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THE INFLUENCE OF SUMMER PRUNING ON BUD DEVELOPMENT IN THE APPLE

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By

JOHN ROBERT MAGNESS

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APPROVED:

Redacted for Privacy

Professor of Research In charge of Major

Redacted for Privacy

Head of Department of Redacted for Privacy

Redacted for Privacy

Dean of School of

Redacted for Privacy

Chairman - Committee on Graduate Students
and Advanced Degrees

THE INFLUENCE OF SUMMER PRUNING ON BUD DEVELOPMENT IN THE APPLE.

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 in the tree, especially in the buds which are said to be changed over into fruit buds by the treatment, but no real evidence has been presented.

A recent publication by a member of this Division deals with the rate and method of growth of apple trees which received summer pruning as a regular treatment.

The investigation upon which this article is a report was planned to determine the exact influence of summer pruning on the buds of the apple. Its effect upon developing flower buds on spurs; upon leaf buds borne on spurs; and upon axillary buds of the current season's growth, whether fruit or leaf, was to be studied.

It will readily be seen that an understanding of what this influence is, and how strongly it is felt, is fundamental to a knowledge of the value of summer pruning, and also to a knowledge of the form this pruning should take, if any is advisable.

REVIEW OF LITERATURE.

It requires but a brief summary of the opinions held by horticulturists, both past and present, to show the lack of real 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 held.

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. Pruning would otherwise be deemed to add to the strength of the tree if it were done before the sap is in motion, but in practicing from the month of April, when already much of the sap has been wasted, you tame, as he says the luxuriance of the tree by the wounds you infliet upon it."

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 certain kind of fruit, but most of the directions given apply to fruit trees in general. The recommendations may readily be grouped into

two classes, i.e., those favoring heading back heavily, and those favoring simply pinching the terminals. Each type has had its advocates, and arguments in its favor have been submitted.

Hovey (3) in 1849 recommends summer pruning to cause fruit spurs to form, but says further, "Merely nipping off the shoot will not do, for if on some kinds it is nipped off too soon or too short, the terminal eye breaks and goes on growing as before." 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.

"The Horticulturist" (4) speaking editorially in 1853 says "The only pruning we hold to be sound at this season (summer) is that of the finger and thumb; in other words, pinching. It is quite inconsistent with good management to rear a crop of shoots and then cut them away. This can only be avoided by nipping superflous or misplaced shoots at two or three inches of growth, before they attain to woodiness."

Queen (5) in 1871 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. If shortened in earlier than the middle of July, it is likely a second growth of wood will

start, which will not often ripen, and therefore may be injured by the cold weather the following winter."

Hifferd (6) in 1888, concludes as follows: "Observations and experience have taught me that summer pruning is too promotive of useless secondary growth to be advantageous and it tends to keep the roots in action until late in the year, when they ought to be at rest."

Pearson (7) 1896, 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."- - -

"The mode of summer pruning one often sees practiced is very different to that here described. It consists in allowing the side buds to grow freely until July, and then cutting them hard back to two buds. The result is that the shoots are far thicker and stronger than they should be, and consequently more liable to make strong wood next season. The tree receives a great check from the removal of as much foliage, and finally the buds left are almost certain to break out into growth the same season. Close pruning like this quickly transforms a tree into a dense

thicket, impervious to sun or air and totally unfitted for bearing fruit."

Bailey (8) 1898 states as one principle of pruning that summer pruning is conducive to fruit production, whereas winter pruning causes wood growth, but does not discuss the advisability or method for summer pruning.

Waugh (9) 1908 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 (10) (1910) 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 (11) 1915 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 "with the idea of trying to induce fruitfulness if possible". Prune when the terminal buds are forming "at that time---- we cut back the terminal growth, cutting it back to the point where it is desired to force out new laterals for another year's growth. The cutting at this time seems to cause a thickening of the branches,

probably an accumulation of tissue around the buds, and with some varieties, probably will lead to direct fruiting the following season. With others, however, it will simply tend to keep the tree in balance, and probably encourage earlier fruiting than would otherwise be true"----.

This brief summary is sufficient to show that while summer pruning has been fairly extensively recommended, it is by no means understood in all its effects on the tree. Different opinions have existed and do at present exist as to what the actual results of summer pruning are, but these opinions are based upon general observation and theory, rather than upon accurate data based upon careful experimental work. The influence of summer pruning upon the potential fruit buds of a tree, and the response of the buds to various pruning treatments as shown by microscopic examination, has never been carefully studied. This article deals with the latter phase of the summer pruning question. In taking up such a study, it is necessary, first of all, to know just what has been accomplished in the way of fruit bud studies. The knowledge of time and manner of fruit bud differentiation, and the rate of development following differentiation is essential to a study of the influences of pruning on these various phenomona. The time of differentiation and method of development, with some evidence on the rate of development is quite well covered in recent literature.

Goff (12) was one of the first men to systematically study fruit bud formation. He studied the time of differ-

entiation and rate of development of flower parts in the Hoadley apple and reached the following conclusions:- The first clear evidence of flowers was found in buds taken June 30. The order of development was as follows:- Calyx and receptacle appear first at about the same time; next the stamens and petals are formed at nearly the same time, evidently as outgrowths from the calyx or receptacle; lastly the pistil appears and develops very slowly.

As a result of his second year's work, Goff (13) reached the following conclusions:- Development in the bud does not take place from the time of freezing in the fall until there is a decided rise in temperature in the spring. In the apple and pear, flower differentiation takes place during a very prolonged period. Many fruit buds may be formed 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 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. The difference seems to be one of nutrition rather than structure. The age at which an apple bud may become a fruit bud is subject to great

fluctuations. Buds of the same season may form flowers, or buds many years of age may never have formed them.

During his third year's work Goff (14) worked on the variation in period of flower formation between different varieties of apple in the same orchard. He says "Out of 114 varieties examined, only 40 appeared to have any embryo flowers in their buds at the beginning of October. Five of these 40 varieties had formed many flowers prior to August 1." He concludes, "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 (15) traced in much detail the development of the flower bud of the Oldenburg apple as it occurs in Virginia. The development as he found it is substantially as follows:

Flower development apparently starts during the last ten days of June. By June 30, the individual flower buds in the cluster are distinguishable by corrugations in the crown. On July 14, considerable development in the individual buds has taken place. The calyx is very conspicuous, and small protuberances near the base of the calyx cup indicate the initial stamens. Early in August the pistil begins to develop, as indicated by slight swellings on the receptacle, but it is August 26, two months after differentiation before the pistil becomes very conspicuous. By the end of September, the cavities

of the ovaries can be discerned. Two months later, the filaments of the stamens have begun to form. During November and December, there is not much gross development in the flower parts but cytological changes are occurring in the stamens. At the end of January, the petals appear as mere pointed projections arising apparently from the calyx. Also the locules of the carpels are distinct by this time. There is considerable growth during February. Early in March, the ovules show in the cavities of the carpels. Also tetrad formation in the spore mother cells is giving rise to mature pollen grains. Growth processes proceed very rapidly, and all parts are complete by April 1st.

Kraus (16) traced the morphological development of the flower parts and in connection with this, the rate and order of their appearance in the Yellow Newtown. In general, his results so far as time and method of appearance are concerned, agree with those of Drinkard. However, he found the petals to appear before the stamens, they being the first organs to appear, following the sepals. Although his study of the development of flower parts is much more detailed and complete than Drinkard's, it is not necessary to review it in this connection, as both reports agree concerning the main points, with the one exception noted.

Bradford (17) studied the development of the buds of Yellow Newtown with reference to their position in the tree. He found that in general buds on spurs are differ-

entiated earlier than terminal and lateral 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. Buds on spurs which are bearing the current year in many cases develop flower parts. Here again, 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 which have borne before, but are not bearing or have not blossomed during the current year.

Picket (18) 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. However, in this work, the number of apples produced was taken as indicative of the number of fruit buds formed. This is not always accurate, for often a tree will have considerable bloom, and still fail to set fruit, due to low vitality in the tree and poor nutrition in the blossom buds.

Gourley (19) explains the tree response to these

various treatments, and from this response, gathers conclusions regarding the conditions in the trees as a whole favorable to fruit bud formation. Of this, more will be said later.

This is a very brief summary of our present knowledge of fruit bud formation and development. The exact cause of fruit bud differentiation remains unsolved, though recent investigations are throwing some light on the question. The response of the buds and of the plant as a whole to summer pruning gives some evidence as to the real cause of fruit buds being formed.

METHODS

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 Doucin roots, but no effort has been made to prevent their rooting above the graft union, so that some of them are 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 are (1) Early Harvest, (2) Gravenstein, (3) Grimes, (4) Bartlett Seedless, (5) Red Astrachan, (6) Jonathan, (7) Yellow Newtown, (8) Lady, (9) Tolman Sweet, (10) Bismark, (11) Cox's Orange (12) Delicious, (13) Waxen, (14) Wealthy, (15) Winter Banana, (16) Ortly, (17) Arkansas, (18) Wagener, (19) Keswick codlin, (28) Yellow Bellflower, (21) Snow, (22) R. I. Greening, (23) Pumpkin Sweet, (24) Opolescent (25) Liveland Raspberry,

(26) Tompkins King, (27) Glowing Coals, (28) Babbitt, (29) Alexander, (30) White Pearmain, (31) Yellow Transparent, (32) Winesap, (33) Tetofsky, (34) Spitzenburg, (35) Northern Spy, (36) Maiden Blush, (37) Oldenburg, (38) Baldwin.

The soil in which the trees are growing is not very uniform. At the south end, there is a low spot with poor drainage and a very heavy soil. In this spot, comprising about one third of the total area, the trees are considerably smaller than the others, also the trees here stopped growth much earlier in the summer. This was shown to a marked extent by the fact that trees in this spot made little growth following the summer pruning.

