Station Bulletin 139 August, 1916

Oregon Agricultural College

Experiment Station

Division of Horticulture

Pruning Investigations

BY

V. R. Gardner, J. R. Magness, and A. F. Yeager

CORVALLIS, OREGON

STATION STAFF

Board of Regents of the Oregon Agricultural College and Experiment Station

Administration

W. J. KERR. D. Sc.................................... President
A. B. CORDLEY, M. S.................................... Director

Department of Animal Husbandry

E. L. POTTER, B. S....................................Chief in Animal Husbandry
G. R. SAMSON, B. S....................................Assistant in Animal Husbandry
O. M. NELSON, B. S....................................Assistant in Animal Husbandry

Department of Bacteriology

T. D. BECKWITH, M. S....................................Chief in Bacteriology

Department of Botany and Plant Pathology

H. P. BARSS. M. S....................................Chief in Botany and Plant Pathology
M. B. McKAY, M. S..........Research Assistant in Botany and Plant Pathology
O. H. ELMER, M. S....................................Assistant in Botany and Plant Pathology

Department of Chemistry

*H. V. TARTAR, B. S....................................Chief in Agricultural Chemistry
BERT PILKINGTON, B. S.,........Research Assistant in Agricultural Chemistry
R. H. ROBINSON, B. S.............Research Assistant in Agricultural Chemistry
R. F. BEARD, B. S....................Research Assistant in Agricultural Chemistry
NAO UYEI, B. S.,....................................Research Fellow

Department of Dairy Husbandry

R. R. GRAVES, M. S.,....................................Chief in Dairy Husbandry

Department of Drainage and Irrigation

W. L. POWERS, M. S....................................Chief in Drainage and Irrigation

Department of Entomology

A. L. LOVETT, B. S....................................Chief in Entomology
W. J. CHAMBERLAIN. B. S.,....................................Research Assistant
G. F. MOZNETTE, B. S.,....................................Research Assistant
L. R. CHIDLS, B. S.,...........Entomologist, Hood River, Acting Superintendent

Department of Farm Crops

G. R. HYSLOP, B. S....................................Chief in Farm Crops
H. A. SCHOTH, M. S.,....................................Expert in Vetch Investigations

Department of Horticulture

C. I. LEWIS. M. S. A...................Vice-Director, and Chief in Horticulture
V. R. GARDNER, M. S.................................... Pomologist
*E. J. KRAUS, B. S. ....Professor of Research
A. G. BOUQUET, B. S.,....................................Assistant in Olericulture
A. F. BARSS, M. S....................................Assistant in Reseach
J. R. MAGNESS. M. S....................................Assistant in Research
G. G. BROWN. B. S.,....................................Horticulturist. Hood River
E. W. MONTELL, B. S....................................Research Fellow

Department of Soils and Farm Management

H. D. SCUDDER, B. S......................Chief in Soils and Farm Management
C. V. RUZEK, B. S....................................Assistant in Soils
J. E. COOTER, B. S....................................Assistant in Soils Laboratory

Department of Veterinary Medicine

B. T. SIMMS. D. V. M....................................Chief in Veterinary Medicine

---

Robert Withycombe. B. S., Supt. Eastern Ore. Branch Experiment Station, Union
D. E. Stephens, B. S.,...Supt. Eastern Oregon Dry-Farm Br. Exp. Station. Moro
L. R. Breithaupt, B. S......Supt. Harney Co. Branch Experiment Station, Burns
R. W. Allen, M. S........Supt. Umatilla Branch Experiment Station. Hermiston
G. H. Roberts, B. S..........Supt. John Jacob Astor Branch Exp. Station, Astoria

* On leave of absence.

THE EARLY SUMMER PRUNING OF YOUNG APPLE TREES

By V. R. Gardner.

INTRODUCTION

The past decade has been one of great expansion in the fruit industry. There have been many new and large plantings, particularly of deciduous fruits. The development of these orchards has naturally brought to the front many new questions; or perhaps, more accurately, old questions that never have been answered satisfactorily. Among these questions none have been more prominent than those dealing with the proper pruning of young trees.

Horticultural literature has much to say regarding the advantages and disadvantages of certain methods of training young trees to best meet the needs of particular conditions; but it is comparatively silent regarding the results that may be expected from different methods of pruning them. Particularly is this true of all questions dealing with the summer pruning of such trees. Much has been written dealing with the summer pruning (or at least summer pinching) of trees that have reached bearing age; but there are to be found very little reliable data upon the summer pruning of trees before they reach the bearing age. Certainly such data are too meagre to warrant making any general recommendations for conditions found in the Northwest.

Nevertheless, it would seem that some system of summer pruning might be worked out that would conserve the energies of the young tree and enable us to make greater use of the growth that it produces. When growing under favorable conditions apple trees two to five years old often develop shoots two to five feet long, a large part of which growth is removed at the time of the annual winter pruning in order to develop and preserve the shape or type of tree it is desired to build. Year after year the trees are forced to produce a large amount of wood that is never used. Is it not possible by summer pruning of the right kind and at the right time to divert the energies of the tree into growth that may be preserved?

With these facts and questions in mind Professor E. J. Kraus and Professor C. I. Lewis, in 1910, started a series of preliminary experiments. These were conducted in a number of orchards at various points in Western Oregon and upon young apple, pear and cherry trees. Opportunity was not afforded for checking the results in detail, but observations made led unmistakably to the conclusion that summer pruning may be of great use in the development of young trees. Consequently for at least three years the Oregon Experiment Station has been recommending the type of summer pruning here described, for at least Western Oregon conditions. These recommendations have been made to individual fruit growers through correspondence, to growers' associations through public addresses, and to growers in general through press notices and bulletins.* The data upon which such recommendations have been based, however, have not been published. The object of this report is to place upon record some of these data.

The Orchard.

The particular investigation upon which this bulletin is a report, was conducted in the Experiment Station orchard in Corvallis. This orchard was planted in the spring of 1912. The soil is a deep, rather heavy clay loam, comparatively level, though with good natural drainage. It would be classed as moderately, though not exceptionally, good land for apples. The elevation is approximately 250 feet.

Previous to being set to trees the land had been producing general farm crops, mainly wheat, oats and vetch, for a period of nearly forty years. The even stand of grain the summer preceding planting furnished evidence of the uniformity of soil conditions. Since planting, the soil treatment has consisted in spring plowing, followed by clean cultivation until late summer, when a cover crop of vetch and oats has been sown.

The varieties set were Grimes, Jonathan, Wagener, and Yellow Newtown. The trees were uniform and of first grade. The stocks were the ordinary "crab" seedlings. At the time of planting the trees were pruned back to a height of 24 to 30 inches. They made a moderate growth the first season. As one-year-olds, they were given the usual dormant-season or winter pruning. This consisted in some thinning out of superfluous shoots and a rather severe heading back of those shoots that were left to form the main framework of the tree. Figures 2 and 5 are of average trees and show the approximate amount of growth made the first season and the way in which they were pruned. Detailed measurements of the amount of shoot growth produced and removed the first year were not made; but it may be said that the trees were fairly uniform. It should be noted that at the first pruning the central shoot or "leader" was pruned less severely than the other shoots; and that this plan of encouraging the leader has been followed up to the present time, except in the case of a few of the largest trees where the last pruning has tended to suppress it. In other words, the trees are all being trained to the "modified leader" type. The experiment, then, is not one in the **training** of young trees. It has to do only with the question of **pruning**.

Object of the Experiment.

As stated in the introduction, preliminary experiments by Kraus and Lewis of this Station indicated that early summer pruning of young apple trees may be a means of conserving their energies and bringing them to a bearing size and condition earlier than is otherwise possible. The investigation was begun, therefore, to find out **to what**

---

* For example, see p. 28 Bull. No. 130, Ore. Agri. Exp. Sta. 1915.

extent this is the case and how the earlier bearing condition is brought about. Consequently, it was deemed necessary to divide the orchard into but two main plots—in one of which the trees would be winter-pruned in the customary manner, and in the other of which they would be both winter- and summer-pruned. Each of these plots contained approximately 150 trees (150 trees originally, but accident befell several, and consequently the number is slightly less). In addition, there was also a small plot of trees that were neither winter- nor summer-pruned. The orchard was so divided that there would be approximately equal numbers of the different varieties in each plot.

The Winter Pruning.

The winter pruning afforded each year to the trees that were winter-pruned only, and that serve as a check by means of which the effects of the summer pruning may be measured, consisted in a more or less severe thinning out of the shoot growth of the past season, coupled with a rather severe heading back of the shoots that were left to form the main framework of the trees. It amounted to a heavy pruning, naturally heavier at the end of the second, than at the end of the third season's growth. Detailed measurements were not recorded of the amount of shoot growth made by each tree during the growing seasons of 1912 and 1913; but it is estimated that the pruning in the spring of 1913 removed 80 to 90 percent of the first summer's growth, and that the pruning in the spring of 1914 removed 75 to 85 percent of the shoot growth of 1913. Accurate measurements were made of the amount of shoot growth produced during 1914 and of the amounts removed by the spring pruning in 1915. These show that this winter pruning removed 64, 65, 68, and 79 percent of the shoot growth of 1914 from Wagener, Yellow Newtown, Jonathan, and Grimes, respectively. The heavier pruning afforded Grimes was due to its greater tendency to produce many short shoots that were taken out entirely in order to open up the tree to the light. It will be seen that the winter pruning afforded these trees is not materially different in amount from that commonly given apple trees of the same age in many parts of the Northwest.

Figures 7, 8, 9, and 10, showing Wagener and Yellow Newtown trees before and after the winter pruning afforded in the spring of 1914; and figures 19, 20, 21, and 22, showing the same trees before and after the winter pruning in the spring of 1915, illustrate very well the kind of pruning given.

The Summer Pruning.

The summer pruning given the trees in the plot that was both summer- and winter-pruned consisted each year in a more or less heavy thinning-out of the shoots of the current season, coupled with a more or less severe heading back of the shoots that remained. No detailed record was made in the summer of 1913 of the amount of shoot growth possessed by individual trees at the time of this summer pruning or of the exact amount removed. Such records, however, were made in 1914 and 1915; and it is estimated that the figures for 1913 would not be materially different from those of the two following seasons. The summer pruning of 1914 removed on the average 71, 70, 78.5 and 68 percent of the shoot growth of the season up to that time from Wagener, Yellow Newtown, Jonathan, and Grimes, respectively. That of 1915 removed 57, 55, 68 and 57 percent from the same varieties. It will thus be seen that the summer-pruning was a heavy pruning, nearly as heavy as the winter-pruning that normally would be afforded trees of the same age and size. As a matter of fact, each year this summer-pruning has been like a winter-pruning in both kind and amount.

Each year the trees were summer-pruned between July 1 and July 10. At that season they are in an active growing condition. Even during exceptionally dry summers, such as 1914, the shoots have not obtained more than one-half to two-thirds of their normal length for the year and show no evidence of any terminal bud formation. As would be expected, July 1 to 10 comes relatively earlier in the normal growing season of some varieties; e. g., Yellow Newtown, than in that of certain others; e. g., Wagener; but in no case has vegetative growth for the year practically ceased. It is probable, however, that by this time the older leaves near the base of the shoots have contributed materially to the general welfare of the tree through the manufacture of food materials and that consequently the removal of much of the shoot growth constitutes much less of a tax upon the trees' vitality than a similar removal three or four weeks earlier.

Figures 1 and 4 show typical Wagener and Yellow Newtown trees just before the summer pruning of 1913; and Figures 3 and 6 show the same trees immediately after their pruning. Figures 15 and 17 and 16 and 18 are similar views of the same trees in 1914. They serve to illustrate the kind and amount of the summer pruning and also afford some idea of the kind of response the trees have made.

The Winter Pruning of the Summer-Pruned Trees.

A word of explanation should be given regarding the winter pruning of the summer-pruned trees. While the general idea was to give the summer-pruned trees a winter-pruning similar in kind and amount to that afforded those that were winter-pruned only, it was found that in some instances the new late-summer shoots produced by these trees were not so numerous nor so long as to require either such severe thinning out or such severe heading back. Consequently the winter pruning of these trees was somewhat lighter than that given the trees that were winter-pruned only. Exact records were not made of the amount of shoot growth removed from individual trees by the winter pruning in the spring of 1914, but it is estimated that it averaged 65 to 85 percent of the new growth developed after the summer pruning. Exact records were made, however, of the amounts of shoot growth formed during the latter part of 1914 and of the amounts removed by the following dormant pruning in the spring of 1915. In terms of percent of late shoot growth formed, the pruning amounted to 66.5, 53.8, 63.9, and 72.5 for Wagener, Yellow Newtown, Jonathan, and Grimes, respectively.

A better idea of the kind and amount of this pruning is afforded by Figures 11 and 13 and 12 and 14, which show Wagener and Yellow Newtown trees both before and after their winter pruning in the spring of 1914. Figures 23 and 25 and 24 and 26 show how these same trees were winter-pruned in the spring of 1915. These photographs are of the same trees shown in Figures 1, 3, 4, 6, and 18, and were taken from approximately the same angle and illustrate the kind of response that follows the summer pruning.

Presentation of Results.

As has been indicated, no detailed records were made of the amount of shoot growth produced by individual trees during their first and second seasons, nor of the exact amount of shoot growth removed by the first two winter prunings and the first summer pruning. Attention is again called, however, to the fact that the trees made a satisfactory growth both of these seasons, that the trees were as uniform as is generally the case, and that an effort was made to prune the trees as uniformly as possible. At the time of the summer pruning in 1914 records were made of the number of centimeters of shoot growth possessed by each tree and of its trunk circumference. These records were made not only for the trees that were summer-pruned but for all of the trees in the orchard. Similar records were made at the time of summer pruning in 1915. In the fall of 1915 trunk circumferences were again measured and also the total shoot length of each of the trees that were not summer-pruned. In the case of the trees that had been summer-pruned, measurements were made of the late summer shoots that were produced after the summer pruning. Counts were also made of the number of fruit spurs possessed by each tree; and these were segregated into groups based upon the age of the wood from which they had developed. Similar records were taken in the fall of 1915. Records for 1914 also included midsummer and fall measurements of the basal and median diameters of each individual shoot on eight trees that were winter-pruned only and on eight trees that were both winter-and summer-pruned.

In presenting the data obtained, it is deemed necessary to give summary tables only. Detailed records for individual trees naturally show considerable variation, but it is average **performance** in which the grower is interested mainly. Records for the different types of growth measured will be presented and discussed separately.

SHOOT GROWTH OF UNPRUNED, WINTER-PRUNED, AND WINTER- AND SUMMER-PRUNED TREES.

Tables 1 and 2 show the average number, length, and total amount of shoot growth made by the trees of the different varieties and under the different pruning treatments in 1914 and 1915. They also show the average amounts removed by the summer pruning of the two seasons and by the winter pruning given in the spring of 1915. Unfortunately, neither of the tables affords an accurate measure of the degree of uniformity existing between the trees of the different plots at the beginning of the investigation. Attention is called to this point here because the figures of column 4 of Table 1 might be taken as such a measure, and these would indicate a lack of uniformity rather than uniformity. As a matter of fact, the figures in this column show rather the first response of the trees to the different pruning treatments that were started the year before.

A study of Tables 1 and 2 brings out a number of interesting points. The first one is that the early heavy summer pruning afforded the trees, cannot be regarded as having checked their growth in the sense of having a weakening or devitalizing effect. This is evidenced most clearly by the average number of new shoots developing in the spring and early summer upon trees in the two main plots (winter-pruned only and both winter- and summer-pruned) and by the average length of these shoots. To mention but a single variety, Yellow Newtown, in 1914 the average number of new shoots to each tree was 20 in the winter-pruned block, and 29 in the winter- and summer-pruned block. The average shoot length July 1 was 45 centimeters in both cases. In 1915, winter-pruned trees of the same variety averaged 57 shoots July 1, and winter- and summer-pruned trees averaged 83 shoots. In length, the shoots on the winter-pruned trees averaged 37 centimeters, those on the other plot 34 centimeters. In other words, the trees that were both summer- and winter-pruned produced considerably more shoot growth during the first half of the seasons of 1914 and 1915 than those that were winter-pruned only. The summer-pruning would thus seem to be a stimulus to shoot growth rather than a check. Corresponding figures for the other varieties lead to the same general conclusion. Additional evidence along this same line is furnished by the figures showing the average amount of shoot growth produced by the trees of the two plots after the one plot was summer-pruned. With the exception of Jonathan in 1915, both years the summer-pruned trees averaged more shoot growth to each tree between the time of summer-pruning and the close of the growing season than the trees of the same variety that were winter-pruned only.

The next to the last column of the two tables brings out the fact still more clearly that the summer-pruned trees made a much larger total amount of shoot growth than those that were winter-pruned only. In the case of Grimes the proportion for 1914 was 131 to 100 and for

Table 1. Shoot growth of unpruned, winter-pruned, and winter- and summer-pruned trees for 1914.

Variety	Pruning Treatment	No. of trees.	Average total shoot growth per tree, in cm. July 1-10.	Average number of shoots per tree July 1-10.	Average length of shoots in cm. per tree July 1-10.	Average amount of shoot growth in cm. per tree removed by summer pruning.	Average percent of shoot growth removed by summer pruning.	Average amount of shoot growth in cm. after time of summer pruning, per tree.	Average number of new shoots per tree after time of summer pruning.	Average increase in shoot length (total shoot length growth in case of summer-pruned trees) in cm. after July 1-10.	Average total shoot length in cm. for season.	Average total gain in shoot length, in cm. for season. (See note.)
Wagener	Winter-pruned only	39	620	15	41			224	1	14	844	844
Wagener	Winter- and summer-pruned	39	1124	27	42	802	71.3	856	31	27	1980	1178
Yellow Newtown	Unpruned	4	834	26	32			406	2	15	1240	1240
Yellow Newtown	Winter-pruned only	44	911	20	45			354	1	17	1265	1265
Yellow Newtown	Winter- and summer-pruned	26	1299	29	45	906	69.8	833	31	27	2132	1226
Jonathan	Unpruned	6	1261	38	33			474	2	12	1735	1735
Jonathan	Winter-pruned only	26	1036	25	42			374	3	14	1410	1410
Jonathan	Winter- and summer-pruned	50	1878	45	42	1474	78.5	1320	49	27	3198	1724
Grimes	Unpruned	10	595	26	23			529	5	17	1124	1124
Grimes	Winter-pruned only	36	881	24	37			367	1	15	1248	1248
Grimes	Winter- and summer-pruned	33	1016	28	36	691	68.	617	21	29	1633	942

NOTE:—The figures presented in the last column do not represent exactly the real increase in size of these trees for the year. Both of the pruned plots were pruned back heavily in the spring, and the amounts of shoot growth removed by that pruning should be subtracted from the figures given in the last column to afford a true index to actual increase in size for the year. As exact measurements of this shoot growth removed by the pruning were not made in the spring of 1914, the subtraction cannot be made.

Table 2. Shoot growth of unpruned, winter-pruned, and winter- and summer-pruned trees for 1915.

Variety	Pruning Treatment	Number of trees.	Average shoot growth in cm. removed by winter-pruning given in Feb. 1915.	Average total shoot growth per tree in cm., July 1-10.	Average number of shoots per tree July 1-10.	Average length of shoots per tree in cm. July 1-10.	Average amount of shoot growth of the current season in cm. at exact time of summer-pruning. (See note.)	Average amount shoot growth of current season in cm. removed by the summer pruning.	Average percent shoot growth of current season removed by summer pruning.	Average amount of shoot growth per tree, in cm. after time of summer-pruning.	Average No. of new shoots per tree after time of summer-pruning.	Average increase in shoot length (total shoot length in case of summer-pruned trees) in cm. after time of summer pruning.	Average total shoot length in cm. for season.	Average total gain in shoot length in cm. for season.
Wagener	Winter-pruned only	39	538	1460	36	40				1230	1	16	2690	2152
Wagener	Winter- and summer-pruned	39	533	2442	62	39	2843	1611	57	1808	59	25	4250	2106
Yellow Newtown	Unpruned	4		1955	72	27				765	3	10	2720	2720
Yellow Newtown	Winter-pruned only	44	826	2082	57	37				1378	3	20	3460	2634
Yellow Newtown	Winter- and summer-pruned	26	488	2846	83	34	3445	1904	55	1485	65	23	4930	2548
Jonathan	Unpruned	5		2925	118	25				651	4	5	3576	3576
Jonathan	Winter-pruned only	26	967	2789	68	41				2376	6	15	5165	4198
Jonathan	Winter- and summer-pruned	50	941	4897	129	38	5654	3837	68	1776	97	24	7430	2652
Grimes	Unpruned	10		1847	79	23				423	1	6	2270	2770
Grimes	Winter-pruned only	36	988	2228	59	38				737	1	12	2965	1977
Grimes	Winter- and summer-pruned	33	501	2539	74	34	2792	1603	57	1568	50	27	4360	2256

NOTE:—The figures in the fifth column show the average shoot growth of the trees in the several plots at the time they were measured- July 1-10. Several days intervened, however, between the time of these measurements of certain individual trees and the time of actual summer pruning. As they were growing very rapidly at the time, it became necessary to measure them again at the exact time of pruning in order to determine accurately the percent of shoot growth removed. This explains why columns 8 and 9 are included in this table.

1915 it was 147 to 100. The proportion was still higher for the other varieties.

The last column of the two tables shows the relative net increase in size of the trees under the different methods of treatment. Especially is this true of the last column in Table 2, in which case it was possible to make accurate subtraction of the amount of shoot growth removed by the preceding winter-pruning. It is noted that in some instances the trees that were winter-pruned only show the greatest net increase in size; in other cases the trees that were both summer-pruned and winter-pruned show the greatest net increase. In the case of Jonathan only is the difference in net increase in size under the two methods of pruning treatment materially different; and in this instance the difference was in favor of the one method one year and of the other method the other year. On the whole the measurements seem to indicate that from the viewpoint of developing the size of the tree it makes little difference whether the tree is winter-pruned only or is winter-pruned and in addition given a severe early summer-pruning. Corresponding figures in the last columns of the two tables for entirely unpruned trees are included because they are interesting for purposes of comparison. The number of trees of the several varieties in the unpruned plot is too small for the growth averages to be conclusive, but nevertheless they are suggestive. They show some variation between the different varieties and for the two seasons, but they indicate that on the average the unpruned tree increases in size as rapidly as, if not a little more rapidly than, the tree that is winter-pruned only or both winter- and summer pruned. Its average annual shoot growth is less, but it loses none of this growth by pruning. These facts are interesting because the idea is often advanced, first that summer-pruning has a checking influence upon vegetative growth, and second that winter-pruning has a distinctly stimulating influence upon wood-growth. The data presented show beyond doubt that early summer-pruning of the type described does not cause an important check to the shoot growth (as measured by shoot length) of young apple trees, and further suggest that winter pruning is a stimulus to vegetative growth only in the sense of indirectly causing new growth to replace the old and not in the sense of causing a net increase in amount of wood growth.

The general influence of these different methods of pruning upon amount and type or character of tree growth is illustrated in Figures 27 to 33. Figures 27 and 29 show average four-year-old Wagener and Yellow Newtown trees that have been winter-pruned only. They are photographs of the same trees shown in Figures 7 to 9 and 19 to 22. Figures 28 and 30 are of average four-year-old trees of the same varieties that have had the heavy early summer-pruning for three successive years in addition to the regular winter-pruning. They, likewise, are photographs of the same trees shown in Figures 11 to 14, 15 to 18, and 23 to 26. Figures 31, 33, and 32 are of average four-year-old Yellow Newtown, Jonathan, and Grimes trees that have been neither winter- nor summer-pruned.

RELATION OF SEVERITY OF WINTER PRUNING TO AMOUNT OF SUBSEQUENT SHOOT GROWTH.

Directly bearing on the question that has just been discussed; namely, that of the stimulating influences of winter-pruning, are data collected for individual trees of the several varieties in 1915 showing the percent of shoot growth removed by winter-pruning early in the spring and the response to that pruning in the way of shoot growth during the following summer. These data, in part, are presented in Table 3, to show the number of units of shoot growth in 1915 to each unit of shoot growth in 1914 in relation to the percent of winter pruning afforded.

Yellow Newtown, rather than one of the other varieties, is selected to illustrate this particular point, because it is slower than the others in coming into bearing and hence at this age a much smaller percentage of the energies of the trees are being devoted to fruit-spur formation. Corresponding tables for the other varieties in this orchard point in the same direction.

While there is considerable variation between individual trees in the units of shoot growth they made in 1915 for each unit of 1914 shoot growth, there is shown no general tendency for the more severely pruned trees to produce more shoot growth for each unit of last year's growth than the less severely pruned trees. In fact, the average for the varying degrees of severity of pruning show a slight tendency in the opposite direction. In other words, the evidence tends to show that at least in the case of young apple trees that have not yet produced many spurs, the amount of shoot growth they produce one season is much more closely correlated with the amount they made the preceding season than with the amount removed by winter pruning.

RELATION OF SEVERITY OF EARLY SUMMER PRUNING TO AMOUNT OF SUBSEQUENT SHOOT GROWTH.

It has been noted that the amount of shoot growth produced late in the season by the summer-pruned trees was greater than that produced during the same period by those that were not summer-pruned. It was also noticed, however, that some of the summer-pruned trees produced a relatively much heavier late summer growth than others; there was considerable variation in the way in which they responded to their summer pruning. This question occurs, as in the case of winter pruning, whether or not this variation was due to the severity of the summer pruning, or to other factors. Tables 4 and 5 bring together the data bearing upon this question. Because of the space required, detailed data are presented for Jonathan only and averages for the other varieties. The figures for Jonathan will serve to illustrate the extreme variability exhibited by individual trees of all the varieties.

