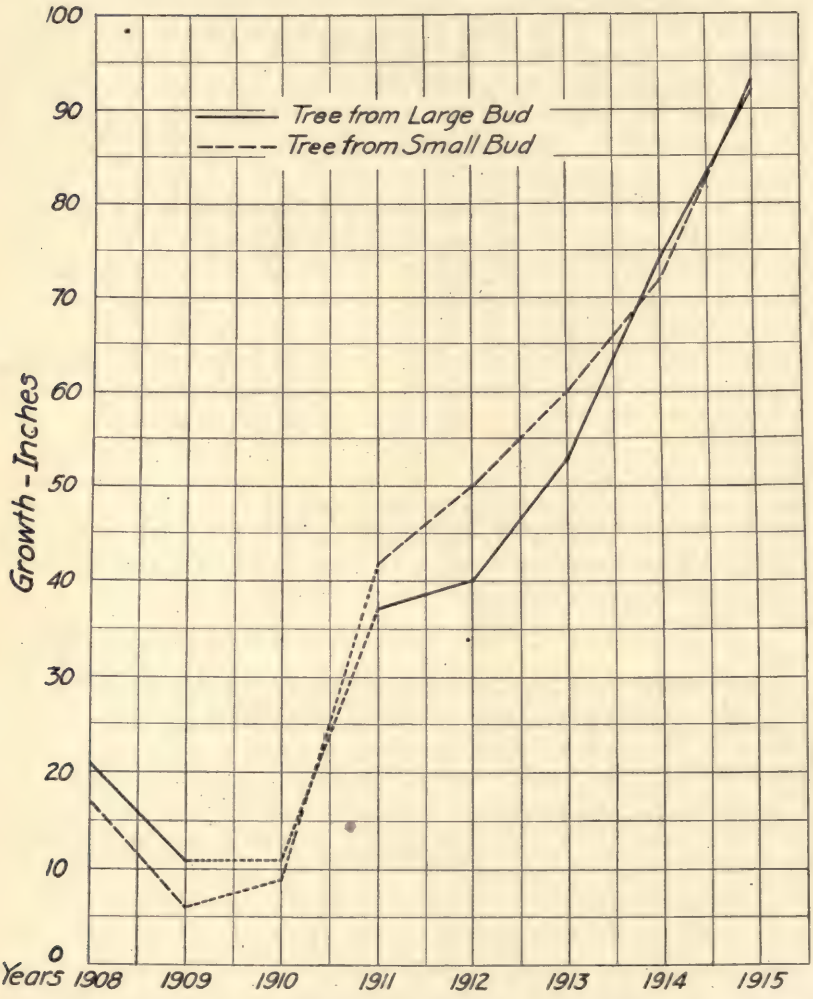

FIG. 1.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: YELLOW TRANSPARENT, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

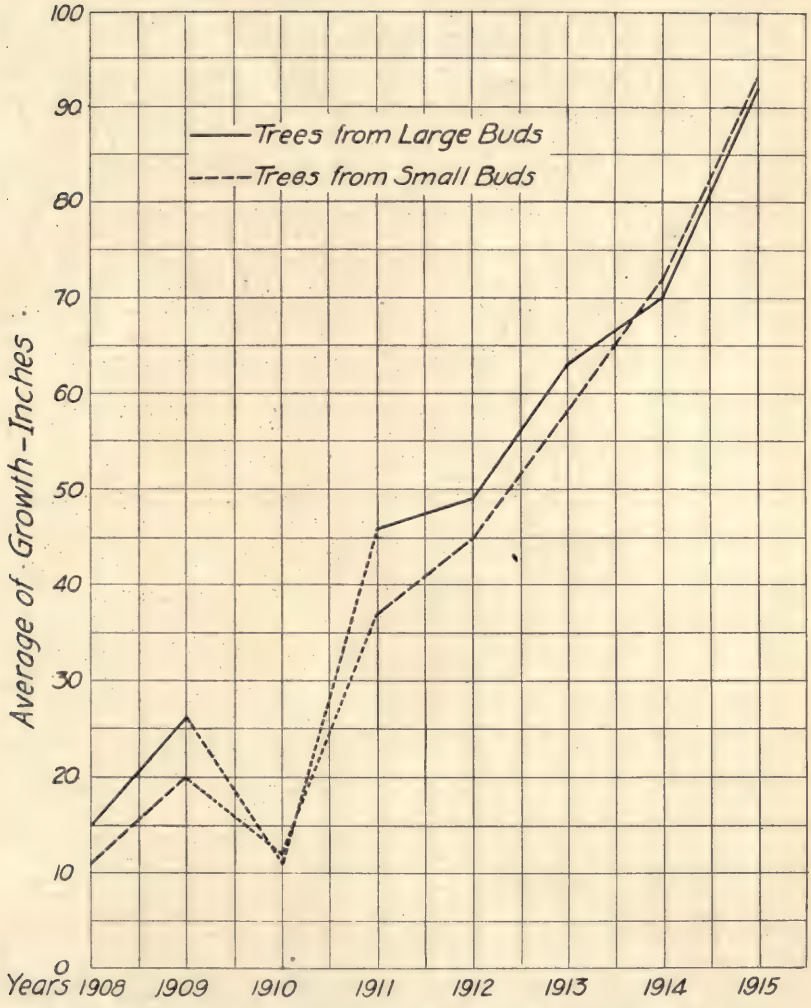

FIG. 2.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: OLDENBURG, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

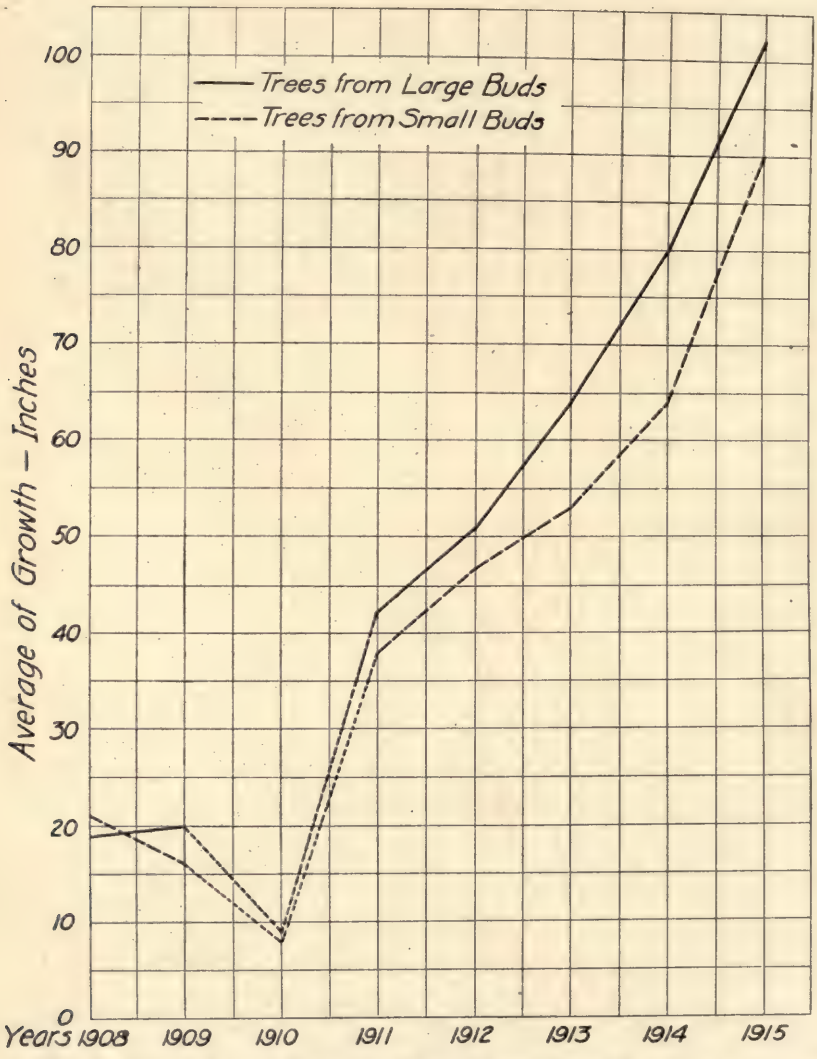

FIG. 3.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: GRIMES, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

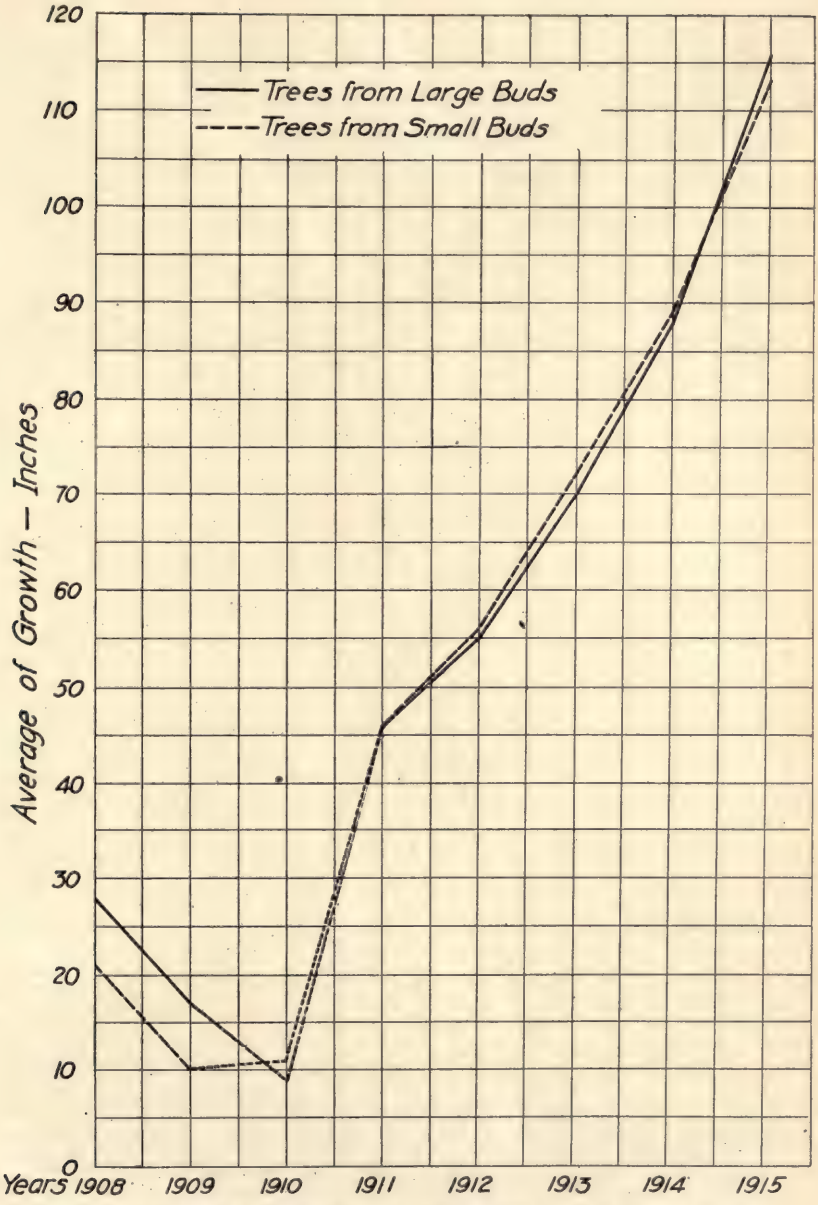

FIG. 4.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: WINESAP, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

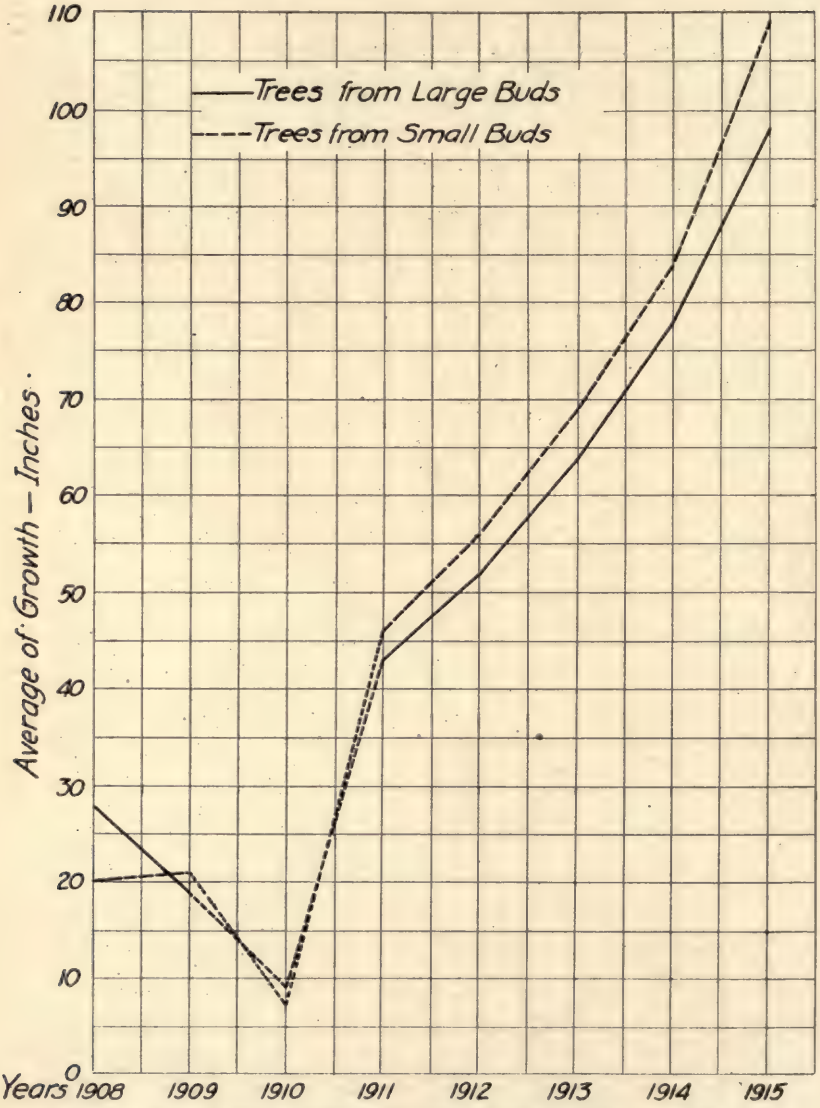

FIG. 5.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: BEN DAVIS, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