The trees of each variety, however, are 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 over most of the lot, with a growth of from 15 inches to 24 inches in the low spot. Those trees in the low spot had for the most part formed terminal buds on the leaders, while the more vigorous trees had not. Thus, while the actual date of the pruning was very nearly the same for all varieties, there was considerable var-

iation in the time relative to the state of development in the tree. This variation was apparent in the amount of growth following the pruning, for while the vigorous trees made 6 inches 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. It consisted of giving to each tree of each variety, one of the following treatments. (1) Simply pinching back the terminals, removing not to exceed 10% of the current season's growth; (2) giving a heavy pruning, removing 50% of the current season's wood; (3) a very heavy pruning, removing 75 to 100% of the current season's growth. If more than three trees of a variety were available, one tree was left unpruned to serve as a check against the summer pruning. In some cases, the heading back was accompanied by some thinning. At the time the pruning was done, buds from spurs, and axillary buds from both the basal and outer region of the current season's growth, were collected. Then, after an interval of two weeks, or from July 16 to 23, buds from both spurs and current season's wood were collected from trees of each variety pruned each of the ways outlined above. Again, August 25 to September 2, and finally 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 use buds from all the varieties in the plot. Consequently, it was necessary to select certain representative varieties, and make as thorough a study of these as possible, rather than to attempt doing some work with all. Seven 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 which does not form axillary fruit buds to any extent. (2) Alexander, (3) Tetofsky and (4) Yellow Transparent, all summer or early fall varieties which tend to bear young, and 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 Winter Pearmain, a winter variety which 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 had one or two varieties which do not form spurs readily been included, but 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. Those trees that had received no summer pruning were given a fairly heavy heading back and thinning out. Those that were heavily summer pruned, and had made little growth following, 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. Growth was fairly well started by this time.

The pruning of the second summer, 1915, was done from June 24 to June 29, the summer varieties being pruned three to four days earlier than the winter varieties. In the case of each variety, one tree was left unpruned, one was clipped only, and one received a heavy pruning. If enough trees were available, one was also given a very heavy pruning. The same trees received the same amount of heading each summer, except in those varieties which had only three trees. 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 taken only from the seven varieties mentioned. Selections were made at the following dates:- (1) June 14, before any pruning was done; (2) June 29, soon after the pruning, on some varieties, but not a complete series; (3) July 9, July 30, September 8, and December 8 to 22.

In preparing the buds, Gilson's mixture was used as a killing and fixing agent. It was taken to the field in vials, and the buds were placed in it as soon as cut. The buds scales were shaved off along two opposite sides

before putting them in the killing agent. It was found that this aided in allowing the various reagents to penetrate, seemed to allow the bud to be more firmly held in the embedding material, and saved time in sectioning.

No new histological methods were introduced in preparing the material. The Gilson's mixture was washed out with 70% alcohol containing a little iodine, and the buds were then dehydrated in 95% and absolute alcohol, being left at least 24 hours in each reagent. Finally, they were placed in ether-alcohol and infiltrated with celloidoin. In infiltrating, a very small amount of celloidoin solution was first poured into the ether-alcohol in which the buds were immersed. After an interval of a day or two, more celloidin was added, and this was continued until the solution in which the buds were immersed became fairly thick. The corks of the vials were then loosened and the ether-alcohol allowed to evaporate gradually. With this method, the celloidin seemed to penetrate the buds quite well, although some trouble was experienced in getting the matrix down into the tissues.

After infiltrating, the buds were imbedded in celloidin, hardened in chloroform and preserved in glycerin-alcohol until needed.

Sections were cut by means of a Leitz sledge microtome. It was found that sections 20 to 25 micrcns in thickness were satisfactory to bring out the points desired. If cut thinner than this, the sections were very difficult

to handle. Sections were stained with Delafield's Hoematoxylin, and cleared in clove oil. A better and clearer color was obtained if the sections were over stained, and the excess stain washed out with acid alcohol.

No attempt was made to keep the sections in series, since only the sections through the very center of the buds are of value. It was found that these sections could be easily and fairly quickly sorted out from among the others by using a binocular microscope, and separating out the desired sections with needles. The depth of focus of the binocular microscope makes this very easy.

The desired sections were then mounted in Canada Balsam.

The photographs were taken by means of Leitz Photomicrographic apparatus Ia.

DEFINITION OF TERMS

There are a few terms that will be used repeatedly in this report which should be clearly defined at the beginning, to avoid any confusion which might otherwise arise in regard to their meaning.

By "axillary" buds is meant those buds borne in the axils of the leaves of the current season's growth. 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.

A "spur" as used here, will apply to a growth of not to exceed four inches. This of course is a purely arbitrary standard.

The term "new spurs" will be applied to those spurs which are forced out from axillary buds by the summer pruning given.

"Spur fruit buds" refers to those buds borne on spurs, which are producing flower parts. "New spur fruit buds" applies to the same thing on new spurs as previously defined. By "spur leaf bud' is meant a bud on a spur which is not producing flower parts during the current season. A terminal bud will mean any bud on the end of a current season's growth of more than four inches. These buds may be forming flowers - "Terminal fruit buds" or they may be leaf buds.

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

BUD DEVELOPMENT.

The development of the buds and the influence of summer pruning upon this development will be taken up in the following order:-

The development of axillary leaf buds, the development of axillary fruit buds, the development of spur buds, both leaf and fruit, the influence of summer pruning on whether or not leaf buds are changed over into fruit buds, and the interpretation of the results obtained.

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 seasons growth, the buds from which the spurs develop, have never been carefully studied. The best methods of securing a good spur system in a tree, especially in young trees, is one of the largest questions in pruning practice today, for with most varieties, a good spur system in a fairly thrifty tree means that the tree will produce bloom. In the case of certain varieties, considerable bloom will be produced without spurs, 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 if not entirely 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 season's work, with the seven varieties previously noted.

A shoot elongates by cell divison in the very tip, or growing point of the shoot. At the sides of this growing point, or crown, and quite close to the apex, areas of rapidly dividing cells appear which quickly develop into protuberances, which are the young leaves. These leaves push out very rapidly, and soon in the axil of this young leaf a heterogenous mass of rapidly dividing cells forms the first evidence of the axillary bud.

Plate I, fig. 1, shows this condition. In the sections studied, no bud was found closer to the growing apex of the shoot than the second leaf axil. This, however, is very close in a rapidly growing shoot. In the earliest stage, the bud seems to be connected with the vascular strands of the stem, but shows no vascular structure of its own.

The young buds develop very rapidly, and buds taken from the axils of young leaves back about one inch from the tip show the buds to be small, but quite well developed. Though stem at this point is still soft and rapidly elongating, the bud is well formed, with a growing point, or apex, and bud scales being rapidly given off in a manner very similar to the way the leaves are given off from the growing shoot. The cells of the grow-

ing tip are not very well defined indicating that growth is still rapidly progressing. The vascular strands of the bud are well formed, connecting with those of the shoot below, and coming upon all sides of the bud, ending in the region of the growing point. Plate I, fig. 2, shows such a bud from Lady. The rapidity with which this development has gone on is indicated by the fact that these buds were taken only one to two inches from the tip of rapidly growing shoots.

Buds well back from the growing tip, located on well seasoned wood half to two-thirds the distance from the base to the tip, were collected at intervals during the summer. Buds from this position, taken June 14, are very much increased in size over those from the growing tip. The axis of the bud has lengthened a great deal by cell division at the crown, and numerous bud scales have formed. The crown, or growing point, in almost every case is well formed, and the cells of which it is composed are well defined. This indicates that growth is taking place much slower at this time than earlier in the life of the bud. Plate I, fig. 3 shows Wagener at this date. In practically every bud sectioned, however, some growth still seems to be taking place. This is shown by the amount of staining in the cells of the crown and young bud scales, by the arrangement of the cells in the crown, and finally by comparing with similar buds taken at a later date. It was found that the younger tissue in the buds stained darker than the more mature portions

so by the amount of darkly stained tissue, and the intensity of the darkening, a very fair idea of the amount of growth taking place could be obtained. It was also found that as the bud ceased to grow, the cells became arranged in even rows across the growing point, or crown. However, this last characteristic was more variable than the former.

Buds of all varieties taken July 9, show considerable development still taking place, though individual buds show some variation, and there appears to be some variation between varieties. Lady and White Pearmain show only a little development taking place. The buds are well formed, and some of them seem almost in a dormant condition. Most of them are making some growth, however. In Alexander, some buds show much activity still going on, while others have apparently almost ceased growing. The other varieties show much development taking place, though in all varieties individual buds vary considerably.

The growth at this date seems to be mainly confined to the crown, where cell division causes the crown to lengthen. Little development is taking place in the bud scales, and the lengthening of the axis raises the crown considerably higher above the bud scales and leaves than it was at the earlier dates. Though this distinct raising of the crown appears more or less on all the varieties studied, it is more prominent in those varieties which tend to form axillary fruit buds. This does not indicate, however, that flower parts are beginning to form at this

time, for later developments show that many of these buds do not become fruit buds. No axillary flower buds have been differentiated, at this date. Plate I, fig. 4, shows a Wagener bud in this condition. Buds taken July 30 still show some variation between varieties. White Pearmain and Lady show only a little development going on. Their buds for the most part show even cell structure across the apex, but some growth is taking place as evidenced by comparison with buds similarily located but gathered at a later date.

In Tetofsky and Jonathan, considerable growth is still occurring. Crowns are rather high and narrow, and in some buds of each variety, definite flower formation has taken place.

Wagener and Yellow Transparent show the crowns very prominently raised, and cells are evenly formed, indicating but little growth.

However, some growth is evident, though no fruit buds are formed as yet. Plate I, fig. 5 shows Wagener of this date.

By September 8, the buds which are not forming flower parts or their antecedents show that they have almost ceased development for the year. Some growth has taken place since July 30, and they show a high, well developed and rounded crown. This is the condition in the bud through which all pass before flower parts begin definitely to form. However, from this condition, they may

develop either as leaf or fruit, so such a bud cannot be definitely called either the one or the other. They are just ready to begin the formation of flower parts, and later development shows that most of them, but not all, do become fruit buds. Many are definitely fruit buds at this time. It is very interesting to note, however, that even at this late date, many of the axillary buds cannot be grouped definitely, either as leaf or fruit. Plate I, fig. 6 shows a Wagener leaf bud.

Leaf buds of December 8 present a very interesting condition. Not many of them were sectioned, but those that were show every variation. Some show little growth since September or even July, while others have developed until the crowns are raised prominently among the surrounding scales and have grown up to rather high, narrow points. This variation in development is shown in Plate III, figs. 1-3. Observation at this time also shows that many of the buds which on September 8 showed no evidence of flower formation, have since become definite fruit buds. Spme of the buds known to be leaf at this time (December 8) might readily have been mistaken for fruit had they reached the same degree of development earlier in the season. But it is almost certain that flower parts will not be developed after this date, so the buds are considered leaf if they do not have flower parts definitely formed.

The influence of the position of the bud on the shoot, on the development of that bud was not very care-

fully studied, though some buds from the basal portion of the shoot were sectioned for comparison with those well out from the base.

It is a matter of common observation that these buds are smaller than those farther out on the shoot. The buds sectioned show that the difference is mainly one of size, though some buds are of different shape. It was noted that some of the basal buds are much narrower between the vascular bundles. This would cause a shoot growing from them to be narrow at first, until thickened by secondary wood from the cambium, and accounts for the slender growth sometimes coming from basal buds.