Table 3. Showing the way in which Yellow Newtown trees responded in 1915 to their last winter pruning.

1914 shoot growth in cm.	Shoot growth in cm. removed by pruning.	Percent pruning	1915 shoot growth in cm.	Cm. of 1915 shoot growth per cm. of 1914 shoot growth.
868	498	57	2281	2.6
791	449	57	2370	3.0
1249	719	58	3790	3.0
				2.87 Average for 3 trees.
1240	752	61	3353	2.7
1044	643	62	2879	2.8
511	317	62	1908	3.7
518	320	62	1661	3.2
1047	651	62	2885	2.8
1399	901	64	3063	2.2
840	540	64	2357	2.8
945	616	65	2308	2.4
2043	1326	65	6011	2.9
838	541	65	2395	2.9
				2.89 Average for 10 trees.
1527	1010	66	4119	2.7
1136	750	66	3695	3.2
1716	1142	67	4599	2.7
1000	678	68	2592	2.6
1150	785	68	2808	2.4
1143	774	68	3139	2.7
1812	1228	68	5226	2.9
859	582	68	2226	2.6
911	629	69	2026	2.2
1314	913	69	2755	2.1
812	562	69	2153	2.7
737	511	69	2418	3.3
2052	1426	69	5230	2.5
1029	716	70	2505	2.4
642	451	70	2283	3.6
987	688	70	2883	2.9
				2.72 Average for 16 trees.
1140	814	71	3401	3.0
3108	221[illegible]	71	7733	2.5
1634	1184	72	4150	2.5
1110	799	72	2673	2.4
1058	759	72	3072	2.9
1692	1218	72	5211	3.1
2229	1603	72	6003	2.7
1273	929	73	3618	2.8
924	674	73	2851	3.1
				2.74 Average for 9 trees.
1407	1063	76	2960	2.1
1407	1070	76	4393	3.1
1517	1172	77	3937	2.6
1618	1355	84	4999	3.1
				2.72 Average for 4 trees.

Table 4. Showing the relation of the severity of early summer pruning to amount of subsequent shoot growth, 1914.

1914 shoot growth in cm. before time of summer pruning.	Amount in cm. removed by summer pruning.	Percent of summer pruning.	1914 shoot growth in cm. after time of summer pruning.	Units of shoot growth after summer pruning per unit of shoot growth before summer pruning.
WAGENER				
		46.5		.715 Average for 2 trees.
		54.0		.950 Average for 2 trees.
		57.0		.780 Record for one tree.
		63.8		.874 Average for 9 trees.
		72.3		.723 Average for 6 trees.
		77.9		.732 Average for 8 trees.
		84.0		.833 Average for 3 trees.
		88.0		.510 Record for one tree.
		96.0		1.000 Record for one tree.
YELLOW NEWTOWN				
		53.0		.894 Record for one tree.
		64.3		.767 Average for 3 trees.
		66.8		.633 Average for 6 trees.
		73.0		.700 Average for 7 trees.
		78.5		.488 Average for 4 trees.
		82.8		.708 Average for 5 trees.
JONATHAN				
1125	663	59	928	.825
1186	736	62	712	.60
1159	717	62	814	.70
805	504	63	813	1.01
2570	1771	64	2176	.85
1543	1001	65	1082	.70
		63.2		.772 Average for 5 trees.
2402	1600	66	1937	.81
1405	922	66	878	.62
1552	1041	67	1083	.70
2130	1424	67	1398	.66
330	225	68	290	.88
1552	1077	69	1337	.86
1996	1401	70	1241	.62
1787	1244	70	1213	.68
		67.5		.729 Average for 8 trees.
1592	1133	71	1254	.79
1686	1221	73	1201	.71
556	415	74	518	.93
601	445	74	604	1.00
1172	872	74	985	.84
3088	2295	74	1379	.45
2111	1588	75	2256	1.07
		73.6		.827 Average for 7 trees.
1853	1402	76	1538	.83
2379	1830	77	1487	.63
1265	989	78	561	.44

Table 4—*Continued.*

1914 shoot growth in cm. before time of summer pruning.	Amount in cm. removed by summer pruning.	Percent of summer pruning.	1914 shoot growth in cm. after time of summer pruning.	Units of shoot growth after summer pruning per unit of shoot growth before summer pruning.	
JONATHAN					
1939	1513	78	1239	.64	
1775	1385	78	1361	.77	
1949	1521	78	1382	.71	
1621	1289	79	1327	.82	
2988	2350	79	1882	.63	
2567	2098	79	1822	.71	
2548	2085	80	1768	.69	
		78.2		.687	Average for 10 trees.
1128	908	81	1026	.91	
2369	1921	81	1271	.54	
3429	2819	82	2579	.75	
2672	2216	83	1573	.59	
2447	2031	83	1038	.42	
1543	1302	84	1464	.95	
2302	1938	84	1877	.81	
2781	2343	84	1775	.64	
2219	1867	84	1210	.55	
2213	1882	85	1293	.58	
		83.1		.674	Average for 10 trees.
1702	1483	87	695	.41	
2748	2416	88	1320	.48	
2949	2659	90	1978	.67	
		88.3		.520	Average for 3 trees.
1983	1827	92	1657	.84	
2875	2715	94	1889	.66	
		93.0		.750	Average for 2 trees.
GRIMES					
		33.0		.749	Record for one tree.
		55.0		1.064	Record for one tree.
		58.2		.646	Average for 5 trees.
		62.3		.620	Average for 3 trees.
		69.7		.687	Average for 3 trees.
		72.9		.624	Average for 13 trees.
		76.5		.795	Average for 2 trees.
		82.5		.730	Average for 4 trees.
		86.0		.832	Record for one tree.

Table 5. Showing the relation of the severity of early summer pruning to amount of subsequent shoot growth, 1915.

1915 shoot growth in cm. before time of summer pruning.	Amount in cm. removed by summer pruning.	Percent of summer pruning.	1915 shoot growth in cm. after time of summer pruning.	Units of shoot growth after summer pruning per unit of shoot growth before summer pruning.
		WAGENER		
		48.6		.506 Average for 5 trees.
		53.2		.504 Average for 12 trees.
		58.2		.465 Average for 15 trees.
		62.2		.503 Average for 6 trees.
		66.0		.474 Record for one tree.
		YELLOW NEWTOWN		
		50.0		.345 Average for 2 rees.
		53.4		.461 Average for 16 trees.
		57.7		.382 Average for 6 trees.
		61.5		.445 Average for 2 trees.
		JONATHAN		
1387	742	·53	1050	.760 Record for one tree.
2148	1291	60	1207	.56
6651	3979	60	4286	.64
		60		.600 Average for 2 trees.
3524	2158	61	836	.24
4826	2944	61	2113	.44
6406	3982	62	3250	.51
3267	2025	62	2035	.62
6705	4155	62	2103	.31
4497	2829	63	2495	.55
2831	1770	63	1507	.53
4455	2795	63	1429	.32
892	561	63	218	.24
6206	3960	64	2845	.46
4304	2815	65	2436	.57
		62.6		.435 Average for 11 trees.
6156	4046	66	2408	.39
7688	5046	66	2164	.28
4651	3049	66	1815	.39
3833	2535	66	977	.25
5844	3934	67	2937	.50
5707	3820	67	2374	.42
4545	3066	67	1529	.34
5452	3672	67	2962	.54
6619	4418	67	2795	.42
7005	4723	67	2588	.37
6294	4281	68	2536	.40
7724	5279	68	3165	.41
5093	3517	69	1502	.29
5711	3937	69	3205	.56
5519	3781	69	2498	.45
6361	4411	69	3172	.50
7542	5217	69	2259	.30
5509	3792	69	977	.18
4101	2849	69	102	.02

Table 5—*Continued.*

JONATHAN

1915 shoot growth in cm. before time of summer pruning.	Amount in cm. removed by summer pruning.	Percent of summer pruning.	1915 shoot growth in cm. after time of summer pruning.	Units of shoot growth after summer pruning per unit of shoot growth before summer pruning.
1552	1065	69	697	.45
4603	3213	70	1586	.34
7696	5415	70	3624	.47
8253	5787	70	5009	.61
6876	4814	70	3306	.48
5912	4131	70	1953	.33
6740	4688	70	1176	.17
		68.2		.379 Average for 26 trees.
8403	5963	71	2836	.34
5892	4212	71	2367	.40
7118	5089	71	3033	.43
5943	4315	72	2323	.39
10918	7843	72	6404	.59
6893	4999	72	3610	.52
9351	6750	72	3134	.34
5630	4084	73	1430	.25
7625	5601	73	3541	.46
		71.9		.413 Average for 9 trees.
GRIMES				
		52.4		.428 Average for 9 trees.
		57.7		.469 Average for 18 trees.
		62.0		.507 Average for 6 trees.

Study of the data presented in Tables 4 and 5 indicates that on the average there is little or no relation between the severity of the early summer pruning given these trees and their subsequent response in shoot growth. Individual trees of any of the varieties might be selected for comparison that would seem to show that heavy early summer pruning results in a more rapid shoot growth than a lighter summer pruning. Conversely other individuals might be selected that would seem to indicate an opposite tendency. The averages, however, clearly show that amount of late summer shoot growth following the summer pruning here described is much more closely correlated with the amount of early shoot growth already possessed by the tree at the time of summer pruning than with the pruning itself. This would indicate that while on the average early summer pruning, like winter pruning, does not check rate of shoot growth, it results in a check to increase in size of tree because rate of growth is not accelerated; and that the heavier the summer pruning the greater is such a check. Attention is called to the fact, however, that the early summer pruning did not check the increase in size of the trees (as measured by shoot growth) to a degree greater than a correspondingly heavy winter pruning. Evidence in support of this last statement is presented in Table 6, compiled from the data in the last columns of Tables 1 and 2. Considerable variation is shown by the different varieties, but on the whole the data tend to show that the early summer pruning of young apple trees is not materially different from winter pruning in its retarding influence upon increase in size of tree.

Table 6. Showing total gain in units of shoot growth in 1915 to each unit of 1914 shoot growth by unpruned, winter-pruned and winter- and summer-pruned trees.

Variety	Pruning Treatment	No. trees.	Average total gain in shoot length in cm. for season of 1914.	Average total gain in shoot length in cm. for season of 1915.	Total gain in units of shoot growth in 1915 per unit of 1914 shoot growth.
Wagener	Winter-pruned only	39	844	2152	2.55
Wagener	Winter- and summer-pruned	39	1178	2106	1.79
Yellow Newtown	Unpruned	4	1240	2720	2.19
Yellow Newtown	Winter-pruned only	44	1265	2634	2.08
Yellow Newtown	Winter- and summer-pruned	26	1226	2548	2.08
Jonathan	Unpruned	6	1735	3576	2.06
Jonathan	Winter-pruned only	26	1410	4198	2.98
Jonathan	Winter- and summer-pruned	50	1724	2652	1.54
Grimes	Unpruned	10	1124	2770	2.46
Grimes	Winter-pruned only	36	1248	1977	1.58
Grimes	Winter- and summer-pruned	33	942	2256	2.40

TRUNK CIRCUMFERENCE OF UNPRUNED, WINTER-PRUNED, AND SUMMER- AND WINTER-PRUNED TREES.

At the same time that records were made of the shoot growth of each tree, trunk circumferences were also measured. In order that each tree could be measured each time at the same point, the circumference was taken just beneath the lowest scaffold limb. Table 7 presents the average trunk circumference of the different varieties at the time of the summer pruning of 1914 and 1915 and at the end of the two growing seasons.

Table 7. Showing trunk circumferences of unpruned, winter-pruned and winter- and summer-pruned trees.

Variety	Pruning Treatment	Number of trees.	Average circumference in cm. July 14, 1914.	Average circumference in cm. November 11, 1914.	Increase in circumference in cm. after summer pruning.	Average circumference in cm. July 13, 1915.	Average increase in trunk circumference in cm. during first half of growing season.	Average trunk circumference in cm. October 8, 1915.	Average increase in trunk circumference in cm. during last half of growing season.	Total average increase in trunk circumference in cm. for the season of 1915.
Wagener	Winter-pruned only	39	6.74	8.04	1.30	10.01	1.97	12.36	2.35	4.32
Wagener	Winter- and summer-pruned	40	8.55	10.06	1.51	12.34	2.28	14.47	2.13	4.41
Yellow Newtown	Unpruned	4		9.17		11.22	2.05	13.37	2.15	4.20
Yellow Newtown	Winter-pruned only	43	7.38	8.84	1.46	10.61	1.77	12.98	2.37	4.14
Yellow Newtown	Winter- and summer-pruned	26	8.23	9.62	1.39	11.59	1.97	13.51	1.92	3.89
Jonathan	Unpruned	6		8.10		10.35	2.25	12.33	1.98	4.23
Jonathan	Winter-pruned only	25	6.22	7.14	.92	9.40	2.26	11.34	1.94	4.20
Jonathan	Winter- and summer-pruned	50	7.50	8.54	1.04	11.33	2.79	13.17	1.84	4.63
Grimes	Unpruned	10		8.97		11.25	2.28	13.28	2.03	4.31
Grimes	Winter-pruned only	36	6.81	8.07	1.26	10.30	2.23	12.35	2.05	4.28
Grimes	Winter- and summer-pruned	33	7.33	8.64	1.31	10.88	2.24	12.71	1.83	4.07

Limiting attention first to the records for 1914, it is noted that in each variety the average trunk circumference of the summer-pruned trees was greater July 1, 1914, than the average trunk circumference of the trees that had been winter-pruned only. It is also noted that, except for Yellow Newtown, each of the varieties showed a greater increase in trunk circumference during the last half of the growing season in the case of the summer-pruned trees than in the case of the trees not summer-pruned. This would seem to indicate that on the average the summer-pruning tends directly or indirectly to stimulate increase in trunk circumference. On the other hand, if actual increases in trunk circumference during the last half of the growing season are reduced to percent gain, the percent gain being based upon circumferences July 14, it will be seen that in all four varieties the trees that had been winter-pruned only made relatively the greatest increase. To be exact, the average percent increase in trunk circumference for this group of Wagener, Yellow Newtown, Jonathan and Grimes was 19.3, 19.8, 14.8, and 18.5, respectively; the average percent increase for the summer-pruned trees of the same varieties was 17.7, 16.9, 13.9 and 17.9.

Turning now to the records for 1915, we find apparently a number of contradictions. At least there is presented no unmistakable evidence that one of the types of pruning employed is more or less conducive to increase in trunk girth than another. In two varieties, Yellow Newtown and Grimes, the unpruned trees showed a greater average gain in circumference than either the winter-pruned or the winter- and summer-pruned trees. On the other hand the winter- and summer-pruned Jonathan trees showed a marked gain over those that were winter-pruned only or not pruned at all. In the case of two varieties, Jonathan and Wagener, the winter- and summer-pruned trees showed a greater total gain in trunk circumference than those that were winter-pruned only. It is noted, however, that this increased gain was made entirely during the first part of the growing season; i. e., before the summer-pruning was done. In fact, in both instances, the average increase in trunk circumference during the latter part of the growing season; i. e., after the summer-pruning, was greater for the winter-pruned trees than for those that were winter- and summer-pruned; but not enough greater to make up for the large gains of the other lots earlier in the season. In the case of two varieties, Yellow Newtown and Grimes, the trees that were winter-pruned only showed a greater gain in trunk circumference than those that were both winter-and summer-pruned. This gain was made entirely during the latter part of the growing season; i. e., after the summer pruning was done. In fact, in both instances the winter- and summer-pruned trees showed greater gains in trunk circumference during the early part of the season than the trees that were winter-pruned only.

Considering these facts in connection with general observations that were made during the growing season, the opinion is ventured that there is a close correlation between increase in trunk circumference at any period during the summer and the leaf area possessed by the tree at that particular time. The unpruned trees and those that had been both summer- and winter-pruned put out more leaves in the spring, because they had a larger number of active growing points. Summer pruning greatly reduced the leaf area on some of the trees and hence materially checked, at least for a time, their increase in trunk circumference while the other trees continued such increase without a check. In at least one case, Jonathan, the unpruned trees were surpassed because the summer- and winter-pruned trees probably had considerably more foliage, especially early in the season. Variety differences in this regard are probably to be explained on the basis of their relative rates of growth during different portions of the season. For instance, Yellow Newtown makes its main vegetative growth comparatively late, hence the larger number of shoots forming on the summer- and winter-pruned trees of this variety would not have a chance to contribute very much to the welfare of the trees before their partial or complete removal at the time of summer pruning. The check to this variety was given at a more critical period in its growth. On the other hand, Jonathan starts to vegetate early in the season and grows rapidly from the start. Consequently, the many new shoots of the summer-pruned trees of this variety would be able to contribute materially to the general development of the trees before their partial removal at the time of summer-pruning.

INFLUENCE OF EARLY SUMMER PRUNING UPON DIAMETER OF SHOOTS.

In order to determine the influence of the early summer pruning here described upon diameter of shoots of the current season, measurements were made with vernier calipers of basal and median diameters of shoots on both summer-pruned and not-summer-pruned trees. Two average trees of each variety and under each system of pruning were selected for these records. The basal diameter was taken midway between two nodes at a point approximately 10 centimeters from the base of the shoot. The median diameter of the summer-pruned shoots was taken midway between the two upper nodes on these shoots after their heading back. In the trees not summer-pruned the median diameter was taken midway between two nodes at approximately the point where similar shoots on the summer-pruned trees were cut. The diameter of every shoot on each of 16 trees was thus measured at the time of summer-pruning and again at the close of the growing season. The points on the shoots where the first measurements were taken were marked so that the autumn measurements would show exact increases in diameter.

Table 8. Showing influence of early summer pruning of shoots upon basal and median diameter of these shoots.

Variety	Pruning Treatment	Number of trees.	Number of shoots.	Average basal diameter in cm. July 10, 1914.	Average basal diameter in cm. November 30, 1914.	Average increase in basal diameter in cm.	Average median diameter in cm. July 10, 1914.	Average median diameter in cm. November 30, 1914.	Average increase in median diameter in cm.
Wagener	Winter-pruned only	2	31	.69	.835	.145	.48	.57	.09
Wagener	Winter- and summer-pruned	2	40	.65	.93	.28	.505	.705	.20
Yellow Newtown	Winter-pruned only	2	46	.68	.91	.23	.47	.65	.18
Yellow Newtown	Winter- and summer-pruned	2	39	.72	.90	.18	.51	.71	.20
Jonathan	Winter-pruned only	2	62	.60	.75	.15	.47	.585	.115
Jonathan	Winter- and summer-pruned	2	55	.64	.78	.14	.48	.61	.13
Grimes	Winter-pruned only	2	48	.63	.82	.19	.46	.61	.15
Grimes	Winter- and summer-pruned	2	54	.66	.80	.14	.495	.645	.15

Table 8 presents averages of these shoot diameter measurements. The data show that in the case of Yellow Newtown, Jonathan, and Grimes the average increase in basal diameter of the unpruned (i. e., not summer-pruned) shoots was greater than that of the summer-pruned shoots. On the other hand, in the case of Wagener the average increase in basal diameter was much greater for the shoots that had been, than for those that had not been, summer-pruned. In all four varieties the average increase in median shoot diameter of the summer-pruned shoots was as great as, or greater than, that of the unpruned shoots; in the case of Wagener the difference was very marked. Evidently the early summer heading of the shoots of certain varieties has a tendency to cause a decided thickening of these shoots; in other varieties there is little, if any, tendency in that direction. Attention is called to the fact that these statements apply only to the shoots that start early in the season. The late summer shoots of the summer-pruned trees are apt to be more slender than the earlier shoots on the same trees or correspondingly late shoot growth on trees not summer-pruned.

INFLUENCE OF EARLY SUMMER PRUNING UPON SPUR FORMATION.

The object most frequently associated with summer pruning practices has been the stimulation of fruit spur and fruit bud formation; and it has been assumed that this is attended by a corresponding check in vegetative growth. It has been pointed out that the early summer pruning of young apple trees does not result in any more of a check to vegetative growth than a correspondingly heavy winter pruning. From this it might be reasoned that such summer-pruning would consequently have no marked stimulating effect upon spur and fruit bud formation. However, inspection of the summer-pruned trees showed clearly that spur formation had been stimulated. Accordingly, in the fall of 1914, accurate counts were made of the number of fruit spurs on each of the trees in the pruning investigation. The spurs were segregated into those that had developed from 1913 or older wood and those that had developed from shoots of the past (1914) season. In the fall of 1915 counts were again made. This time the spurs were segregated into groups as follows: those that had developed from 1913 or older wood; those that had developed on the lower portion of the 1914 wood (that portion formed before the summer pruning of 1914); those that had developed on the upper portion of the 1914 wood (that portion formed after the summer pruning of 1914); and those that had formed on the 1915 wood (shoots of the past season). Table 9 summarizes the fruit-spur records of the trees of the different varieties under the different pruning treatments. Both years the fruit-spur records were made in October before many of the leaves had fallen, so as to make sure the recognition as such of very short spurs that appear quite like dormant lateral buds after the trees have shed their leaves. In this way every lateral bud that had "broken" and started to form a branch, no matter how short, could be recognized and counted as a spur. At first, it seemed impossible to draw an exact line between short vegetative shoots and long fruit spurs. After considerable preliminary observation, 10 centimeters was taken as an arbitrary division line—those laterals shorter than that being recorded as spurs, and those longer being measured as shoots. Without question this arbitrary line did not result in absolute accuracy; but it is believed that it is very close to the real division line between spurs and shoots for the four varieties under investigation. At least any error due to the resulting classification would be negligible.

Limiting attention first to the records obtained in 1914, the statement seems warranted that the average number of spurs to each tree on 1913, or older, wood is much greater on the winter- and summer-pruned trees than on those that were winter-pruned only. In the case of Wagener the proportion is 2.5 to 1; for Yellow Newtown, it is 2.6 to 1; for Jonathan, it is 3 to 1; and for Grimes, 1.8 to 1. It is impossible to prove that this was due entirely to the summer pruning of the preceding season (1913), but the records for 1914 and those for 1915 suggest strongly that such is the case. The data also show that the average number of fruit spurs on the shoots of the past season (1914) is very much greater for the summer-pruned trees than for those that were winter-pruned only. This holds for all of the varieties studied. In the case of Wagener, the proportion is 19.1 to 1; for Yellow Newtown, it is 12.2 to 1; for Jonathan, it is 5.7 to 1; and for Grimes, it is 57 to 1. It is evident that an early heavy summer pruning has a marked tendency to force the development of fruit spurs upon the current season's growth. Incidentally, the table affords interesting comment on the readiness with which certain varieties are thrown into bearing and the reluctance of others to come into bearing.

Column 6 of Table 9 shows the fruit-spur record of the 1913 or older wood made in the fall of 1915. Comparison with the corresponding record taken in the fall of 1914 is interesting. Some might expect an increase in total number of spurs on this older wood. On the contrary, there was a decrease; and this decrease was not a small, but a large one. The actual average decreases are given in column 7. Added significance is attached to the averages given in these columns when it is stated that not a single one of the 303 trees for which these particular records were made was an exception to the general rule. It is impossible from the data at hand entirely to explain this loss. In the spring of 1914, it was noted that an occasional fruit spur had been damaged by the bud-moth. Some spurs may have been lost from this, or some other kind of insect injury. Without doubt a few spurs were mechanically broken and destroyed when the trees were pruned, sprayed, and cultivated. Probably the largest loss occurred in the case of the very small spurs, those that barely started in 1914, or

Table 9. Showing fruit-spur formation on different parts of trees under different pruning treatments.

Variety	Pruning Treatment.	Number of trees.	Average number spurs on 1913 or older wood (October, 1914).	Average number spurs on 1914 wood (October, 1914).	Average number of spurs on 1913 or older wood (October, 1915).	Increase or decrease in average no. of spurs on 1913 or older wood during 1915.	Average no. of spurs on lower portion of 1914 wood (October, 1915).	Increase or decrease in average no. of spurs on lower portion of 1914 wood during 1915.	Average no. of spurs on upper portion of 1914 wood (October, 1915).	Average no. spurs on 1915 wood in October 1915.	Average total number of spurs per tree in October 1915.
Wagener	Winter-pruned only	39	20.1	1.5	11.4	-8.7	52.6	51.1		2.2	66.2
Wagener	Winter- and summer-pruned	39	57.1	28.6	38.7	-18.4	71.6	43.0	88.3	43.6	242.2
Yellow Newtown	Unpruned	4			25.5		180.7			....	206.2
Yellow Newtown	Winter-pruned only	44	13.7	.6	7.0	-6.7	30.6	30.0		2.1	39.7
Yellow Newtown	Winter- and summer-pruned	26	35.5	7.3	22.7	-12.8	48.9	41.6	27.1	19.8	118.5
Jonathan	Unpruned	6			46.3		294.3			.8	341.4
Jonathan	Winter-pruned only	26	11.4	4.3	5.9	-5.5	35.8	31.5		20.0	51.7
Jonathan	Winter- and summer-pruned	49	34.6	25.2	22.0	-12.6	76.7	51.5	59.2	50.5	208.4
Grimes	Unpruned	10			59.5		276.9			.3	336.7
Grimes	Winter-pruned only	36	16.5	.2	8.6	-7.9	57.4	57.2		6.6	72.6
Grimes	Winter- and summer-pruned	34	29.7	11.4	17.0	-12.7	71.0	56.6	52.6	17.0	157.6

earlier. Such spurs were weak, and perhaps larger and more favorably situated spurs have grown at their expense. Probably many of the spurs counted in the fall of 1914, but not found a year later were really alive, but dormant at that time. (It will be remembered that the 1915 counts included only those that had vegetated during 1915). It is suggested that some of these dormant spurs may be the starting points from which water-sprouts may arise if conditions favorable for them are brought about in future years. In connection with this reduction in number of spurs on 1913 or older wood, it is interesting to note that the loss was relatively greater on the winter-pruned trees than on those that were both winter- and summer-pruned. This is true for all the varieties under investigation. The loss in the case of the winter-pruned trees averaged about 45 percent; in the case of the winter- and summer-pruned trees it averaged about 35 percent. Evidently the summer pruning resulted not only in more spurs but in stronger and longer-lived spurs. The figures also suggest that two-year-old or older wood is not very apt to give rise directly to new fruit spurs, else there would not be such a severe dropping off or reduction in the number of spurs on 1913 or older wood.