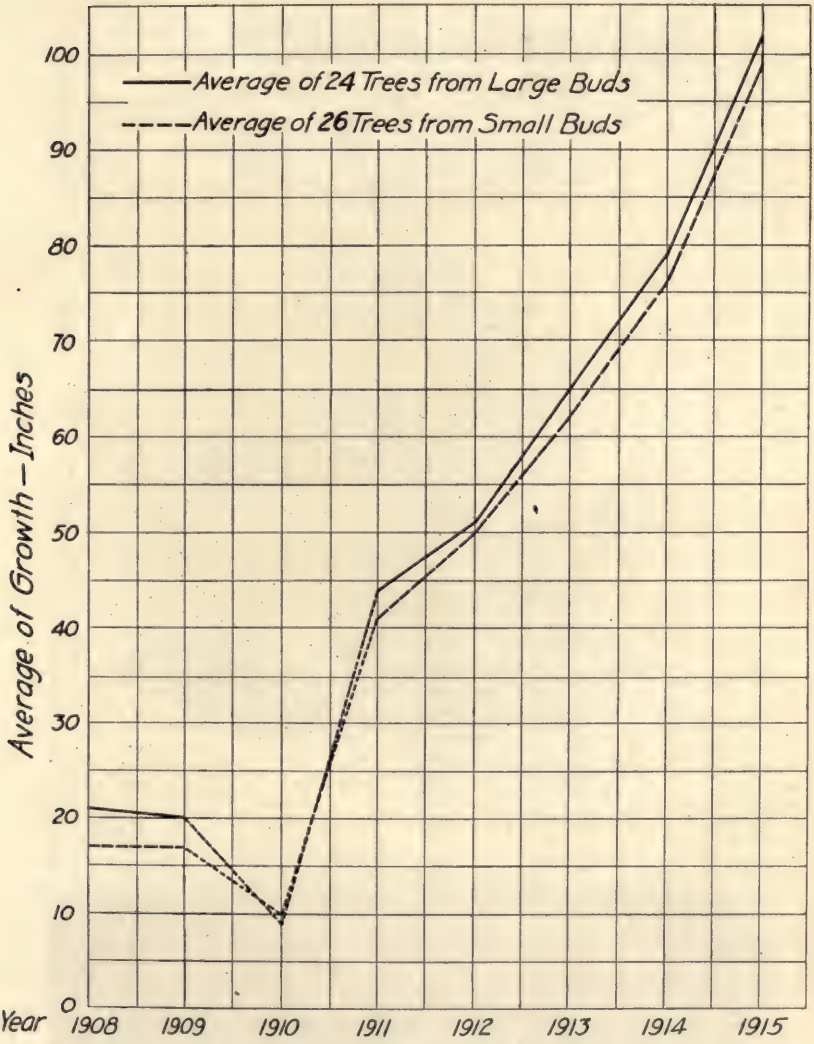

FIG. 6.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: THE FIVE VARIETIES COMBINED, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

FIG. 7.—NO. 1085: BEN DAVIS FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET. PHOTOGRAPHED JULY 13, 1915

FIG. 8.—No. 1093: BEN DAVIS FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET. PHOTOGRAPHED JULY 13, 1915

FIG. 9.—NO. 1047: GRIMES FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 1 INCH. PHOTOGRAPHED JULY 14, 1915

FIG. 10.—No. 1051: GRIMES FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 7 FEET, 2 INCHES. PHOTOGRAPHED JULY 14, 1915

FIG. 11.—No. 1068: WINESAP FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 6 INCHES. PHOTOGRAPHED JULY 14, 1915

FIG. 12.—No. 1073: WINESAP FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES. PHOTOGRAPHED JULY 14, 1915

Other Factors Affecting Growth of Trees

In general it would seem that plumpness and healthy appearance of the scion shoot should offer a better basis upon which to judge value for purposes of propagation than does size of buds.

In each of the years 1912, 1913, 1914, and 1915, an inspection of the trees in this series was made, from which judgment was recorded as to grade, rating them as "good," "fair," and "poor." The results are shown in Table 4.

TABLE 4.—GRADES OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: 1,000 SERIES

	Number of trees											
	1912			1913			1914			1915		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Large buds..	7	12	5	10	12	2	20	2	2	22	1	1
Small buds..	8	12	6	11	12	3	15	9	2	23	2	1

These figures exhibit a rather striking improvement in quality with each succeeding year. Trees from large buds rated as good jumped from 29 percent in 1912 to nearly 92 percent in 1915, and trees from small buds rated as good changed from 31 percent in 1912 to 88 percent in 1915. While five trees from large buds and six from small buds were rated as poor in 1912, only one from large bud and one from small bud were so rated in 1915. Further changes in the same direction are expected in succeeding years.

This expectation is based upon the aggregate of experiences, of the past ten years, in growing apple root-grafts and apple seedlings on the black soil of this locality. The top soil does not appear to be adapted to the promotion of growth in young apple trees. Whether this is because of texture, deficiency in some essential food element, the presence of some deleterious ingredient, or the presence or absence of some soil organism, is not known. The difficulty may be physical, chemical, or biological, surely one or all of these factors, because it is habitually the case that newly planted root-grafts or transplanted seedlings make very unsatisfactory growth during the first, second, third, and sometimes fourth years. After the third or fourth year there is usually a very marked increase in the annual growth increment, which continues to augment until fruiting maturity is reached. It appears that a certain period is necessary for roots to penetrate to and become established in the subsoil, and that the subsoil supplies conditions more favorable to growth than those encountered in the top soil. This is only suggested as one possible cause for the behavior observed. The subject is one that offers attractions as a field for investigation.

THE 11,000 SERIES

The 11,000 series, selected in 1910, consisted of 240 buds representing twelve varieties. With ten of the varieties all the losses occurred in the first year; with two varieties the losses occurred in the second year. No losses occurred after the second year in this series. With Rome the loss was total in the second year, altho at the close of the first year nine trees were living in each group. Isham was reduced to one tree in each group at the end of the second year. Only one tree each of Ben Davis and Twenty Ounce survived the first year, the Ben Davis a tree from large bud, the Twenty Ounce a tree from small bud. Living trees of other varieties ranged from three to nine in each group. At the end of the sixth year there were living 57 trees from large buds and 41 trees from small buds. Growth increments of trees from large buds compared with those of trees from small buds were almost identical. Trees from large buds had a slight advantage in the first year, the increment was equal in three years, and differed by only one inch in the other two. The uniformity in growth of trees in the two groups was even more marked here than in the 1,000 series.

THE 14,000 SERIES

The 14,000 series, selected in 1911, included 260 buds representing thirteen varieties. The losses in this series aggregated greater than in either of the other series in the test of size, and, instead of being confined to the first two years as in the 11,000 series, were distributed thru the five seasons. There were living in 1915, 39 trees from large buds, or 30 percent of the original selections, and 34 trees from small buds, or 20 percent. The small-bud groups of Fameuse and Willow were lost entirely, and those of Oldenburg and Isham were reduced to one tree each. The large-bud groups of Twenty Ounce and Huntsman were also reduced to one tree each. The curve of average growth for all varieties shows that the two groups made equal growth in the first year, that for the second year the small-bud group gained a slight advantage, then dropped slightly below in the third year and remained below in the two following years, altho exhibiting a tendency to greater growth that promised to bring the two groups to equality in another year.

DISCUSSION OF RESULTS

In the three series of trees here considered in detail there were, in 1915, 221 trees living in orchard. Of these, 120 were grown from large buds and 101 from small buds. Divided according to age, 24 from large buds and 26 from small buds were eight years old, 57 from large buds and 41 from small buds were six years old, and 39 from large buds and 34 from small buds were five years old.

In the fall of 1915 the trees were carefully inspected and classified as follows:

	Large buds	Small buds
Good	77	65
Fair	31	25
Poor	12	11

The percentages are very nearly the same for the two groups—approximately 65 percent good, 25 percent fair, and 10 percent poor. Here, as in every other comparison attempted between trees from large buds and those from small buds, there were no tangible differences by which the two groups could be separated.

Individual growth differences between trees within groups, as has already been mentioned, were in some cases extreme. Thus, nine Oldenburg trees of the 1,000 series grown from small buds, had, at the close of the eighth year, a height range from 36 inches to 127 inches—the tallest more than three and one-half times the height of the shortest. The companion group of five trees of Oldenburg from large buds had an individual range from 62 inches to 104 inches; in this group the shortest would have to be increased by nearly 68 percent to make it equal the tallest. Other similar groups of the same series showed differences requiring additions to the shortest of from 21 to 55 percent to make them equal the tallest.

The comparisons that have been given between trees propagated from large buds and those propagated from small buds, together with the aggregate of impressions derived from careful inspections of trees of all groups, leave no question regarding conclusions. The only possible conclusion from the summarized data is that there are no differences in value, for purposes of propagation, between buds of large size and those of small size.

COMPARATIVE VALUE OF BUDS FROM DIFFERENT LOCATIONS ON TREE

Investigations were made in an attempt to determine whether or not there are differences in value, for purposes of propagation, between buds taken from different parts of the tree. Five classes of buds, all from mature trees, were determined upon as representative of possible differences that might arise from exposure or situation. These were as follows:

1. Terminal buds from central terminal shoots
2. Terminal buds from extreme lateral shoots on south side of tree in full exposure to sun
3. Terminal buds from extreme lateral shoots on north side of tree and for the most part shaded
4. Terminal buds from short interior branches
5. Terminal buds or scions from centrally located water sprouts

The same procedure as that adopted for the test of size was used; that is, ten buds were chosen to represent each of the five groups for

each variety, and as many varieties were used as time for the work allowed. Scions were grafted on ordinary apple-seedling stocks and the grafts were handled according to common practice with root-grafts. The one departure from this practice was in one series of 1909, where the buds, instead of being selected and grafted in late winter, were chosen and budded on seedling stocks in August.

For the sake of uniformity, the attempt was made to include only terminal buds, and this was with few exceptions carried out for three of the variety groups, but in the two remaining variety groups difficulty was encountered, especially in regard to buds from water sprouts. With some varieties water sprouts were absent, and when they were present it was frequently the case that terminal buds had not been formed, or, if formed, they had gone into the winter in such an immature condition that they were destroyed by even moderate freezing. Where water-sprout tips had been injured, the uninjured lateral buds nearest the extremity of the shoots were chosen. Where short interior branches were present, there was usually no difficulty in obtaining terminal buds, but some varieties did not possess branches such as were desired for this group and in these cases the group was of necessity omitted.

The work of selecting and measuring buds was begun in the spring of 1908, and additions were made in each of the three seasons following. Locating the position and recording the dimensions of the buds established individuality for each, and for purposes of identification at any time thruout the life of the prospective tree, some designation was necessary that should be inseparable from the individual until the tree was permanently planted and its position accurately platted in permanent record. This identity of individuals was secured by a system of numbering. The buds selected in any one season constituted what has been called a "series." Thus the "2,000 series" was composed of 450 buds from five varieties selected and root-grafted in 1908; the "7,000 series" included 290 buds from six varieties selected and budded in August, 1909; the "9,000 series," 840 buds from twelve varieties selected and grafted in 1910; and the "12,000 series," 530 buds from eleven varieties selected and grafted in 1911. In each series the individual numbers were from one up. Thus the ten terminal buds on top central shoots of Ben Davis bore the numbers 2,001 to 2,010, the ten terminal buds from lateral shoots south, the numbers 2,011 to 2,020, and so on thru the series. On painted wooden labels about two inches long and one-quarter inch wide, notched at both ends, the numbers were painted with shellac and lampblack, and a label with number corresponding to the number in the descriptive record of the bud was attached, when the graft was made, by a copper wire band at each end. After the grafts were planted in nursery in strictly numerical order it was necessary to remove the labels, but this was not done until stake

labels for each group of ten were in place and the whole planting had been carefully checked with a previously prepared record. In the fall, if the plants were to be lifted for winter storage, the labels were again adjusted.

This matter of individual labels for several hundred small plants may appear as a simple detail, but in reality it was the most important, and, at the same time, the most exacting procedure in connection with the test undertaken. If the identity of a plant is lost, the plant is of no value and must be discarded; not only is the labor expended upon it lost, but the value of the ultimate results of the experiment are more or less imperiled, because in any such experiment, numbers have weight and any decrease in numbers diminishes by a definite amount the value of final results. Therefore effort expended in devising and applying means of insuring permanent identity for individuals is imperative.