Some of the buds at the base of the shoot are large and show practically the same development shown by those farther out. These are probably buds more advantageously placed, subtended by leaves having a good exposure to the light. There is nothing in the sections cut to indicate that there is any inherent difference between these buds and those farther out. The whole difference seems to be in degree of development, due to nutrition.

SUMMARY OF THE NORMAL DEVELOPMENT OF AXILLARY LEAF BUDS.

Axillary leaf buds rise in the axils of leaves just back of the growing point of the shoot. They develop very rapidly at first, and then grow slowly during the whole summer and early winter. They show considerable variation in the degree of development attained during this first season.

THE INFLUENCE OF SUMMER PRUNING ON THE DEVELOPMENT OF AXILLARY LEAF BUDS.

Axillary buds from trees pruned lightly and heavily, were collected at the same intervals noted for the buds of unpruned trees, and a careful study made of them to determine the influence of the summer pruning.

The first influence to note is that on those buds in the immediate vicinity of the cut. These buds, of course, are forced out into active growth by the pruning given. A good many buds so treated, taken at intervals of four to ten days after the pruning, were sectioned and the method noted by which these buds which were showing very slight activity pushed out into active shoot growth. At the end of four days, on vigorously growing shoots, rapid changes are taking place in the bud. The crown shows rapid cell division, and at the sides of the crown, regions of increased cell division form the young leaves. The crown elongates very rapidly, but not so fast as the leaves, and at the end of a week to ten days, the young leaves are extending up and forcing the bud scales apart. Even before this time, the growing bud has assumed exactly the same appearance, when seen in section, as a rapidly growing terminal. The crown continues to elongate, new leaves are given off, buds in their axils are formed, and a new shoot is the result. Plate II, Fig. 1 and 2 show Yellow Transparent buds taken four and thirteen days after pruning.

Of very much interest in this connection is the re-

lative number of buds that break into active growth following a summer pruning and an equally severe winter pruning. General observation indicates that usually there are fewer budsthat break, forming shoots, following a summer pruning. Records taken on the dwarf trees in this block show less than half as many shoots formed as were formed following winter pruning with the same number of cut shoots. Very often only one to three shoots are formed following summer pruning on varieties that usually form four to six following dormant pruning. If the pruning is very light, consisting of merely pinching the terminal, it is almost the rule to find only one bud breaking into growth.

Just why this should be true cannot be entirely explained at present, but a theory may be advanced based on the condition of buds during the summer and in the early spring. The buds at the time of summer pruning are in a condition of very slow growth. It is not the tendency for them to push out into active growth unless some special stimulus is given them. With this stimulus supplied however, they respond readily. Following a summer pruning, the terminal bud left is probably in the most active condition and also receives the greatest food supply, consequently it begins to grow very quickly. This soon cares for the food that is being carried to the point of the pruning, and removes the stimulus to the buds below.

If the terminal is merely pinched, there is a

great deal of activity in the terminal bud left, and much less activity in even the next bud below, consequently very frequently only this one bud breaks.

Following dormant pruning, the buds all start into growth together. They normally all break in the spring even if the branch is unpruned. The food supply which gives them an opportunity to grow is better for the terminal bud left following a pruning, consequently it produces a stronger growth. But a number of the buds, already, pushing out as spurs receive enough of the food supply coming up into the shoot to allow them to push out into shoots.

The Influence of Summer Pruning on Axillary Leaf Buds so Far Removed from the Pruning cut that they are not forced into Active Vegetative Growth.

Such buds collected at the same times previously mentioned were sectioned to see if there is any influence of the pruning on the rate of development in the bud, or on the form of this development. The question of the influence of the pruning so far as changing them over from leaf into fruit, or vice versa, is concerned can best be discussed under the influence of summer pruning on gross fruit bud formation as shown by bloom records for all the trees. So far as the influence of pruning on the leaf bud development is concerned, absolutely none is apparent. In the buds from both pruned and unpruned trees of the variety, considerable variation naturally occurs. Some buds develop faster than others and become larger; some apparently become dormant earlier in the

fall than others. Yet in no case could this variation be to the least degree associated with the pruning given. Development apparently went forward with the same average degree of rapidity regardless of the pruning treatment. Buds on September 8 and again December 8, show that these buds go into the winter in the same condition as buds similarly located on unpruned trees. The pruning seems in no way to change the development of the axillary leaf buds not directly forced out into shoot growth.

This is of the greatest importance in understanding the action of these buds the following year. Since they are in the same condition that they would be in had no summer pruning been done, it is to be expected that they will respond in the same way that buds on a shoot not summer pruned would respond.

Gardner (20) in discussing heading back vs. thinning out, shows that shoots headed back heavily develop relatively few spurs, but that a shoot not headed develops a great many during the following season. In the latter case most of the buds all along the shoot produce spurs. Since buds not forced out into growth by the summer pruning are in the same condition as buds in the same relative position on unpruned shoots, it is to be expected that they will function in the same way--in other words, develop into spurs or shoots, depending on the severity of the following winter pruning.

Field observation shows that those buds do function just as similarly located buds on unpruned shoots,

and will form spurs the following season, to the same extent. The distance that these buds are from the base of the shoot, rather than the distance from the tip, must be considered in comparing their functioning.

The Development of Buds on Shoots formed following Summer Pruning.

There is no apparent change in the method of the formation and development of the buds produced on the shoots that grow following a summer pruning. They are, of course, formed later in the season than most of the other axillary buds and they grow until later in the fall. Such buds taken September 8, from Alexander, Tetofsky, Lady and Yellow Transparent, while not so advanced as buds from the unpruned shoots, all show very active growth processes in operation. Plate II, figs. 3-6 show such buds from Lady and Yellow Transparent, compared with buds of unpruned shoots. By December 8 these buds are in about the same condition as those of the same date on unpruned shoots. Plate III, figs. 4-6 show such buds on this date. This late development is to be expected for shoots following summer pruning grow later in the fall than do unpruned shoots, and the buds of each show some development, even after shoot growth has ceased.

It is interesting to note that the buds formed at the base of the new growth do not differ materially from those farther out on the growth. They develop to

the same extent. The growth produced following summer pruning corresponds so far as bud development is concerned to the terminal portion of an unpruned shoot, rather than to the whole shoot. Only in form do the two portions of a summer pruned shoot in any way correspond to the two seasons of growth. The buds and shoot below the cut correspond to the basal portion of an unpruned shoot, the bud response showing this to be true; while the growth produced following summer pruning corresponds to a terminal portion.

The two year form of a summer pruned shoot, with its one year old bud response offers an explanation of the great increase in the number of fruit spurs formed when summer heading is regularly given to a tree. Unpublished data held by this division shows that from two to four times as many spurs, depending upon the variety, are formed following an annual heavy summer pruning as are formed if only a winter pruning is given. Owing to the form of the shoot, very little ifany heading will be required the following winter, and it leaves a large number of buds from which spurs will develop. Gardner (21) points out that the cause of few spurs being developed following a winter heading back is because so many of the axillary buds are entirely removed or are forced out into growth. Summer pruning leaves the tree in good form without removing a large number of the axillary leaf buds, or potential spurs. Plate VIII shows spur formation following summer pruning with no dormant pruning.

THE DEVELOPMENT OF AXILLARY FRUIT BUDS.

The importance of the axillary fruit buds in producing the bloom crop in the apple has often been overlooked by horticultural writers. Kraus (22) speaking of bearing from buds on one year wood says that varieties of apples and pears vary greatly in regard to the number of these 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." For certain varieties, at least on the Pacific coast, the axillary fruit buds are an extremely important factor in the bearing of the trees. Many of these buds from the varieties noted have been sectioned during the progress of this investigation, and the time of their differentiation and their development has been determined for Western Oregon conditions.

The development of the leaf bud to the time of fruit bud differentiation has already been traced. In those varieties that tend to form these axillary fruit buds, the crown is raised prominently and is well developed by the latter part of July. The first step in the formation of flower parts is for this crown to grow up into a high, narrow point. At about the same time, down at the sides of crown, some distance below the apex, small regions of rapidly dividing cells appear. These regions are the beginnings of the lateral flowers in the cluster. Plate IV shows axillary buds of three varieties taken

September 8th. Some are definitely fruit, and others present the condition before referred to during which it cannot be positively known whether they will become fruit or not. It is impossible to determine before the small side buds appear whether a bud will develop as flower or leaf. Some buds that do not show this lateral development by September 8th are so well advanced that they appear just ready to form flower parts, yet a comparison of these buds with leaf buds of December 8th (Plate III, fig. 1-3) show the latter to be much more developed, without flower formation.

TIME OF DIFFERENTIATION

During the summer of 1914, Tetofsky was the only variety which showed enough axillary fruit buds to afford any idea as to the time of differentiation. Spur fruit buds of this variety form as early and develop as rapidly as in any variety studied so it is probable that the axillary buds do likewise.

Material collected September 2nd show fruit buds well formed. In the most advanced buds, all the flower parts, including the protuberances from which the carpels develop, are present. In this case, it is probable that differentiation occurred at least a month earlier. Other buds taken on this same date show only the sepals forming. It is interesting to note that spur buds of July 23d show as much development as the most advanced axillary buds of September 2nd.

In 1914, the axillary fruit buds of Tetofsky were formed for the most part during the month of August, fully a month to six weeks later than the spur fruit buds.

During 1915, the time of differentiation was definitley established in several varieties. The earliest buds sectioned which definitely showed flower parts were of Jonathan and Tetofsky taken July 30. In a very few buds taken at this date, the very earliest stages of flower formation are apparent. No other varieties examined show any fruit buds on this date.

Buds of most varieties taken September 8th show some axillary fruit buds. Wagener shows some buds in the earliest stages of flower formation, while others as yet show no flower parts. It is apparent that on this date, differentiation is just occurring. Yellow Transparent shows no flower parts, but the buds are well developed and some give every appearance of the condition just prior to fruit bud formation previously noted. From the fact that a number of axillary fruit buds were formed on this tree, it isprobable that differentiation took place even after this late date. Tetofsky shows variations all the way from having the prinordia for the petals just appearing in the most advanced buds to the condition noted for Wagener, which marks the earliest stage that fruit buds can definitely be known. Some Jonathan buds show the first evidence of sepals on this date, while others show the early condition of the side buds just beginning to form. These buds indicate that during 1915

most of the axillary fruit buds were formed after the first of August. The main differentiation seemed to be taking place during the early part of September and it is certain that considerable took place after September 8th.

The time of formation of spur fruit buds on these same varieties and on the same trees will be discussed later, but it is interesting to note at this point that the main bulk of axillary buds are formed much later than are most of the spur buds.