The next point to be especially noted is the total number of spurs in the fall of 1915 for the different varieties and under the different pruning treatments. The trees that had not been pruned since planting averaged from four to five-and-one-half times as many spurs as those that had been winter-pruned in the ordinary way each year; and they averaged from 50 to 100 percent more than those that had been both summer- and winter-pruned. The trees that had been both winter- and summer-pruned averaged from two to four times as many spurs as those that had been winter-pruned only. In the case of Grimes, the proportion is approximately two to one, in Yellow Newtown, three to one, and in Jonathan and Wagener, four to one. These proportions are almost exactly the same as for the same varieties the preceding year. Thus, it is seen that the results obtained cannot be attributed to any seasonal peculiarity.

Of no less interest than the total number of spurs in the fall of 1915, is the number and distribution of those formed during the season of 1915. Data bearing on this question are presented in columns 9 and 10 of Table 9. These data show that the basal portions of the 1914 shoots (that is, those early-formed shoots that remained after the summer pruning of 1914) produced just as many new spurs in 1915 as corresponding portions of shoots on the trees that were winter-pruned only. This is particularly interesting since this shoot growth had already developed a good many spurs during the latter part of the preceding season as a direct response to the summer pruning. In other words, early summer pruning of the type given does not have the effect of making the basal portion of the current season's growth function as though it were a year older than it actually is,* even though this growth comes to have much of the appearance of wood that is older. The data presented in column 10 of Table 9 are particularly significant. They show that in 1915 a great many spurs were formed on the late summer shoot growth of the summer-pruned trees—on the new shoots put out in 1914 after the summer pruning. Herein, apparently, lies the chief gain in fruit-spur production from the type of summer pruning given. The late summer growth stimulated by the summer pruning is not so great in amount that a heavy pruning is required the winter following. Much of this late, or secondary growth is left; and there is nothing exactly to correspond to it in the trees that are winter-pruned only; and that portion of their growth that most nearly corresponds with it, namely the terminal one-half or one-third of their shoots, is practically all pruned away at the time of winter pruning. This is a distinct gain for the summer-pruned trees. Some of the reasons why such a large percentage of the buds on this late shoot growth grows out into fruit spurs are presented in another portion of this bulletin.

Figures 27 and 29, showing average Wagener and Yellow Newtown trees that were winter-pruned only, and Figures 28 and 30, showing trees of the same varieties that have had both the winter and summer pruning, afford some idea of the relative number and distribution of fruit spurs under the two methods of treatment. The tendency of entirely unpruned trees to develop large numbers of fruit spurs is well illustrated by Figures 31 to 33. A better idea of the distribution of the fruit spurs under the different pruning treatments is afforded by Figures 34 to 39. Figures 34, 35, and 36 are of average one- and two-year-old wood of Wagener, Jonathan, and Grimes trees that have been winter-pruned only. Figures 37, 38, and 39 are of average one- and two-year-old wood of trees of the same varieties that have been both winter- and summer-pruned. In each figure, a-c represents shoot growth made during the season of 1914, and c-e, shoot growth of the past (1915) season. In Figures 37 to 39, the early summer shoot growth of the two seasons (that is, the shoot growth produced before the time of the summer pruning) is represented by the letters a-b and c-d; and the late summer shoot growth (that is, the shoot growth produced after the time of summer pruning) is represented by the letters b-c and d-e. Attention is called particularly to the relatively large number of spurs formed on the **non-headed** late summer shoots of Wagener and Grimes.

---

* In a preceding paragraph attention has been called to the fact that only wood of the past season shows any marked tendency to develop fruit spurs; that is, after 1914, fruit spurs cannot be expected to develop in any siderable number directly from 1913 or older vegetative growth.

RELATION OF SEVERITY OF EARLY SUMMER PRUNING TO FRUIT-SPUR FORMATION.

As in the case of shoot growth, the question naturally arises "Is there, or is there not, a correlation between the severity of summer pruning and the subsequent formation of fruit spurs." Table 10 brings together the data bearing on that question for the seasons of 1914 and 1915, and shows the computed number of spurs per meter of early summer shoot growth remaining after the summer pruning. Detailed records are given for Jonathan; averages only are given for the other varieties.

If the records for 1914 only were available, one would infer that on the average there is a positive correlation between the severity of the summer pruning and the number of spurs formed later in the season on the early summer shoot growth. In some of the varieties the correlation is a marked one, though in others, it is practically negligible. Records for the same trees in 1915 indicate that there is no such correlation in any of the varieties. The one season's results thus apparently contradict or partly contradict those of the other season. It will be noted, however, that the trees were pruned relatively much more severely in 1914 than in 1915. If now the averages for the trees that were pruned from say 50 to 65 percent in 1914 are compared with those that were pruned equally severely in 1915, variations within the two groups show about the same relation between severity of pruning and fruit-spur formation. In other words, if the 1914 response of the more lightly pruned trees is compared with the 1915 response of the similarly pruned trees, there is little evidence to indicate that heavy summer pruning is a greater stimulus to fruit-spur production than light summer pruning. This at least suggests that the very marked (as measured by number of fruit spurs per meter of shoot growth) fruit-spur production in 1914 following the very severe pruning given that summer was probably due to the great reduction in number of growing points—a reduction so great as to force out into growth a very large percentage of the remaining buds. This would make it appear that heavy summer pruning stimulates into growth a larger number of buds, but more careful study indicates that the number of buds stimulated into growth does not vary closely with the severity of summer pruning. Rather, it is the **proportion** of buds remaining on the shoots after summer pruning that varies. Thus, the records for 1915 are seen to be more nearly representative of the true relation between severity of summer pruning and subsequent fruit-spur formation. At this point it is interesting to call attention to the fact that the records showed a similar lack of correlation between the severity of this early summer pruning and subsequent late summer shoot growth.

A point of interest brought out by a comparison of the two tables is that the average number of spurs per meter of shoot growth was less in 1915 than in 1914 under the same pruning treatment—that is,

Table 10. Showing relation of severity of early summer pruning to fruit-spur formation in 1914.

Percent pruning.	Centimeters shoot growth remaining after summer pruning.	Number of fruit spurs formed after summer pruning.	Number of fruit spurs formed after summer pruning per meter of shoot growth remaining after summer pruning.
		WAGENER	
46.5			4.55 Average for 2 trees.
54.0			5.35 Average for 2 trees.
57.0			6.70 Record for one tree.
63.8			6.47 Average for 9 trees.
68.5			8.65 Average for 4 trees.
72.4			7.78 Average for 5 trees.
77.9			12.22 Average for 8 trees.
84.0			18.43 Average for 3 trees.
87.5			19.20 Average for 2 trees.
		YELLOW NEWTOWN	
53.0			.7 Record for one tree.
64.3			2.33 Average for 3 trees.
66.8			2.15 Average for 6 trees.
73.0			2.64 Average for 7 trees.
78.3			2.47 Average for 3 trees.
82.8			2.50 Average for 5 trees.
		JONATHAN	
59	462	17	3.7 Record for one tree.
62	450	4	.9
62	442	12	2.7
63	301	16	5.3
64	799	35	4.4
65	542	19	3.5
63.2			3.36 Average for 5 trees.
66	802	31	3.9
66	483	22	4.6
66	549	39	7.1
67	511	19	3.7
67	706	24	3.4
68	105	3	2.9
69	475	27	5.7
70	595	21	3.5
70	543	34	6.3
67.7			4.57 Average for 9 trees.
71	459	15	3.3
73	465	25	5.4
74	141	6	4.3
74	176	6	3.8
74	300	27	9.0
74	793	27	3.4
75	523	23	4.4
73.6			4.80 Average for 7 trees.

Table 10—*Continued*

Percent pruning.	Centimeters shoot growth remaining after summer pruning.	Number of fruit spurs formed after summer pruning.	Number of fruit spurs formed after summer pruning per meter of shoot growth remaining after summer pruning.
		JONATHAN	
76	451	18	4.0
78	428	33	7.7
78	390	11	2.8
78	426	24	5.6
78	276	16	5.3
79	332	31	9.3
79	638	44	6.9
79	469	34	7.2
80	463	39	8.4
78.3			6.36 Average for 9 trees.
81	220	17	7.7
81	448	30	6.7
82	610	59	9.7
83	456	19	4.2
83	416	29	7.0
84	241	25	10.4
84	364	25	6.9
84	438	23	8.4
84	352	23	7.5
85	331	24	7.3
83.1			7.48 Average for 10 trees.
87	219	33	15.1
88	332	34	10.2
90	290	47	16.2
88.3			13.8 Average for 3 trees.
92	156	30	19.2
94	160	44	17.5
93			18.3 Average for 2 trees.
		GRIMES	
33.0			2.70 Record for one tree.
55.0			3.00 Record for one tree.
58.2			1.82 Average for 5 trees.
62.7			1.77 Average for 3 trees.
69.7			3.77 Average for 3 trees.
72.9			5.16 Average for 13 trees.
77.9			3.73 Average for 3 trees.
81.0			6.50 Average for 2 trees.
86.0			5.90 Record for one tree.

Table 11. Showing relation of severity of early summer pruning to fruit-spur formation in 1915.

Percent pruning.	Centimeters shoot growth remaining after summer pruning.	Number of fruit spurs formed after summer pruning.	Number of fruit spurs formed after summer pruning per meter of shoot growth remaining after summer pruning.
		WAGENER	
48.6			3.73 Average for 5 trees.
53.2			3.19 Average for 9 trees.
58.2			3.94 Average for 15 trees.
62.2			4.23 Average for 5 trees.
66.0			3.42 Record for one tree.
		YELLOW NEWTOWN	
50.0			1.61 Average for 2 trees.
53.4			1.47 Average for 16 trees.
57.7			1.38 Average for 6 trees.
61.5			1.55 Average for 2 trees.
		JONATHAN	
53	645	30	4.65 Record for one tree.
60	857	23	2.69
60	2642	73	2.73
60			2.71 Average for 2 trees.
61	1366	43	3.15
61	1822	58	3.08
62	2424	50	2.06
62	1242	50	4.02
62	2550	42	1.65
63	1668	47	2.82
63	1061	40	3.77
63	1660	48	2.89
63	331	18	5.44
64	2246	59	2.63
65	1489	40	2.69
65	1359	43	3.17
62.8			3.11 Average for 12 trees.
66	2110	70	3.32
66	2642	52	1.97
66	1602	38	2.37
66	1278	28	2.19
67	1910	80	4.19
67	1887	52	2.76
67	1479	60	4.05
67	1780	57	3.20
67	2201	49	2.23
67	2282	83	3.64
68	2013	76	3.77
68	2445	56	2.29
69	1576	32	2.03
69	1774	48	2.71
69	1738	63	3.62
69	1950	50	2.56
69	2325	81	3.49
69	1717	29	1.69
69	1252	15	1.20
69	487	9	1.85
70	1390	45	3.24

Table 11—*Continued*

Percent pruning.	Centimeter shoot growth remaining after summer pruning.	Number of fruit spurs formed after summer pruning.	Number of fruit spurs formed after summer pruning per meter of shoot growth remaining after summer pruning.
		JONATHAN	
70	2281	41	1.80
70	2466	58	2.35
70	2052	39	1.90
70	1781	34	1.91
70	2052	45	2.19
68.2			2.64 Average for 26 trees.
71	1680	87	5.18
71	2440	60	2.46
71	2029	36	1.78
72	1628	38	2.33
72	3075	104	3.38
72	1894	56	2.96
72	2602	84	3.23
73	2024	45	2.22
73	1546	32	2.07
71.9			2.85 Average for 9 trees.
		GRIMES	
52.4			1.56 Average for 9 trees.
57.7			1.46 Average for 18 trees.
62.0			1.63 Average for 6 trees.

when the pruning was equally severe in the two cases. In other words the summer pruning of 1915 proved to be less of a stimulus to fruit-spur formation than that of 1914. Whether this was due to slightly different environmental conditions or is to be attributed to some tendency on the part of older trees to show less of a response to this type of summer pruning, is not known.

INFLUENCE OF EARLY SUMMER PRUNING UPON LENGTH OF GROWING SEASON.

It was noticed each year that terminal bud formation was appreciably delayed in the summer-pruned trees. It was also noted each fall that the trees that had been summer-pruned were slower to mature their wood and shed their leaves than those that had not been summer-pruned. It would be difficult, however, to state just how long the summer pruning delayed the various growth processes. It is possible that the delay would be sufficient in some sections and with some varieties to increase considerably the danger from winter injury. In no instance, however, in the Station orchard was there any evidence of winter injury either to the trees that were winter-pruned only or to those that were both winter- and summer-pruned. It is true that the lowest temperatures registered in the orchard during the course of the investigation were 10° to 15° F., and such temperatures are not apt to cause killing back of apple shoots. On the other hand, the trees were put to at least one rather critical test during the late winter and spring of 1915-1916. Weather conditions were such as to cause considerable bark and even trunk splitting in fruit trees in close proximity to the Station orchard. Though both summer-pruned and non-summer-pruned trees were carefully examined for this kind of injury, none was found.

EARLY SUMMER PRUNING OF YOUNG APPLE TREES

Its Place in the Development of the Orchard.

From the experimental data presented in this report and from observations made in a number of large commercial orchards, the conclusion is warranted that early summer pruning has a place in the development of many young apple orchards. In kind and severity this pruning does not differ materially from the winter pruning ordinarily given trees of the same age. It serves as a slight check to their increase in size, but in this respect operates in almost identically the same way as a corresponding winter pruning. As ordinarily the summer-pruned trees do not need to be winter-pruned so heavily as those that are winter-pruned only, the yearly set-back in size accompanying the two systems of pruning is not materially different. Thus the winter-pruned and the winter- and summer-pruned trees grow (i. e., increase in size) at about the same rate. The great advantage from early summer pruning comes as a result of its direct and indirect stimulus to fruit-spur formation. Trees that were summer-pruned, in addition to being winter-pruned during their second, third, and fourth summers, possessed two to four times (depending upon variety) as many fruit spurs at four years of age as those that were winter-pruned only. This means that approximately one year is saved in bringing the orchard into bearing without sacrificing symmetry of form, size or other important features. It is believed that the method of summer pruning here described will prove especially valuable in the developing of young orchards on very rich soils, or with a very abundant water supply and consequently with shoot growth that is strong and vigorous. Its judicious use may be a means of largely avoiding that so-called critical period with young trees, when it is desired to bring them into bearing but when they persist in producing mainly shoot growth. It is possible that varieties, like Rome, that produce a large percentage of their first two or three crops directly upon shoots of the past season (in this respect resembling peaches and certain varieties of plums) would not show such a favorable response to this kind of summer pruning; and with such varieties, it should be tried rather carefully. It may be recommended, however, for those apple varieties that bear the bulk of their early crops upon spurs. It is probable that it should not be begun in some orchards until their third or even fourth season, especially if the trees are inclined to be weak and lacking in vigor. It is possible that it may be begun to advantage the first season in orchards that give evidence of producing extremely vigorous growth.

Caution should be exercised in practicing heavy early summer pruning in a section having a very short growing season and very severe winters, even though it is evident that such pruning does not render the trees particularly susceptible to certain forms of winter injury.

SUMMARY.

Preliminary experiments started by Professors C. I. Lewis and E. J. Kraus, of this Station, as early as 1910 suggested that early summer pruning of young apple trees might often be practiced to good advantage—the general effect of such pruning being to aid in the development of the framework of the tree and to stimulate fruit-spur formation.

The investigation upon which this is a report was begun in 1912. At that time the trees were in their second season of growth. At the close of the experiment the trees had completed four seasons growth. There were 313 trees under observation, the varieties being Wagener, Yellow Newtown, Jonathan, and Grimes. Some of the trees received no pruning; some were pruned in the ordinary way late in the dormant season; others were similarly pruned during the dormant season and also given a heavy early summer (July 1 to 10) thinning out and heading back.

Records of growth under the varying pruning treatments included number and length of shoots, shoot diameter, trunk circumference, number and distribution of fruit spurs.

The data relating to shoot growth indicate that on the average the unpruned tree increases in size a little more rapidly than the tree that is winter-pruned only or that is both winter- and summer-pruned. Its average annual shoot growth is less, but it loses none of this by pruning and hence its net increase is greater. Broadly speaking, there is but little difference in increase in size between trees that are winter-pruned only and those that are both winter- and summer-pruned. The summer-pruned trees lose more shoot growth from pruning, but they produce nearly enough more to compensate for the additional loss.

The amount of shoot growth produced any one season by young apple trees that have not yet developed many spurs is closely correlated with the amount they made the preceding season and shows little correlation with the amount of (i. e., the severity of) their winter-pruning.

Likewise the amount of shoot growth produced late in the summer, following early summer pruning, is closely correlated with the amount

of the shoot growth possessed by the tree at the time of summer pruning and shows little correlation with the amount of (i. e., the severity of) the summer pruning.

During certain portions of the growing season the winter-pruned trees of certain varieties increase in trunk circumference more rapidly than trees that have been both summer- and winter-pruned; during other portions of the year, the reverse is the case. There seems to be a close correlation between increase in trunk circumference at any period during the summer and the leaf area possessed by the tree at that particular time.

In some varieties heavy early summer pruning has the effect of causing those shoots remaining after the pruning to thicken and become more stocky than those in trees that are not summer-pruned. In other varieties the shoots in the trees that are winter-pruned only are the thicker and stockier. In all the varieties studied the late shoot growth on the summer-pruned trees (i. e., the shoot growth formed after the summer-pruning) is comparatively slender.

Summer pruning of the type described affords a direct stimulus to fruit-spur formation. Some of the buds on the basal portions of the shoots that are left after the summer-pruning almost invariably grow out into fruit spurs during the latter part of the summer. Those that remain dormant during the latter part of the summer are just as apt to develop into spurs the following year as similarly situated buds on shoots that are not summer-pruned.

The late summer shoot growth of the summer-pruned trees is very productive of fruit spurs the season following its formation. A high percentage of its buds develop into spurs. Herein, apparently, lies the chief gain in fruit-spur production from the summer pruning. On the trees that are winter-pruned only, there is no growth to correspond with it. There is little or no relation between the severity of the summer pruning and the number of spurs to each unit of shoot length that remains.

Summer-pruning of the type described affords a means of developing a fruit-spur system in young apple trees earlier than is possible with the ordinary method of winter pruning only; it is estimated that its judicious use with varieties bearing mainly upon spurs will enable the apple grower to bring his trees into bearing approximately a year earlier than is otherwise possible, and still maintain and develop a good framework.

Summer-pruned trees show a tendency to mature their wood a little later in the fall and might consequently be expected to be more susceptible to winter injury. They have not, however, proved more susceptible to bark splitting caused by severe winter weather.

ACKNOWLEDGMENTS.

As stated in the introduction, the type of summer pruning here described was first developed by Professors E. J. Kraus and C. I. Lewis, and the investigation upon which this is a report was suggested by them. Professor Kraus, particularly, has rendered assistance in the progress of the investigation through criticisms and suggestions. Grateful acknowledgment is also made of the help rendered in record taking by certain other members of the Division, particularly Messrs. G. L. Philp and W. P. Tufts.

EXPLANATION OF PLATES.

Except for Figures 2 and 5 in Plate I and for Plates VIII and IX the illustrations show various stages in the development of typical Wagener and Yellow Newtown trees under the two systems of pruning described in this report.

Plates II and V illustrate the winter pruning of the trees of these varieties that were winter-pruned only; and Figures 27 and 29 in Plate VII the 4-year-old trees resulting from such pruning treatment.

Plates I and IV illustrate the summer pruning of typical trees of the same varieties; Plates III and VI illustrate the winter pruning of these summer-pruned trees; and Figures 28 and 30 in Plate VII the 4-year-old trees resulting from such pruning treatment.

Attention is called to the fact that the photographs show successive stages in the development of the same individual trees; Figures 7, 8, 19, 20, and 27 constituting a series for winter-pruned Wagener; Figures 9, 10, 21, 22, and 29 constituting a series for winter-pruned Yellow Newtown; Figures 1, 3, 11, 12, 15, 16, 23, 24, and 28 constituting a series for winter- and summer-pruned Wagener; and Figures 4, 6, 13, 14, 17, 18, 25, 26, and 30 constituting a series for winter- and summer-pruned Yellow Newtown.

Plate VIII shows typical 4-year-old Yellow Newtown, Jonathan, and Grimes trees that have not been pruned.

Plate IX illustrates the relative number and distribution of fruit spurs on the shoots and branches of the several varieties under the different pruning treatments. Figures 34, 35, and 36 are of branches of trees that were winter-pruned only; Figures 37, 38, and 39 are of branches of trees that were both winter- and summer-pruned. In these Figures a-c represents wood growth developed during one season and c-e wood growth developed during the following season. In the case of the winter- and summer-pruned trees, a-b and c-d represent wood growth developed early in the growing season, or before the time of summer-pruning; b-c and d-e represent wood growth developed late in the growing season, or after the time of summer pruning.

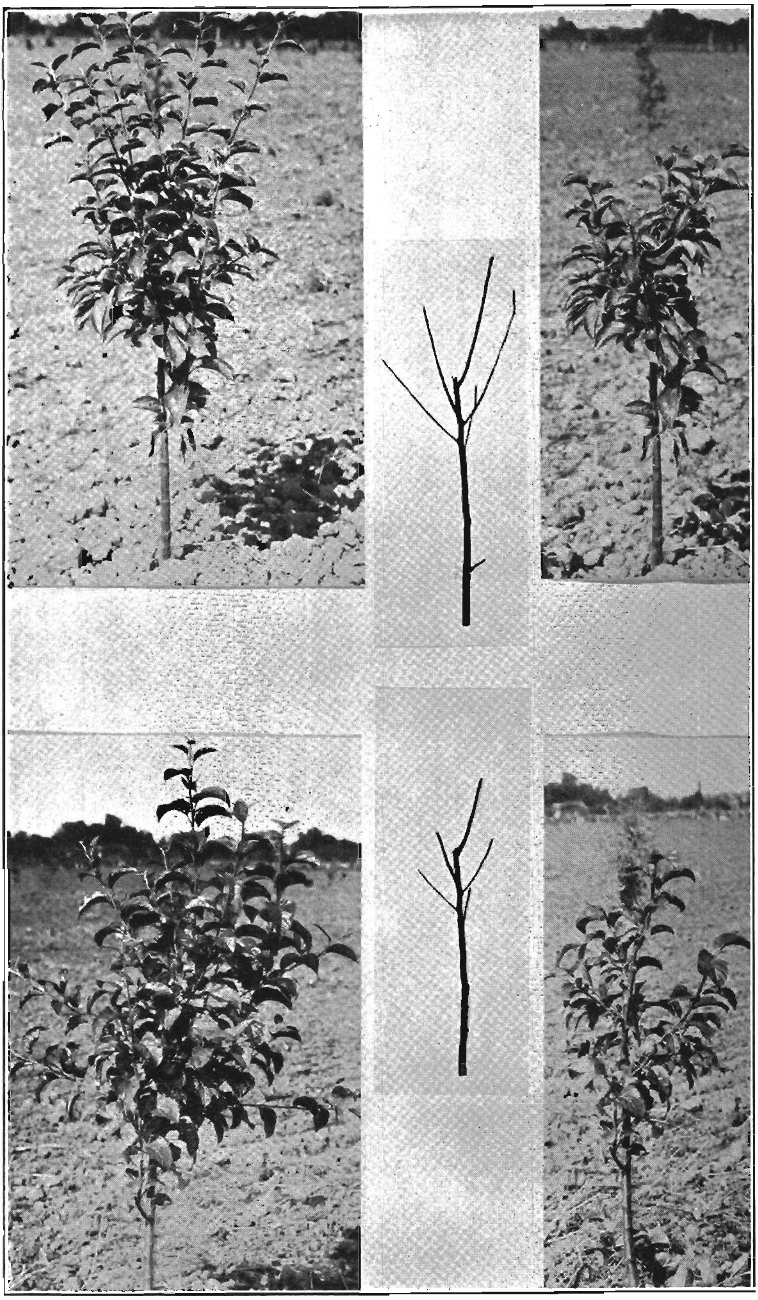


Plate I, Figs. 1-6.