LOSSES IN THE VARIOUS SERIES

In this test of buds from different locations on the trees the aggregate of buds selected, measured, and propagated was 2,110, divided unequally among fifteen varieties. Nearly 70 percent of the buds were from the five varieties Ben Davis, Winesap, Oldenburg, Yellow Transparent, and Grimes, for the reason that these varieties, being most readily available, were represented in all the series, while the others appeared in only one or two of the later series and were, in large part, from selected trees in orchards in the southern part of the state. The varieties thus represented by smaller numbers were Jonathan, Arkansas Black, Kinnard, Minkler, Huntsman, Whitney, Fameuse, Rome, Willow, and Isham.

Altho careful attention was given to all details of propagation and storage thru the interval between grafting and planting in nursery, the losses during the first season were heavy with all series, particularly with the 7,000 series, which was budded in August, 1909. In this series the loss resulted chiefly from failure of the buds to take, and this failure is ascribed to extreme drouth during and following the budding season. In the grafted series a considerable share of the loss occurred by reason of failure of chosen buds to vegetate, but this source of loss was not so pronounced as in the budded series. With all series losses occurred thru the breaking of young shoots by storms, and thru depredations by cutworms, mice, and rabbits. The number of living plants in the various series, after growing one year in nursery, is shown in Table 5.

Losses continued to occur in succeeding seasons, due in part to winter injury, in part to the death of weak individuals that had made but feeble growth from the beginning, and in part to accidents resulting from wind. The total number of living trees in 1915 was 734,

representing approximately 35 percent of the 2,110 buds selected. They were distributed as shown in Table 5.

TABLE 5.—LOCATION OF BUD ON TREE: ENDURANCE OF TREES, BY SERIES

Series	Number of buds selected	Trees living after one year in nursery			Trees living at close of eighth year		
		Year	Number	Percentage of total	Age (years)	Number	Percentage of total
2 000	450	1908	278	61.77	8	129	28.66
7 000	290	1909	64	22.06	6	23	7.93
9 000	840	1910	561	66.78	6	436	51.90
12 000	530	1911	226	42.64	5	146	27.54

ENDURANCE OF TREES BY VARIETAL GROUPS

Classification of the trees according to varieties is not wholly satisfactory because of differences in age and in numbers of buds selected, but for purposes of record the status of the varieties as to number of trees living in November, 1915, together with the percentage of the original selections, is given in Table 6; the varieties are arranged in sequence from the higher to the lower percentages.

TABLE 6.—LOCATION OF BUD ON TREE: ENDURANCE OF TREES, BY VARIETIES

Variety	No. of buds selected	Trees living after eight years	
		Number	Percentage of total
Minkler	50	36	72.00
Arkansas Black	30	20	66.66
Whitney	80	46	57.50
Willow	50	25	50.00
Fameuse	100	46	46.00
Grimes	310	141	45.48
Huntsman	90	36	40.00
Oldenburg	260	84	32.30
Kinnard	50	16	32.00
Isham	50	16	32.00
Winesap	290	90	31.03
Ben Davis	320	97	30.31
Rome	50	12	24.00
Jonathan	140	30	21.42
Yellow Transparent	240	48	20.00

The higher percentages here fall to varieties having few buds and representation in but one or, at most, two of the series in which the trees were in part six years old and in part five years old. The five varieties Grimes, Oldenburg, Winesap, Ben Davis, and Yellow Transparent were all represented in each of the four series and together represented over 67 percent of the buds selected and about 62 percent of living trees. They give a basis for judging endurance that is perhaps better than that given by the complete list of varieties. Per-

centages of trees of these varieties living in the fall of 1915, or after eight years, ranged from 45.48 percent for Grimes to 20 percent for Yellow Transparent. Other percentages are 32.3 for Oldenburg, 31.03 for Winesap, and 30.31 for Ben Davis. The average for the five varieties is 31.82 percent.

Eliminating the 7,000 series, in which budding was substituted for grafting and wherein failure of buds to start resulted in very few trees, and considering the three grafted series only, it may be noted that there were differences in these series that were in the nature of seasonal differences. Thus, for the 2,000 series, of 1908, Oldenburg led with 35 percent of the buds selected persisting as trees in the fall of 1915. Ben Davis and Grimes were equal and followed a little below Oldenburg, Winesap followed next, and last Yellow Transparent with only 15.5 percent of the buds represented as living trees. For the 9,000 series, of 1910, Grimes was far in the lead in number of living trees, nearly 70 percent of the selected buds being represented by trees; this was followed by Oldenburg, Yellow Transparent, Winesap, and Ben Davis in the order named. In the 12,000 series, of 1911, Grimes was again in the lead, but with a much lower percentage than that shown in the 9,000 series. This was followed by Winesap and Yellow Transparent in descending order and then by equal values for Ben Davis and Oldenburg. In general, Grimes proved the most satisfactory; the other four varieties followed in this order: Oldenburg, Winesap, Ben Davis, and Yellow Transparent.

ENDURANCE OF TREES FROM BUDS GROUPED ACCORDING TO LOCATION ON TREE

The endurance of grafted buds having been considered as expressed in percentage of living trees, when grouped by varieties, examination may now be made of the behavior of the same selected buds as expressed when grouped according to location on tree. Using the five varieties represented in each of the three series propagated by grafting, the aggregate of buds selected was 1,180. The number represented by living trees at the end of the first year was 670, or 57 percent, and in the fall of 1915 there remained 430 living trees, which represented 36.5 percent of the buds selected. In Table 7 are shown the number of living trees arranged according to location of the buds from which they were propagated.

Here trees from buds from short interior branches led by a small margin in percentage of trees living. After eight years the percentage of trees living in this group was 44.28, followed by trees from top central buds with 43.84 percent living; trees from extreme lateral buds on north side came next with 34.61 percent living; then came the group of trees from extreme lateral buds on south side with 31.15 percent living, and last trees from buds from water sprouts with 27.36

percent living. Considering the four series separately, the groups of trees in no two series had the same order of ascendency in this matter of percentage of living trees. Trees from top central buds occupied first place in three series and took third place in the fourth; trees from extreme lateral buds from south side had second place in one, third place in two, and fourth place in one; trees from extreme lateral buds from north side had third place in two and fourth in two; trees from buds from short interior branches had first place in one, second place in two, and third place in one; while trees from buds from water sprouts occupied second place in one, fourth place in one, and fifth place in two. Of the five locations from which buds were chosen, buds from no one location produced trees that exhibited any marked or constant advantage over others in percentage of living trees at the end of eight years.

TABLE 7.—ENDURANCE OF TREES FROM BUDS GROUPED ACCORDING TO LOCATION ON TREE

Location of buds	No. of buds selected	Trees living fall of first year		Trees living after eight years	
		Number	Percentage	Number	Percentage
Top central	260	162	62.30	114	43.84
Lateral south	260	140	53.84	81	31.15
Lateral north	260	135	51.92	90	34.61
Short interior	210	139	66.19	93	44.28
Water sprouts	190	94	49.47	52	27.36

GROWTH THE ONLY BASIS FOR COMPARISON

For determination of possible differences between trees produced from buds from different locations on the tree, the only available basis is the recorded measurements of yearly increments, or better, because more practicable, the two dimensions indicated by total height and spread. When this test was begun it was proposed to measure and record all growth made by each tree. The sum of growth of leader and of all lateral shoots was recorded as the growth of the tree for the particular year. This plan was carried out for two seasons with each series, but the impracticability of the method soon became apparent. Each additional year multiplied the number of shoots and the labor involved in making the measurements soon made a change of plan imperative. For the third season of the experiment, only the growth of the leader of each tree was recorded. At this stage another factor came in to modify greatly the form and dimensions of trees. Pruning became a necessity in order to insure future symmetry and correct habit of trees. Most trees required removal of branches to enable formation of the head at proper height. Some demanded cutting back of too vigorous leaders, and in the interest of symmetry, rampant laterals required shortening. Application of this treatment, looking to good form, was in most cases coincident with removal from nursery

to orchard where the trees are planted 15 by 15 feet to remain until the end of the test. After planting in orchard, four measurements,—namely, total height, spread, and diameter and length of trunk, were recorded, together with notes regarding the amount of branching and general vigor. Without going into details of the measurements of each year, data showing the height and spread of the five varieties having representation in the three grafted series are given as recorded at the end of the season of 1915, segregating these series because of age differences (Table 8).

TABLE 8.—LOCATION OF BUD ON TREE: SHOWING GROWTH OF TREES, BY VARIETIES, FALL OF 1915

Variety	No. of trees	Average (inches)	
		Height	Spread
The 2,000 Series, Trees Eight Years Old			
Ben Davis	35	110.08	90.65
Winesap	25	110.68	97.32
Oldenburg	28	112.60	58.85
Yellow Transparent	14	92.00	37.42
Grimes	31	106.90	89.87
The 9,000 Series, Trees Six Years Old			
Ben Davis	53	81.73	54.05
Winesap	39	86.74	57.43
Oldenburg	47	83.08	39.46
Yellow Transparent	22	74.77	25.95
Grimes	90	85.85	65.51
The 12,000 Series, Trees Five Years Old			
Ben Davis	8	62.62	34.30
Winesap	14	64.21	38.07
Oldenburg	8	57.25	25.12
Yellow Transparent	9	57.55	12.44
Grimes	15	52.60	35.40
Combining the three series, ignoring age differences, the varieties range as below:			
Ben Davis	96	90.47	64.21
Winesap	78	90.37	72.00
Oldenburg	83	101.39	44.63
Yellow Transparent	45	78.91	26.82
Grimes	136	86.98	67.74

In both height and spread Ben Davis was slightly in advance of Grimes, but the differences were no greater than would be expected between varieties following their normal characteristics. Oldenburg and Yellow Transparent showed less spread than the other varieties because of the naturally more erect habit.

Arranging the 438 trees of these five varieties according to the locations from which the buds were taken and segregating the three series as before, the tabulation showing number of trees and average height and spread appears in Table 9.

TABLE 9.—LOCATION OF BUD ON TREE: SHOWING GROWTH OF TREES OF THE FIVE VARIETIES, BY SERIES, FALL OF 1915

Location of buds	2,000 series			9,000 series			12,000 series		
	No. of trees	Average (inches)		No. of trees	Average (inches)		No. of trees	Average (inches)	
		Height	Spread		Height	Spread		Height	Spread
Top central	39	110.82	84.87	64	84.95	55.00	10	58.50	23.00
Lateral south	21	108.00	71.23	57	84.56	55.33	11	56.63	28.09
Lateral north	30	105.60	72.36	56	84.71	55.19	4	61.25	39.25
Short interior	25	112.08	84.24	56	82.60	56.35	14	60.14	28.00
Water sprouts	18	100.83	75.22	18	80.98	49.83	15	58.66	37.53

Reducing this tabulation to a single expression by combining the trees of different ages, in order to facilitate comparison of growth from buds from the different locations, Table 10 is given as a condensed result of the last measurements made.

TABLE 10.—LOCATION OF BUD ON TREE: COMPARISON OF GROWTH OF TREES OF THE THREE SERIES COMBINED, AS MEASURED IN THE FALL OF 1915

Location of buds	No. of trees	Average (inches)	
		Height	Spread
Top central	113	91.54	62.47
Lateral south	89	86.64	55.71
Lateral north	90	90.63	60.21
Short interior	95	87.05	59.51
Water sprouts	51	81.41	55.17

The foregoing gives the results to November, 1915, for five of the varieties in the three series propagated by grafting and points to a close approximation in the development of trees from buds from the different locations. Tabulations in detail for each variety show no regularity in sequence of locations when arranged in order on the basis of total height of the trees. In some cases trees from buds from short interior branches showed greatest growth, in others trees from buds from water sprouts were in ascendency, and in still others the trees from buds from central terminal shoots had first place. In no case, however, was there any marked or significant departure from the general trend shown by the trees when grouped either by varieties or by the locations from which buds were taken. The cases of maximum departures from the general average were with single varieties, in single series, where the number of trees was small. Grouping single varieties within a series, or combining the series, either by varieties or by bud location, has immediate effect in smoothing out and bringing growth curves into close approximation. In all computations the effect of numbers is strikingly shown, and apparently it would require only small additions to bring the results to absolute zero, thus demonstrating conclusively that for purposes of propagation it makes no difference from what position on the tree the bud is taken.

To illustrate further the results of this test of buds from different locations, the following tabulations and graphs are presented. Each tabulation with its accompanying graph stands for one complete series in which the trees were of equal age. In Table 11 is presented the growth record for eight years for the 2,000 series, which included five varieties, and in Fig. 13 the same data are presented graphically. It would be more satisfactory and the curves in all probability would be more nearly coincident if the numbers of trees for the various locations were equal, but even as it is there is remarkable uniformity in the development of the trees from buds from the different locations. The 7,000 series, propagated, as already explained, by budding, and including six varieties, sustained such heavy losses that the number of trees remaining was too small for satisfactory comparison; however, even here the departures from the general trend of development were not great, as is shown in Table 12 and in Fig. 14. The 9,000 series included twelve varieties and was started with 840 selected buds; Table 13 and Fig. 15 show the growth for six seasons of the 436 remaining trees. Greater uniformity in the distribution of trees in location groups would doubtless have given curves that more nearly coincided, but as it is, there is close approximation in the growth of the different groups. The 12,000 series began with 530 buds distributed among eleven varieties; in Table 14 and in Fig. 16 are given the growth records of 146 trees for five years, and here there is shown a more nearly equal distribution in the location groups.