It is to be expected, however, that occasional buds will begin the formation of flower parts much earlier than the main portion of them. This is true of spurs as well as axillary buds. One such axillary bud of Tetofsky was sectioned which apparently had formed flower parts prior to June 24.

DEVELOPMENT OF AXILLLARY FRUIT BUDS.

The development of axillary fruit buds following their differentiation, does not differ greatly from that of the spur buds. As is to be expected, the flower parts appear in the same order as in spur buds, so it is unnecessary to discuss in detail that phase of their development. Plate V shows steps in the development of these buds.

It has already been pointed out, and can be seen by comparison with spurs later on that axillary buds are decidedly behind spurs in time of differentiation. Apparently, they do not regain any of this time until the

following spring. It has already been mentioned that during 1914, Tetofsky spurs of July 23 were as far advanced as any axillary buds of September 2nd. Spurs showed more development by September 2nd than was shown by any axillary bud of November 5th that was sectioned. During 1915, the main differentiation did not take place until about September. Of the buds gathered in December, so late that probably all development except microscopic changes within the anthers and carpels had ceased, the axillary fruit buds show a much less advanced condition than do the spurs. The axillary buds vary from having the prinordia of the carpels barely formed to having them showing distinct longitudinal growth. Most of the spurs at the same date show the locules or cavities in the carpels well formed. Not only are the axillary buds behind those born on spurs during the winter, but in the spring the axillary buds fail to entirely catch up with the others. Often axillary buds will open a full week or sometimes even more, later than spurs on the same tree. The difference is so great that it very materially increases the length of the blooming season for those varieties that bear from axillary buds.

THE INFLUENCE OF SUMMER PRUNING ON RATE OF DEVELOPMENT OF AXILLARY FRUIT BUDS.

The pruning was done before practically any axillary fruit buds were formed, so no effect of the pruning on buds already formed could be determined. A pruning

would have to be delayed until September to exert such an influence. Such fruit buds as did form, either on the old wood below the pruning cut, or on the growth produced following pruning, were not affected by the pruning. Not many such buds are formed but those that are, develop just about as buds on unpruned shoots. Those buds formed on growth produced following summer pruning show considerable variation. The time of differentiation of these buds was not determined, but a number of them from Wagener and Tetofsky, taken December 22nd show variations from having the carpels just beginning to form to being well developed and making considerable longitudinal growth. However, this is not a greater amount of variation than is found in the buds of unpruned shoots.

Only one bud was sectioned that had apparently started to form flowers before the pruning was done. This bud was taken July 9th, from immediately below one of the cuts made in pruning a Tetofsky tree heavily, June 24th. This bud is shown in Plate V, fig 6. The bud is pushing out rapidly into vegetative growth, but the flower parts also are developing. When the pruning cut was made, the bud must have been in a very young state, and it is probable that the vegetative parts will develop at the expense of the flower parts.

It has been observed several times, however, that axillary fruit buds may be forced out into bloom by a summer pruning cut being made just above them. This indicates that such a bud will force out, rather than

revert to the vegetative if it is well formed when the summer pruning is done.

Thus we see that while summer pruning may occasionally force axillary fruit buds out into bloom, if the buds are adjacent to that cut, it apparently exerts no influence upon their rate of development if they are some distance away.

THE INFLUENCE OF SUMMER PRUNING ON SPUR BUD DEVELOPMENT.

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. They were taken regardless of whether or not they appeared to be fruit buds. The development in all varieties is similar enough to render a separate discussion unnecessary.

The complete collection taken June 14 failed to reveal any flower parts being formed in any variety. Some variation in conditions within the buds naturally occurs between varieties and between buds of a variety. Some are in a condition indicating little growth in progress. The crowns of such buds are broad and rather flat, and the cells of which they are composed are well formed and arranged in even rows. It is probable that such buds will remain leaf.

On the other hand, a few buds were found with their crowns somewhat raised and thickened, and giving evidence of being in a state of active growth. These buds with reasonable certainty may be said to be those that will soon form flower parts, though as yet no flower parts are to be seen. Most of the buds are between these two extremes, however, and in no case can the buds sectioned be said to

have definitely differentiated, either as fruit or leaf buds.

By July 9, some of the spur buds have formed flower parts, which have reached various stages of development. Those showing no evidence of flower parts present all gradations from the broad flat crown described above to the condition at which they can be recognized as definite flower buds.

It is noticeable that just before flower parts begin to appear, or perhaps more accurately, as the first step in their development, the crown of the bud becomes raised and thickened, in a manner very similar to the corresponding stage in the development of axillary fruit buds. All spur buds have some development taking place at this time, though in some the growth is very slight.

Some buds taken July 30, are still in the earliest stages of flower part formation, while those that are showing no indication of becoming fruit buds show some slight development in progress.

By September 8, the leaf buds seem to have reached the condition in which they will pass the winter. Very little growth has been made since early in July, and buds taken in December show no more growth to have been made. These buds for the most part go into the winter with the crown very slightly developed and raised. Plate VI, figs. 1 and 2 show Jonathan spur buds of June 14 and December 8 respectively. It will be noted that the bud collected in December was not much more developed than is the one

taken in June.

THE INFLUENCE OF SUMMER PRUNING ON LEAF BUDS ON SPURS.

Considering that summer pruning has no influence upon the rate of development of axillary leaf buds, unless those buds are adjacent to the pruning cut, it is to be expected that there will be no influence in leaf buds on spurs, which are even farther removed from the place of cutting.

This supposition is borne out by a study of the sections of leaf buds on spurs. Altho many buds from different varieties, taken following the different pruning treatments outlined above, have been studied, absolutely no variation in degree of development, time of becoming dormant, etc. which might in any way be correlated with the pruning given can be detected. This is aside from the question of whether or not leaf buds are induced to become fruit buds by the treatment, and does not apply to those spurs immediately below the cut on very heavily pruned trees.

A number of spur leaf buds from such trees were forced out into active shoot growth. Sections cut thru spur leaf buds which are starting into growth show that growth proceeds in these buds exactly as it does in axillary leaf buds. The cells of the crown begin to divide rapidly, and young leaves, and in the axils of these buds, are produced at the sides of the crown. Soon the leaves push out, and growth continues as in any other shoot.

Plate VII, fig. 2 shows a spur bud of Lady, starting into growth.

The angle which such a shoot makes with the old axis of growth is worth noting. The spur is growing nearly perpendicular to the axis of growth and a shoot developing from the spur, grows almost at right angles to the old branch. This wide angle makes a very strong crotch.

DEVELOPMENT OF FRUIT BUDS ON SPURS AND THE INFLUENCE OF SUMMER PRUNING

The time of the first differentiation of spur fruit buds under conditions in the station orchard, and for the varieties studied was about the same as that given by the investigators previously mentioned. The earliest stages of flower formation are not shown in the 1914 sections, but from the degree of development attained by the latter part of the summer, it is evident that flower parts must have started in 1914 even earlier than in 1915.

As previously mentioned, none of the 1915 buds taken June 14 can be called definitely either fruit or leaf buds, though some on this date give an indication as to which way they will develop.

By July 10, all varieties noted except Wagener and Alexander show definitely formed fruit buds. Lady and Jonathan buds are all in the youngest stages of flower formation, while Tetofsky and Yellow Transparent show variations from buds barely differentiated to having sepals well formed. Some of the White Pearmain buds have the stamens forming. This is the most advanced condition

found in any variety.

By July 30, White Pearmain, Tetofsky and Yellow Transparent buds vary from the earliest stages of flower formation, to having all flower parts, including the carpels, beginning to form. The other four varieties in no case are further advanced than having the sepals formed. However, since two of these varieties showed fruit buds formed three weeks earlier, it is probable that other buds would have shown more development.

White Pearmain and Tetofsky buds of September 8 have the carpels well formed, and showing considerable longitudinal growth as the most advanced condition. No locules are present, however, Yellow Transparent buds are somewhat less developed though they have the carpels well formed. Buds of Jonathan, Lady, Alexander and Wagener vary from having the carpels just formed in the most advanced cases, to being just well differentiated in the younger fruit buds. Wagener, however, shows stamens forming as the youngest condition.

Buds of 1914 show more development by September than do those of 1915. It is difficult to determine just how much seasonal variation there was, because of variation between individual buds of a variety. Tetofsky buds of September 2, 1914 seem slightly more advanced than those of September 8, 1915. The averages for the buds of Yellow Transparent, taken the same dates, also shows a more advanced condition in the 1914 buds. Wagener buds of August 27, 1914, and September 8, 1915, present almost

the same degree of development. It is interesting to note that the varieties which developed fruit buds earliest in 1914 did the same in 1915, and the other varieties were in the same order during the two seasons.

Spur buds gathered during December, 1915 indicate the extent to which development had proceeded when checked by winter conditions. Lady, Jonathan and White Pearmain are in about the same state of development. All show the carpels well developed and growing longitudinally, and in some of the carpels, locules are formed. Wagener is more advanced than any of the above. All the carpels are very highly developed, showing locules formed. This is particularly interesting, since White Pearmain buds formed flowers much earlier than did Wagener. It shows that those varieties which form flower parts earliest in the summer do not necessarily develop ahead of other varieties. Tetofsky is still the most advanced variety at this time. All the buds show well developed locules in the carpels, though no ovules are present.

The different varieties are still behind the 1914 development on the same date. This is most strikingly shown by Tetofsky. Several buds of this variety, taken November 5, 1914, show the ovules formed in the carpels. But none of these appear in the buds taken December 8, 1915, indicating a much higher degree of development on the former date. Plate VII, figs. 5 and 6, show this difference. Wagener buds of October 27, 1914 are fully as well developed as are those of December 22, 1915. Other varieties did not have enough fruit buds formed

during 1914 to fully determine this point, but the few that were sectioned indicate the same thing.

In this connection, it is well to mention that the blooming season during the spring of 1915 was fully one week earlier than that of 1916. It is quite probable that the season of blooming for our orchard fruits is materially influenced by the degree of development attained by their flower buds during the previous summer and fall, as well as by weather conditions in the spring.

INFLUENCE OF SUMMER PRUNING UPON THE DEVELOPMENT OF FRUIT BUDS ON SPURS.

Absolutely no influence of summer pruning can be detected in the rate or manner of development of the fruit buds on spurs. This does not apply in those cases in which the spur buds that have formed flower parts are forced out into growth by the pruning. But the pruning which was confined to the current season's growth, whether it was light or heavy has no apparent effect upon the flower parts formed. Buds from pruned and unpruned trees of the same variety are formed at the same time, develop at the same rate, and have exactly the same appearance at any time.