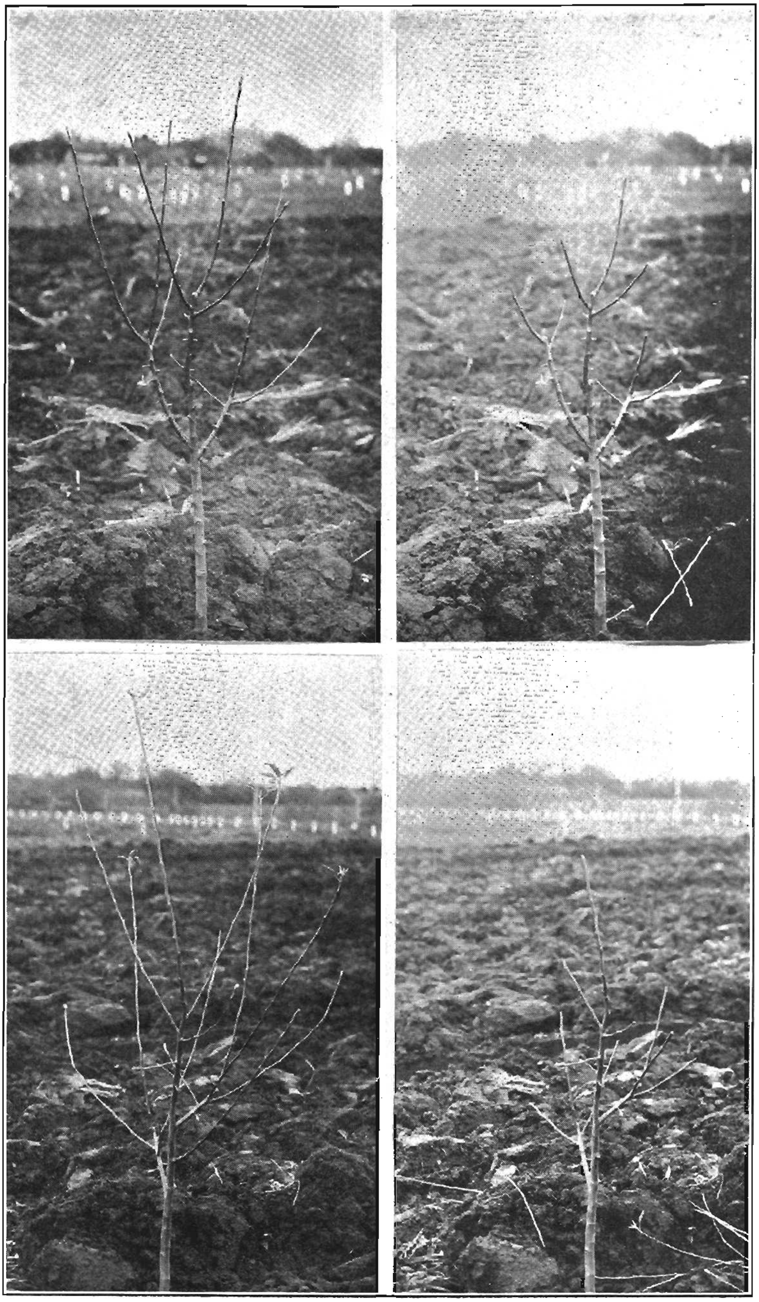


Plate II, Figs. 7-10.

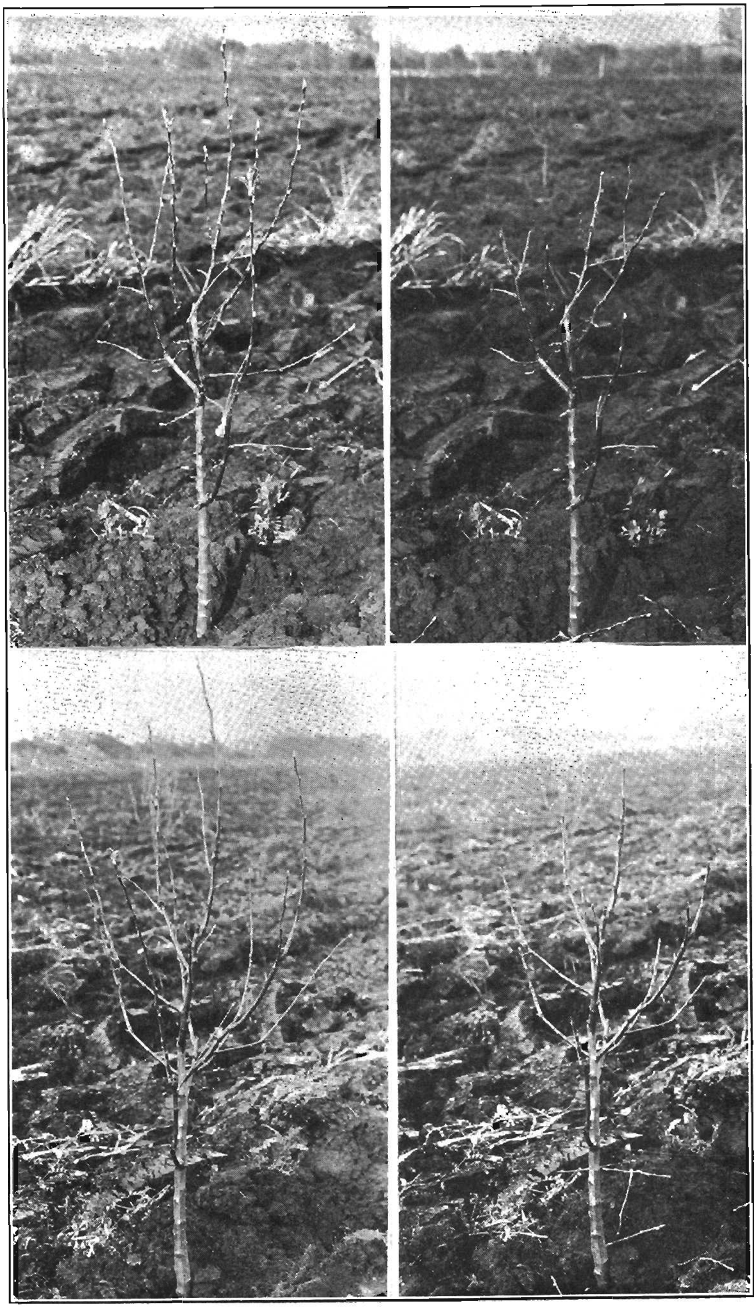


Plate III, Figs. 11-14.

Plate IV, Figs. 15-18.

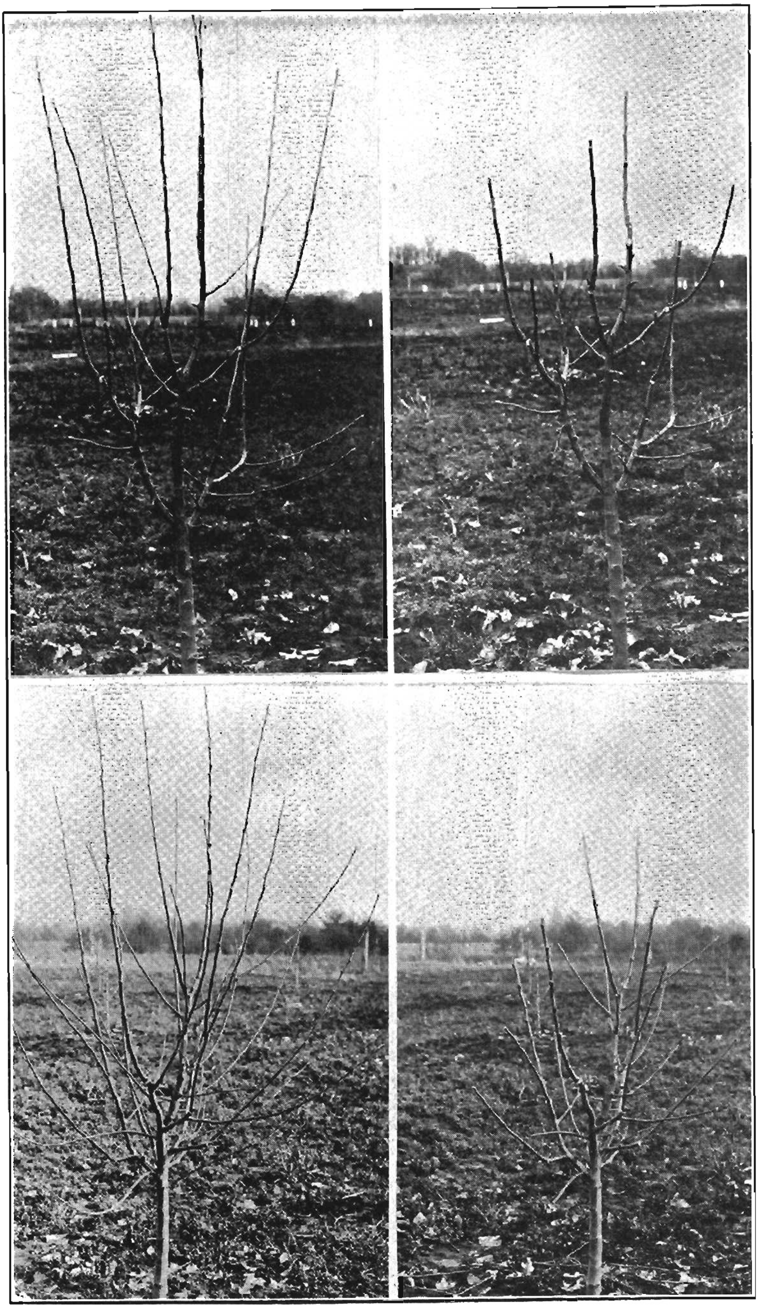


Plate V, Figs. 19-22.

Plate VI, Figs. 23-26.

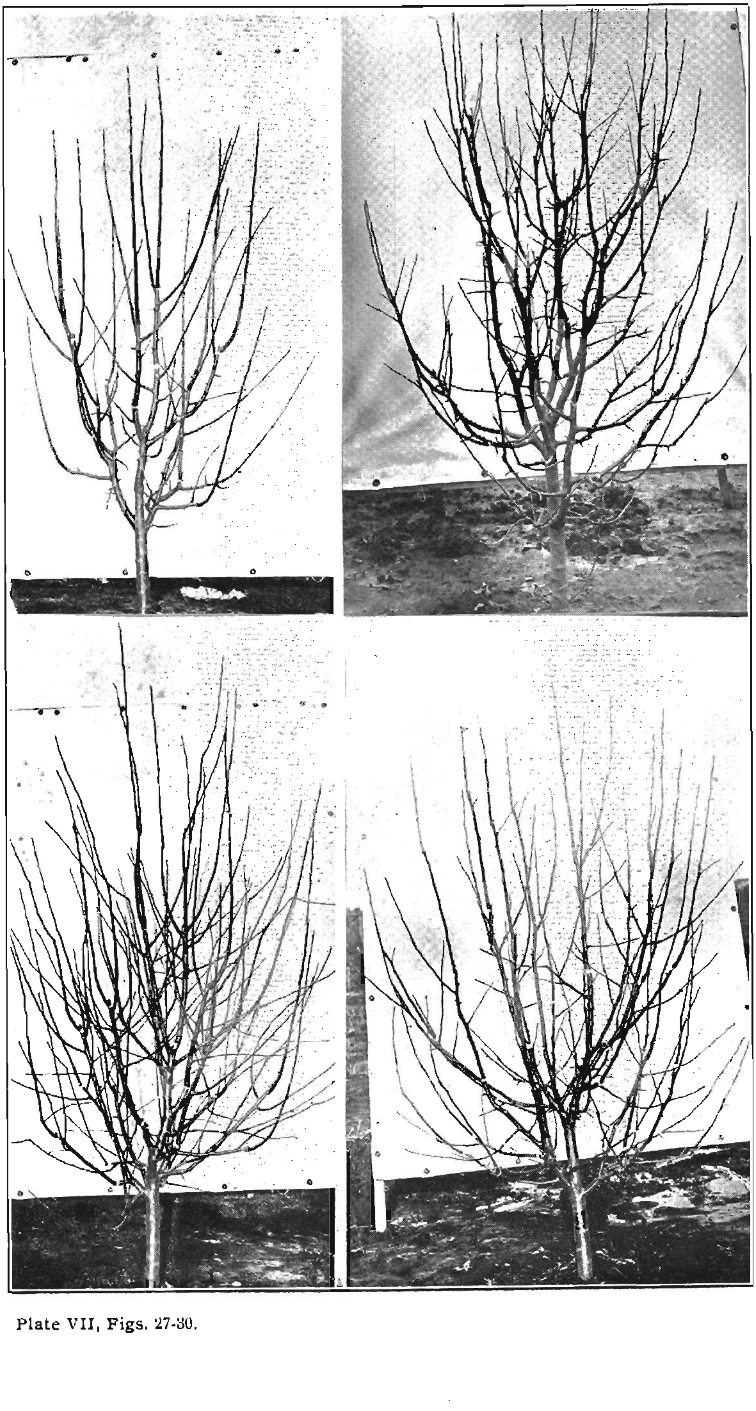


Plate VII, Figs. 27-30.

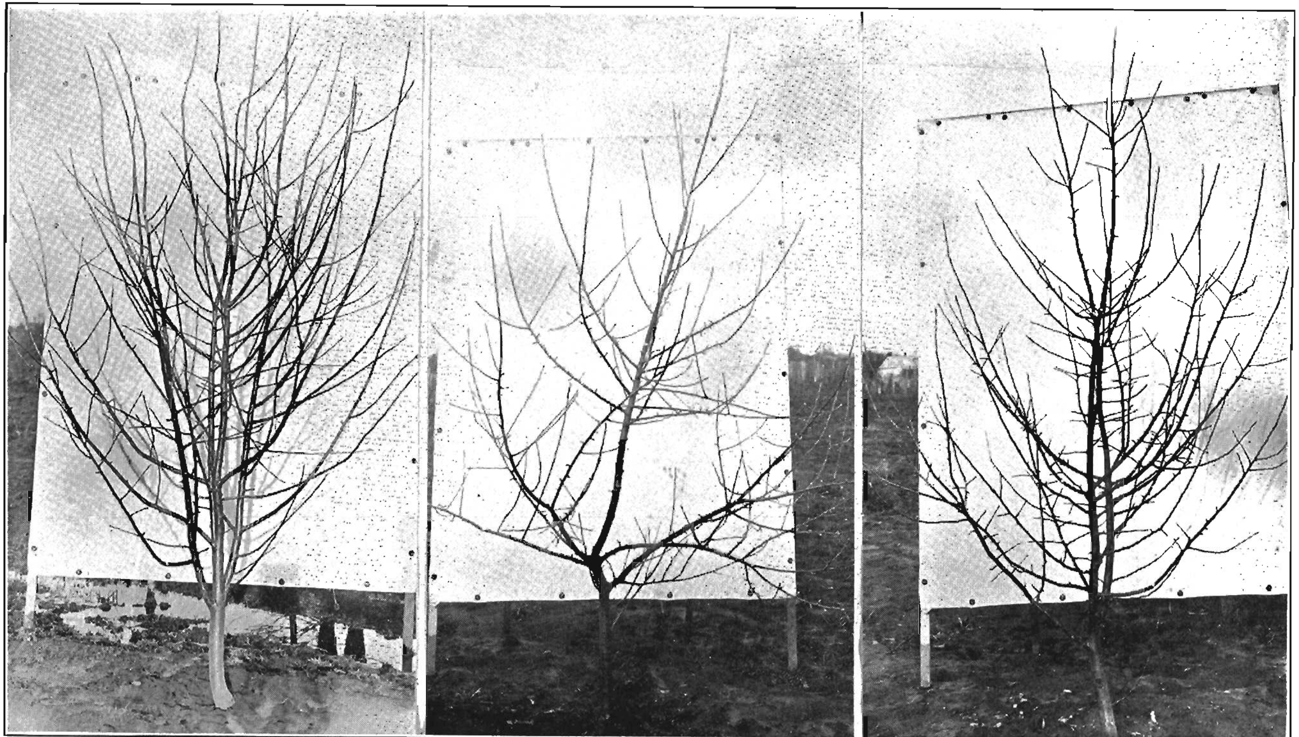


Plate VIII, Figs. 31-33

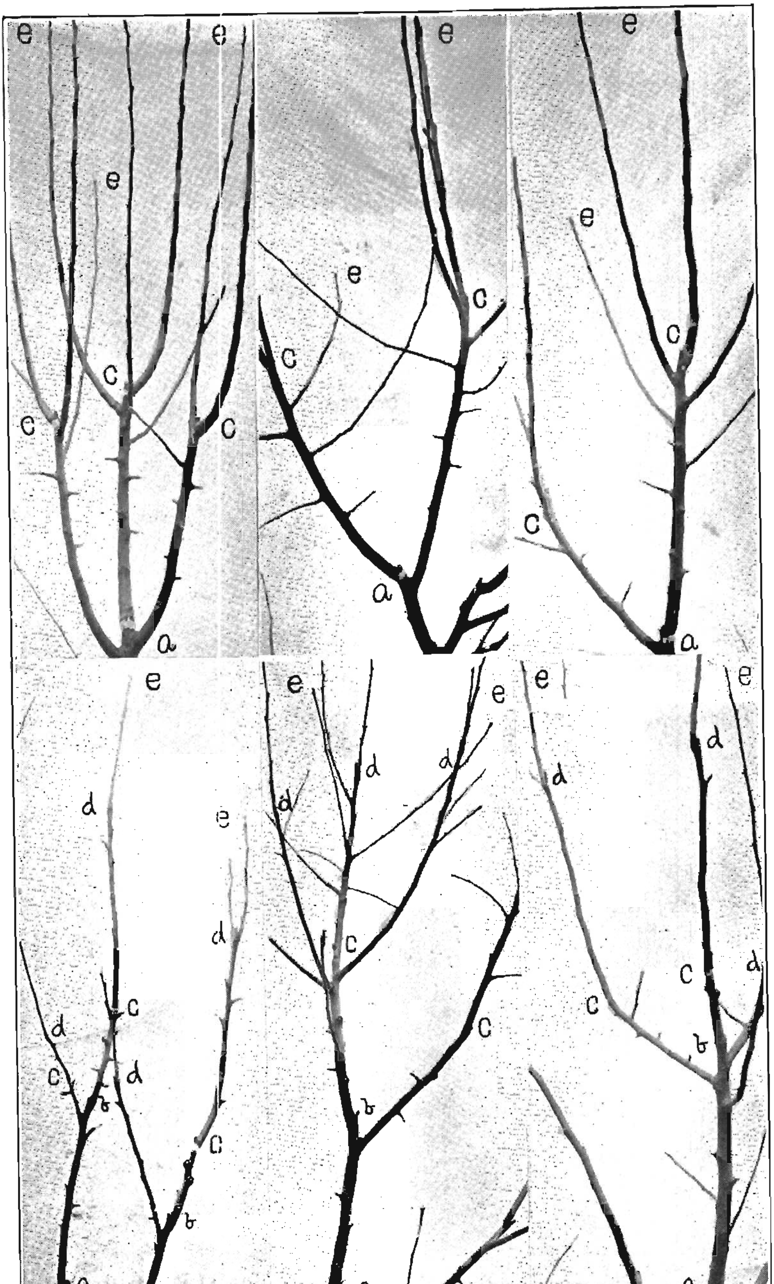


Plate IX, Figs. 34-39.

THE INFLUENCE OF SUMMER PRUNING ON BUD DEVELOPMENT IN THE APPLE

By J. R. Magness.

INTRODUCTION.

Summer pruning has long been recommended as a remedy for certain conditions that may arise in an orchard. It has been said to check vegetative growth, and special emphasis has been laid upon summer pruning as a means of bringing shy- or non-bearing trees into full bearing. There has been some conjecture as to how these changes are accomplished, and as to the exact effect of summer pruning upon the tree, especially upon the buds which are said to be changed over into fruit buds by the treatment, but little real evidence has been presented.

REVIEW OF LITERATURE.

It requires but a brief summary of the opinions held by horticulturists, both in the past and at present, to show the lack of definite information concerning the response to be expected from summer pruning. Although references to this type of pruning are fairly abundant in horticultural literature, a few will suffice to show the opinions generally expressed.

One of the earliest writers on this subject, according to Nochden (1) was Henry Van Oosten, the Leyden gardener, whose book appeared, translated from the Dutch into English, in the year 1711. He mentions several ways of improving the productiveness of fruit trees. "But as the most effective, he considers the repeated pruning of the tree in summer, by which, as it causes the tree to bleed, the current of the sap is naturally weakened * * *."

La Quintinye (2) states that summer pruning induces the formation of fruit buds for the following spring.

Summer pruning recommendations of the past century vary considerably in their application. Some are very specific, applying only to dwarfs or some one kind of fruit, but most of the directions given are supposed to apply to fruit trees in general. The recommendations may readily be grouped into two classes—those favoring heading back heavily, and those favoring simply pinching the terminals. Each class has had its advocates, and arguments in favor of each have been submitted.

Hovey (3) recommends summer pruning to cause fruit spurs to form. He recommends both pinching and heading back, and at frequent intervals. He says, "There is no fixed time for performing the operation," but recommends the month of July.

Queen (4) says "Summer pruning, which is quite simple, is mainly practised to bring about fruitfulness. It consists in shortening in the young growth of the present year one-half and sometimes two-thirds, with a knife or the thumb and finger when the growth is fragile. This can be done at any time between the 15th of July and the 10th of August."

Pearson (5) in writing of espaliers, says, "I have no hesitation in saying that as ordinarily carried out, summer pruning is the main cause of our garden fruit trees being unfruitful, whereas, if properly done, it should have the most beneficial effect." He then recommends pinching the laterals at successive times during the summer, making them become "thin and weak and so predisposed to form fruit spurs, whilst the leading shoots and those required for extension will have had an extra amount of sap thrown into them, and will consequently be strong, clean and vigorous."

Waugh (6) summarizes the matter as follows: "The most important difference between winter and summer pruning lies in the physiological effect. Winter pruning has a tendency to promote wood growth * *. Summer pruning has a tendency to promote the formation of fruit buds and to check wood growth."

Paddock and Whipple (7) make the following statement: "Prune in summer to induce fruitfulness and in winter to promote wood growth. This is true for the reason that summer pruning checks the growth of the tree by removing a part of the leaf surface. An injury of any kind will have the same effect."

Lewis (8) recommends heading back of very vigorously growing, two- to four-year-old trees during mid-growing season to gain time in building the frame work of the tree. With older trees, it is recommended to prune when the terminal buds are forming "with the idea of trying to induce fruitfulness if possible."

Kraus (9) discusses various types of summer pruning and their influence in maintaining a good fruit-spur system in the tree. He recommends early summer heading back and thinning out, followed by winter thinning and heading back. This gives two years form in one season, avoids the necessity for excessive winter pruning, and gives a more advantageous placing and probably an increased number of fruit buds.

Goff (10) was one of the first systematically to study fruit-bud formation. In the Hoadley apple, the first clear evidence of flower parts was found in buds taken June 30. As a result of his second year's work, Goff (11) concludes that in the apple and the pear, flower differentiation takes place during a very prolonged period. Many fruit buds may be initiated up to and after September 1. "There must either be two periods of flower formation in the apple and pear, or else the formation of flowers must continue from early in summer until cold weather." He favors the former hypothesis, and suggests that flowers are formed as a result of a check in growth, and that this check may be caused first, by dry conditions during late summer, and second, by the advent of cool nights in the fall.

He suggests further, that reversion of fruit buds to leaf buds very seldom, if ever, occurs in our fruit trees, and that there is apparently no fundamental difference between flower buds and leaf buds. Whether a bud forms flower parts or remains a leaf bud seems to depend on nutrition rather than on structure.

From his third year's work, Goff (12) concluded, "Evidence gained points strongly to the conclusion that a bearing apple tree may begin to form flowers at any time after growth ceases until toward the middle of September, or it may not begin at all."

Drinkard (13) traced in much detail the development of the flower bud of the Oldenburg apple as it occurs in Virginia. He states that flower development apparently starts during the last ten days of June, and proceeds throughout the summer. No mention is made of any flower parts being initiated later than July 1.

Bradford (14) studied the development of the buds of Yellow Newtown in relation to their position in the tree. He found that in general, fruit buds on spurs are differentiated earlier than terminal buds on the current season's growth. Fruit buds on spurs that have borne in previous years, but are not bearing during the current year, show less variation in time of differentiation and more uniformity in development than any other group. Buds on spurs which have blossomed in the spring, but failed to set fruit, show every range of variation. In buds on spurs that are bearing during the current year and at the same time forming flower parts, much variation in time of differentiation is found. Buds on spurs on two or three year old wood, but which have never borne, present on the average about the same condition found in the spurs that have borne before, but are not bearing or have not blossomed during the current year.

Pickett (15) investigated the causes of fruit-bud formation in the case of the Baldwin. Working with plots in sod, and under various systems of cultivation, in an orchard that had formerly been in sod, he found a very decided increase in fruit buds formed in the case of clean cultivation and cultivation with cover crops as compared with the sod plots. In this work, however, the number of apples produced was taken as indicative of the number of fruit buds formed. This is not an accurate method of measurement, for often a tree will have considerable bloom, and still fail to set fruit, due to low vitality in the tree, poor nutrition in the blossom buds, or to other factors.

Gourley (16) discussed the tree responses to the cultural treatments carried on by Pickett, and from these responses suggests conditions in the tree as a whole which seem correlated with fruit-bud formation.

This is a very brief summary of the present knowledge of fruit-bud formation and development, together with some of the opinions that have been expressed regarding the effects of summer pruning upon them.

OBJECT.

If we are to learn the true value of various types of summer pruning and thus assign to them their proper places in orchard management, it is clear that we must have accurate information regarding the bud response to such pruning practices. The investigation upon which this is a report was planned to obtain some of this information,—to determine some of the influences of certain types of summer pruning on the buds of the apple. This included a study of their effect upon developing flower buds on spurs, upon leaf buds borne on spurs, and upon axillary buds of the current seasons growth, whether leaf or fruit.