Figs. 17 to 32 illustrate some of the trees of the 2,000 series, testing buds from different locations on the tree. These plates are all from photographs made in July, 1915.

TABLE 11.—LOCATION OF BUD ON TREE: 2,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED
(Expressed in inches)

Year	1908	1909	1910	1911	1912	1913	1914	1915
Top Central: Average of 39 Trees								
Height	20	18	10	44	54	68	84	111
Spread	..	..	..	..	30	44	58	85
Lateral South Side: Average of 21 Trees								
Height	18	21	10	43	52	67	85	108
Spread	..	..	..	..	24	36	50	70
Lateral North Side: Average of 30 Trees								
Height	18	17	9	41	52	66	82	105
Spread	..	..	..	..	25	36	47	71
Short Interior: Average of 25 Trees								
Height	18	16	9	42	53	69	87	112
Spread	..	..	..	..	28	42	56	84
Water Sprouts: Average of 18 Trees								
Height	18	15	9	39	51	64	79	101
Spread	..	..	..	..	25	39	65	75

NOTE.—Total growth is recorded for 1908 and 1909, for 1910 length of leader only, and for each succeeding year total height of tree.

TABLE 12.—LOCATION OF BUD ON TREE: 7,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED
(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Top Central: Average of 7 Trees						
Height	21	7	41	51	63	86
Spread	..	..	..	17	33	57
Lateral South Side: Average of 5 Trees						
Height	30	7	43	52	66	92
Spread	..	..	..	22	35	63
Lateral North Side: Average of 4 Trees						
Height	24	6	40	54	69	94
Spread	..	..	..	26	43	74
Short Interior: Average of 4 Trees						
Height	21	4	35	46	65	85
Spread	..	..	..	16	29	49
Water Sprouts: Average of 3 Trees						
Height	25	8	43	47	60	85
Spread	..	..	..	14	36	67

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 13.—LOCATION OF BUD ON TREE: 9,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Top Central: Average of 112 Trees						
Height	19	9	41	49	64	88
Spread	..	..	..	21	31	60
Lateral South Side: Average of 102 Trees						
Height	18	10	41	49	65	88
Spread	..	..	..	18	29	65
Lateral North Side: Average of 92 Trees						
Height	16	11	41	50	63	87
Spread	..	..	..	16	30	58
Short Interior: Average of 84 Trees						
Height	15	12	36	44	60	83
Spread	..	..	..	17	30	55
Water Sprouts: Average of 46 Trees						
Height	16	10	36	46	60	82
Spread	..	..	..	15	29	59

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 14.—LOCATION OF BUD ON TREE: 12,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1911	1912	1913	1914	1915
Top Central: Average of 26 Trees					
Height	7	17	25	37	56
Spread	..	..	..	9	26
Lateral South Side: Average of 29 Trees					
Height	8	18	24	36	60
Spread	..	..	..	12	32
Lateral North Side: Average of 29 Trees					
Height	9	18	28	42	65
Spread	..	..	..	12	34
Short Interior: Average of 28 Trees					
Height	10	18	29	41	64
Spread	..	..	..	12	34
Water Sprouts: Average of 34 Trees					
Height	9	19	30	41	64
Spread	..	..	..	15	38

NOTE.—Measurement for 1911 is given for length of leader only; for each succeeding year total height of tree is given.

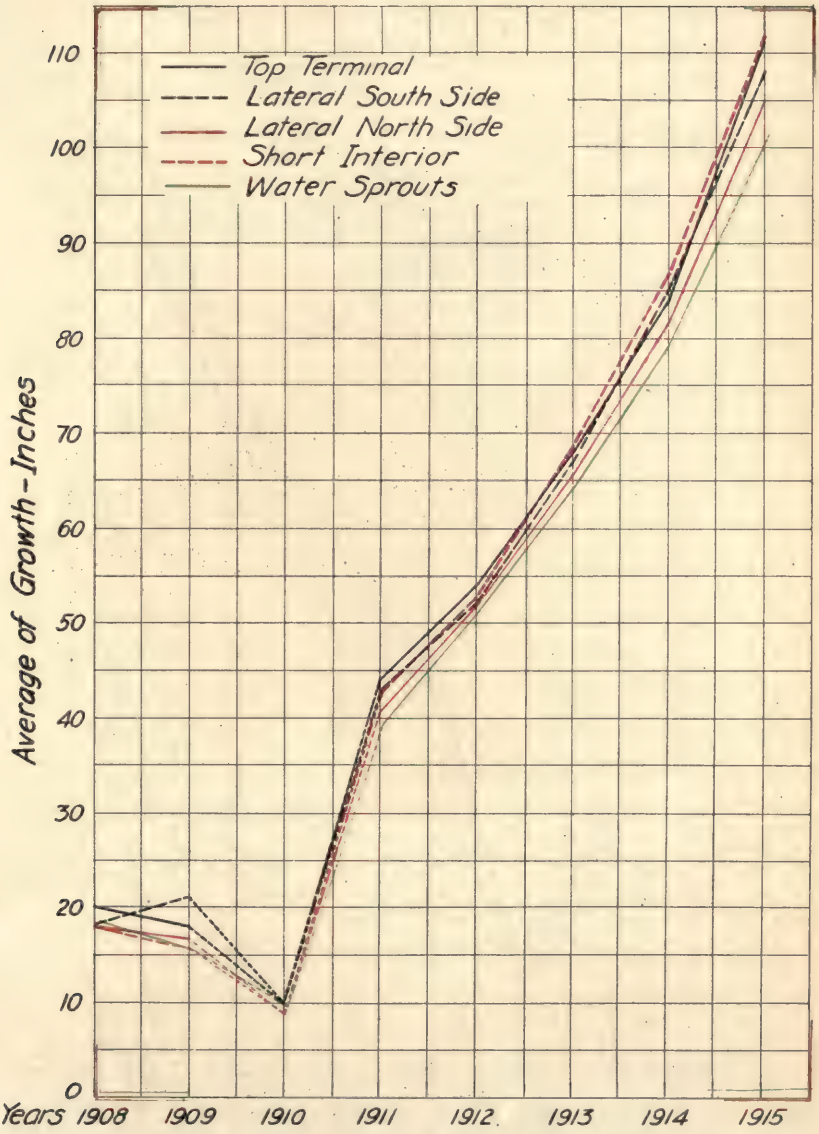

FIG. 13.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 2,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

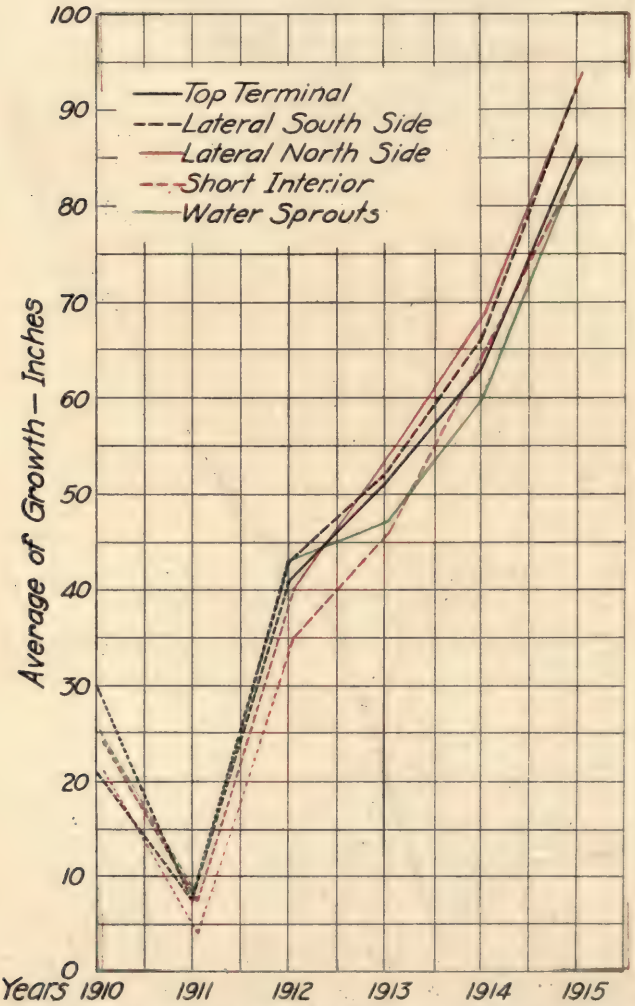

FIG. 14.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 7,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

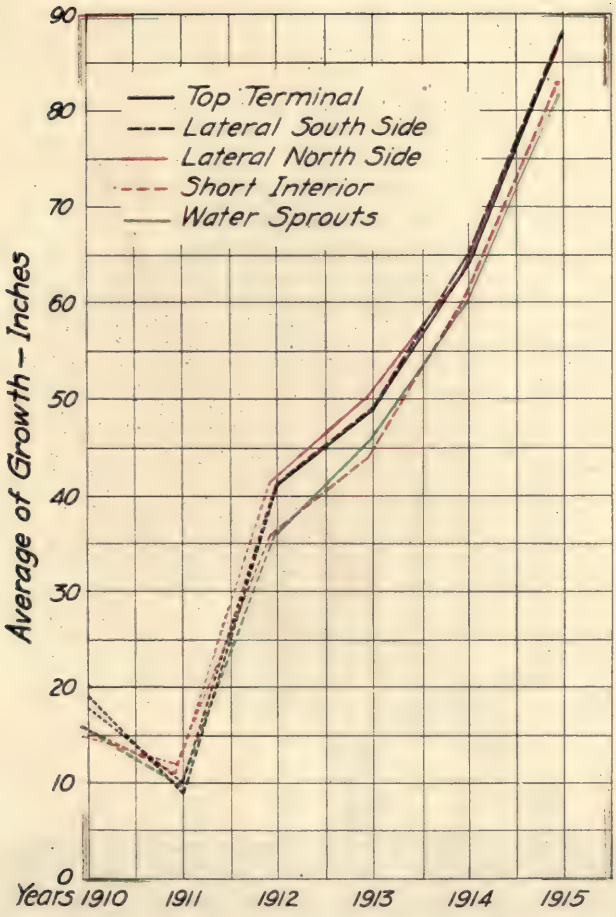

FIG. 15.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 9,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

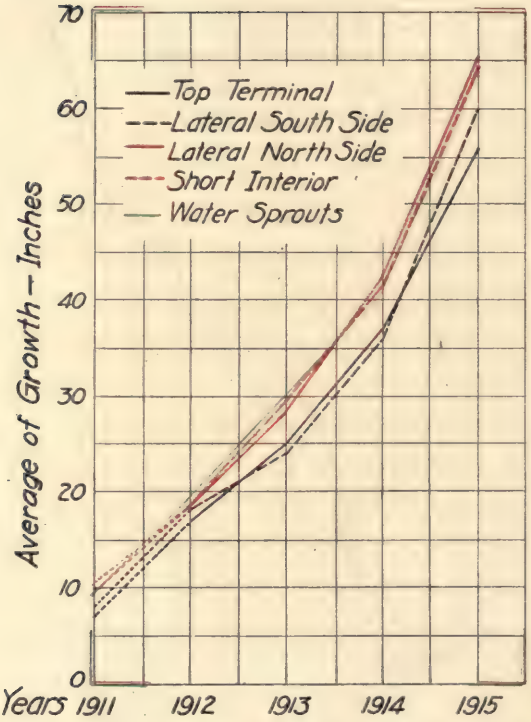

FIG. 16.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE TREE: ALL VARIETIES COMBINED, 12,000 SERIES

Growth in 1911 was measured by the length of leader only, and in 1912 to 1915 by the total height.

FIG. 17.—No. 2451: GRIMES FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 2 INCHES

FIG. 18.—NO. 2218: GRIMES FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

FIG. 19.—No. 2229: GRIMES FROM NORTH LATERAL BUD · HEIGHT, OCTOBER 13, 1915, 9 FEET, 9 INCHES

FIG. 20.—No. 2235: GRIMES FROM BUD FROM SHORT INTERIOR BRANCH HEIGHT, OCTOBER 13, 1915, 9 FEET, 1 INCH

FIG. 21.—No. 2247: GRIMES FROM BUD FROM WATER SPROUT
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES

FIG. 22.—No. 2009: BEN DAVIS FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 6 INCHES

FIG. 23.—No. 2016: BEN DAVIS FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 11 FEET, 2 INCHES

FIG. 24.—No. 2109: OLDENBURG FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 3 INCHES

FIG. 25.—No. 2111: OLDENBURG FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET

FIG. 26.—No. 2122: OLDENBURG FROM NORTH LATERAL BUD HEIGHT, OCTOBER 13, 1915, 10 FEET, 5 INCHES

FIG. 27.—No. 2137: OLDENBURG FROM BUD FROM SHORT INTERIOR BRANCH HEIGHT, OCTOBER 13, 1915, 10 FEET, 9 INCHES

FIG. 28.—No. 2052: WINESAP FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES

FIG. 29.—NO. 2363: WINESAP FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 8 INCHES

FIG. 30.—No. 2078: WINESAP FROM NORTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 5 INCHES

FIG. 31.—No. 2087: WINESAP FROM BUD FROM SHORT INTERIOR BRANCH HEIGHT, OCTOBER 13, 1915, 9 FEET, 9 INCHES

FIG. 32.—No. 2393: WINESAP FROM BUD FROM WATER SPROUT
HEIGHT, OCTOBER 13, 1915, 10 FEET, 7 INCHES

COMPARATIVE VALUE OF BUDS FROM DIFFERENT LOCATIONS ON SHOOT

The third division of the bud-selection project is a test for differences in value, for purposes of propagation, of buds from different locations on the same shoot. Four locations are represented; namely, terminal buds, lateral buds at distal end of shoot, buds from middle of shoot, and buds from near the base of the shoot. As in the other divisions of the project, selections were made in series, extending over the four years 1908 to 1911. In three of the series propagation was by grafting. The 8,000 series of 1909 was propagated by budding in August of that year. The number of buds selected and their distribution as to location are given in Table 15.