In one variety, White Pearmain, the summer pruning on one tree each summer consisted in cutting the shoots back to spurs. Each year, the flower buds were forced out into bloom by the pruning. Plate VI, fig. 3 shows a section through such a bud, taken while the

flower parts are forcing out. The bud is making rapid vegetative growth, but flower parts as well are pushing out. These flowers forced out into bloom in August, and that they were normal in every way is shown by the fact that during the summer of 1914, apples, developed from them, attained good size before winter.

The pruning of this variety in 1915 was done on June 29, a time when the flower buds formed must have been in a very young state of development. The fact that the flower parts failed to give way to purely vegetative growth under the stimulus of the summer pruning indicates that buds once definitely differentiated as fruit buds can not readily be changed in character.

NEW SPURS.

Very often, as a result of summer pruning, axillary buds below the cut are forced out as spurs. These so-called new spurs very often form fruit buds the same season. Very few of the buds from this type of spur were sectioned, but those that were indicate that the development of flower parts in such buds is much behind the development in normal spurs of the same date. This is to be expected, since such buds are not formed until late in the summer, after many of the ordinary spurs already have well developed flower parts. Plate VII, figs. 1 and 2 show such a bud from White Pearmain, taken December 22, compared with an ordinary spur bud of the same date.

TERMINAL FRUIT BUDS.

Only a few of the terminal buds from shoots making over four inches of growth annually were sectioned. Those few indicate that the terminals develop very unevenly in different varieties. Tetofsky terminals of July 30, show very well developed flower parts, with the sepals formed. On the other hand, Jonathan terminals of December 8 contain only the earliest evidences of carpels. This is much less development than has occurred in any other kinds of buds on the variety on that date.

This variation between varieties is probably due to the variation which exists in the time the shoots of different varieties stop growth. Shoots variously located in any one tree will also vary greatly in this regard. The Tetofsky tree in question stopped growth much earlier in the summer than did the Jonathan. Plate VIII, figs. 3 and 4 show a Jonathan terminal of December 8, compared with an average spur bud of the same date.

SUMMARY.

The development of buds in the apple as influenced by summer pruning may be summarized as follows: Aside from the question of whether or not summer pruning induces leaf buds to become fruit buds, the rate or time of development of buds, whether they be leaf or fruit,

borne on the current season's growth or on spurs, apparently is little influenced by the pruning. This of course does not apply to those buds forced out into growth by the summer pruning, and the time of development does not apply to buds on growth produced following summer pruning.

THE INFLUENCE OF SUMMER PRUNING UPON THE FORMATION OF FRUIT BUDS.

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 this connection. 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 summer pruning. Batchelor (22) 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 (23) found a negative correlation to exist between summer pruning and early bearing in young trees.

In this 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

blossoms, but their position on the tree, and whether from axillary, terminal, or spur buds was also recorded.

Owing to so much variation in the individual trees of some varieties, the results are unreliable so far as they are concerned. Consequently a careful study of the trees in the plot was made, and twenty-four varieties were selected, the individual trees of each of which were so nearly uniform in size and condition that a direct comparison between them may safely be made. There were at least three trees of each of the varieties selected, each of which had received one of the treatments before mentioned, i.e., unpruned, light heading and thinning, or heavy heading and thinning.

TABLE I (a)

1915

Variety	Row & Tree	Treat-ment	Old spurs	New spurs	Ax B.	Ax A.	Term. before	Term. after
Bismark	5-22	T	29	1	0	3	0	3
"	5-23	L	18	0	0	0	3	1
"	5-24	P	32	0	23	0	0	5
"	5-25	O	2	0	0	0	0	0
Cox Orange	5-26	S	0	0	0	0	0	0
"	5-27	R	0	0	0	0	0	0
"	5-28	P	0	0	0	0	0	0
Early Harvest	6-1	R	0	0	0	0	0	0
"	6-2	P	0	0	0	0	0	0
"	6-3	O	0	0	0	0	0	0
Red Astr.	6-13	T	2	0	2	0	0	1
"	6-14	R	1	0	0	3	0	1
"	6-15	P	9	3	0	31	5	3
"	6-16	O	2	0	54	0	2	0
Lady	6-21	T	3	0	0	0	0	0
"	6-22	R	7	0	0	0	0	0
"	6-23	P	0	0	0	0	0	0
"	6-24	O	7	0	0	0	0	0
Wint.Banana	7-7	O	0	0	0	0	0	0
"	7-8	P	0	4	2	0	1	1
"	7-9	T	2	0	0	0	0	0
"	7-10	R	0	1	1	0	1	0
Ark. Black	11-2	S	5	0	0	0	0	0
"	11-3	R	9	0	0	0	0	0
"	11-4	P	4	0	0	0	0	0
Wagener	11-5	P	0	14	5	9	1	3
"	11-6	O	0	0	45	0	0	0
"	11-7	R	0	0	8	0	0	1
"	11-8	R	11	1	0	0	0	0
Yel.Bell-flow.	11-16	P	0	0	0	0	0	0
"	11-17	R	0	0	0	0	0	0
"	11-18	O	2	0	0	0	0	0
Waxen	11-19	R	1	0	0	0	1	0
"	11-20	P	0	0	0	0	0	0
"	11-21	O	0	0	0	0	0	0
Snow	11-28	S	0	0	0	0	0	0
"	11-29	P	0	0	0	0	0	0
"	11-30	O	0	0	0	0	0	0
R.I.Greening	12-2	S	0	0	0	0	0	0
"	12-3	R	0	0	0	0	0	0
"	12-4	P	1	0	0	0	0	0

TABLE I (a)

1916

Variety	Row & Tree	Treat-ment	Old spurs	New spurs	Ax B.	Ax A.	Ax O.	Term. before	Term. after
Bismark	5-22	T	46	8	1	12	27	5	34
"	5-23	R	114	6	76	3	20	5	15
"	5-24	P	92	6	118	35	6	3	18
"	5-25	O	50				155	17	
Cox Orange	5-26	R	20	1	0	0	0	2	0
"	5-27	P	82	0	5	0	0	0	0
"	5-28	O	167				55	10	0
Early Harvest	6-1	R	22	20	0	0	0	7	3
"	6-2	P	52	6	2	4	0	11	2
"	6-3	O	12	0	0	0	0	6	0
Red Astr.	6-13	T	75	0	0	17	0	2	9
"	6-14	R	45	2	1	19	0	6	1
"	6-15	Q	174	14	3	99	18	6	8
"	6-16	O	22	0	0	0	155	42	0
Lady	6-21	R	100	0	0	0	0	0	0
"	6-22	Q	79	3	0	0	0	0	0
"	6-23	T	67	0	0	0	0	0	1
"	6-24	O	144	0	0	0	8	4	0
Wint. Banana	7-7	T	54	0	0	0	0	5	2
"	7-8	R	44	13	5	0	4	6	6
"	7-9	Q	40	8	2	0	6	16	1
"	7-10	O	135	0	0	0	350	70	0
Ark. Black	11-2	R	80	8	0	0	1	1	1
"	11-3	Q	237	9	1		0	0	1
"	11-4	O	141	0	0	0	20	18	0
Wagener	11-5	Q	242	23	38	217	0	4	67
"	11-6	R	17	0	0	1	0	1	1
"	11-7	T	175	3	0	40	1	2	9
"	11-8	O	65	0	0	0	248	51	0
Yel.Bell-flow.	11-16	R	6	0	1	0	0	2	0
"	11-17	Q	41	17	3	0	0	3	4
"	11-18	O	97	0	0	0	286	65	0
Waxen	11-19	R	52	18	0	0	0	9	7
"	11-20	Q	49	54	8	0	2	28	0
"	11-21	O	16	0	0	0	0	22	0
Snow	11-28	R	20	4	0	0	0	1	7
"	11-29	Q	12	7	1	0	10	5	3
"	11-30	O	7	0	0	0	14	23	0
R.I.Greening	12-2	O	75	0	0	0	48	52	0
"	12-3	R	5	0	0	0	0	1	1
"	12-4	Q	77	14	5	7	1	15	16

TABLE I (b)

1915

Variety	Row & Tree	Treat-ment	Old spurs	New spurs	Ax B.	Ax A.	Term. before	Term. after
Opalescent	12-8	R	0	0	0	0	0	0
"	12-9	P	7	0	0	0	3	0
"	12-10	S	8	0	0	0	0	0
Livelana Asp.	12-14	R	0	0	0	0	0	0
"	12-15	R	0	0	0	0	0	0
"	12-16	P	3	0	0	0	0	0
Glowing Coals	12-19	R	0	0	0	0	0	0
"	12-20	P	0	0	0	0	0	0
"	12-21	0	0	0	0	0	0	0
Alexander	12-28	R	27	0	1	0	3	0
"	12-29	P	0	0	0	0	0	0
"	12-30	0	0	0	0	0	0	0
Yel. Trans.	13-7	R	6	0	0	0	2	0
"	13-8	Q	20	0	0	0	3	0
"	13-9	T	61	1	0	0	0	0
"	13-11	0	6	0	0	0	0	0
Wint. Banana	13-22	R	0	0	0	0	0	0
"	13-23	P	0	0	0	0	0	0
"	13-24	0	27	0	0	0	5	0
Tetofsky	14-10	0	7	0	21	0	7	0
"	14-11	P	12	0	0	2	0	1
"	14-12	R	13	0	6	0	2	1
Spitz.	14-16	R	0	0	0	0	0	0
"	14-17	0	0	0	0	0	0	0
"	14-18	0	0	0	0	0	0	0
Ortly	15-5	R	0	1	0	5	0	1
"	15-6	S	0	0	0	0	0	0
"	15-7	Q	1	0	0	0	0	0
Jonathan	15-28	P	20	0	5	0	0	0
"	15-29	0	46	0	0	0	0	0
"	15-30	0	27	0	0	0	0	0
Oldenburg	16-13	S	5	0	0	0	0	0
"	16-14	R	0	0	0	0	0	0
"	16-15	P	19	0	3	0	2	0
Delicious	16-19	R	0	0	0	0	0	0
"	16-20	0	7	0	0	0	0	0
"	16-21	0	6	0	0	0	1	0

TABLE I (b)