METHODS AND MATERIALS.

The trees used in this investigation were in their fourth season of growth when the first summer pruning was given them. They were originally dwarfed on Paradise stock, but no effort was made to prevent their rooting above the graft union, so that some of them were partly on their own roots. There was a total of 38 varieties of apples used, with an average of about 4 trees of each variety. These varieties were Early Harvest, Gravenstein, Grimes, Bartlett Seedless, Red Astrachan, Jonathan, Yellow Newtown, Lady, Tolman, Bismark, Cox Orange, Delicious, Waxen, Wealthy, Banana, Ortley, Arkansas, Wagener, Keswick, Yellow Bellflower, Fameuse, Rhode Island, Pumpkin Sweet, Opalescent, Livland Raspberry, Tompkins King, Glowing Coal, Babbitt, Alexander, White Pearmain, Yellow Transparent, Winesap, Tetofski, Esopus (Spitzenburg), Northern Spy, Maiden Blush, Oldenburg, and Baldwin.

Some variation occurs in the soil in which the trees were growing. While most of the soil is a medium heavy, fairly well drained clay loam, one spot, comprising about one-fourth the total area, is a poorly drained, very heavy soil type. In this spot, the trees were much smaller and stopped growth much earlier in the fall than in most of the plot.

The trees of each variety, however, were set eight feet apart in the rows, so there is little variation in the soil in which the individual trees of any one variety are growing. Thus the results obtained from the various pruning treatments are directly comparable.

The first summer pruning was given the trees from the first to the tenth of July, 1914. At that time they had made a growth ranging from 18 inches to 30 inches except for the trees in the poorer soil, whose shoot growth ranged from 15 inches to 24 inches. These latter trees for the most part had formed terminal buds on the leaders, while terminal formation had not taken place in the most vigorous trees. Thus, while the actual date of the pruning was very nearly the same for all varieties, there was considerable variation in the relative stage of development of the tree. This variation was apparent in the amount of growth following the pruning, for while the vigorous trees made 6 to 15 inches of growth, many of those with terminals formed when the pruning was done produced no shoot growth at all.

The pruning given was practically the same for each variety. Trees of each variety received the following types of pruning: (1) pinching back the terminals, removing not to exceed 20% of the current season's growth; (2) a heavy heading back, removing 50% of the current season's wood; (3) a very heavy heading, removing 75 to 100% of the current season's growth. This heading back was accompanied by enough thinning to open the trees and admit light. The actual amount of thinning varied with the variety and with the individual trees. Such an early summer heading back and thinning out is essentially a form pruning or training rather than primarily a treatment to increase fruitfulness. If more than three trees of a variety were available, one was left unpruned to serve as a check against the summer pruning.

At the time the pruning was done, buds from spurs, and axillary buds both from the regions of the base and from immediately back of the terminals on current season's shoots were collected. After an interval of two weeks buds from both spur and current season's wood were collected again from trees of each variety pruned according to each method outlined above. The portion in the tree from which the spurs were taken was not recorded except in the case of those trees that were cut back into previous seasons' wood. In the latter case, spurs adjacent to the cut were collected separately. August 25 to September 2, and November 2 to November 10, further collections were made from all trees.

It was soon apparent, however, that the great amount of time required to prepare, section, stain, mount and study the buds would make it impossible to examine buds from all the varieties in the plot. Consequently, seven representative varieties were selected, as follows: (1) Lady, a small winter apple, the tree of which is a very upright grower with a tendency to form spurs, but that does not form axillary fruit buds to any extent; (2) Alexander, (3) Tetofski and (4) Yellow Transparent, all summer or early fall varieties that tend to be early bearers and that form both spurs and axillary fruit buds readily; (5) Wagener and (6) Jonathan, early winter varieties, bearing both axillary and spur fruit buds; and (7) White Pearmain, a winter variety that produces spurs readily, but does not form many axillary fruit buds. This selection includes varieties covering a considerable range so far as growth and general habit are concerned. It would have been better to have included one or two varieties that do not form spurs readily, though the selection made was entirely satisfactory in most regards.

As a dormant pruning, the trees were given only what was necessary to keep them in fairly good shape. On those trees that had received no summer pruning a fairly heavy heading back and thinning out was necessary. Those that were heavily summer-pruned, and had made little secondary growth, received very light thinning out and heading back in the winter. This pruning was not given until after growth started in the spring and accurate records of the bloom had been taken.

The pruning of the second summer, 1915, was done from June 24 to June 29. The summer varieties were pruned three to four days earlier than the winter varieties. In the case of each variety, one tree was left unpruned, the terminals of one were clipped, and one received a heavy heading back, removing about 50% of the current growth. If enough trees were available, one was given a very heavy heading, removing 75 to 100% of the current growth. The same trees received the same amount of heading each summer, except in those varieties in which only three trees were available. In most of these varieties, the tree that had the terminals pinched in 1914 was left unpruned in 1915; the one that was cut fairly heavily in 1914 was pinched in 1915; and the one that was cut very heavily the first summer was pruned only fairly heavily in 1915. Practically all trees received some thinning as well as the heading mentioned. Buds were collected for study on the following dates: (1) June 14, before any pruning was done; (2) June 29, soon after the pruning, on some varieties; (3) July 9; (4) July 30; (5) September 8; and (6) December 8 to 22.

In preparing the buds, Gilson's mixture was used as a killing and fixing agent, and the usual micro-technical methods were followed. The photomicrographs were taken by means of a Leitz Photomicrographic apparatus.

DEFINITION OF TERMS.

There are a few terms that will be used repeatedly in this report, that should be clearly defined to avoid any confusion that otherwise might arise in regard to their meaning. Axillary buds will refer to those buds, borne in the axils of the leaves on current season shoots, that themselves have not broken into growth and produced leaves. These may be axillary leaf buds, those which have not produced and are not producing flower parts; or axillary fruit buds, those which have produced or are producing flower parts. Spur as used here, will apply to any branch or shoot, either lateral or terminal, that makes an annual growth of less than four inches. This, of course, is a purely arbitrary standard. The term axillary spurs will be used to designate those spurs that are formed on current season's shoots, by the growth of axillary buds. Spur fruit buds will refer to those buds borne on spurs, in which flower parts are being produced. Axillary spur fruit buds will apply to similar buds on axillary spurs. Spur leaf bud will mean a bud on a spur which is not producing flower parts during the current season. A terminal bud will be the bud on the end of a current season's growth of more than four inches. These buds may be forming flowers, that is, terminal fruit buds, or they may be leaf buds.

In connection with summer-pruned shoots, primary will refer to that portion of the shoot produced before the summer pruning was given. Secondary shoots will denote those formed following the summer pruning.

The amount of pruning will usually be given specifically, but when not so given a light pruning will be understood to consist in a thinning out and heading of all branches amounting to a removal of about 25% of the current season's growth. A heavy pruning will be understood to consist of heading back and thinning the current growth, removing 50 to 60%; while a very heavy pruning will mean the removal of 75 to 100% of the current growth.

THE DEVELOPMENT OF AXILLARY LEAF BUDS.

While the development of fruit buds on spurs has been very carefully traced, and the manner of formation of flower parts has been fully investigated, apparently the axillary buds on the current season's growth, the buds from which the spurs develop, have never been carefully studied. The best methods of securing a good spur system, especially in young trees, is one of the largest questions in pruning practice today. In the case of certain varieties, considerable bloom will be produced from axillary and terminal buds, but this does not lessen the importance of obtaining spurs as early as possible in trees of the average variety. Spurs develop from the axillary leaf buds mainly during the first season following the one during which the axillary buds are formed. In this investigation, it has been possible to trace these buds from the time of their formation until the close of the growing season. The results here recorded are based on two seasons' work, with the seven varieties previously noted.

The axillary buds originate very close to the tip or apex of rapidly growing shoots. As the shoot elongates, the leaves are given off at the sides of the growing point, and the young bud appears first as simply an undifferentiated mass of rapidly dividing cells in the axils of these leaves. Plate X, Fig. 40, shows such a young bud at (a).

From the sections studied, it was impossible to determine exactly when the buds begin to form, but no primordia were found developing in the axils of leaves that were not fairly well formed.

The buds developed very rapidly and those subtended by half-grown leaves, one to two inches from the terminal, were well differentiated, with a growing point or apex, and bud scales being rapidly formed. The cells of the growing tip were not well differentiated and this, with the high staining reaction of this region, indicated that much growth was still taking place. Fig. 41 shows such a bud from Lady.

Buds well back from the growing tip, located on well-seasoned wood half to two-thirds the distance from the base of the shoot to the terminal, were collected at intervals during the summer. Such buds, taken June 14, were much increased in size over those previously mentioned. The axis of the bud had lengthened a great deal, and numerous scales had been formed. The cells of the crown were much better differentiated, though apparently considerable growth was still occurring. Fig. 42 shows such a bud from Wagener.

July 9. Buds of all varieties indicated considerable development still taking place. Individual buds showed much variation and it was evident that some had almost reached the condition in which they would pass the winter. The growth at this date was mainly confined to the region of the crown. Few bud scales were being formed, and cell activity in the crown was raising it above the base of the bud scales. While a distinct raising and rounding of the crown was apparent in all varieties studied, it seemed more pronounced in those which tended to produce axillary fruit buds. So much variation occurred, however, that this point could not be definitely established. This cannot be considered fruit-bud differentiation, however, for many buds reached this degree of development without forming flower parts.

July 30. Some development was still taking place, though entirely confined to the crowns, as on the earlier date. This was still more pronounced in those varieties which develop many axillary fruit buds. Tetofski and Jonathan buds showed the first distinguishable differentiation into flower parts. Other varieties showed no axillary buds which might be definitely recognized as fruit buds. Fig. 44 shows a Wagener bud of this date.

September 8. Many of the axillary buds had developed definite, recognizable flower parts. This was true of all varieties, except Lady and White Pearmain. The crowns of the buds not distinguishable as fruit were raised and well rounded out and developed. This was the condition through which the buds passed prior to definite flower part formation. Many of the buds in this condition at this time would undoubtedly become fruit buds later. Fig. 46 shows such a bud from Wagener.

December 8. Leaf buds showed a great deal of variation, as shown in Plate XII, Figs. 52-54. This represents the condition in which they passed the winter. Most of them showed little growth since September, or even July. Crowns were well differentiated, and rounded evenly. Some, as Fig 52, were so well developed that had this condition been found earlier in the season, they would almost certainly have been mistaken for fruit buds.

THE DEVELOPMENT OF AXILLARY FRUIT BUDS.

The importance of the axillary fruit buds in the apple has often been overlooked by horticultural writers. Kraus (17) speaking of bearing from buds on one-year wood says that varieties of apples and pears vary greatly in regard to the number of such buds formed. Some varieties "have a large proportion of their fruit buds on one year wood, especially while young, while others bear very few such buds."

The manner of differentiation of axillary fruit buds was very similar to that of buds on spurs. The crown of the bud was prominently raised, until more or less conical in shape. This condition is shown in Plate XIII, Figs. 58 and 60. Soon at the sides of the crown appeared regions of rapidly dividing cells, the primordia of the lateral blossoms in the flower cluster. Figs. 59, 61, 62, and 63 show this condition in several varieties. Before the appearance of these lateral blossom primordia, it was impossible to foretell how the bud would develop. A comparison of Plate XII, Figs. 52-57, showing the condition of leaf buds of December 8, with Plate XIII, Figs. 58 and 60, shows that a well developed and raised crown cannot be considered as satisfactory evidence that fruit-bud differentiation has occurred or is occurring.

Time of Differentiation.

During 1914, Tetofski was the only variety from which enough axillary fruit buds were sectioned to afford any definite idea as to time of differentiation. Material collected September 2, showed fruit buds well formed. In those most advanced all flower parts, including the primordia of the carpels, were formed. It is probable that differentiation in these most advanced buds occurred at least a month earlier. It is interesting to note that spur buds of July 23 showed as much development as the most advanced axillary buds of September 2.

During 1915, the time of differentiation was definitely established for several varieties. The earliest evidence of floral parts in axillary buds was found in a few of the Jonathan and Tetofski buds taken July 30. Other varieties examined showed no axillary fruit buds on this date.

September 8. Buds of the five varieties studied that normally form many axillary fruit buds showed flower parts well differentiated. Yellow Transparent and Wagener buds were in the earliest stage at which flower parts can be distinguished. Tetofski buds varied from the earliest stage of visible differentiation to having the primordia for the petals appearing. Jonathan varied from the earliest stage to having the sepals formed.

During this season the main period of axillary fruit bud formation in the varieties studied began after August 1, and a great many buds were apparently still being differentiated on September 8. This was fully one month later than spur buds on the same trees.

Occasional buds may begin the formation of flower parts much earlier than the season during which the main differentiation occurs. That this is true of axillary buds as well as those on spurs is shown by one Tetofski bud sectioned, which apparently had formed flower parts prior to June 24.

Later Development of Axillary Fruit Buds.

The later development of axillary fruit buds was apparently exactly like that of those on spurs. Plate XIV, Figs. 64 to 68 show stages in the development of these buds. It has already been pointed out that axillary buds were differentiated later than those on spurs of the same tree. Apparently they regained but little of this time before winter. During 1914, Tetofski spur buds of September 2 were more advanced than axillary buds of November 5. 1915 buds of both kinds gathered during December showed the buds from spurs much advanced over the axillary buds. In the spring, the axillary buds do not entirely catch up with the others, and often open as much as a full week later than the blossoms on spurs.

THE DEVELOPMENT OF BUDS ON SPURS.

The growth from the time the axillary bud breaks in the spring until the spur is developed has not been traced, but the response of the established spur to the pruning given has been studied.

Spur buds of the seven varieties noted were collected on the dates mentioned for axillary buds, regardless of whether they appeared to be leaf or fruit. The development in all varieties is so similar that a separate discussion of each is unnecessary.

June 14. Material collected at this time failed to reveal any flower parts being formed. Considerable variation was found between individual buds. Some were in a condition indicating that little growth was occurring. Such would probably not become fruit buds. On the other hand, a few were evidently in a state of active growth. Their crowns were somewhat raised, and they gave evidence of soon forming flower parts. Most of the buds were between these two extremes, however, and in no case could the buds sectioned be considered visibly differentiated on this date.

July 9. Most varieties had formed flower parts in some of the buds. Lady and Jonathan were in the youngest stages of flower formation, while Tetofski and Yellow Transparent in some cases had the sepals well formed. White Pearmain had the stamens forming in some buds. Those buds which could not be recognized as differentiated showed all variations between the two extremes noted for June 14.

July 30. All varieties showed differentiation just occurring in some buds. In others, there was evidence of differentiation having taken place considerably earlier and in that case flower parts had reached varying stages of development.

September 8. Leaf buds seemed to have reached the condition in which they would pass the winter. Little development was taking place in them. Some buds of four varieties, Jonathan, Lady, Alexander and Wagener, were in the youngest stages of flower formation. Since all varieties showed axillary fruit buds forming by this date, it is apparent that there was a continuous period of fruit bud formation from July until late September, rather than two distinct periods, one for the buds on spurs, and a later one for buds on one year wood.

December 8. Leaf buds were not advanced over those of September, and gave evidence of very little development since early July. Plate XV, Figs. 70 and 71, show a spur bud of June 14 compared to one of December 8. The degree of development attained by the fruit buds varied somewhat with the variety. Lady, Jonathan, and White Pearmain were in about the same stage of development; Wagener was somewhat more advanced, and Tetofski was slightly ahead of Wagener. This is especially interesting, since White Pearmain is the variety in which fruit buds were first differentiated, and Wagener was one of the last. It indicates that varieties which form flower parts earliest in the summer do not necessarily continue to develop faster than other varieties.

The fruit buds formed during 1914 were somewhat more advanced at the close of the growing season than were those of 1915. Buds collected in September, 1914, were slightly more advanced than at the same time in 1915, and it was very noticeable when buds of November, 1914, and December, 1915, were compared. Tetofski showed this to a very marked degree. Fruit buds of this variety, taken in November, 1914, showed the ovules in the carpels well formed in many cases, whereas, no evidence of ovules was present in buds taken in December, 1915. Such buds are compared in Plate XVI, Figs. 80 and 81. The blooming season during the spring of 1915 was fully one week earlier than that of 1916. It is quite probable that factors operating during the late summer and fall to hasten or retard flower development, as well as factors operating during the spring, materially influence the time of blossoming in our orchard fruits.

It is interesting to note the similarity that exists between buds borne on spurs and axillary buds. At the close of the growing season, leaf buds from the two positions, with their well differentiated crowns, appear to be very similar. The initial formation of flower parts, with the development of the crown that precedes this initiation, is apparently exactly alike. The difference between spur buds and axillary buds seems to be entirely in degree of development. rather than method. That they often function differently, is probably due to differences in nutrition caused by their positions in the tree in relation to the distribution of leaves about them.

THE INFLUENCE OF SUMMER PRUNING ON BUD DEVELOPMENT.

Influence on Fruit-Bud Formation.

The question of whether summer pruning does or does not encourage the formation of fruit buds is one of the most vital that must be considered in connection with the summer pruning problem. As was shown in the review of literature, the general opinion of writers during the past two centuries has been expressed in the words, "Summer Prune for Fruit." Some of the best authorities of recent years have expressed the same opinion. Very recently, however, two investigators have reported a lessened yield of fruit as a result of certain types of summer pruning. Batchelor (18) found that under the semi-arid conditions prevailing in Utah, Jonathan and Gano trees that were both summer and dormant thinned gave a lower average yield over a five-year period than did similar trees that received only dormant thinning. Alderman (19) found a negative correlation to exist between early bearing and varying amounts of summer pruning, the exact type of which is not stated.

In this present investigation, careful records were taken of the number of blossom clusters formed on each tree each of the two years. Not only the total number of clusters, but also their position on the tree, and whether from axillary, terminal, or spur buds was recorded. To make the blossom records as directly comparable as possible, a careful study of the varieties in the block was made, and twenty four selected, the individual trees in each of which were so nearly uniform in size and condition that most of the variation found to exist in number of fruit buds formed seemed directly attributable to the pruning received.

The number of clusters formed on each tree in these twenty-four varieties, together with the pruning given is shown in Table 12.

Table 12. Blossom Cluster Record, 1916.

Variety	Row and tree	Treat-ment	Old spurs	Axil-lary spurs	Ax. pri-mary	Ax. secon-dary	Ax. X	Term. X	Term. secon-dary
Bismark	5-22	ow	46	8	1	12	27	5	34
Bismark	5-23	hht	114	6	76	3	20	5	15
Bismark	5-24	lht	92	6	118	35	6	3	18
Bismark	5-25	X	50	0	0	0	155	17	0
Cox Orange	5-26	hht	20	1	0	0	0	2	0
Cox Orange	5-27	lht	82	0	5	0	0	0	0
Cox Orange	5-28	X	167	0	0	0	55	10	0
Early Harv.	6-1	hht	22	20	0	0	0	7	3
Early Harv.	6-2	lht	52	6	2	4	0	11	2
Early Harv.	6-3	X	12	0	0	0	0	6	0
Red Astr.	6-13	ow	75	0	0	17	0	2	9
Red Astr.	6-14	hht	45	2	1	19	0	6	1
Red Astr.	6-15	lht	174	14	3	99	18	6	8
Red Astr.	6-16	X	22	0	0	0	155	42	0
Lady	6-21	hht	100	0	0	0	0	0	0
Lady	6-22	lht	79	3	0	0	0	0	0
Lady	6-23	ow	67	0	0	0	0	0	1
Lady	6-24	X	144	0	0	0	8	4	0
Banana	7-7	ow	54	0	0	0	0	5	2
Banana	7-8	hht	44	13	5	0	4	6	6
Banana	7-9	lht	40	8	2	0	6	16	1
Banana	7-10	X	135	0	0	0	350	70	0
Arkansas	11-2	hht	80	8	0	0	1	1	1
Arkansas	11-3	lht	237	9	1	0	0	0	1
Arkansas	11-4	X	141	0	0	0	20	18	0
Wagener	11-5	lht	242	23	38	217	0	4	67
Wagener	11-6	hht	17	0	0	1	0	1	1
Wagener	11-7	ow	175	3	0	40	1	2	9
Wagener	11-8	X	65	0	0	0	248	51	0
Yel. Bellflower	11-16	hht	6	0	1	0	0	2	0
Yel. Bellflower	11-17	lht	41	17	3	0	0	3	4
Yel. Bellflower	11-18	X	97	0	0	0	286	65	0
Waxen	11-19	hht	52	18	0	0	0	9	7
Waxen	11-20	lht	49	54	8	0	2	28	0
Waxen	11-21	X	16	0	0	0	0	22	0
Fameuse	11-28	hht	20	4	0	0	0	1	7
Fameuse	11-29	lht	12	7	1	0	10	5	3
Fameuse	11-30	X	7	0	0	0	14	23	0
Rhode Island	12-2	X	75	0	0	0	48	52	0
Rhode Island	12-3	hht	5	0	0	0	0	1	1
Rhode Island	12-4	lht	77	14	5	7	1	15	16
Opalescent	12-8	hht	150	6	8	0	2	4	0
Opalescent	12-9	lht	180	5	9	1	3	5	0
Opalescent	12-10	X	120	0	0	0	80	18	0
Livland Rasp.	12-14	hht	17	6	5	0	4	7	0
Livland Rasp.	12-15	lht	48	0	4	0	333	8	0
Livland Rasp.	12-16	X	51	0	0	0	311	42	0

Table 12—*Continued*

Variety	Row and tree	Treat-ment	Old spurs	Axil-lary spurs	Ax. pri-mary	Ax. secon-dary	Ax. X	Term. X	Term. secon-dary
Glowing Coals	12-19	hht	10	20	2	20	3	7	12
Glowing Coals	12-20	lht	8	11	4	45	9	4	17
Glowing Coals	12-21	X	1	0	0	0	68	20	0
Alexander	12-28	hht	7	8	0	0	1	1	7
Alexander	12-29	lht	42	3	5	3	15	6	14
Alexander	12-30	X	11	0	0	0	119	32	0
Yel. Trans.	13-7	hht	27	8	0	2	4	4	6
Yel. Trans.	13-8	lht	25	7	0	8	2	5	14
Yel. Trans.	13-9	X	34	0	0	0	83	57	0
Yel. Trans.	13-11	ow	53	5	0	0	0	1	0
Banana	13-22	hht	10	1	0	0	4	6	5
Banana	13-23	lht	61	4	5	2	0	8	7
Banana	13-24	X	62	0	0	0	78	45	0
Tetofski	14-10	X	42	0	0	0	145	25	0
Tetofski	14-11	lht	27	9	2	100	6	5	33
Tetofski	14-12	hht	18	12	19	43	10	1	20
Esopus	14-16	lht	8	0	0	0	1	7	0
Esopus	14-17	hht	9	4	0	0	0	0	0
Esopus	14-18	X	0	0	0	0	0	8	0
Ortley	15-5	X	67	0	0	0	82	4	0
Ortley	15-6	lht	56	2	0	0	0	2	1
Ortley	15-7	hht	179	4	0	0	0	11	3
Jonathan	15-28	lht	19	3	0	40	3	4	3
Jonathan	15-29	hht	4	0	0	4	5	4	0
Jonathan	15-30	X	41	0	0	0	342	23	0
Oldenburg	16-13	hht	157	16	6	0	6	10	2
Oldenburg	16-14	lht	39	0	0	0	0	17	0
Oldenburg	16-15	X	86	0	0	0	290	16	0
Delicious	16-19	hht	1	0	0	0	0	0	0
Delicious	16-20	lht	22	0	0	0	0	3	0
Delicious	16-21	X	30	0	0	0	0	8	0

Primary axillary refers to buds on wood produced before the summer pruning; Secondary axillary, to buds on growth following summer pruning; Axillary X, to axillary buds on unpruned shoots; Terminal X, to terminals on unpruned shoots, and Secondary terminals to those on shoots produced following summer pruning, i. e., secondary shoots.

Trees marked X in the table received no summer pruning; lht, light heading and thinning; hht, heavy heading and thinning; ow, headed to the base of current season's growth, or into previous season wood.

Only the 1916 records are given here. The bloom during the spring of 1915 was so light on all the varieties that the difference between trees under different pruning treatments cannot be regarded as significant. The number of trees of any one variety from which these 1916 data were taken is too small to make the results for that variety conclusive. The fact, however, that twenty-four varieties, selected because of the uniformity of the individual trees, are represented, makes the combined results very suggestive.

The total number of blossom clusters formed on each group of trees, with the average number per tree, is shown in Table 13.

Table 13. Gross Blossom Records.

Type of Pruning	No. trees	Total No. blossom clusters	Average No. blossom clusters per tree
Unpruned	24	5,127	214
Lightly pruned	24	3,198	133
Heavily pruned	24	1,962	82
Very heavily pruned	6	656	109

These figures show bloom records very much in favor of no summer pruning. Not considering the six very heavily pruned trees, a group too small for the results to be conclusive, light gave decidedly more bloom than heavy summer pruning. While these figures are interesting as representing more or less average conditions, the records of the kinds of buds from which these blossoms were produced, indicate more definitely the influence of the summer pruning. Table 14 shows the blossom clusters produced on the old spurs, down in the tree.

Table 14. Blossom Buds on Old Spurs.