TABLE 15.—LOCATION OF BUD ON SHOOT: SHOWING DISTRIBUTION OF BUDS SELECTED

Series	Year	Number of buds				
		Terminal	Lateral at distal end	Middle	Near base	Total
3 000	1908	80	80	80	80	320
8 000	1909	10	60	60	60	190
10 000	1910	..	150	150	150	450
13 000	1911	110	...	110	110	330
	Total	200	290	400	400	1 290

Fifteen varieties were represented. Ben Davis, Winesap, Oldenburg, Yellow Transparent, and Grimes appeared in all series; the other ten varieties appeared in one or both of the 10,000 and the 13,000 series. Here, as in the test of location of buds on trees, many chosen buds failed to grow and some of those starting were lost thru accidents, so that the number of trees living in the fall of 1915 was much below the number of buds selected. Living trees classified according to the locations from which buds were taken for each series are given in Table 16.

TABLE 16.—LOCATION OF BUD ON SHOOT: SHOWING DISTRIBUTION OF TREES LIVING IN 1915

Series	Number of trees				Age of trees (years)
	Terminal	Lateral at distal end	Middle	Near base	
3 000	23	29	17	26	8
8 000	..	10	12	6	6
10 000	..	64	74	48	6
13 000	36	..	24	15	5

Of the 384 trees living in 1915, about 25 percent were eight years old, nearly 56 percent were six years old, and about 20 percent were five years old. Of the five varieties represented in all series, Ben Davis stood first in percentage of living trees with a percentage of 41. Grimes followed with 32.5 percent, Winesap with 29 percent, Oldenburg with

20 percent, and Yellow Transparent with a little less than 18 percent. Arranging the trees of these five varieties according to the locations from which the buds were taken, it appears that, with Ben Davis and Winesap, the highest percentage of trees surviving was with those from lateral buds from the distal ends of shoots; with Oldenburg and Yellow Transparent the highest percentage was with those from buds from the middle of shoots; while with Grimes the trees from terminal buds survived in greatest numbers.

In general, the losses of trees from selected buds were greater with terminal buds and those near the base than with buds taken from central and distal portions of shoots. There appears no evident reason why losses should be greater with terminal buds than with central buds or lateral buds from the distal end; they were, in general, larger than buds from other situations, and so far as could be judged from external appearances, perfectly sound and healthy. It is possible that winter injury occurred sufficient to prevent growth, but insufficient to be externally apparent; this does not seem probable, however, because no general failure of terminal buds on trees from which buds were selected was observed. No wholly satisfactory reason for the failures that occurred suggests itself, but it is a fact that an unexpectedly large percentage of terminal buds failed to grow.

In selecting buds near the bases of shoots, effort was made to take them from as near the base as possible and yet to preserve sufficient scion length for grafting. Scions were made as short as possible, varying from two to four inches according to the length of the shoot. These basal scions were often of greater diameter than is desirable in scions. They were short, rigid, and often curved, and were adjusted to stocks with difficulty, and were easily displaced. It is probable, therefore, that a considerable portion of the losses in this group of buds should be ascribed to imperfections in the mechanical operations of grafting. However, observations upon the starting of grafts representing the four groups of buds convince the writer that buds near the bases of shoots do not start as readily nor as vigorously as do buds from the central portion of the shoot; neither do they equal in vigor of initial growth those lateral buds situated just below the terminal, altho this tardy and often weak start is in no sense a measure of subsequent growth.

GROWTH OF TREES

Measurements of growth of trees in this test of buds from different locations on the shoot were taken in the same manner and on the same dates as were those in the test of buds from different locations on the tree. Comparing the measurements made in 1915, there appear the same irregularities in sequence of groups, when arranged in order of merit, and the same close approximations between the different groups under test, as were found in the groups from buds from different locations on the tree.

Examining the measurements by series and considering first the 3,000 series, trees eight years old, it appears that trees from buds from middle of shoot and from near the basal end were equal in height and stood first, followed in order by trees from lateral buds at distal end and trees from terminal buds.

The 8,000 series, with trees six years old, had no trees from terminal buds. Trees from buds near the base took precedence in height, followed by trees from buds near distal end, and then by trees from buds from middle of shoot.

In the 10,000 series, also with six-year-old trees, and also with no trees representing terminal buds, trees from buds from distal end took the lead in height, while those from buds near base and from middle of shoot were of equal height.

In the 13,000 series, with five-year-old trees, trees from buds near the basal end stood first in height, followed by trees from buds from middle of shoot and then by trees from terminal buds.

But in all of the four series no group of trees representing any one of the four locations had sufficient advantage in growth over other groups to make it stand out in any distinctive way. The differences were so insignificant as to encourage the belief that repetition of the work, or any moderate addition to the numbers of trees involved, would be quite likely to change or even to reverse entirely the sequence of greatest height. In Tables 17 to 20 are shown, by series, the averages of total growth by years for trees from buds from each location. In Figs. 33 to 36 these data are presented in graphic form.

Figs. 37 to 43 show individual trees of the 3,000 series testing buds from different locations on the shoot. All are from photographs made in July, 1915.

TABLE 17.—LOCATION OF BUD ON SHOOT: 3,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1908	1909	1910	1911	1912	1913	1914	1915
Terminal Buds: Average of 23 Trees								
Height	18	19	10	40	48	60	75	98
Spread	..	..	..	..	..	37	49	76
Lateral at Distal End: Average of 29 Trees								
Height	20	17	10	42	52	65	78	102
Spread	..	..	..	..	..	40	52	79
Middle of Shoot: Average of 17 Trees								
Height	20	17	10	44	54	68	83	107
Spread	..	..	..	..	..	47	56	82
Near Basal End: Average of 26 Trees								
Height	19	18	10	49	59	70	82	107
Spread	..	..	..	..	..	45	56	83

NOTE.—Total growth is recorded for 1908 and 1909, for 1910 length of leader only, and for each succeeding year total height of tree.

TABLE 18.—LOCATION OF BUD ON SHOOT: 8,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Lateral at Distal End: Average of 10 Trees						
Height	25	4	36	37	53	73
Spread	..	..	..	11	23	50
Middle of Shoot: Average of 12 Trees						
Height	18	5	33	39	51	68
Spread	..	..	..	11	24	39
Near Basal End: Average of 6 Trees						
Height	16	6	36	45	57	76
Spread	..	..	..	13	27	47

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 19.—LOCATION OF BUD ON SHOOT: 10,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Lateral at Distal End: Average of 64 Trees						
Height	20	5	39	49	60	82
Spread	..	..	..	16	29	57
Middle of Shoot: Average of 74 Trees						
Height	18	7	37	48	57	78
Spread	..	..	..	14	28	57
Near Basal End: Average of 48 Trees						
Height	21	7	37	48	57	78
Spread	..	..	..	15	28	58

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 20.—LOCATION OF BUD ON SHOOT: 13,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1911	1912	1913	1914	1915
Terminal Buds: Average of 36 Trees					
Height	8	22	27	39	57
Spread	..	..	..	12	32
Middle of Shoot: Average of 24 Trees					
Height	9	20	30	38	60
Spread	..	..	..	12	34
Near Basal End: Average of 15 Trees					
Height	10	20	30	42	65
Spread	..	..	..	13	38

NOTE.—Length of leader only is recorded for 1911, and for each succeeding year total height of tree.

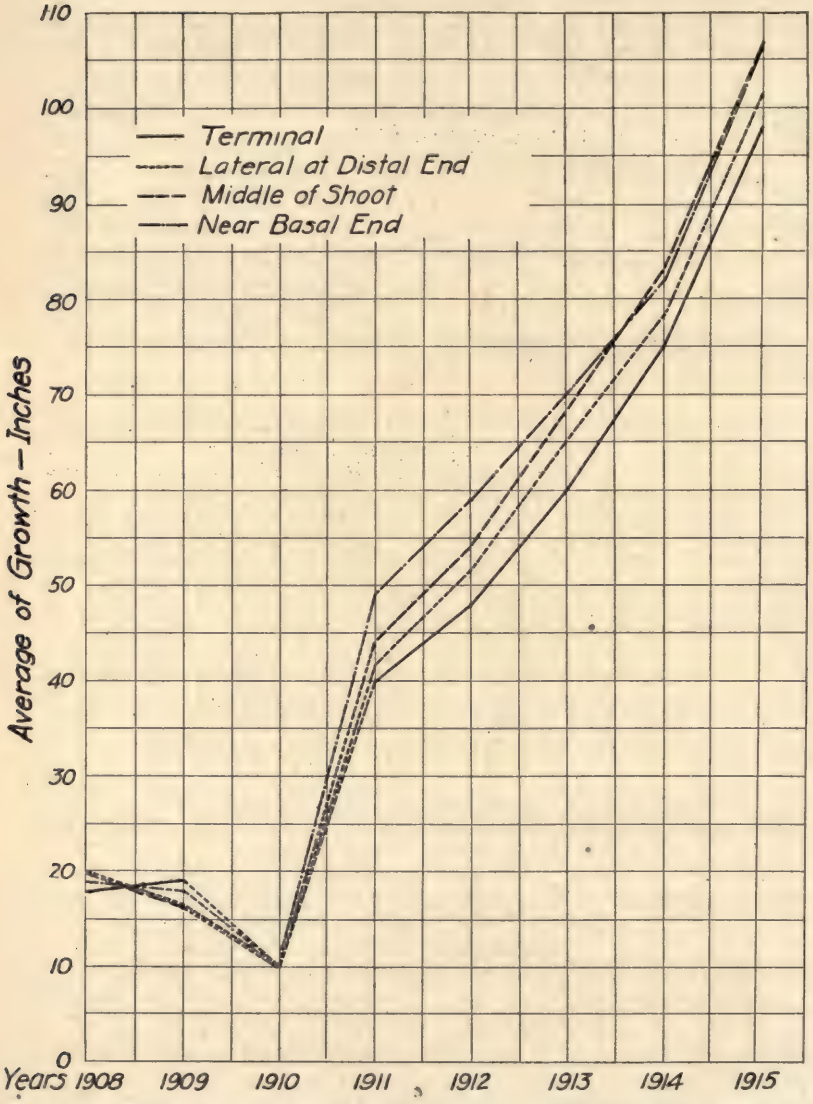

FIG. 33.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 3,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

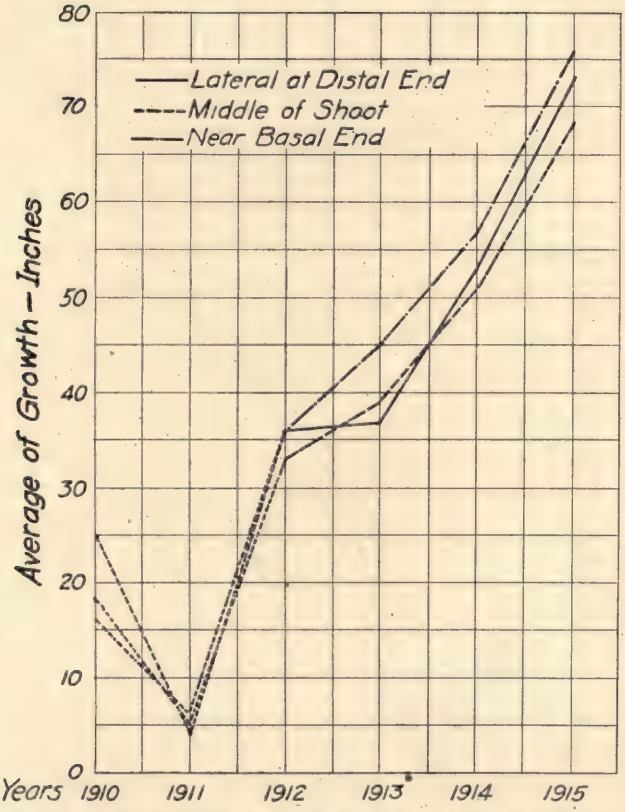

FIG. 34.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 8,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