1916

Variety	Row & Tree	Treat-ment	Old spurs	New spurs	Ax B.	Ax A.	Ax 0	Term. before	Term. after
Opalescent	12-8	R	150	6	8	0	2	4	0
"	12-9	Q	180	5	9	1	3	5	0
"	12-10	O	120	0	0	0	80	18	0
Riverand Rasp.	12-14	R	17	6	5	0	4	7	0
"	12-15	Q	48	0	4	0	3	8	0
"	12-16	O	51	0	0	0	311	42	0
Glowing Coals	12-19	R	10	20	2	20	3	7	12
"	12-20	Q	8	11	4	45	9	4	17
"	12-21	O	1	0	0	0	68	20	0
Alexander	12-28	R	7	8	0	0	1	1	7
"	12-29	Q	42	3	5	3	15	6	14
"	12-30	O	11	0	0	0	119	32	0
Yel.Transpar.	13-7	R	27	8	0	2	4	4	6
"	13-8	P	25	7	0	6	2	5	14
"	13-9	O	34	0	0	0	83	57	0
"	13-11	S	53	5	0	0	0	1	0
Winter Banana	13-22	R	10	1	0	0	4	6	5
"	13-23	Q	61	4	5	2	0	8	7
"	13-24	O	62	0	0	0	78	45	0
Tetofsky	14-10	O	42	0	0	0	145	25	0
"	14-11	P	27	9	2	100	6	5	33
"	14-12	R	18	12	19	43	10	1	20
Spitz.	14-16	P	8	0	0	0	1	7	0
"	14-17	R	9	4	0	0	0	0	0
"	14-18	O	0	0	0	0	0	8	0
Ortly	15-5	O	67	0	0	0	82	4	0
"	15-6	Q	56	2	0	0	0	2	1
"	15-7	R	179	4	0	0	0	11	3
Jonathan	15-28	Q	19	3	0	40	3	4	3
"	15-29	S	4	0	0	4	5	4	0
"	15-30	O	41	0	0	0	342	23	0
Oldenburg	16-13	R	157	16	6	0	6	10	2
"	16-44	Q	39	0	0	0	0	17	0
"	16-15	O	86	0	0	0	290	16	0
Delicious	16-19	T	1	0	0	0	0	0	0
"	16-20	R	22	0	0	0	0	3	0
"	16-21	O	30	0	0	0	0	8	0

Table I shows the blossom response from each kind of bud during the springs of 1915 and 1916 following the different pruning treatments of 1914 and 1915. Those trees marked O in the table received no summer pruning; those marked P were given only a light heading; Q, a light heading and some thinning out; R, a heavy heading and thinning; S, a very heavy heading, and T, a cutting into old wood.

The number of trees of any one variety from which these data were taken is too small to consider the results for that variety entirely reliable. Nevertheless, the fact that twenty-four varieties are represented, and that the varieties were selected because of the uniformity of the individual trees makes the combined results very suggestive.

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

TABLE II

Type of pruning	No. of trees	Total No. blossom clusters	Ave.No.Blossom clusters per tree
Unpruned	24	5,127	214
Lightly pruned	24	3,198	133
Heavily pruned	24	1,962	82

The figures in this table show bloom records very much in favor of no summer pruning. Light summer pruning gave decidedly more bloom than heavy. While these figures

are interesting as representing more or less average conditions, the records of the types of buds from which these blossoms were produced, indicate more definitely the influence of the summer pruning. Table III shows the blossom clusters produced on the old spurs, down in the tree.

TABLE III

Type of pruning	No. of trees	Total No.blossoms on old spurs	Ave.No.per tree blossoms on old spurs
Unpruned	24	1,484	62
Lightly pruned	24	1,712	72
Heavily pruned	24	1,272	53

The difference in number of such blossoms between the trees receiving the different pruning treatments is so small that it might easily be due entirely to natural variation in the trees. It would seem that the interpretation to be placed upon the figures is that summer pruning, unless it is so heavy that practically all the current season's growth is removed, has very little influence upon the development or non development of fruit buds on the spurs down in the tree. This conclusion is strongly supported by the general appearance of the trees.

Table IV shows the total number and average number per tree of fruit buds borne on one year wood. On the unpruned trees, these are all axillary buds and terminals, while for the pruned trees it includes also new spurs.

TABLE IV

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

Here is evidence that far more fruit buds are produced on the one year wood if no summer pruning at all is practiced. Even a light pruning reduced the number more than half, while a heavy pruning reduced still farther the number of such buds. Rather than causing the axillary leaf buds to be changed over into fruit buds, it appears from the above that summer pruning actually prevents many buds from making this change. Added weight is given to the figures substantiating this conclusion by the blossom records of the spurs for the same trees--records affording some measure of the degree of uniformity between the trees under different pruning treatments.

Before discussing a possible explanation of this influence of summer pruning, it will be well to examine the position of the fruit buds following each type of pruning. In the unpruned trees, most of the fruit buds are produced toward the tips of the shoots, though some are fairly well back toward the base. That many of these buds would normally be removed in a subsequent winter pruning is pointed out by Kraus (21). The position of the buds of each variety under the different pruning treatments are given in

Table I. Table V gives the totals in each position for these groups.

TABLE V

Treatment	New spur	Axillary before pruning	Axillary after pruning	Axillary unpruned	Terminal before pruning	Term. after pruning
Unpruned	---	---	---	2967	678	---
Lightly pruned	205	215	561	85	162	228
Heavily "	157	123	88	59	95	97

Axillary before pruning refers to axillary fruit buds formed on the growth below where the pruning cut was made. Axillary after pruning refers to those formed on shoots produced following the pruning. Axillary unpruned are those fruit buds formed on unpruned shoots. Terminal before pruning refers to the terminals of unpruned shoots, and terminal after pruning to the terminals on shoots produced following the summer pruning. The blossom buds on new spurs, and the axillary buds below where the summer pruning cut is made, will not be disturbed by any winter pruning. Unless a very considerable amount of growth has been made following summer pruning most of the terminals will need but very little, if any, heading back. Hence most of the bloom that is produced on one year wood, following summer pruning will be saved. This is especially true if the summer pruning has been in the nature of a rather severe heading back. Plates X to XV inclusive, show the response to summer pruning on several varieties.

From this it is apparent that the actual loss in

axillary fruit buds from summer pruning is not nearly so great as appears from simply noting the totals in Table IV. While a great many are lost when the summer pruning is done, those that do become fruit buds following a summer pruning are in a position where they may be saved without sacrificing the form and the strength of the tree. However, the fact remains as definitely established, that early summer heading back tends to prevent the formation of fruit buds on the one year wood.

The question naturally arises in this connection--why does summer pruning tend to prevent the formation of axillary fruit buds, when no such influence is apparent so far as buds on spurs are concerned? Some evidence on this question, and also on the question of the fundamental cause of fruit bud formation is afforded by the results of the present investigation taken in conjunction with the results attained by men working along related lines.

HOW DOES SUMMER PRUNING INFLUENCE FRUIT BUD FORMATION?

In presenting this phase of the summer pruning question, it is necessary first to say something about the conditions under which flower buds are believed to be formed in plants, and to show how these conditions are changed by summer pruning.

There have been many ideas and conjectures on the question of the condition in the plant most favorable to fruit bud formation. However, Gourley (19) in listing the more

prominent opinions that have been held concerning the cause of fruit bud differentiation, says, "It is interesting to note the large percentage of these factors which we may conveniently group under the general factor of storage of food in the tissues of the tree". The general opinion is that flower parts are formed as a result ofcertain favorable conditions of nutrition, usually associated with a check in vigor. Just what this condition of nutrition is, is not very definitely understood.

It is interesting and very suggestive in this connection to note the results of experiments that have been carried on with lower forms of plant life, in which the food supply of the plant has been absolutely under control. Davis (24) records Klebs work with two species of algae. He found that when they were placed in a solution of inorganic salts, they made a luxuriant vegetative growth, but formed no sexual gametes. However, these same plants placed in an organic solution formed sexual gametes readily, but produced little vegetative growth. Here, organic or elaborated food was definitely associated with sexual reproduction. In nature, elaborated food is obtained in the alga by photosynthesis, just as in higher plants, and only when it is in excess, whether this excess is obtained naturally or artificially, do the plants form gametes.

Any check in vegetative vigor in a plant usually means that there will soon be an abundance of elaborated food. When a plant is growing vigorously, most of the

food manufactured in the leaves is used up in cell building in the growing regions, As soon, however, as something happens to check this growth, unless at the same time the functioning of the leaves is interrupted, there will soon be an excess of elaborated food in the plant.

All through the plant kingdom, there seems to be a more or less definite relation between vegetative vigor and sex response. When plants are growing very vigorously, no sex organs appear, but any condition which will check this vegetative growth, causes flower buds, or other sex organs as the case may be, to form. So generally is this true that plants have been said to form flowers whenever any unfavorable condition comes on, thus reproducing themselves and perpetuating the race.

The experimental work that has been carried on appears to bear out the theory that the sex organs, or flowers, which contain sex organs of the higher plants, are formed when there is a high organic food supply in the plant. Klebs (25) working with Sempervivum (Hen and Chickens) and some other genera found that vigorous carbon assimilation and small water supply caused flower production. On the other hand, a large supply of inorganic salts and water forced the plant into vegetative growth. After a great deal of experimentation and observation, he concludes that for the various forms of the plant, there are certain favorable conditions of nourishment. This condition depends upon the relative amount of various products, rather than the absolute amounts present.

He reaches the conclusion that a relative abundance of organic food is essential to flower and gamete formation.

Gourley (19) records experimental work on the factors governing flower bud formation in the apple. He compared two Yellow Transparent trees which grew side by side, under practically identical conditions. One of these trees bears a heavy crop one year, with absolutely no fruit the second year, while the other bears during the "off" year of the first. He found that in every case, more starch was stored in the twigs of the tree that was not bearing a crop during the current season, but that is forming fruit buds. The leaf area, or organic food manufacturing area, is very much larger during the "off" year. These records cover two years, so that each tree bore a crop one year. In each case, fruit bud formation and a high organic food content in the tree was associated.

The bud studies that have been made in various parts of the country bear out this hypothesis as to the cause of fruit bud differentiation. Buds on spurs have been found to be diffentiated from July 1 to September 1. This is the season when vegetative growth becomes checked by dry, hot weather, and the leaf area is at its fullest expanse. Under these conditions, the organic food supply is naturally increased in relation to the inorganic salts and water in the plant. Furthermore, the comparative time of differentiation of buds on spurs and on current season's wood as previously recorded corresponds with what would

be expected if this theory is correct. On spurs, there is a relatively large leaf area, and only a small amount of annual growth takes place. Consequently, the organic food supply in those spurs should become abundant earlier in the season than in rapidly growing shoots. These shoots are not only growing rapidly until late in the summer, but their leaf area is also much less per unit of growth made than is the leaf area on spurs. Consequently, the organic food supply is presumably much smaller in these shoots, and it is but natural that if organic food must be abundant in the plant before fruit buds can be formed, the axillary fruit buds will be very late in forming. It has been noted that these buds do not form flower parts until August and September, when all shoot growth has practically ceased.