Type of Pruning	No. of trees	Total No. blossom clusters on old spurs	Ave. No. per tree blossom clusters on old spurs
Unpruned	24	1,484	62
Lightly pruned	24	1,712	72
Heavily pruned	24	1,272	53
Very heavily pruned	6	472	79

The difference in number of such blossoms between the trees receiving the different pruning treatments was so small that it might easily have been due entirely to natural variation in the trees. It would seem that the interpretation to be placed upon the figures is that summer heading back had very little influence upon the development or non development of fruit buds on the spurs down in the tree. This conclusion was strongly supported by the general appearance of the trees.

Table 15 shows the total number and average number per tree of fruit buds borne on one year wood. On the unpruned trees, these were from axillary buds, axillary spurs sometimes formed without pruning, and terminals; while for the pruned trees it included also those from axillary spurs stimulated to form by the pruning.

Table 15. **Blossom Buds on Current Season's Wood.**

Treatment	No. of trees	Total fruit buds on current wood	Ave. per tree buds on current wood
Unpruned	24	3,643	152
Lightly pruned	24	1,486	62
Heavily pruned	24	690	29
Very heavily pruned	6	184	31

Here is evidence that far more fruit buds are produced on the one year wood if no summer heading is practiced. Even a light pruning reduced by more than half the number of such buds, while a heavy pruning led to a still further reduction. Rather than causing the axillary leaf buds to be changed over into fruit buds, it appears that the summer heading actually prevented many from making this change. Added weight is given to the figures substantiating this conclusion by the blossom records for the spurs of the same trees, for the number of blossom clusters formed on spurs was nearly uniform, indicating that the great variation in buds on one year wood must have been due to the pruning given. Furthermore, the influence of the pruning apparently was not felt to any great extent in shoots of the tree that remained unpruned. Plate XVIII, Fig. 89, shows an unpruned shoot in the midst of a heavily headed White Pearmain tree. Very few fruit buds were formed on the shoots that were cut back, while the unpruned shoot was lined with axillary fruit buds. This same condition was observed in several varieties.

It is well in this connection to note the position of the fruit buds following each type of pruning. In the trees not summer pruned most of the axillary fruit buds were formed well out toward the terminal of the current season shoots. In certain varieties occasional axillary fruit spurs were formed toward the base of these shoots. That many such buds would normally be removed in a winter heading back is pointed out by Kraus (17). The position of the buds of each variety under the different pruning treatments is given in Table 12. Table 16 gives the totals in each position for these groups.

Table 16. Distribution of Fruit Buds on One Year Wood.

Treatment	No. trees	New spur	Primary axillary	Secondary axillary	Axillary X	Term. X	Term. secondary
Unpruned	24	...	...	...	2967	678	...
Lightly pruned	24	205	215	561	85	162	228
Heavily pruned	24	157	123	88	59	95	97

Blossom buds on new spurs forced out by the summer pruning, and from primary axillary buds will not be disturbed by most types of subsequent winter pruning. Unless a considerable amount of secondary growth has been made, most of these shoots will need little heading back the following winter. Hence, most of the fruit buds that are produced on one year wood, in connection with an early summer heading back, will be saved. Plates XVIII and XIX show how two varieties have responded to the summer pruning.

From this it is apparent that the actual loss in axillary fruit buds from early summer heading was not nearly so great as appears from simply noting the totals in Table 15. While there was a much smaller number formed, those that did develop were in such a position that they could be saved without sacrificing the form and strength of the tree. Probably the number of such buds formed on the lightly summer-pruned trees was not far from what would be left on the trees not summer-pruned following an average dormant heading back. The fact remains, however, that early summer pruning of the type practiced tended to lessen the number of fruit buds formed on one year wood.

These results indicate further that we must have more than simply records of the total yield of a tree following "summer pruning" if we are to arrive at the fundamental influences of the pruning treatment. In the first place, numbers or pounds of fruits produced are not accurate measures of the number of fruit buds formed, though over a long period, such data show some of the influences of the pruning. Again, the position in the tree of fruits or fruit buds is of the greatest importance. It is certain that the different types of summer pruning cause a greater response in some parts of the tree than in other parts, and records for the tree as a whole are not nearly so significant as records for its different portions. Finally, the type of pruning, whether thinning or heading back, pinching the terminals or heading heavily, combinations of all these, or any other treatment, together with the time of the pruning, must be considered in connection with the response obtained. All too often the term "summer pruning" which alone means but little, has afforded the only description of the type of pruning given.

INFLUENCE OF SUMMER PRUNING ON FRUIT BUDS FOLLOWING DIFFERENTIATION.

Frequently, it has been observed, that axillary fruit buds may be forced out into bloom by a summer pruning cut being made just above them. Owing to the early date of the pruning, only one such bud from immediately below the pruning cut, was among those sectioned. This bud, shown in Plate XVI, Fig 69, was taken July 9, from a Tetofski tree pruned heavily, June 24. The bud was rapidly pushing out into vegetative growth, but flower parts were also developing. This bud must have been in a very young state of flower differentiation when the pruning was done. Whether or not it would have properly developed its flower parts, and blossomed following the pruning, is questionable, but it is very interesting to note that flowers even started to push out when the bud was in such a young stage.

The same effect was noted in the case of buds on spurs. Each year, certain trees were cut back to spurs. On White Pearmain trees so treated, the spur buds forced out, and several blossom clusters opened during August. During the summer of 1915, the pruning was done on these trees on June 29, when the flower parts were in a very early stage of development. Plate XV, Fig. 75, shows one of these buds collected July 9. That they would push out from this stage, forming flowers rather than shoot growth, indicates that buds once differentiated as fruit will not revert readily to shoot growth as a result of summer pruning. It also indicates that some fundamental change must take place in the bud when it is differentiated as fruit.

No influence of the summer heading could be detected in axillary fruit buds or in buds on spurs so far removed from the pruning cut that they were not forced out into growth. The rate of development was not affected, and no difference could be detected between these buds and similarly located ones from unpruned trees. Records of set of fruit from these buds, which might have been indicative of the conditions of nutrition in them, were not taken.

Summer pruning may alter the time of differentiation of fruit buds, and thus alter the degree of development attained on any given date, but the extent to which this occurred was not definitely established. Fruit buds taken from secondary current season's wood in December apparently were as far advanced as those from unpruned trees. Fruit buds on axillary spurs formed as a result of summer pruning showed about the same stage of development found in axillary buds of the same date. One of these buds, compared with one from an old spur of White Pearmain is shown in Plate XVI, Figs. 76 and 77. That buds on such spurs would be behind those of old spurs in differentiating is to be expected, since the axillary spurs were not formed until after differentiation had taken place in the buds of established spurs.

The greatest influence of early summer heading back, so far as fruit buds are concerned, apparently is exerted in the potential fruit buds, determining whether or not they shall form flower parts. Apparently the buds responded to it but little after differentiation had occurred. Furthermore, this influence seems to be largely restricted to the one year wood.

THE INFLUENCE OF EARLY SUMMER HEADING BACK ON LEAF BUDS.

Leaf buds from the immediate region of the pruning cut were sectioned to determine their method of pushing out into active vegetative growth. At the end of four days, on vigorously growing shoots, the terminal buds remaining on the primary wood began to show rapid cell division in the crown. At the sides of this crown, leaves are formed as at the terminal of a growing shoot. The crown elongates, the leaves push out through the bud scales, and the bud continues to grow as a new shoot. Plate XI, Figs. 45 and 46, show Yellow Transparent buds taken five and thirteen days respectively after pruning.

Of much interest in this connection is the relative number of buds that break into active growth following a summer pruning and an equally severe winter pruning. While varieties tending to form many shoots following winter pruning have the same tendency following summer heading, and while the number of shoots produced varies with the vigor of the tree, a much smaller number are produced following summer than following winter heading. The number of shoots produced in summer varies somewhat with the severity of the heading back. Very often shoots that are merely pinched will only force out one bud. Also relatively few axillary spurs are formed following summer heading. Usually one to two such spurs per shoot will push out, the rest of the buds on the primary growth not breaking, though this also varies considerably with the variety and with the vigor of the tree.

What has been said for axillary buds seems to be equally true for spurs, when the pruning is a cutting back into old wood. The method of pushing out into growth is very similar to that in axillary buds.

A careful study was made of the buds on the primary wood not forced out into growth by the pruning, to determine the influence of the pruning in such buds. Many of them were sectioned, both from trees lightly and heavily pruned, but no influence of the pruning could be detected. So far as amount or rapidity of development or appearance of the buds at the end of the growing season is concerned, apparently summer heading exerted little influence. This does not indicate that there may not have been some variation in nutrition or food storage in these buds, but so far as any visible influence of the pruning is concerned, none was found to exist.

The response of these buds the following spring was noted. They apparently tended to form fruit spurs to about the same degree as buds an equal distance from the base of unpruned shoots. In other words, the summer pruning seemed to exert little influence on whether or not these buds developed into spurs during the following season.

LEAF BUDS ON SECONDARY SHOOTS.

There is no apparent change in the method of formation and development of leaf buds on secondary shoots from that shown on primary shoots. They were formed later in the season, and grew until later in the fall than most of the axillary buds on unpruned shoots. On September 8, buds showed very active growth taking place. Plate XI, Figs. 47 to 51 show such buds from two varieties, compared with buds of unpruned shoots. By December, these buds were in much the same condition as those on unpruned shoots. These buds are illustrated in Plate XII, Figs. 55-57.

On a normal, unpruned shoot of practically all varieties, there are a few small, poorly developed buds at the base, which usually do not break into growth the following spring. The number of such buds varies with the variety, with particular trees of a variety, and with individual shoots in a tree. It is interesting to note that shoots formed following an early summer heading, i. e., secondary shoots, exhibit the same condition though to a smaller degree. There are fewer buds that fail to break. Since this area of dormant buds is smaller in secondary than in unpruned shoots, even a larger percentage of the buds on secondary shoots form spurs or shoots the season following, unless many of them are removed in a subsequent winter pruning. This is of the greatest importance in explaining the large increase in number of spurs formed following early summer heading and thinning, as discussed in another part of this bulletin.

Gardner (20) has pointed out that few spurs are developed following a rather heavy winter heading back because so many of the axillary buds are entirely removed or are forced out into shoot growth. Through early summer pruning and the subsequent growth response, the tree is left in good form and it is unnecessary to remove a large number of the axillary leaf buds, or potential spurs, in a subsequent winter pruning. Plate XVII, Figs. 82 and 84, show spur formation following summer pruning with no dormant heading on two varieties.

SUMMARY.

A study of the influence of summer pruning the apple upon bud development under Western Oregon conditions, warrants the following statements:

1. The method and season of spur fruit bud differentiation and development was found to be identical with that described by previous investigators.
2. Spur leaf buds developed during early summer, but little growth occurred later than July in those varieties investigated.
3. Axillary buds developed very rapidly for a time following their initial formation, then grew slowly until about the time shoot growth ceased.
4. Initial differentiation of axillary fruit buds occurred about one month later than in spur buds on the same trees. The main differentiation took place during late August and September.
5. Method of development of axillary fruit buds seemed to be exactly like that of spur fruit buds. However, they followed spur buds in point of time of differentiation, and never entirely caught up with them.
6. The difference between axillary buds in general and buds on spurs in general seemed to be in degree of development, rather than in method.
7. No influence of the early summer heading back could be detected in the number of fruit buds formed on established spurs.
8. Early summer heading back tended greatly to reduce the number of fruit buds formed on the one year wood.
9. Leaf buds on pruned shoots, both on the primary and secondary

growth, were not visibly influenced by the pruning. They appeared to function like similarly located buds on unpruned shoots.

10. This, coupled with the fact that the form of the summer-pruned shoot, which allows many axillary buds to be left at the time of the following winter pruning, accounts for the greatly increased number of spurs in trees that have received regularly an early summer heading back.

ACKNOWLEDGMENTS.

The writer wishes to express his appreciation for assistance received during the progress of this investigation. Thanks are due Professor C. I. Lewis, Chief of the Division of Horticulture, for affording opportunity to carry on the work. Also to Professor E. J. Kraus, under whose immediate supervision the investigation was carried on, for his criticism of the work and many helpful suggestions; Professor V. R. Gardner for his criticism of the manuscript and Mr. A. F. Barss, for aid at various times.

LITERATURE CITED.

1. Nochden, G. H. A Method of Improving the Productiveness of Fruit Trees, Trans. London Hort. Soc. Vol. II, p. 262, 1817.

2. Quintinye, Jean de la. Instructions pour les Jardins Fruitiers et Potagers, Pt. 2, p. 579, 1746.

3. Hovey, C. M. A Few Hints on Summer Pruning Pyramidal Pear Trees, Hovey's Mag. of Hort., Vol. XV, p. 301, 1849.

4. Quinn, P. T. Pear Culture for Profit, p. 72, 1889.

5. Pearson, A. H. Pruning Fruit Trees, Jour. Roy. Hort. Soc., Vol. XIX, p. 274, 1896.

6. Waugh, F. A. The American Apple Orchard, p. 90, 1912.

7. Paddock, W. and Whipple, O. B. Fruit Growing in Arid Regions, p. 112, 1910.

8. Lewis, C. I. Pruning Young Trees, Oregon Agr. Exp. Station, Bul. 130, Pt. 3, 1915.

9. Kraus, E. J. Fruit-Bud Formation Related to Orchard Practice. Proceedings, Wash. State Hort. Assn. 1915.

10. Goff, E. S. The Origin and Early Development of the Flowers in the Cherry, Plum, Apple and Pear, Sixteenth Report, Wisconsin Agr. Exp. Station, 1899.

11. Goff, E. S. Investigation of Flower Buds, Seventeenth Report, Wisconsin Agr. Exp. Station, 1900.

12. Goff, E. S. Investigation of Flower Buds, Eighteenth Report, Wisconsin Agr. Exp. Station, 1901.

13. Drinkard, A. W. Fruit-Bud Formation and Development, Report Virginia Agr. Exp. Station, 1909 and 1910.

14. Bradford, F. C. Fruit-Bud Development of the Apple, Oregon Agr. Exp. Station, Bul. 129, 1915.

15. Pickett, B. S. Fruit-Bud Formation, New Hampshire Agr. Exp. Station, Bul. 153, 1911.

16. Gourley, J. H. Studies in Fruit-Bud Formation, New Hampshire Agr. Exp. Station, Tect. Bul. 9, 1915.

17. Kraus, E. J. The Study of Fruit Buds, Oregon Agr. Exp. Station, Bul. 130, Pt. 2, 1915.

18. Batchelor, L. D. and Goodspeed, W. E. The Summer Pruning of a Young Bearing Apple Orchard, Utah Agr. Exp. Station, Bul. 140, 1915.

19. Alderman, W. H. The Results of Apple Pruning Investigations, Proceedings Soc. for Hort. Science, p. 59, 1915.

20. Gardner, V. R. Pruning the Bearing Apple and Pear Tree, Oregon Agr. Exp. Station, Bul. 130, Pt. 4, 1915.

EXPLANATION OF PLATES.

Plate X. The development of the axillary leaf bud.

- Fig. 40. Terminal of growing Spitzenburg shoot, showing at (a) the first indication of the axillary bud.
- Fig. 41. Axillary bud of Lady, from near growing tip.
- Figs. 42-45. Wagener buds from median portion of shoot, June 14, July 9, July 30, September 8.

Plate XI. Axillary leaf buds as affected by pruning.

- Fig. 46. Yellow Transparent, forcing out five days after pruning, and Fig. 47, same, 13 days after pruning.
- Fig. 48. Yellow Transparent of September 8 from primary wood, and Fig. 49, from secondary wood of lightly pruned tree.
- Fig. 50. Bud from unpruned shoot of Lady, taken September 8.
- Fig. 51. Bud taken September 8 from secondary shoot of Lady following a heavy pruning.

Plate XII. Axillary leaf buds of December 8.

- Fig. 52. From unpruned Jonathan shoot.
- Fig. 53. From Tetofski.
- Fig. 54. From White Pearmain.
- Fig. 55. From secondary growth produced following a light pruning on Tetofski.
- Fig. 56. Same, following a very heavy pruning.
- Fig. 57. From secondary growth following moderately heavy pruning on Wagener.

Plate XIII. Axillary fruit-bud differentiation September 8.

- Fig. 58. Wagener, not yet distinguishable as a fruit bud.
- Fig. 59. Wagener, early state of differentiation.
- Fig. 60. Tetofski, not yet recognizable as a fruit bud, and Fig. 61, an early stage of flower formation.
- Figs. 62 and 63. Early stages in flower formation of Jonathan showing primordia of lateral buds.

Plate XIV. Various stages in the development of axillary fruit buds.

Fig. 64. Tetofski, September 8.

Fig. 65. Tetofski, September 8 (more advanced).

Fig. 66. Tetofski, December 8.

Fig. 67. Tetofski, December 8 (more advanced).

Fig. 68. Wagener, December 22.

Fig. 69. Young axillary fruit bud of Tetofski, forcing out into growth.

Plate XV. Spur bud development.

Fig. 70. Average Jonathan leaf spur of June 14.

Fig. 71. Average Jonathan leaf spur of December 8.

Fig. 72. Leaf bud from axillary spur of Wagener, December 22.

Fig. 73. Leaf bud from old spur of Wagener, December 22.

Fig. 74. Leaf bud from spur of Lady, forcing into growth.

Fig. 75. Fruit bud from spur of White Pearmain, forcing out.

Plate XVI. Spur fruit buds.

Fig. 76. White Pearmain, fruit bud from old spur, Dec. 22.

Fig. 77. White Pearmain, fruit bud from axillary spur, Dec. 22.

Fig. 78. Jonathan, average spur fruit bud, December 8.

Fig. 79. Jonathan, average terminal fruit bud, December 8.

Fig. 80. Tetofski, average spur, November 5, 1914.

Fig. 81. Tetofski, average spur, December 8, 1915.

Plate XVII.

Figs. 82-83. Spur formation following summer pruning with no winter heading on Arkansas.

Fig. 84. Same, on Rhode Island.

Fig. 85. Waxen, headed June 25, 1915, showing new spurs formed as result of summer pruning, photographed April 15, 1916.

Plate XVIII. Response to summer pruning.

Fig. 86. Alexander, unpruned during summer of 1915, photographed April 8, 1916.

Fig. 87. Alexander, pruned lightly, June 25, 1915, photographed April 8, 1916.
graphed April 8, 1916.

Fig. 88. Alexander, pruned heavily, June 25, 1915, photo-

Fig. 89. Unpruned shoot of White Pearmain in heavily pruned tree.

Plate XIX. Response to summer pruning in Yellow Bellflower.

Fig 90. Unpruned during summer of 1915, photographed April 8, 1916.

Fig. 91. Pruned lightly, June 28, 1915, photographed April 8, 1916.

Fig. 92. Pruned heavily, June 28, 1915, photographed April 8, 1916.

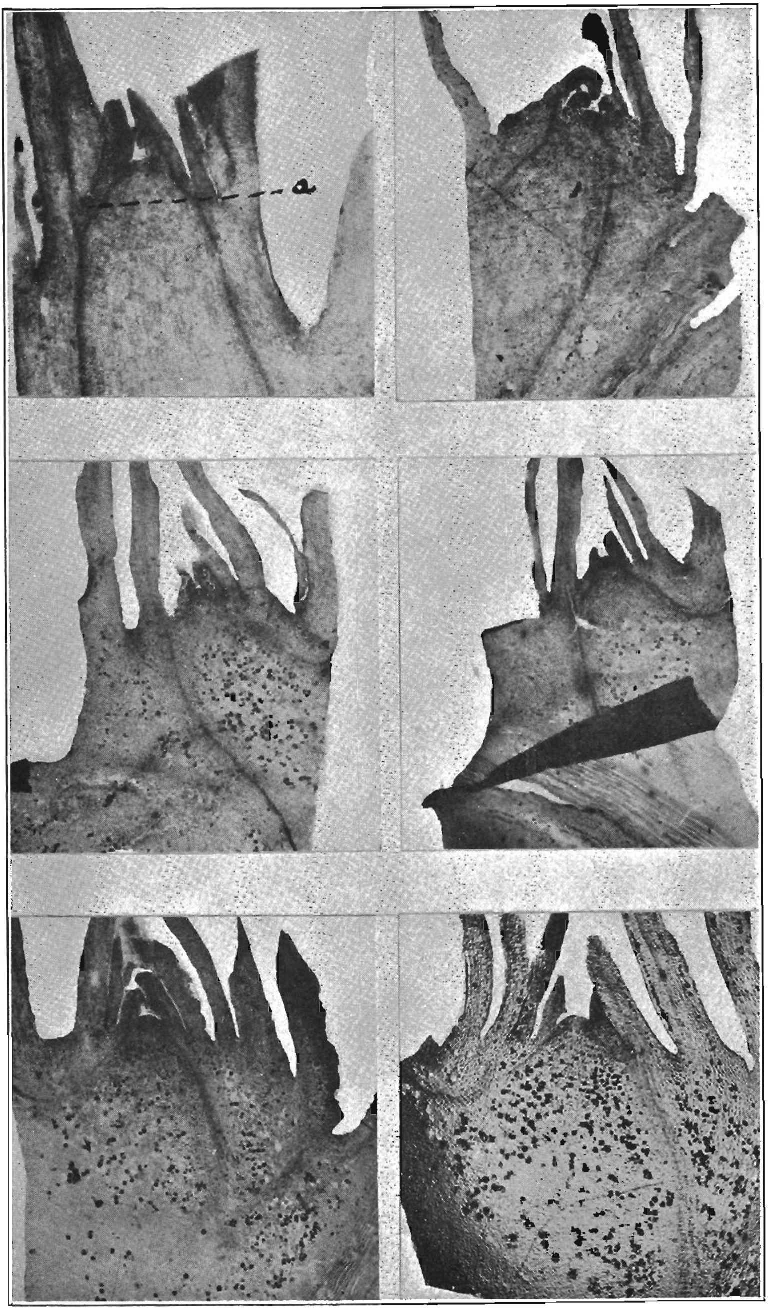


Plate X, Figs. 40-45

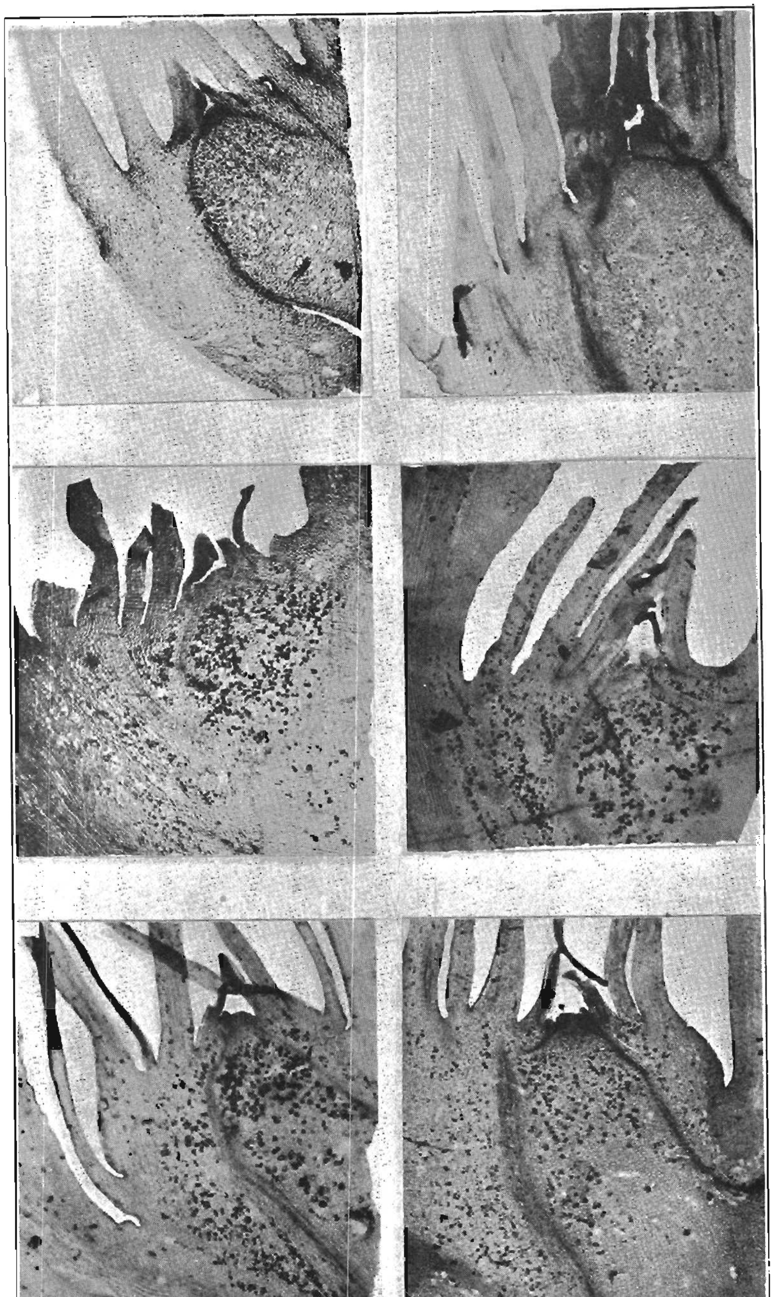


Plate XI, Figs. 46-51.