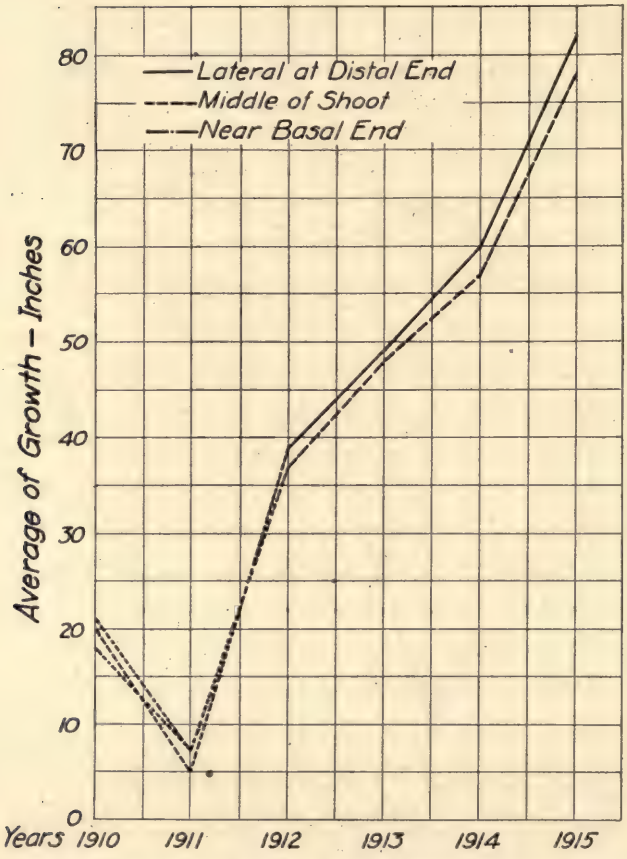

FIG. 35.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 10,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

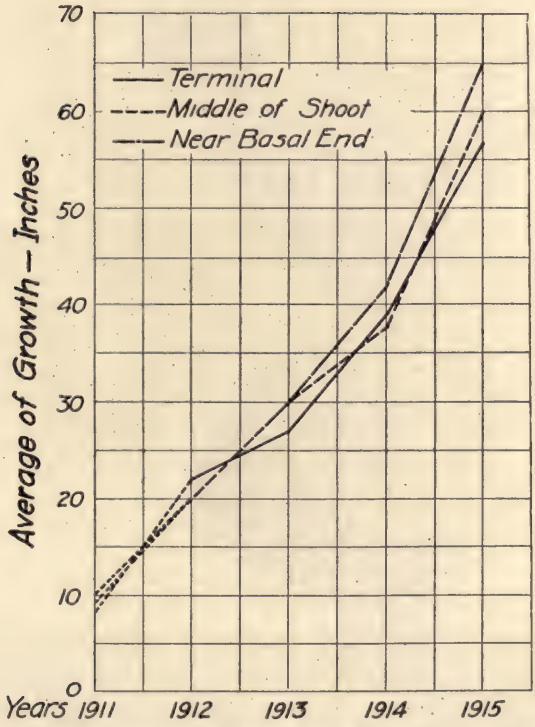

FIG. 36.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 13,000 SERIES

Growth in 1911 was measured by the length of leader only, and in 1912 to 1915 by the total height.

FIG. 37.—NO. 3170: GRIMES FROM TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET

FIG. 38.—No. 3191: GRIMES FROM BUD FROM DISTAL END OF SHOOT HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

FIG. 39.—No. 3177: GRIMES FROM BUD FROM MIDDLE OF SHOOT
HEIGHT, OCTOBER 13, 1915, 10 FEET, 3 INCHES

FIG. 40.—No. 3185: GRIMES FROM BUD NEAR BASE OF SHOOT HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

FIG. 41.—NO. 3083: OLDENBURG FROM TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 9 INCHES

FIG. 42.—No. 3106: OLDENBURG FROM BUD NEAR BASE OF SHOOT HEIGHT, OCTOBER 13, 1915, 9 FEET, 8 INCHES

FIG. 43.—No. 3079: WINESAP FROM BUD AT DISTAL END OF SHOOT
HEIGHT, OCTOBER 13, 1915, 11 FEET

When the results thus far obtained in this test of buds for purposes of propagation are platted, a striking uniformity in the growth curves is shown. The lines are so nearly coincident and indicate such slight departures from absolute uniformity that there remains no basis for any assumed differences in value of the buds tested. Results are negative. As large and as well-formed trees were grown from small buds as from large. Central terminal buds exhibited no advantages over extreme lateral buds, or over buds from interior branches, or even over buds from water sprouts, and the same results prevailed with reference to location on the shoot. Buds from near the base, from central, and from terminal locations gave equally good trees. These conclusions are based upon comparisons between the different lots of trees from buds from the different locations, but they should not convey the idea that there was perfect uniformity in the trees. Averages for the lots show uniformity, but within the groups of trees from buds from the same locations or from buds of uniform size, either large or small, there were often striking individual differences. For example, in comparing six trees of Grimes propagated from large buds, and eight years old, with six trees of the same age propagated from the smallest buds to be found on the tree, the average growth of the trees from large buds was found to be almost identical with the average of those from small buds, but the range of variation among the individuals of either group was considerable. Of the six trees from large buds the largest exceeded the smallest by 2 feet in height, 2 feet in spread, and ½ inch in trunk diameter. Of the six trees from small buds, the largest exceeded the smallest by 2 feet 8 inches in height, 2 feet in spread, and ⅞ inch in trunk diameter. These individual differences, sometimes greater, sometimes less, were common to all groups; they show the necessity of considerable numbers in order to make right comparisons between group averages.

Changes in the relative positions of individuals within a group when contrasted as to growth increments were quite common. Of two trees one might exceed the other in growth the first year, fall below it in the second, regain its advance position in the third year, again lose it, and again regain it, and so on for several years. The annual growth of two Winesap trees, which may be distinguished as A and B, illustrate this variation. Both were grafted on the same day in 1908; the buds chosen for the two trees were similarly situated near the bases of shoots; and the stocks upon which the scions were grafted were, to all appearances, similar. During the season of 1908, A made 33 percent more growth than B. In 1909, B exceeded A in total growth by 38 percent. In 1910, when the leaders only were measured, the length produced by B was two and one-half times that produced by A. In 1911, when measurements of total height were recorded, A exceeded B by 38 percent; in the next year, it maintained the lead by about 14

TABLE 21.—OLDENBURG: SHOWING GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS

Bud class	Serial number	The bud			Total growth (inches)		Length of leader	Total height (inches)				
		Location	Length (mm.)	Breadth (mm.)	1908	1909	1910	1911	1912	1913	1914	1915
Large	1021	Terminal	6.25	4.25	15	26	9	34	34	34	39	62
Small	1033	Lateral	2.00	2.00	8	21	12	34	36	48	59	88
Large	1023	Terminal	5.00	4.50	14	20	9	40	44	60	69	94
Small	1034	Lateral	1.50	2.00	9	27	14	47	52	65	68	92
Large	1027	Terminal	6.00	4.25	17	25	13	52	47	78	83	104
Small	1038	Lateral	1.25	1.50	18	29	12	56	64	78	96	119
Large	1026	Terminal	6.25	5.00	13	34	12	48	56	72	80	101
Small	1031	Lateral	2.00	2.25	7	8	18	46	54	66	78	100
Large	1028	Terminal	6.00	3.75	18	24	14	56	64	73	81	99
Small	1035	Lateral	1.25	1.50	10	28	15	55	59	86	106	127

percent, but in 1913, B made the greater growth, exceeding A by 21 percent. In the two remaining years for which there is record, B continued to lead, exceeding A in 1914 by 18 percent, and in 1915 by 21 percent. Whether A will again lead, or remain in second place, is impossible to predict, but from many observations of these individual differences in growth it appears that, in general, differences become less with increase in age, provided the trees remain healthy. When two apparently healthy trees fluctuate in growth, as in the example cited, it is usually not possible to assign definite causes. Visible parts of the trees appear normal, but agencies that may operate to accelerate or retard root functions are hidden and cannot easily be discovered. The fluctuations in rate of growth here considered were apparent in all groups; hence their occurrence was entirely independent of the size of the initial buds from which the trees were grown or of the situation on tree or shoot from which the original buds were taken.

Growth of Selected Oldenburg Trees.—As a further exhibit of the relation between size of the chosen bud and subsequent growth, the measurements of ten Oldenburg trees, eight years old, may be given. Five of the trees were grown from buds selected as large and five from buds selected as small. Original bud measurements and growth records up to and including 1915 are given in Table 21. For convenience in comparing, the trees are arranged in pairs, a tree from a large bud associated with one from a small bud.

Four of the large buds were terminal, one was a lateral from just below an undeveloped terminal; two of the shoots from which buds were taken were top terminal, and three were short laterals from near the apex of the shoot of the preceding year. The small buds were all lateral from shoots from short interior branches. All the buds were selected to represent extremes in size; that they did this seems evident from the individual measurements. The large buds were all more than three times and in two cases nearly five times the length of the small; in all cases they were more than twice the breadth of the small buds. It may also be noted, altho not shown in the table, that scions carrying the large buds were in all cases larger than those carrying the small buds. Large buds, therefore, had not only the advantage that is supposed to belong to great size, but the additional advantage of the presumably larger store of reserve plant food to be found in the larger scions.

But larger size of bud and more robust scions appear to have had no influence upon subsequent growth other than is shown by the fact that, in the first season, four of the five pairs showed greater growth from the large buds. The remaining pair, in which the growth from the small bud slightly exceeded that from the large bud, chanced to be the one showing the greatest difference between the buds paired; the large bud was 4.8 times as long and 2.83 times as broad as the small

bud. In two of the four pairs in which trees from large buds showed greater growth in the first year, the trees from small buds in the second year exceeded those from large buds, and in the other two pairs the advantage gained in the first year was maintained. For the third year the trees from small buds exceeded those from large buds in these four pairs. In the following five years there were fluctuations, and for the last year, 1915, the advantage in growth remained with trees from small buds in three of the pairs and with those from large buds in the other two pairs. The same irregularities in growth shown by Oldenburg appeared in other varieties and in other series of the test of size of buds. Nowhere was there any evidence tending to support the contention that large buds possess advantages over small buds for purposes of propagation.

COMPARATIVE VALUE OF ROBUST AND SLENDER SCIONS

The possible advantage accruing to buds borne on robust scions, because of the presumably greater supply of reserve nutrients than is to be found in slender scions, referred to above, may be studied by comparing a random selection of scions on the basis of scion diameters as shown by diameters of distal internodes. Ten scions were selected in which these diameters ranged from 4.5 to 7 mm., with an average of 5.15 mm., and for which the average length was 6.4 inches. These were all from top terminal shoots and were equally divided between Ben Davis and Oldenburg. Ten other scions selected had distal internode diameters of from 1.75 to 2 mm., with an average of 1.97 mm., and an average length of 5.77 inches. Of these scions seven were from shoots from short interior branches, two were from extreme lateral shoots, and one was from a water sprout. Four were from Grimes, three from Winesap, and three from Oldenburg.

To facilitate a comparison of records, the averages for each season are brought together in Table 22.

TABLE 22.—COMPARISON OF GROWTH OF TREES FROM ROBUST AND FROM SLENDER SCIONS

(Average in inches)

	No. of scions	Diam. of distal internode	Length of scion	Total growth		Growth of leader	Total height				
				1908	1909	1910	1911	1912	1913	1914	1915
Robust scions..	10	0.206	6.40	17.5	20.3	12.2	41.2	49.4	63.4	78.8	101.9
Slender scions..	10	0.079	5.77	16.7	15.4	10.7	39.8	50.7	64.1	81.8	110.9

This record shows that the initial growth from buds on robust scions was slightly greater than that from buds on slender scions and

that the relative positions of the two groups remained the same to the end of the fourth season. In the fifth season the positions were reversed. The trees from buds on slender scions exceeded the others in height and continued this advantage thru 1915, or to the end of the record. However, neither in the first years, in which trees from robust scions had the advantage, nor in the last years, in which trees from slender scions made the greater growth, were differences such as to indicate marked superiority of one group over the other in growth.

While the differences in growth averages for the groups were insignificant, the fluctuations in growth of individuals within each group were decided, often extreme, and worthy of note. Arranging the trees from scions of large diameter according to the magnitude of growth in 1908, with No. 1 representing maximum growth and No. 10 the minimum, the top terminal scion of Ben Davis numbered 2009 occupied the position of No. 1. In 1909 it dropped to tenth place, having the minimum growth. In 1910 it rose to fifth place and in 1911 regained the position as No. 1, and this it held thru 1915. Another top terminal scion of Ben Davis, No. 2005, occupied second place in the list of 1908. In 1909 it dropped to fifth place and in 1910 to the bottom of the list. In 1911 it ascended to fifth place, then dropped to seventh, and still farther to ninth place in 1913; it rose to eighth place in 1914, then dropped to ninth in 1915. Third place in 1908 was occupied by No. 2004, another top terminal scion of Ben Davis; this fell to ninth place in 1909, rose to second place in 1910, then occupied fourth place for two seasons, had sixth place in 1913, dropped to tenth place in 1914, and remained in this position in 1915. The eighth place in 1908 was filled by the top terminal scion of Oldenburg numbered 2104. This rose to first place in 1909 and held it thru 1910. In 1911 it dropped to sixth place, occupied the eighth place in 1912 and 1913, rose to seventh in 1914, and remained in that position in 1915. Another similar scion, No. 2110, was in ninth place in 1908, second in 1909, third in 1910, eighth in 1911, tenth in 1912 and 1913, ninth in 1914, and eighth in 1915. At the bottom of the list in 1908 was No. 2103, also a top terminal Oldenburg scion. This rose to eighth place in 1909, and to first in 1910; then it dropped to sixth, remaining there two seasons, after which it rose thru fourth place in 1913 to second place in 1914 and 1915. Remaining numbers of the group fluctuated in like manner. Not one maintained an even course or exhibited any approach to uniformity in the increments of successive seasons. In the companion group of trees grown from attenuated scions, fluctuations in growth were shown by each individual just as extreme and irregular as those given as illustrations from the group of trees from scions of large diameter.