The question arises in this regard--to what degree are the various parts of plants dependent on their own leaves, and to what extent are they contributing to and drawing from the rest of the plant body? While this question cannot be answered entirely, indications are that often a shoot or a spur is largely independent of the organic food manufactured in the rest of the tree. It was noted on several varieties, that practically the whole tree may be cut back, and almost no axillary fruit buds be formed, but the buds on one or two shoots, left unpruned, will function exactly as they would were the whole tree unpruned. Often such shoots will produce many

fruit buds. Plate IX, fig. 1 shows such an unpruned shoot in the midst of a rather heavily headed White Pearmain.

Furthermore, if this hypothesis regarding conditions under which fruit buds are formed is accepted, the results obtained as the influence of summer pruning are readily explained. Summer pruning not only directly removes a portion of the leaf area of the tree, but it also stimulates the tree to later vegetative growth. Shoots produced following a summer pruning grow later in the fall, consequently they use up much of the elaborated food in vegetative growth. This, with the reduced leaf area, so decreases the amount of elaborated food in the current season's shoots that fewer axillary fruit buds are formed.

The number of such buds formed is directly proportional to the severity of the pruning given. More than double the number of fruit buds formed on one year wood on trees heavily pruned were formed on trees that received only a light pruning.

Of still greater interest in this connection, however, is the number of buds formed on growth produced following summer pruning. Those trees receiving light pruning formed 561 axillary and 228 terminal fruit buds on such wood, while the heavily pruned trees formed only 88 of the first, and 97 of the latter. Since these new shoots all started at the same time, it appears that the difference indicated by these figures must be due largely

to the greater amount of leaf area removed in the one case than in the other.

The fact that the spurs were affected but little if at all by the pruning out on the current season's growth indicates that they are largely independent of this part of the tree.

The question naturally arises--how has the idea of summer pruning causing fruitfulness gained such general acceptance when in fact it actually tends to reduce the number of axillary leaf buds? As a matter of fact, there is some foundation for the idea. Unpublished data in the hands of this Division shows that trees of certain varieties, receiving summer pruning regularly develop many more spurs than do those receiving only winter pruning. If certain types of summer pruning are practiced year after year, as has been done on the dwarfs and espaliers of Europe, abundant fruit spurs will be formed. The blossoming of these spurs will probably more than compensate for the direct loss from summer pruning. Even one year's pruning will do much to increase the number of spurs in a tree, and an increased number of spurs in a young, vigorous tree means increased fruitfulness later on.

Summer pruning is thus seen to be a practice that cannot be counted on to increase the production for the following year. In fact, its influence is in the opposite direction, at least so far as those varieties which tend to produce most of their first few crops from axillary fruit buds are concerned. On the other hand, it

may lead indirectly to increased fruitfulness through stimulating spur production in those varieties that tend to bear much from spurs.

SUMMARY

1. Axillary leaf buds rise just back of the growing point of the shoot, develop very rapidly for a time, then show slow development as long as the shoot is growing.

2. This development is neither retarded nor hastened by summer pruning, nor can any influence of the summer pruning be detected in these buds.

3. The buds on the two portions of a summer pruned branch in no way correspond to two seasons of growth. It is a two-season form with one season buds.

4. Axillary fruit buds are differentiated about the time that active shoot growth ceases. This is from a month to six weeks later than the spur buds on the same trees.

5. Axillary fruit buds develop just as do the buds on spurs. However, they are much later in forming, hence are behind spur buds in beginning to develop, and never regain this loss. They show a less advanced condition during the winter than do spur fruit buds, and they open later in the spring.

6. Leaf buds on spurs show slight growth during the summer, but unless they become differentiated as fruit buds, little development occurs after July.

7. Fruit buds on spurs of the varieties used and for the seasons mentioned were formed at about the time men-

tioned by former investigators. Considerable variation between varieties, so far as rate of development is concerned, could be detected.

8. Summer pruning exerts no influence upon the rate of development of leaf or fruit buds on spurs, unless such buds are immediately below the pruning cut. Fruit buds may be forced out into bloom in the latter case.

9. Summer pruning materially reduced the number of fruit buds formed on one year wood. This reduction was proportional to the severity of the pruning. No influence of the summer pruning could be detected in the number of fruit buds formed on old spurs.

10. The reduction in axillary fruit buds is probably due partly to reducing the number of axillary buds, but largely to reducing the leaf area and stimulating the shoot to later growth.

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EXPLANATION OF PLATES

Plate I. The development of the axillary leaf bud.

Fig. 1, Terminal of growing Spitzenburg shoot, showing at (a) the first formation of the axillary bud.

Fig. 2. Axillary bud of Lady, from near growing tip.

Fig. 3. Wagener bud from median portion of shoot, June 14.

Fig. 4. Same for July 9.

Fig. 5. July 30.

Fig. 6. September 8.

Plate II. Axillary leaf buds as affected by pruning.

Fig. 1. Yellow Transparent, forcing out five days after pruning.

Fig. 2. Same, 13 days after pruning.

Fig. 3. Yellow Transparent of September 8, from wood produced before a light pruning.

Fig. 4. Same from wood produced following the pruning.

Fig. 5. Bud from unpruned shoot of Lady, taken September 8.

Fig. 6. Bud taken September 8 from shoot produced on Lady following a heavy pruning.

Plate III. Axillary leaf buds of December 8.

Fig. 1. From unpruned Jonathan shoot.

Fig. 2. From Tetofsky.

Fig. 3. From White Pearmain.

Fig. 4. From growth produced following a light pruning on Tetofsky.

Fig. 5. Same, following a very heavy pruning.

Fig. 6. From new growth following moderately heavy pruning on Wagener.

Plate IV. Axillary fruit bud differentiation September 8.

Fig. 1. Wagener not yet fruit.

Fig. 2. Same, fruit.

Fig. 3. Tetofsky, not yet fruit.

Fig. 4. Same, fruit

Fig. 5. Jonathan, not yet fruit.

Fig. 6. Same, fruit.

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

Fig. 1. Tetofsky, September 8.

Fig. 2. Tetofsky, September 8 (more advanced).

Fig. 3. Tetofsky, December 8.

Fig. 4. Tetofsky, December 8 (more advanced).

Fig. 5. Wagener, December 22.

Fig. 6. Young axillary fruit bud of Tetofsky, forcing out into growth.

Plate VI. Spur buds from old and new spurs.

Fig. 1. Average Jonathan leaf spur of June 14.

Fig. 2 Average Jonathan leaf spur of December 8.

Fig. 3. Leaf bud from new spur of Wagener, December 22.

Fig. 4. Leaf bud from old spur of Wagener, Decem-

ber 22.

Fig. 5. Leaf bud from spur of Lady, forcing into growth.

Fig. 6. Fruit bud from spur of White Pearmain, forcing out.

Plate VII. Study in spur fruit buds.

Fig. 1. White Pearmain--fruit bud from old spur, December 22.

Fig. 2. White Pearmain--fruit bud from new spur, December 22.

Fig. 3. Jonathan--Average spur fruit bud, December 8.

Fig. 4. Jonathan--Average terminal fruit bud, December 8.

Fig. 5. Tetofsky--Average spur, November 5, 1914.

Fig. 6. Tetofsky--Average spur, December 8, 1915.

Plate VIII. Spur formation following summer pruning with no winter heading.

Fig. 1. On R. I. Greening.

Fig. 2. On Oldenburg.

Plate IX.

Fig. 1. Unpruned shoot of White Pearmain in midst of heavily pruned tree.

Fig. 2. New spur formation on Snow.

Plate X.

Fig. 1. Jonathan. No summer pruning in 1915. Taken April 15, 1916.

Fig. 2. Jonathan lightly pruned, June 25, 1915. Taken April 8, 1916.

Plate XI.

Fig. 1. Jonathan, very heavily pruned, June 25, 1915. Taken April 15, 1916.

Fig. 2. Yellow Bellflower, not summer pruned in 1915. Taken April 8, 1916.

Plate XII.

Fig. 1, Yellow Bellflower, pruned lightly, June 28, 1915. Taken April 8, 1916.

Fig. 2. Same, pruned fairly heavily, June 28, 1915.

Plate XIII.

Fig. 1. Wagener, not summer pruned during 1915. Taken April 8, 1916.

Fig. 2. Wagener, lightly pruned June 26, 1915. Taken April 8, 1916.

Plate XIV.

Fig. 1. Wagener, heavily pruned June 26, 1915. Taken April 8, 1916.

Fig. 2. Alexander, unpruned during summer of 1915. Taken April 8, 1916.

Plate XV.

Fig. 1. Alexander pruned lightly, June 25, 1915. Taken April 8, 1916.

Fig. 2. Alexander, pruned heavily, June 25, 1915. Taken April 8, 1916.