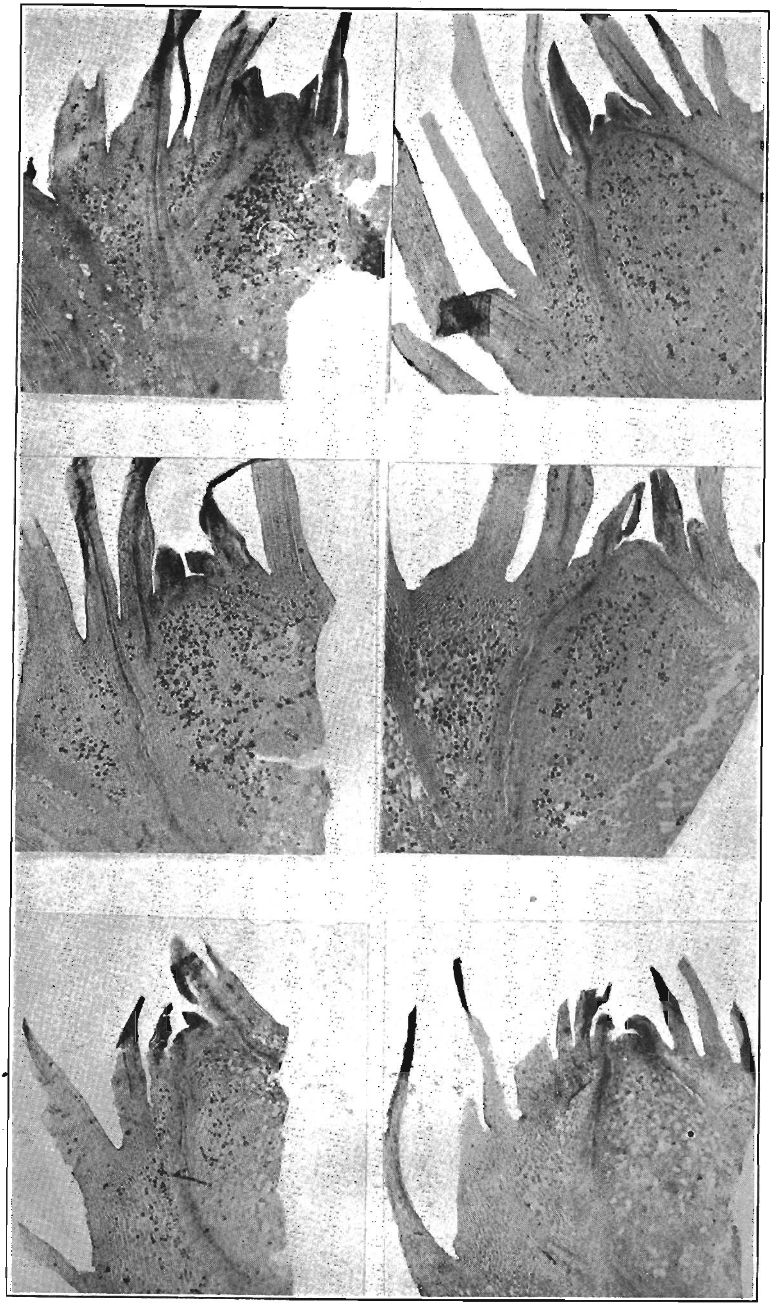


Plate XII, Figs. 52-57.

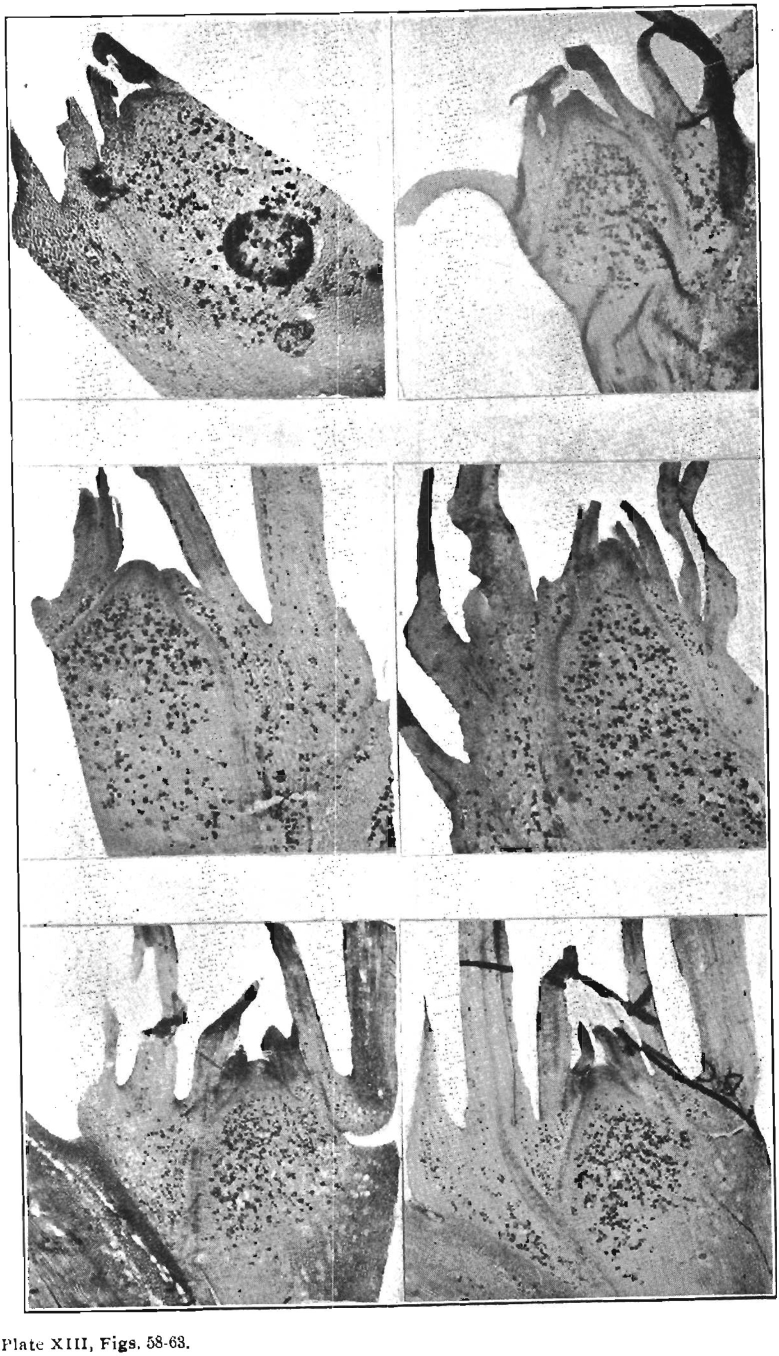


Plate XIII, Figs. 58-63.

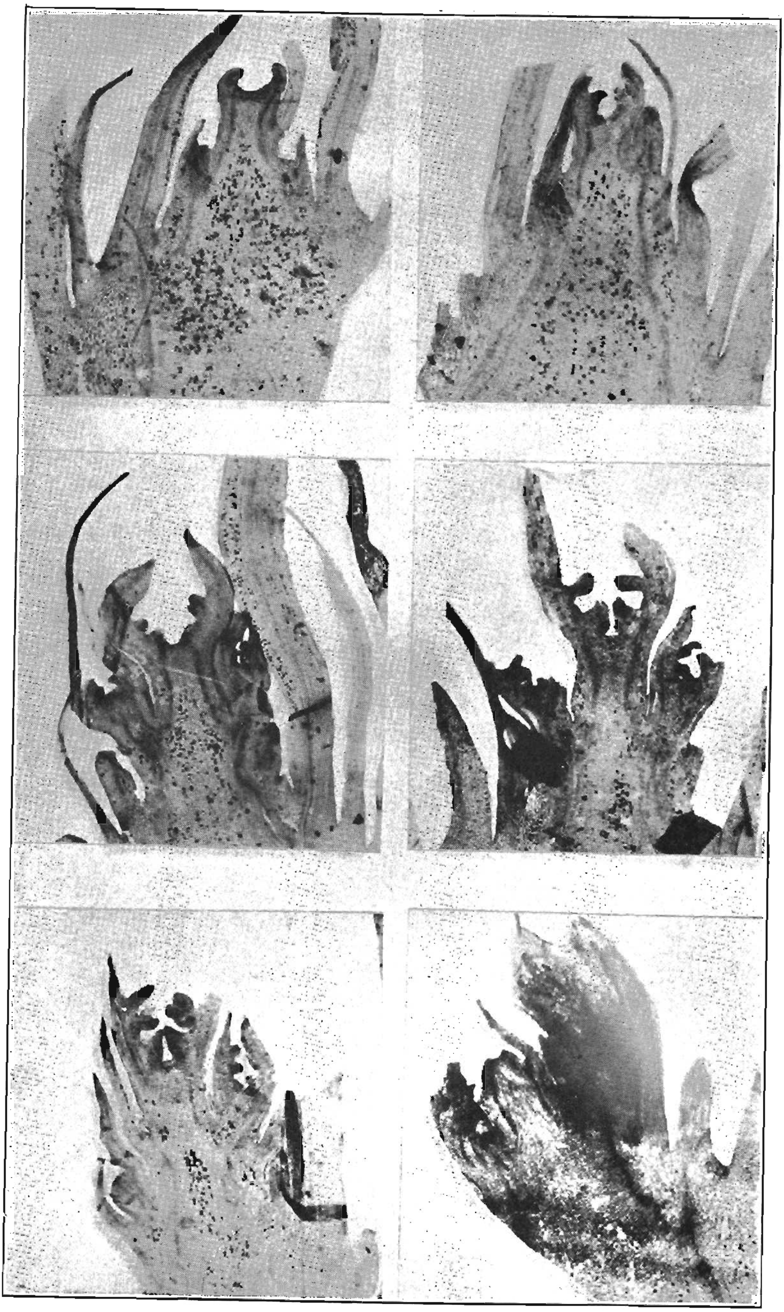


Plate XIV, Figs. 64-69.

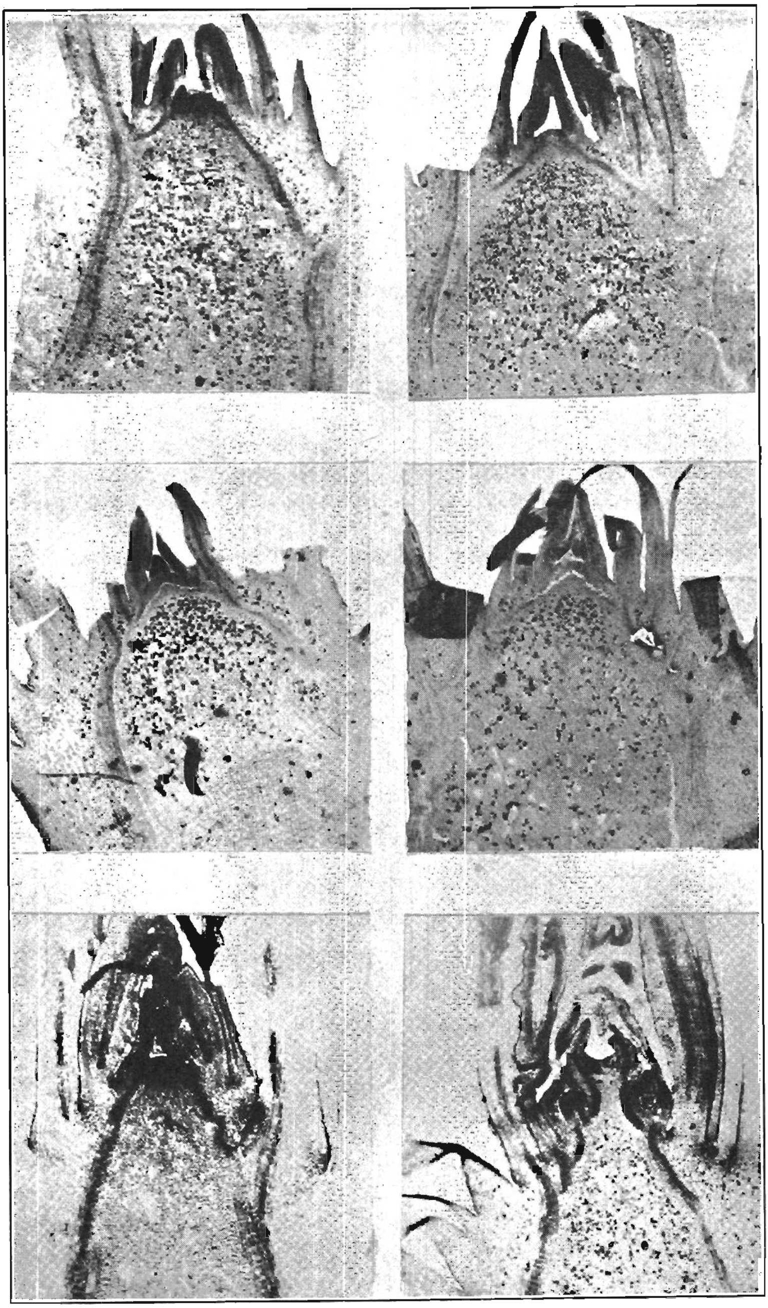


Plate XV, Figs. 70-75.

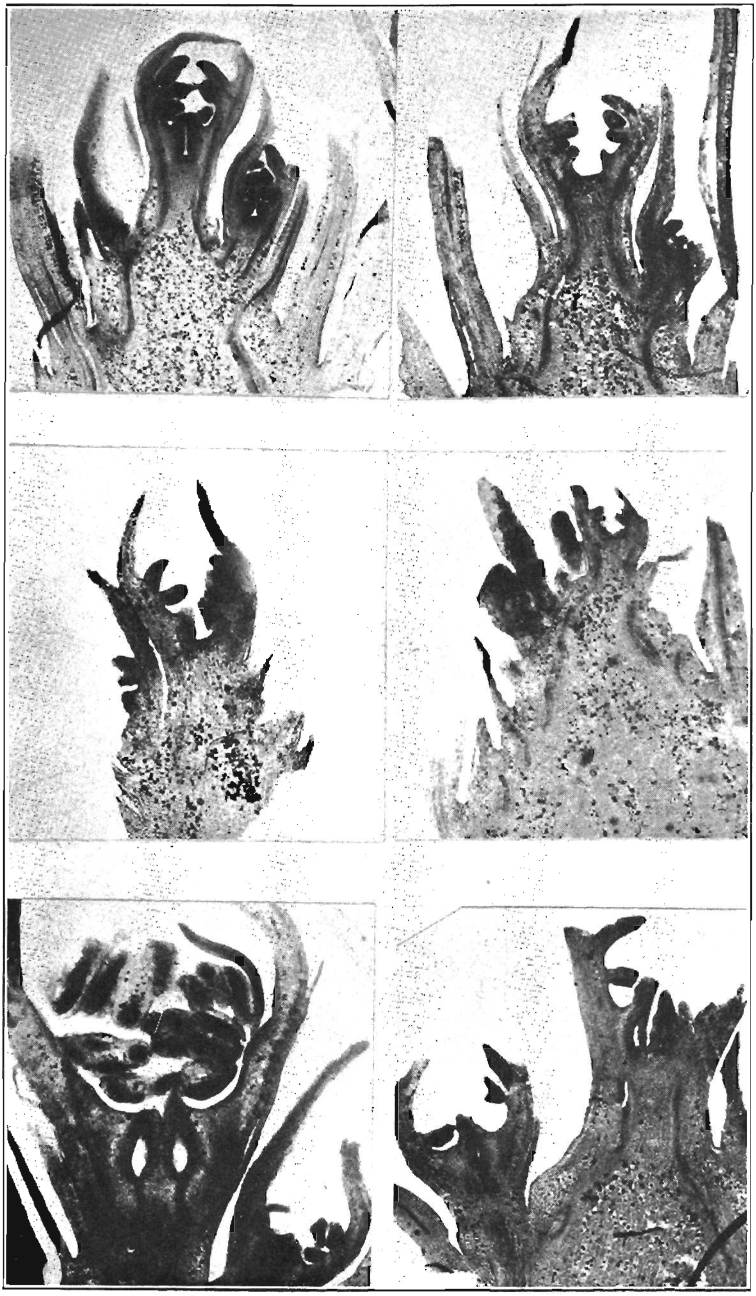


Plate XVI, Figs. 76-81.

Plate XVII. Figs. 82-85.

Plate XVIII, Figs. 86 89.

Plate XIX, Figs. 90-92.

A STATISTICAL STUDY OF THE FRUIT-SPUR SYSTEM OF CERTAIN APPLE TREES

By A. F. Yeager.

INTRODUCTION.

While extensive pruning and cultural experiments have been conducted on apple trees, and their effects on fruit production determined in a general way, we have been prone to consider the apple tree as a whole. There never has been made, so far as the writer has been able to discover, any definite statistical record of the part of the tree most closely associated with fruit production—namely, the fruit spur.

OBJECT.

This investigation was made in an effort to determine what relation the various characteristics of the spur bear to fruit production. If certain characteristics are found to be associated with large production, we can then adopt such pruning and cultural methods as will tend to develop these characteristics.

An attempt was made to obtain evidence throwing light upon the following questions: What is the relation between the age of a spur and its production? What is the relation between the diameter of a spur and its production? What is the relation between the length of a spur and its production? What is the relation between the length of growth of the spur one season and its production the following season? What is the relation between the diameter of the branch to which a spur is attached and its production? What is the relation of the position of a spur in the tree to its production?

DEFINITION OF TERMS.

When the work was started, the writer was immediately confronted with the question, "What is a fruit spur?" It is generally defined as a short lateral branch that bears fruit, but since there is a variation in annual growth of these lateral branches that bear fruit from a few millimeters to twenty or more centimeters, it was thought best to fix some arbitrary limit beyond which such a lateral growth would be considered to be a shoot or branch and not a spur. This limit was fixed at ten centimeters of growth in one year.

In this report it will be necessary to refer to spurs as being of a certain age. A spur during its first year's growth is regarded as one year old, during its second year's growth as two years old. From this classification it is evident that fruit cannot be borne on a one-year-old spur. Shoots often bear lateral fruit buds, however, and these fruit buds not only develop fruit the following season but give rise to true fruit spurs as well. Such fruit spurs a year later would naturally be classed as two years old. Consequently in this study, fruits that developed from axillary fruit buds have been considered as borne on one-year-old spurs.

MATERIALS AND METHODS.

Two series of data were collected. One entire series was furnished by a single twenty-five-year-old Grimes tree. This tree is located in the southwest corner of the College orchard at Corvallis, and stands free from all other trees with the exception of a small portion of the top of the north side, which touches another tree of the same variety. In the fall of 1915 all the apples were gathered from this tree, each apple being marked with a number. At the same time a tag bearing the same number was tied to the spur. The apples were then taken to the laboratory, weighed to the closest five grams, and the weights recorded. Later, as it became convenient, the spurs were cut from the tree, in each case the location in the tree and the size of the branch from which the spur came being marked on the reverse side of the tag. They were then taken to the laboratory, and their lengths, diameters, lengths of growth the previous season (1914), and their life-histories recorded. This provided a complete record for each spur. Table 17 presents three such records.

Table 17. Record of three average spurs.

Age	Part tree	Fruit wt. gms.	Branch diam. cm.	Spur diam cm.	Spur. length cm.	Growth in 1914 cm.	History of spur
13	N. U. X.	220	2.8	.9	11.0	.5	OFBOFOFOFOFO
7	N. L. I.	105	.7	.4	12.0	.5	OOOOOO
3	W. L. X.	215	.9	.8	7.5	2.0	OF

Meaning of Symbols. O-no flower. B-flowers but no fruit. F-fruit. N-north. S-south. E-east. W-west. L-lower. U-upper. T-top. I-inside. X-outside.

The second series of data was obtained for the purpose of learning something about the life-histories of old spurs. The spurs were obtained from Grimes, Domine, and Yellow Bellflower trees, all approximately twenty-five years old. The Domine was an extremely open-centered tree; the trees of the other varieties were moderately open. All of them are to be classed as moderately strong, vigorous, and healthy. All have been producing satisfactory crops. The oldest spurs that it was possible to find were taken to the laboratory and their life-histories traced out and recorded in tabular form. Table 18 is one of these tabular records for a single spur of the Domine.

Table 18. Record of Life-History of Oldest Fruit Spurs.

Year of Growth.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
											O	O	B	O
									O	F	O	F	O	B
													O	B
											O	F	O	F
O	F	F	O	F	O	B	O	F	O	F	O	F	O	B
					O	O	F	O	F	O	F	O	F	O
												O	B	O
									O	O	O	O	B	O
					O	O	F	O	F	O	F	O	F	O
												O	B	O
		F	O	O	F	O	F	O	B	O	B	O	F	O
								O	F	O	B	O	B	O
												O	B	O
		O	O	O	B	O	B	O	B	O	B	O	B	O
												O	B	O
						O	F	O	B	O	F	O	O	O

O-no flower. B-flowers, but no fruit. F-fruit.

In studying these life-histories it was occasionally impossible to be absolutely certain as to whether a spur fruited or merely bloomed some particular year. Especially was this true of the older portion of the spur, but it is thought that the records are reasonably accurate.

PRESENTATION OF DATA.

What is the relation between age and production of a spur?

This question must be considered from two viewpoints. First, which bears the more regularly, an old or a young spur? Second, when they do bear, which produces the larger amount of fruit?

Evidence on the first of these questions was obtained from a study of the life-histories of old spurs. Their average behavior is shown best by means of curves. The dotted lines in Plate XX present the average record of 125 rather old Grimes spurs. This average record is reduced to a 100-spur standard **for** each **year,** since the spurs themselves were of different ages, few of them being more than fifteen years old. Curve A shows the number of growing points or terminals, curve B shows the number of terminals that flower, and curve C shows the number of terminals that mature fruit for each one hundred spurs. Curve A indicates that there was a steady increase with age in the number of terminals for each spur and this in turn means that there was a corresponding increase in number of chances for flowering and setting fruit. The decline during the fifteenth and sixteenth years has no particular significance, for the small number of 15- and 16-year old spurs from which these points on the curve were determined, do not give us dependable averages. From curve B we see that the second year of the spur's growth gave us very nearly our maximum number of flower clusters, but that there was a slight increase up to the tenth year, when a marked decline began. Thus while the number of chances for blooming increased rapidly as the spur became older, there was not a proportional increase in number of flowers; and after the tenth year there was a rapid decline. In the matter of setting and maturing fruit, the contrast is still more marked. Curve C indicates that the second year was the spur's best year from this viewpoint and that thereafter it slowly but steadily decreased in value. A slight tendency toward alternate bearing will be noted.

The solid lines in Plate XX present corresponding records for 208 Yellow Bellflower spurs. Here, as the spurs become older, we notice a somewhat more rapid increase in the average number of terminals than we found in the Grimes, and likewise a greater increase in number of flower clusters to each spur. In the matter of fruiting, there seemed to be no appreciable decline with age, but rather a tendency for a given number of spurs to produce the same amount of fruit year after year. It is noticed, too, in the case of the Yellow Bellflower, that the tendency of such a large group of spurs toward alternate bearing was not marked.

Plate XXI presents for Domine records corresponding to those in Plate XX for Grimes and Yellow Bellflower. In this variety the number of terminals to each spur increased much more rapidly than in the case of either of the other varieties. In the number of flower clusters to each spur there was a very marked increase up to the fourteenth year, but from that point on the decrease was rapid in spite of the fact that the number of chances for flowering was increasing as fast or faster than previously. While the high point in number of flower clusters to each spur was reached at the fourteenth year, the high point in number of fruits set was reached at the eighth year, after which there was a steady decline until zero was reached at the twentieth year. In the case of the Domine the tendency toward alternate bearing is very noticeable.

In this connection it is interesting to note that two parts or branches of a spur may behave entirely different in so far as their time of bearing is concerned—not infrequently two branches of the same spur fruiting in alternate years with each other. Such spurs may bear fruit annually for quite a period of years. Table 18 shows the life-history of such a spur.

From the examination of 538 spurs taken from the three different varieties we would be led to believe that there is generally an increase in the number of flower clusters to each spur for a time, the length of time varying with the variety, but that as the spurs become older the percentage of spurs flowering gradually decreases. While the number of flower clusters gradually decreases the number of spurs fruiting decreases much more rapidly. From this we are led to the conclusion that on the average old spurs are not so efficient in the sense of being regular producers, as are young spurs.

An interesting question which arose in connection with this study is, "What becomes of the old spurs, and why do they disappear in some varieties earlier than in others?"; for while these trees were all of the same age, there was considerable difficulty in finding old spurs on the Yellow Bellflower and Grimes, though many old Domine spurs were found far back on the scaffold limbs. From a careful examination of these trees it appears that practically the only way in which the Domine spurs disappeared was through their being killed by shading or some mechanical injury. On the other hand, it appears that there is a marked tendency for the spurs of the Grimes and Yellow Bellflower to go into vegetative growth, continuing as branches for two or three years, then producing a large number of fruit spurs along these branches. (See Plate XXII, Figure 97.) Often one part of a spur may do this while the other still continues as a spur.

We have seen that as the spur becomes older there is a tendency for it to fruit less frequently. The next question is, how does the amount of fruit produced on an old spur when it does fruit compare with that of a young spur? Table 19 gives the average weight of fruit found on Grimes spurs of various ages.

Table 19. Average weight of fruit on Grimes spurs of various ages.

Age	Number spurs averaged	Average weight fruit
1	31	206
2	452	201
3	292	177
4	224	169
5	194	175
6	78	178
7	37	169
8	31	160
9	13	175
10	15	151
11	11	136
12	2	140
13	3	193

In addition to the product of the fruit spurs given in the table, there were also fifty-two shoots which bore fruit terminally with an average production of one hundred seventy-seven grams each.

From Table 19 we see that there seems to be a gradual diminution in weight of fruit produced as the spurs grow older. The table itself does not afford an exact measure of this decrease in weight; so in order to obtain an accurate expression of the actual relationship between the age of spur and the weight of fruit the correlation coefficient between the two was determined. The values afforded by this correlation table are presented in Table 20.