Summarizing the direction of movement of growth magnitudes after the first year (1908), it appears that for the ten trees from large

scions, three made less growth in 1909, four increased in growth for that year, while the remaining three made the same growth in 1909 as in 1908 and then began fluctuating, one moving to less and two to greater growth. For the trees from attenuated scions six made less growth in 1909 than in 1908, three increased in growth for that year, while one made growth in 1909 equal to that of 1908 and after that fluctuated up and down within comparatively narrow limits, going from fourth place in the first two years to second place in the third year, fourth in the fourth year, third in the fifth year, fourth in the sixth year, and fifth in the last two years.

Now, the only fact that may be regarded as indicating superiority on the part of scions of large diameter, is that trees from such scions showed slightly greater averages of growth in the first years than did trees from the slender scions. Differences in the averages, however, were very small, and when it is considered that some individuals from slender scions in the first year showed equal growth with others from stout scions and in some cases even exceeded them, that in all seasons following the first, all trees fluctuated in amount of growth in a remarkable manner, and further, that in the last four years the differences in average growth transferred the apparent advantage to trees from slender scions, it appears that there is no tangible basis upon which to establish the idea that scions of large diameter, by virtue of size and presumably larger store of available nutrients, are superior to scions of small diameter for purposes of propagation. Each tree appeared to pursue its own course independently of others of its class; each added a yearly increment the magnitude of which was greater or less according as its surroundings were favorable or unfavorable to growth.

EFFECT OF VIGOR OF STOCK ON GROWTH

Aside from any influence upon growth that may be inherent in a particular bud or scion, there is the influence of the stock upon which the scion is grafted. All scions used in this test of buds were grafted, by the veneer method, upon crown pieces of ordinary apple seedlings as stocks. Any lot of seedlings exhibits wide variations in vigor and habit of growth; so these stocks, altho graded to eliminate weak individuals, still showed wide differences. Some were supplied with abundant roots and correspondingly large stems; others had few roots and slender stems. Vigor of stocks as measured in root production and stem growth existed in all degrees and each individual stock reflected its habit in some degree on the scion grafted upon it.

INFLUENCE OF CARE IN GRAFTING

Degree of perfection in the mechanical operations of grafting may also exercise an important influence upon growth of the scion. Among

several hundred veneer grafts, even when made with extreme care, differences may be found in degree of perfection of contact between stock and scion. Slight convexities or concavities in the surfaces brought together prevent the complete and continuous contact of cambium essential to that prompt and efficient union which has an undoubted influence in advancing development from scion buds. Care of grafts during the period between making and planting in nursery, particularly with reference to temperature and uniformity in the supply of moisture, has an influence on subsequent growth and so also have care in planting, character of soil, and all those atmospheric conditions which singly or collectively operate to advance or retard plant growth.

VARIETAL AND INDIVIDUAL DIFFERENCES

Studies of the differences in annual increments and general behavior in growth of the trees grown from selected buds support and emphasize the fact of distinct individuality. In general habit the trees follow the parent varieties: Yellow Transparent, Whitney, and Oldenburg are upright, Grimes and Rome tend to rounded, symmetrical forms, while Ben Davis, Winesap, and Jonathan exhibit the usual irregularity in branch growth, tending to spreading and to more or less unsymmetrical shapes. But within any varietal group no two trees are alike. Often casual examination of a group gives the impression of great similarity, but close observation and measurements invariably bring out differences and show that the trees have reached their present state of development by very unequal increments.

Some extreme cases occurred in which individuals showed differences so conspicuous as to be readily noticed even by casual observers, as for example, two Ben Davis trees of exactly the same age, both from selected large buds from the same tree, the trees grown side by side in nursery and for the five years ending with 1915 fifteen feet apart in orchard. Both appeared healthy, but one was 54 percent taller than the other, had 87.5 percent more spread, and 100 percent greater trunk diameter. There were several other cases of equally great individual differences, but in general differences between individuals, altho appreciable, were much less. In most cases it is no more possible to assign specific causes for extreme individual differences than it is to assign them for the minor differences. In the example just given, the trees thruout life had been grown in such close proximity and so nearly under the same conditions that moisture, temperature, and other atmospheric conditions could not be considered as causes of the differences; for the same reason it appears improbable that soil conditions were in any way responsible for the wide differences observed in the other trees. Causes for the differences in growth, then, must lie with the individual plants, either in inherent qualities that belong to the

stocks or to the scions, or to both, or to differences in the mechanical operation of grafting. The influence of these things is indeterminable and the causes of the differences remain unknown.

DISCUSSION OF RESULTS

In these tests many comparisons have been made between individuals of different groups and between entire groups, but no acceptable evidence has been found that growth of trees is in any way dependent upon size of scion, size of individual bud, location of bud upon the tree, or location of bud upon the shoot. No other conclusion is possible from the records than this: that all buds from healthy shoots are of equal value for purposes of propagation, at least so far as growth of trees is concerned.

GROWING SEEDLINGS FROM SEEDS OF FRUITS FROM TREES CHOSEN AS POSSESSING SPECIAL MERIT

This project was begun in 1908 and was considerably extended in 1909. The initial planting in the spring of 1909 was, in large part, a failure from various causes, so that few trees of that group survived and details of the group need not be given here further than to record something of the history of the remaining trees. Better success attended the planting made in the spring of 1910, of the seeds secured in the fall in 1909; this lot in 1915 was represented by more than three thousand living trees. Results under this project are not to be attained until the seedlings are established in fruit production; the little that need be recorded at this time concerns growth only.

SEEDLINGS FROM FRUITS OF 1908

In September, 1908, the Station received Grimes apples from the orchard of Perrine Brothers at Centralia. The fruits, 545 in number, all came from one tree that had an established reputation for productiveness. They were separated into two grades on the basis of size. All fruits having transverse diameters of 65 mm. or more were included in the group designated as "large"; those having transverse diameters of 64 mm. or less fell into the group designated as "small." Average weights and measurements of the two groups were as follows:

	Large	Small
Number of apples	293.00	252.00
Average weight of apples (grams)	130.70	106.31
Average longitudinal diameter (mm.)	57.00	57.25
Average transverse diameter (mm.)	67.00	62.00
Total apparently good seeds	2 079.00	1 417.00
Average seeds to the fruit	7.09	5.62

Among the large apples one had six cells; all others had the normal number of five. The seeds were stratified in sand in boxes and buried in earth for the winter. In the spring of 1909 there was unavoidable delay in preparation of ground for reception of the seeds, and when they were taken up and separated from the sand, germination had already begun. Some, presumably the seeds possessing greatest vitality, had progressed so far in germination that they did not survive shifting to nursery; thus a serious loss was incurred at the beginning. Of the seedlings that started growth, many were weak and a large proportion of these did not survive the first season.

The young trees were grown in nursery until they were four years old because no land was available upon which to plant at orchard distances. The number living at planting time in 1911 was 123; when finally planted 15 by 15 feet in orchard, on May 3, 1913, there remained 112 trees. Fourteen trees died later, so that at the end of 1915 there were living 98 trees seven years old.

All the trees were slow in starting growth after being planted in orchard and made but feeble growth that season. There was some improvement the next year and still further improvement in 1915, but the trees still had a stunted appearance which seemed likely to linger for some time if not permanently. The average height was a little less than six feet with an average spread of four and one-half feet. The last rating as to grade divided the trees as follows: good, 20 percent; fair, 58 percent; poor, 22 percent.

At about the same time that the Grimes apples were received, 452 Jonathan apples, taken from one of the most productive trees in the orchard of Mr. J. C. B. Heaton of New Burnside, Johnson county, were also received. These apples were graded into two size-groups on the same basis used in the division of the Grimes apples. The average weights and measurements were as below:

	Large	Small
Number of apples	374.00	78.00
Average weight of apples (grams)	141.46	93.83
Average longitudinal diameter (mm.)	60.31	52.26
Average transverse diameter (mm.)	70.91	60.59
Total apparently good seeds	2 157.00	423.00
Average seeds to the fruit	5.77	5.42

The Jonathan seeds were treated in exactly the same manner as the Grimes, and the seedlings of the two varieties were grown in contiguous rows each year. The Jonathan losses occurring were about equal to those sustained by Grimes; the number of trees remaining was small. In 1910 there were 78; in 1911 this number had fallen to 61, and this was the number planted in orchard 15 by 15 feet on May 3, 1913. Nine weak trees died later, leaving but 52 to represent this variety group. These trees had the same stunted appearance charac-

terizing the Grimes seedlings; they had an average height of five and one-half feet and an average spread of five feet. Rated as to quality, at the same time the Grimes were rated, they classified as good, 27 percent; fair, 56 percent; poor, 17 percent.

The division of the apples of these two varieties into size-groups, at the time the seeds were collected, was made with the intention of testing the relative vigor of seedlings from seeds of large fruits as compared with those from seeds of small fruits. At the same time record was made of the number and distribution in cells of the seeds of each apple in an effort to determine whether or not there is a definite relation between seed production and size of fruit. The seedlings of these 1908 groups, however, were so few in number that the division between those from large fruits and those from small was abandoned, and further records, to be maintained until the seedlings are established in fruit production, consider them only as variety groups. The seed-production record was combined with other like records since obtained, and the whole is treated in a separate publication (Bulletin 203).

SEEDLINGS FROM FRUITS OF 1909

Seedlings from seeds collected in 1909, numbered, in 1915, above three thousand and represented six varieties. Such results as the project may yield when the fruiting characteristics have been determined will be derived mainly from these groups, and it therefore seems best to record the history of the trees in some detail.

All apples used in 1909 were supplied by Mr. J. C. B. Heaton from his orchards at New Burnside in Johnson county. They were barreled and shipped to the Station late in October. When received they were at once placed in storage, where they remained until the work of weighing and measuring them and extracting the seeds could be undertaken. Six varieties were represented, each by apples from a single tree that had been selected because of exceptional fruiting qualities.

Removal of seeds was begun November 9 and continued intermittently until finished November 29. The fruits of each variety were separated into two size-groups. The division point between large and small apples was fixed at 65 mm. as the minimum transverse diameter for large apples of Arkansas Black, Ben Davis, and Minkler, and at 58 mm. as the minimum transverse diameter for large apples of Rhenish May, Winesap, and Smith Cider. The groups of large fruits thus very closely correspond with the No. 1 grade for the classes to which the varieties belong. Each fruit was weighed, calipered for longitudinal and transverse diameters, then cut transversely for determination of the number and distribution of the seeds. As each lot was completed the seeds were sorted for the removal of those which had been accidentally injured by the knife in opening the fruit, or

which had been partially eaten by codling-moth larvæ, or otherwise subjected to apparent injury. This process reduced the total of seeds by about 11 percent and left only those that, so far as could be judged by appearance, were capable of germination. Each lot of seeds was then stratified in sand in bulb pans and buried in earth.

Comparison of size-groups is not very satisfactory because of the wide differences in numbers of apples. In the aggregate of all varieties the large fruits were 2.8 times as many as the small and contained 3.22 times as many seeds. With each variety the averages of seeds to the fruit were larger for large fruits than for small. Bringing the groups of large apples together, Rhenish May led in number of seeds to the fruit with an average of 11.76; Minkler was the least productive, as shown by the average of 4.22 seeds. Assembling the groups of small apples, Winesap had the highest average, 8.91 seeds to each fruit, and here also Minkler had the lowest, 2.91 seeds to each fruit. Discarding size-groups and considering the aggregate of fruits for each variety, Rhenish May showed greatest productiveness with an average of 10.83 seeds for each fruit. The other varieties ranked in descending order as follows: Winesap, Smith Cider, Arkansas Black, Ben Davis, and Minkler.

To avoid repetition of the experience of the preceding year, when a considerable portion of the buried seeds germinated before it was possible to plant them, all the seed pans were taken up in February and placed in cold storage at a temperature of 31°F. On March 28, 1910, the seeds were separated from the sand and planted in nursery rows; they were then in excellent condition. It was the intention to determine the percentage of germination in each lot of seeds, but the demands of other projects were such that it was found impossible to do this, hence it is only known that germination was abundant.

During the first season the seedlings made that same slow, weak growth that appears to be characteristic of all apple seedlings grown on the black soil of this locality. About midsummer, at the time of hand-weeding the nursery, many weak seedlings were taken out to make more room for the better ones. In the fall of 1910 all were taken up for winter storage and again planted in nursery in the spring of 1911. This was repeated in the fall of 1911 and again in 1912. The aggregate of seedlings taken up for storage in the fall of 1911 was 5,648. In the fall of 1912 they numbered 5,315. In May, 1913, the seedlings, being then three years old, were permanently planted in orchard, 15 by 15 feet. The number thus planted was 4,988; of these, 4,568 were planted on the Station farm at the University and 420, 35 of each size-group of each variety, were sent to the Station farm at Olney in Richland county.

The losses indicated by the differences in the aggregates here given were mainly due to the death of seedlings that from the beginning had exhibited very low vitality. Many of these weak seedlings existed thru

TABLE 23.—MEASUREMENTS OF FRUITS AND ENUMERATION OF SEEDS FROM FRUITS OF 1909

Variety	Size-group	Number of apples	Average weight (grams)	Average diam. (mm.)		No. of seeds produced	No. of seeds discarded	Total seeds stratified	Aver. No. of seeds per fruit
				Longitudinal	Transverse				
Arkansas Black	Large	225	165.54	60.23	71.15	1 653	109	1 544	7.34
	Small	35	98.94	49.86	60.63	204	19	185	5.83
Ben Davis	Large	743	154.50	60.47	72.88	4 852	601	4 251	6.53
	Small	89	92.13	49.97	60.15	516	63	453	5.79
Minkler	Large	748	174.63	57.55	73.87	3 163	1 289	1 874	4.22
	Small	24	106.31	47.38	61.05	70	1	69	2.91
Rhenish May	Large	2 159	105.74	50.63	62.73	25 403	2 557	22 846	11.76
	Small	469	73.42	44.02	54.15	3 081	352	2 729	6.57
Smith Cider	Large	328	125.58	53.83	66.40	2 624	402	2 222	8.00
	Small	305	74.56	44.68	55.02	2 398	325	2 073	7.86
Winesap	Large	1 085	106.31	50.99	61.37	10 235	1 001	9 234	9.43
	Small	965	75.97	43.96	53.49	8 605	454	8 151	8.91
Total		7 175				62 804	7 173	55 631	

the second year in nursery and some thru the third year without making any appreciable growth. It is not to be understood that all weak seedlings had been eliminated at the time of planting in orchard. Some that were set out were but little more promising than many that had died, but were given their chance to overcome the weakness, if possible. Most of these weak trees did not improve; many died the first year in orchard, and others have since succumbed.

A few words are here necessary in explanation of the loss of a large number of trees during the first two seasons in orchard. The planting in the spring of 1913 was divided between two areas. In one forty-acre tract which was largely occupied by trees grown under other projects but which still had some unused space, there were planted 1,205 seedlings of three varieties as follows: Arkansas Black from seeds from large fruits, 108, from small fruits, 50; Ben Davis from large fruits, 392, from small fruits, 7; Smith Cider from large fruits, 328, from small fruits, 320. The trees were planted May 7 to 9. The soil here was well cultivated and in excellent condition for planting.

At the opening of spring in 1914, 159 trees, or 13 percent, had died. It was the small, weak trees that died, largely from inherent lack of vitality, but in part because of the extremely dry conditions that prevailed thruout the season. The second enumeration, made in the fall of 1915, two seasons after the first enumeration, showed an additional loss of only twenty-five trees, or a little more than 2 percent of the original planting. This small loss indicated that the weak trees had been eliminated. There remained at this time 1,021 trees: 352 classed as good, 429 as fair, and 240 as poor. These trees appeared to be established and most of them should reach maturity, produce fruit, and fulfil the purpose for which they were grown. They are by no means an even lot, but exhibit great diversity in growth habit and in vigor.

Seedlings of the remaining varieties, Rhenish May, Minkler, and Winesap, together with a few trees of Arkansas Black remaining after filling the area referred to above were planted May 15 to 22 on another forty-acre tract that at this time became available. This tract had been used for farm crops and had been neglected. It was not in satisfactory condition for the reception of trees, but the season was so far advanced that further delay was out of the question; the trees were planted as quickly as possible and much labor was expended in an effort to improve the unfortunate surroundings. No rain fell following planting and extreme drouth prevailed thruout the season. Three times at short intervals during July and August water was hauled in tanks and applied to the trees, but little benefit was derived from this treatment.

No enumeration of the trees was made until the spring of 1914, when the aggregate loss was ascertained to be 1,339 trees, or 40 per-

cent of the number planted. The largest losses fell on Rhenish May, in which variety they amounted to 55 percent, while with Winesap the loss was only 21 percent. Of the 3,363 trees planted in the spring of 1913, there remained 2,024 in the spring of 1914. Some of these were shifted in the process of filling gaps and consolidating rows. From the time of enumeration in 1914 to the end of 1915 there was an additional loss of 175 trees, making the total loss 1,514 trees, or 45 percent of the number planted. Most trees made satisfactory growth in 1915, and, when the difficulties thru which they had lived are considered, the unfavorable conditions at time of planting and two summers of extreme drouth, it would seem that they had proved their resistant qualities and were safely on the way to full development and fruit production.

All the trees in this planting had a more or less stunted appearance; all were below normal size for trees six years of age. The growth made in 1915, however, gave promise that the stunted appearance would soon be overcome and that control of direction and amount of branch extension by pruning would, within a few years, bring the trees into satisfactory forms.

As the project stood at the close of the year 1915, six years from the planting of the seeds, there were in the two plantations on the University farm, 2,868 trees. Add to these the 365 trees which were living at the time of the last enumeration of the 420 planted at Olney, and the total number of surviving trees becomes 3,233, distributed as follows:

	Number of Trees in 1915	From seed of large fruit	From seed of small fruit
Arkansas Black	University Farm	85	41
	Olney Farm	30	30
Ben Davis	University Farm	365	0
	Olney Farm	34	24
Minkler	University Farm	39	0
	Olney Farm	34	19
Rhenish May	University Farm	587	104
	Olney Farm	32	30
Smith Cider	University Farm	279	257
	Olney Farm	33	30
Winesap	University Farm	630	481
	Olney Farm	35	34

If the total number of living trees be compared with the total number of seeds planted, it appears that there was one tree for 17.2 seeds planted, or, expressed in percentage, 5.81 percent of the seeds planted persisted as living trees at the end of six years. The propor-

tion of seeds surviving as trees was small and did not fairly represent the possibilities in apple-seedling production. No germination record was made, nor was any record kept of the seedlings destroyed in thinning during the first summer. The seedlings were first enumerated when two years old; at that time the number represented a little more than 10 percent of the seeds planted. The losses in the succeeding four years amounted to 43 percent, chiefly thru unfortunate conditions that were beyond control.

From the standpoint of future work on the project it is perhaps fortunate that the number of seedlings is no larger. To maintain accurate annual growth records, and particularly to diagram and describe the fruits of individuals as they are produced, is not a serious task when no more than one hundred trees are involved, but multiply these by thirty-two and the work is destined to tax the resources of the Department, especially in view of the fact that some thousands of trees grown under other projects promise demands for attention at the same time.

The six varieties here included showed considerable differences in numbers of seedlings living at the time of the first enumeration, when they were two years old, as contrasted with the numbers of seeds planted, and also in relative resistance as shown by a similar comparison of numbers of trees living in 1915. The groups of seedlings from seeds from large fruits will illustrate this. In 1911 the ratio of seedlings to seeds planted was 1 to 6 for Arkansas Black and Smith Cider, 1 to 10 for Ben Davis, 1 to 11 for Winesap, 1 to 12 for Rhenish May, and 1 to 25 for Minkler, while the ratio in 1915 was 1 to 8 for Smith Cider, 1 to 12 for Ben Davis, 1 to 15 for Winesap, 1 to 18 for Arkansas Black, 1 to 39 for Rhenish May, and 1 to 48 for Minkler; or, to indicate the losses during the four years by percentages, Ben Davis had the least, 17 percent, followed in order by Smith Cider with 23 percent, Winesap with 24 percent, Minkler with 48 percent, Arkansas Black with 68 percent, and Rhenish May with 69 percent.

Except for the two varieties Smith Cider and Winesap, comparisons between size-groups are unsatisfactory because of disparity of numbers. Two of the small size-groups are entirely eliminated, namely, Ben Davis and Minkler. The small size-group of Ben Davis was represented by only eighty-nine fruits, from which 455 seeds were planted. Only fifty-four seedlings were living at two years of age; only seven were planted in orchard, and these died that same year. The small size-group of Minkler had only twenty-four apples, which yielded 69 seeds; only fifteen weak seedlings survived to be planted in orchard in 1913 and these soon died. The small size-group of Arkansas Black had but thirty-five apples, from which 185 seeds were planted; most of the seeds germinated and seventy-seven trees

lived to be planted in orchard in 1913. More seedlings in proportion to the number of seeds planted were produced by the seeds from small apples than by those from large apples. The ratio for the small size-group was 1 to 2.4, and for the large size-group, 1 to 14.29. Three years later the ratios between living trees and seeds planted were 1 to 4.51 for the small size-group and 1 to 18.16 for the large size-group. These ratios indicate a higher productiveness on the part of seeds from small fruits than is shown by seeds from large fruits. If, however, the percentage of trees lost in the three-year period between planting and the end of 1915 be examined, it is found that for the seedlings from seeds from small fruits the loss was more than twice as great as for those from seeds from large fruits. This indicates less resistance to adverse conditions and presumably a less degree of vitality in the seedlings from small fruits than is possessed by the seedlings from large fruits.

In Rhenish May the disparity in numbers between the size-groups was not so great as in Arkansas Black, Ben Davis, and Minkler, but the numbers of fruits, and hence of seeds, were much larger. Here the ratios between seedlings living in 1911 and seeds planted were 1 to 12.17 for seedlings from large fruits and 1 to 6.77 for those from small fruits. Four years later, in 1915, these ratios became 1 to 39 for seedlings from large fruits and 1 to 26.25 for those from small fruits, showing that the small fruits gave a larger number of seedlings in proportion to the number of seeds planted than did the large fruits, but, as with Arkansas Black, the percentage of loss between the first enumeration of seedlings and the end of the season of 1915, in this case four years, was greater for the seedlings from small fruits. With this variety the percentages of loss were much greater than with Arkansas Black, but the difference between loss percentages of the two size-groups was much less, 68.71 percent for seedlings from large fruits and 74.2 percent for those from small fruits. The difference is too small to indicate any clear superiority, in matters of resistance and vitality, of seedlings from fruits of large size over those from small fruits.

With Smith Cider and Winesap, parity of numbers of fruits and of seeds planted renders comparison of size-groups more satisfactory. These varieties, at the time of first enumeration in 1911, gave ratios between number of seedlings and number of seeds planted as follows: for Smith Cider 1 to 6 for seedlings from large fruits, 1 to 5 for seedlings from small fruits; for Winesap 1 to 11 for seedlings from large fruits and 1 to 10 for seedlings from small fruits. At the time of the last enumeration, four years later, the ratios were for Smith Cider 1 to 8 for each of the two groups; for Winesap 1 to 15 for progeny of large fruits, and 1 to 17 for progeny of small fruits. The ratios for Smith Cider showed, for 1911, a slight advantage in

productiveness on the part of the small size-group, and equality for the two size-groups at the last count. For Winesap the advantage in productiveness was with the group from small fruits at the time of the first enumeration, but was transferred to the group from large fruits and was somewhat increased at the last enumeration. When percentages of loss for the four-year period between the enumerations considered are examined, the advantage is found to lie with the seedlings from large fruits in both varieties. These percentages are, for seedlings from large fruits, 23 for Smith Cider and 24 for Winesap; for seedlings from small fruits, 37 for Smith Cider and 43 for Winesap.

Bringing together the evidence bearing upon comparison of size-groups, it appears that relative productiveness as exhibited in ratios between numbers of trees living in 1915 and numbers of seeds planted was slightly better for seedlings from large fruits in the varieties having nearly equal numbers of fruits and seeds, and markedly to the advantage of seedlings from small fruits in the varieties in which the small size-groups were represented by too small numbers for satisfactory comparison.

Death of trees during the four-year period from the first enumeration, in the fall of 1911, to the close of the season of 1915, offers a better basis for comparison of the relative resistance to adverse conditions and the possession of sustaining vitality. In each of the four varieties having both size-groups represented, the losses were greater among seedlings from small fruits than among those from large fruits. In the two varieties Arkansas Black and Rhenish May, in which there was disparity of numbers in the groups, the differences between the loss percentages of the groups were small, but in Smith Cider and Winesap, where the numbers approximated equality, the differences were decided.

Combining the records here considered with many observations on the relative vitality of seedlings of the two size-groups, as indicated by the character and amount of growth, gives warrant for the conclusion that, in a general way, seedlings from seeds of large fruits are somewhat more resistant to adverse conditions and possess a higher degree of vitality than do seedlings from seeds of small fruits. Differences, however, were not perfectly constant and were often quite small, indicating that further definite records are needed before the question can be regarded as finally answered.

CONCLUSIONS

1. Summarized data giving comparisons between trees propagated from large buds and those propagated from small buds, together with the aggregate of impressions derived from careful inspections of trees of all groups, admit but one conclusion, namely, that

there are no differences, for purposes of propagation, between buds of large size and those of small size.

2. Growth curves of trees propagated from buds from different situations on the trees so closely approximate as to leave no basis for assuming that it makes any difference from what situation on the tree the buds are taken.

3. All buds from healthy shoots are of equal value for purposes of propagation, at least so far as growth of trees is concerned.

4. Fluctuations in growth of individuals within particular groups are decided, often extreme. In general, differences become less with increase in age, provided the trees remain healthy.

5. There is no tangible basis upon which to establish the assumption that robust scions are superior to scions of small diameter for purposes of propagation.

6. Studies of annual increments support and emphasize the fact of distinct individuality in growth of trees.

7. In general, seedlings from seeds of large fruits are somewhat more resistant to adverse conditions and possess a higher degree of vitality than do seedlings from seeds of small fruits.