Table 20. Relation between age of spurs and weight of fruit.

182 grams	Mean weight of fruit per spur.
3.74 years	Mean age of spurs.
73.2 grams	Standard deviation for weight of fruit.
1.945 years	Standard deviation for age of spurs.
.165	Correlation coefficient.

While .165 is not an extremely high degree of correlation, it does afford distinct evidence that old spurs in the Grimes tree studied were weaker and less efficient than young ones, and furthermore that the difference was large enough to be of importance in economic production.

What is the relation between diameter of spurs and their production?

A preliminary study indicated that this relationship could best be determined by means of correlation coefficients. As it would be unfair to compare the diameters of two-year-old spurs with those of spurs six or eight years old, it seemed necessary to group them according to age. Correlation tables were then constructed. Table 21 summarizes the data thus collected on this question.

Table 21. Relation between diameter of younger spurs and their production.

Age yrs.	No. of fruits averaged	Mean wt. fruit gms.	Mean. diam. spur cm.	St. dev. wt. gms.	St. dev. diam. cm.	Corr. Coeff.
2	542	201	.5335	78.2	.0903	.391
3	292	177	.494	73.	.0818	.382
4	224	169	.5215	71.7	.1115	.555
5	194	174	.5422	66.2	.1085	.325
6	78	178	.557	62.2	.1355	.355
7-8	68	165	.626	61.6	.1155	.407

While the number of spurs above eight years of age was not sufficient to warrant making correlation tables, a comparison of the average production of spurs of different ages of large diameter with the production of those of small diameter furnished some evidence on this question. Table 22 presents such a comparison.

Table 22. Relation between diameter of older spurs and their production.

Age	Below .8 cm. in diameter. Number spurs	Below .8 cm. in diameter. Ave. wt. fruit gms.	Above .8 cm. in diameter Number spurs	Above .8 cm. in diameter Ave. wt. fruit gms.
9	11	169	2	210
10	13	144	2	200
11	9	123	2	198
12	1	125	1	155
13	1	140	2	220

Table 21 shows a relatively high degree of correlation between diameter of spur and weight of fruit produced, and this correlation is much the same for the older as for the younger spurs. This indicates that fruit production was dependent to a marked degree upon the vegetative vigor of the spur. Table 22 is significant in that it shows that the weight of fruit produced on old spurs of large diameter was considerably above the average weight of fruit produced on young spurs, in spite of the fact that the average of old spurs was below that of the young. This would indicate that the old spurs produced less, not because they were old, but because on the average they were less vigorous than younger ones.

What is the relation between amount of growth of the spur one season and its production the following season?

In obtaining a measure of this relationship spurs of all ages were grouped together, and a correlation table between length of growth and amount of fruit was constructed. Fruits from axillary fruit buds were not included for obvious reasons. Table 23 shows the values obtained from this statistical study.

Table 23. Relation between production of spurs and their wood growth the preceding season.

182.	grams	Mean weight of fruit.
.784	centimeters	Mean length of growth.
74.2	grams	Standard deviation for weight.
.895	centimeters	Standard deviation for length growth.
.128		Correlation coefficient.

A correlation coefficient of .128 is not very high, but it indicates a tendency for the spurs making the longest growth the season before bearing to produce the largest amount of fruit. It furnishes still further evidence on the important relation between vegetative vigor of spurs and their production.

It was noticed that 125 of the 1435 spurs had fruited in 1914. This brought to mind the question as to whether a spur makes more length growth during an unproductive year or during a productive one. It was found that the average amount of growth during 1914 for the spurs that bore during that year was 1.15 centimeters while the average amount of growth for the spurs that did not fruit that year was .757 centimeters, or a difference of .293 centimeters in favor of the bearing spurs in the Grimes for that year.

Since all these spurs bore in 1915, the year in which fruiting records were taken, another question was suggested; namely, which produced the greater amount of fruit in 1915, the ones which bore in 1914 or the ones which did not? Average production was found to be 171 grams for the ones bearing in 1914 and 183 grams for those not bearing, or a difference of 12 grams in favor of the non-bearing spurs. The numbers averaged were not large but they were large enough for the averages to be suggestive.

What is the relation between the total length of spurs and their production?

As in the case of determining the effect of diameter on production, the spurs were grouped according to age, and the correlation coefficients between the length and production determined. The values obtained from this study are shown in Table 24.

Table 24. Relation between lengths of spurs and their production.

Age	No. of fruits averaged	Mean wt. fruit gms.	Mean length of spurs cm.	St. dev. wt. gms.	St. dev. length cm.	Corr. Coeffi.
2	452	201	2.218	78.2	1.43	.128
3	292	177	3.125	73.	1.79	.286
4	224	169	4.57	71.7	3.05	.371
5	194	174	5.556	66.2	2.73	.378
6	78	178	6.14	62.2	2.757	.253
7-8	68	165	8.34	61.6	3.59	.379

From the data presented in Tables 21, 22, and 23 showing the relation of the diameter of a spur and of its growth the preceding season to production, a series of positive correlation coefficients was to be expected in Table 24, for without doubt total length of spurs was likewise associated with vegetative vigor. The significant feature of this table is the fact that there is a gradual increase in correlation between total length and production as the spurs become older. In the case of the two-year-old spurs the correlation coefficient is comparatively small, while in the case of the seven- and eight-year-old spurs it is three times as great. This would indicate that satisfactory vegetative growth becomes more and more essential as the spur ages.

What relation is there between the diameter of the branch upon which the spur is borne and the spur's production of fruit?

The spurs were again classified according to age and correlation tables between diameter of branch and fruit production constructed. Table 25 presents a summary of the results obtained.

Table 25. Relation between branch diameter and spur production.

Age	No. of spurs averaged	Mean wt. fruit gms	Mean diam. branch cm.	Standard dev. wt. gms.	St. dev. diameter cm.	Corr. Coeff.
2	452	201	.707	78.2	.28	.2223
3	292	177	.776	73.	.362	.162
4	224	169	.848	71.7	.4524	.1284
5	194	174	.963	66.2	.512	.1915
6	78	178	.952	62.2	.561	.2625
7-8	68	165	1.136	61.6	.725	.327

In this case the amount of correlation is rather more than one might expect. That there should be correlation in the younger spurs was not to be wondered at, but that there should be an actual increase in correlation as the spurs grow older was something of a surprise. The inference is that either directly, because of closer connection to larger channels of food distribution, or indirectly through increased vigor imparted to the spurs, the diameter of the branch had a material influence on the fruit production of spurs attached to it.

What is the effect of position in the tree on spur production?

Shaw reports that there is a slight tendency toward larger fruit in the upper part of the tree.[1]

In this investigation the Grimes tree was divided into parts. Divisions were made first into north, south, east, and west quarters. Then each quarter was separated into inside and outside portions. The tree was further divided into lower, upper, and top sections, the top including only those branches extending up beyond the main part of the

1. Shaw, J. K., Variation in Apples. Annual Rept. Mass. Agr. Exp. Sta. for 1909, Part I, pp. 194-213, 1910.

tree and having an upright growth. Table 26 shows the distribution of the spurs, the average age, and the total and average production of these spurs, for each of the main divisions.

Table 26. Production of spurs in different parts of the tree.

Part of tree	No. spurs bearing	Av. age of spurs	Total product in gms.	Average production per spur in gms.
North	704	4.4	106685	152
East	279	3.3	51980	186
South	244	2.8	57455	235
West	208	3.	45235	217
Lower	309	4.1	53565	173
Upper	987	3.7	180920	183
Top	139	2.6	26870	193
Inside	320	4.6	55070	172
Outside	1115	3.4	206285	185

From the data presented in Table 26 it appears that the spurs on the south side of the tree produced the largest fruits. These were followed closely by those on the west, then the east, and finally the north, sides of the tree. Apparently the higher in the tree, the greater the production to each spur. The outside of the tree is seen to have produced a larger amount of fruit to each spur than the inside, and a much larger proportion of the total amount. We must remember, however, that there was a much larger proportion of the bearing surface on the outside.

The proportionally heavier bearing on the north part of the tree and the close proximity of another tree on that side may account in some degree for the relatively smaller fruit of that part, but differences between other divisions of the tree cannot be explained in that way. A study of the average age of the spurs in these various sections would seem to throw some light on that question. By a comparison between the average age of the spurs and their average production in the various parts, we see that in every case where production for each spur was less than the mean, the average age was more. In the light of the evidence bearing upon the relation of age of spurs to production, this would seem to indicate that at least a part of the variation in weight of fruit was due to the difference in the age of the spurs; however, this difference was not great enough to account for all of the variation shown. We should be led to infer, therefore, that the position of the spur in the tree had some influence either directly or indirectly upon its average production. On the other hand the question may be raised, as to whether or not the position of a spur in the tree was not an important factor in determining its longevity, and consequently its average age. The tendency of Grimes spurs to force out into shoot growth after several years of normal functioning as spurs has already been noted. May it not be true that, in the part of the tree receiving the greatest light supply, the spurs go into vegetative growth more readily than in those parts with a more limited light supply? This would result in a lowering of the average age of the spurs in that part of the tree, and at the same time in increased average production to each spur. Opportunity was not afforded to make a first-hand study of this question.

DISCUSSION OF RESULTS.

It is realized that if a similar study were made of the fruit spurs of other varieties, or perhaps even of the same varieties under quite different conditions, somewhat different results might be obtained. The evidence indicates clearly, however, that strong, vigorous fruit spurs are superior to those that are weak. They flower more frequently, are more prone to set fruit, and produce larger fruits. If old spurs are not kept strong and vigorous through proper pruning and other cultural methods, provision should be made for the more or less constant renewal of the fruit-spur system of the tree. On the other hand, relatively less attention need be given to the question of new fruit spurs if the old ones are kept strong and vigorous. From the viewpoint of the size of fruit they produce, as well as from the viewpoint of danger from breaking under heavy loads, the spurs growing directly from the slenderer and weaker branches are less efficient and less satisfactory than those growing directly from limbs of greater diameter, though, in some instances, danger from blight and other diseases may more than compensate for this difference.

SUMMARY

A statistical study was made of 2000 fruit spurs of Grimes, Yellow Bellflower, and Domine. The results of that study may be summarized as follows:

As a general rule, the percentage of spurs which flowered decreased more or less rapidly with age, depending on the variety. The percentage of spurs bearing fruits decreased much more rapidly than the percentage blooming.

On the average, spurs decreased in amount of fruit to each bearing spur as they became older, though the more vigorous of the older spurs produced more than the average of the younger spurs.

Among spurs of uniform age, there was a marked degree of correlation between their length and production. This correlation was more pronounced as the spurs became older.

There was considerable correlation between the amount of growth that a spur made one year and its production the following year. The average Grimes spur grew more during the year that it produced fruit, than the year it was not fruiting. Spurs bearing two years in succession averaged somewhat less to each spur the second season than other spurs that bore no crop the first season.

There was a high degree of correlation between the diameter of spurs and their production. This was practically the same for old spurs as for young.

Spurs of the same age borne on branches of large diameter bore a larger amount of fruit than those on smaller branches.

In the Grimes tree studied the largest average production for each spur was found in the south quarter. The upper part of the tree produced more to each spur than the lower, and there was a slightly greater production for each spur on the outside of the tree than on the inside. Wherever the average production for each spur was less than the mean, the average age was more.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Professor C. I. Lewis, Chief of the Division of Horticulture, for the opportunity afforded for carrying on this investigation. Thanks are especially due to Professor V. R. Gardner, under whose direction the work was conducted, for many valuable suggestions and criticisms.

EXPLANATION OF PLATES

Plate XX. Chart of Grimes and Bellflower Spurs.

Figure 93. Chart showing average performance record of 125 Grimes and 208 Yellow Bellflower spurs. Dotted lines show records for Grimes and solid lines for Yellow Bellflower. Curves AAA and MMM show average number of terminals for each 100 spurs; curves BBB and NNN average number of terminals flowering; and curves CCC and OOO average number of terminals setting and maturing fruit.

Plate XXI. Chart of Domine Spurs.

Figure 94. Chart showing average performance record of 205 Domine spurs. Curve XXX shows average number of terminals for each 100 spurs; curve YYY average number of terminals flowering; and curve ZZZ average number of terminals setting and maturing fruit.

Plate XXII. Spurs of Grimes and Domine.

Figure 95. This is an old branched spur of Grimes. It will be noted that all three branches spring from the one-year growth in which the terminal was destroyed.

Figure 96. This shows a portion of a scaffold limb of the Domine. Note the retention of old spurs in this variety.

Figure 97. This illustrates the way in which many of the old spurs of the Grimes disappear. One part of this spur went into vegetative growth for several years, while the other continued as a spur.

Plate XXIII. Types of Domine Spurs.

Figure 98. This shows three different types, or rather conditions, of Domine spurs. Note the similarity between (b) and one of the branches of (a). In (c) we have a weak non-bearing spur; while (c) is five years older than (a) it is practically the same length.

Figure 99. This shows the Domine spur whose life-history is given in Table II. The two parts of this spur have fruited in alternate years.

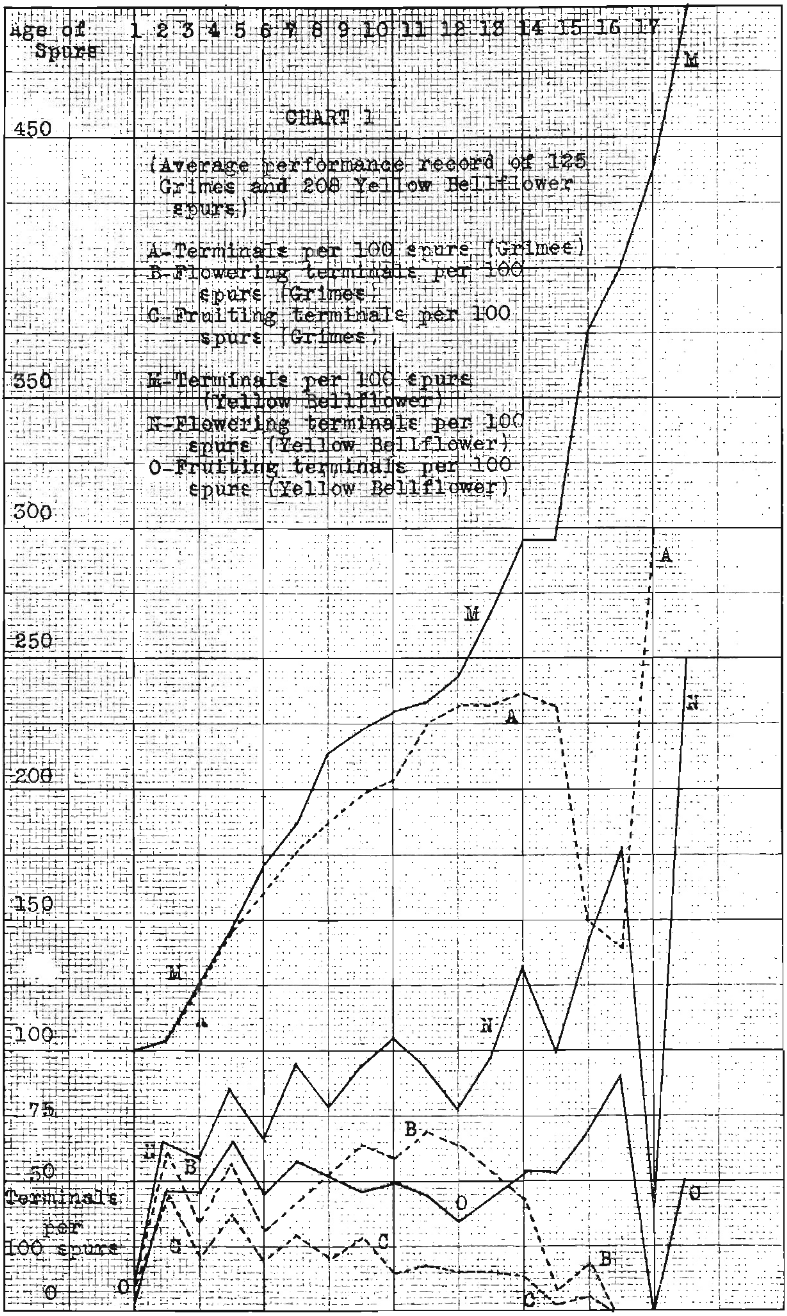


Plate XX, Fig. 93.

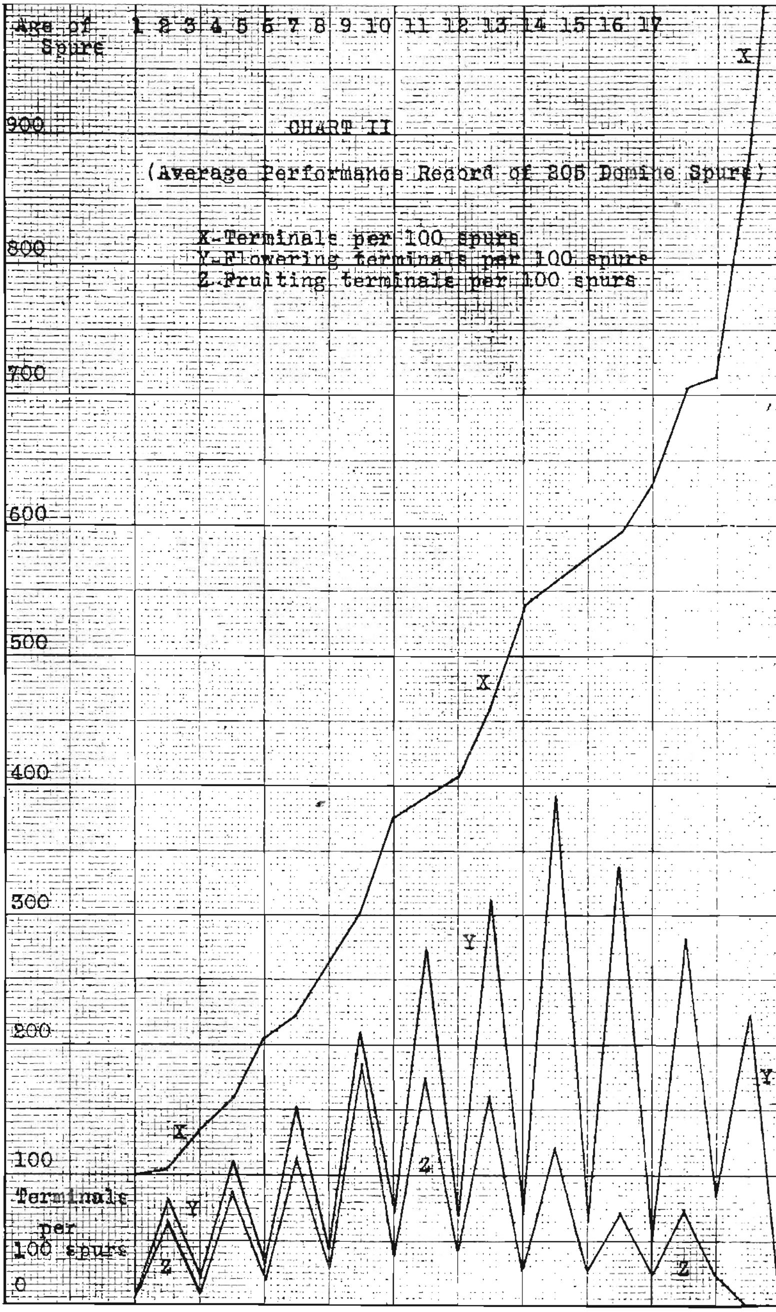


Plate XXI, Fig. 94.

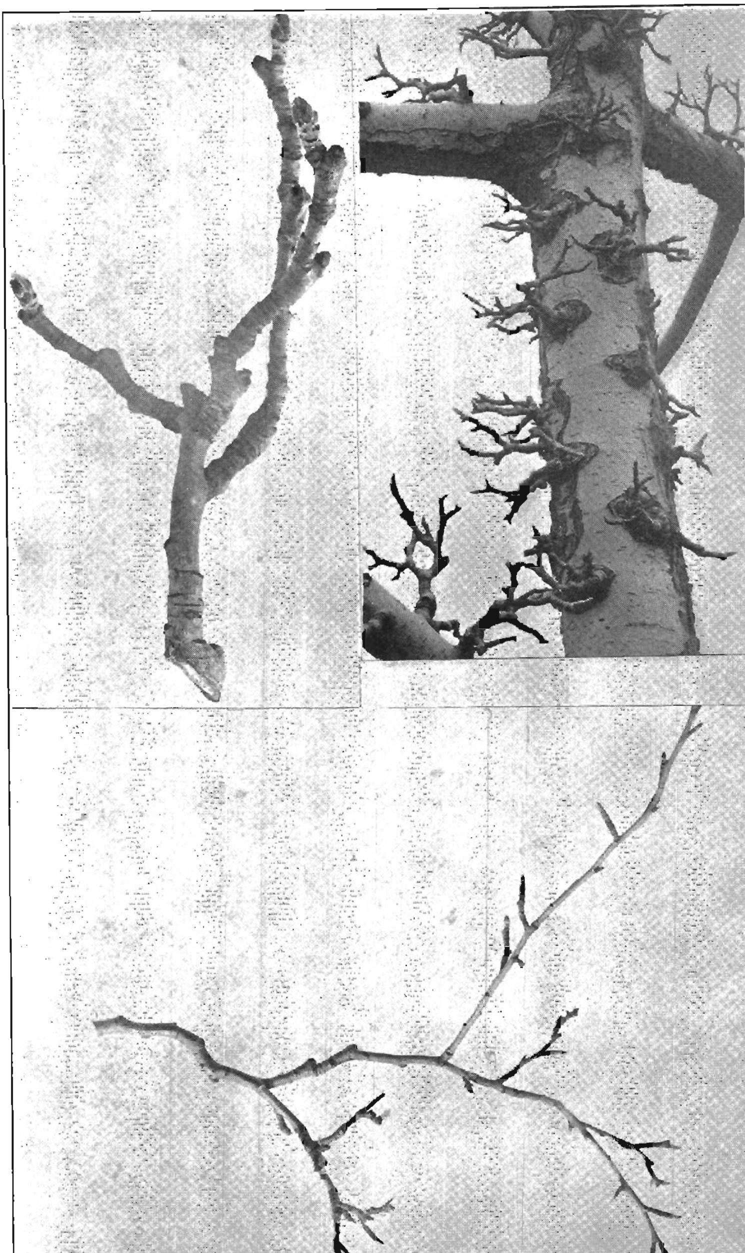
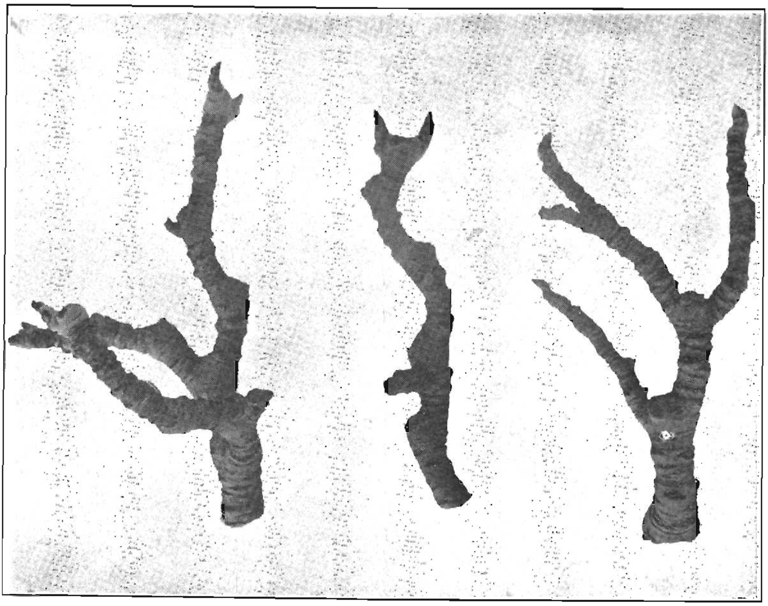


Plate XXII, Figs. 95-97.



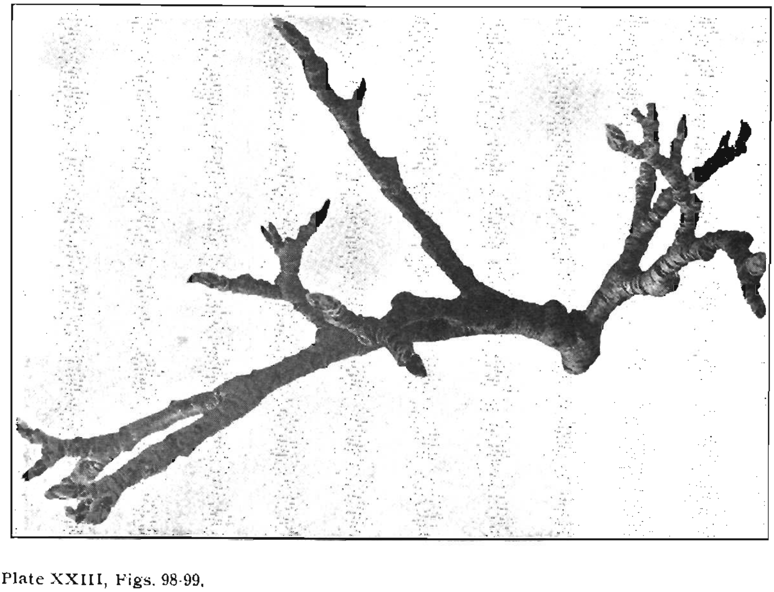


Plate XXIII, Figs. 98-99.