PLATE I

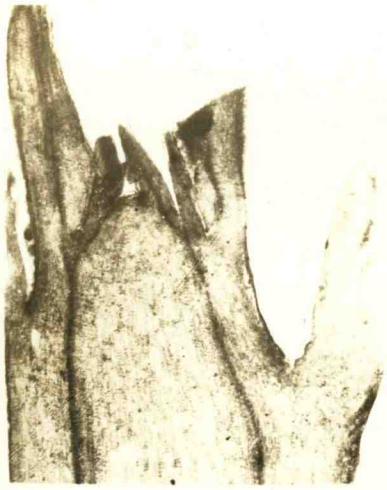

Fig. 1

Fig. 2

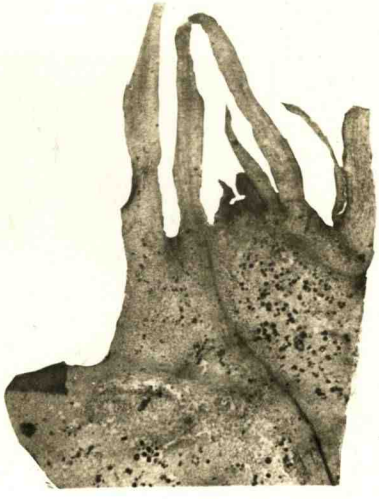

Fig. 3

Fig. 4

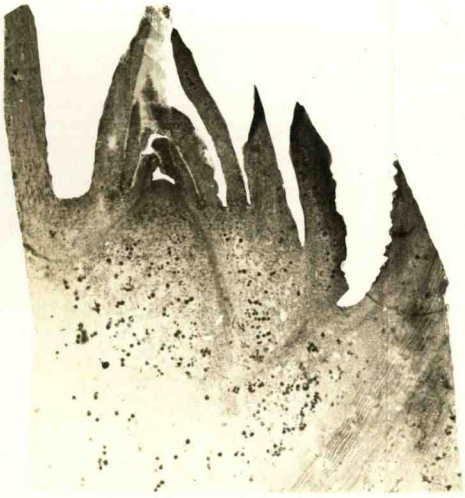

Fig. 5

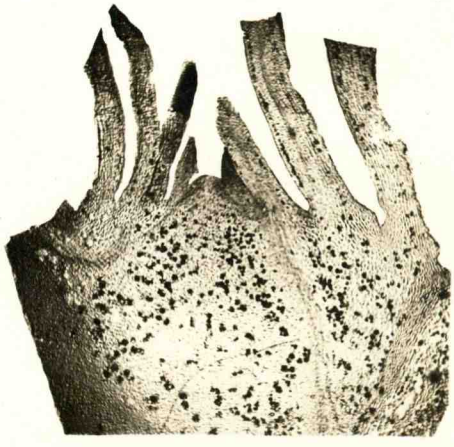

Fig. 6

PLATE II

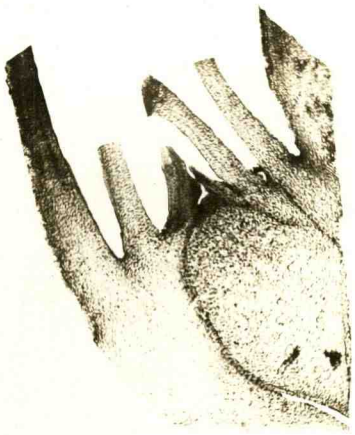

Fig. 1

Fig. 2

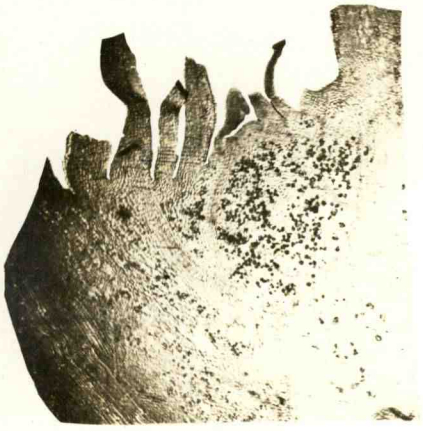

Fig. 3

Fig. 4

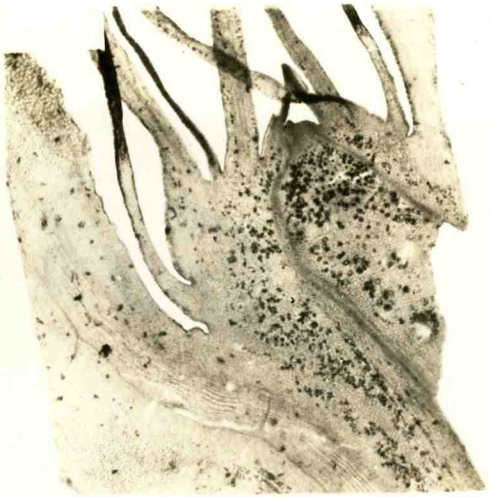

Fig. 5

Fig. 6

PLATE III

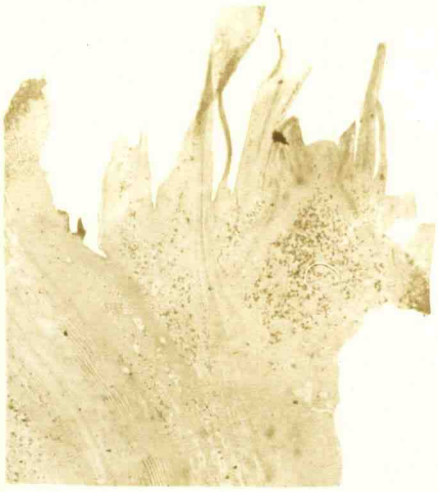

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

PLATE IV

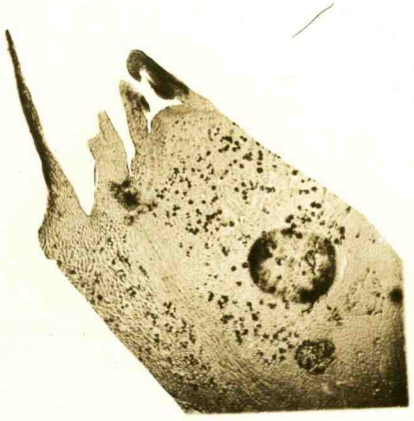

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

PLATE V

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 1

Fig. 2

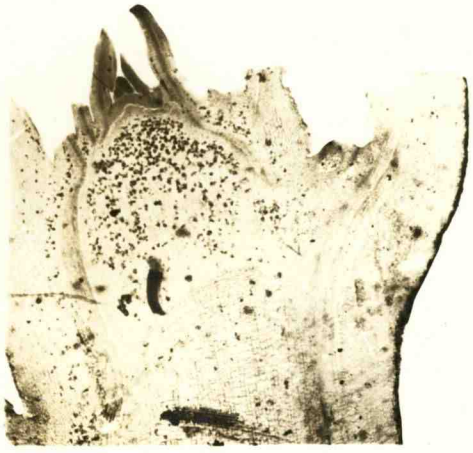

Fig. 3

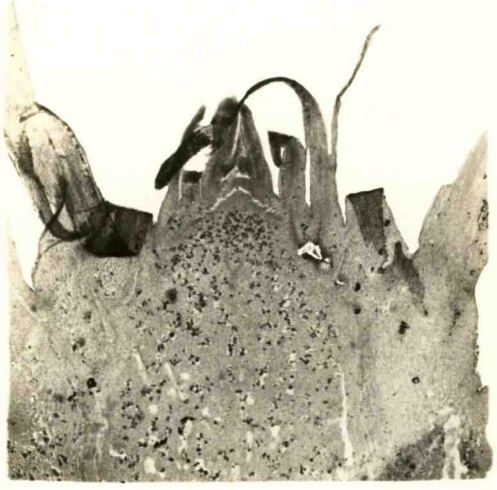

Fig. 4

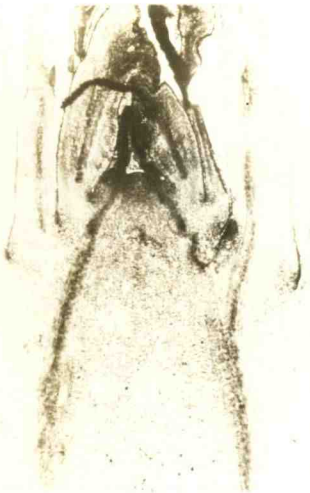

Fig. 5

Fig. 6

PLATE VII

Fig. 1

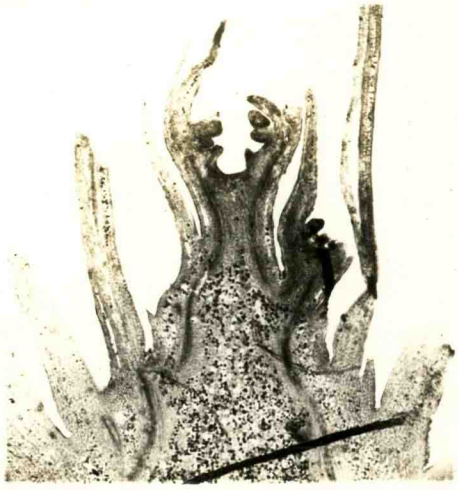

Fig. 2

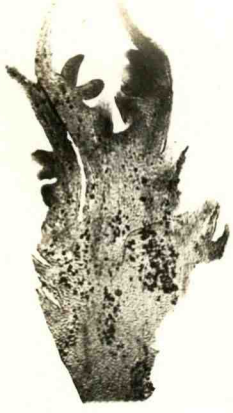

Fig. 3

Fig. 4

Fig. 5

Fig. 6

PLATE VIII

Fig. 1

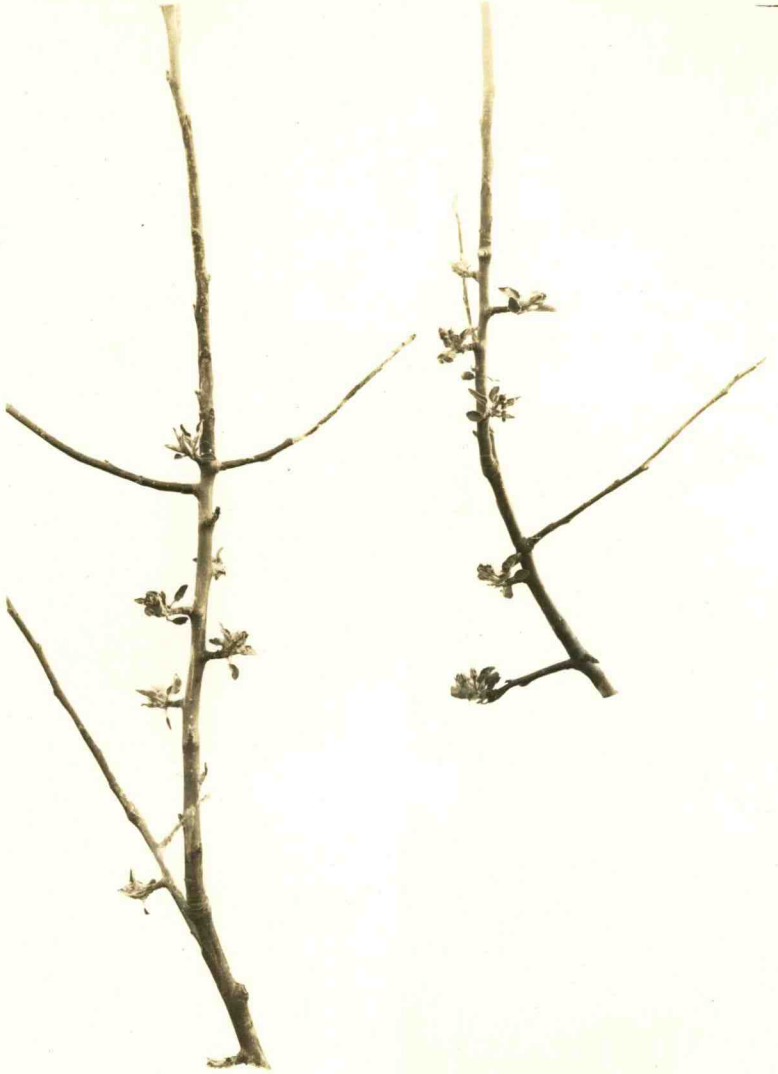

Fig. 2

PLATE IX

Fig. 1

Fig. 2

PLATE X

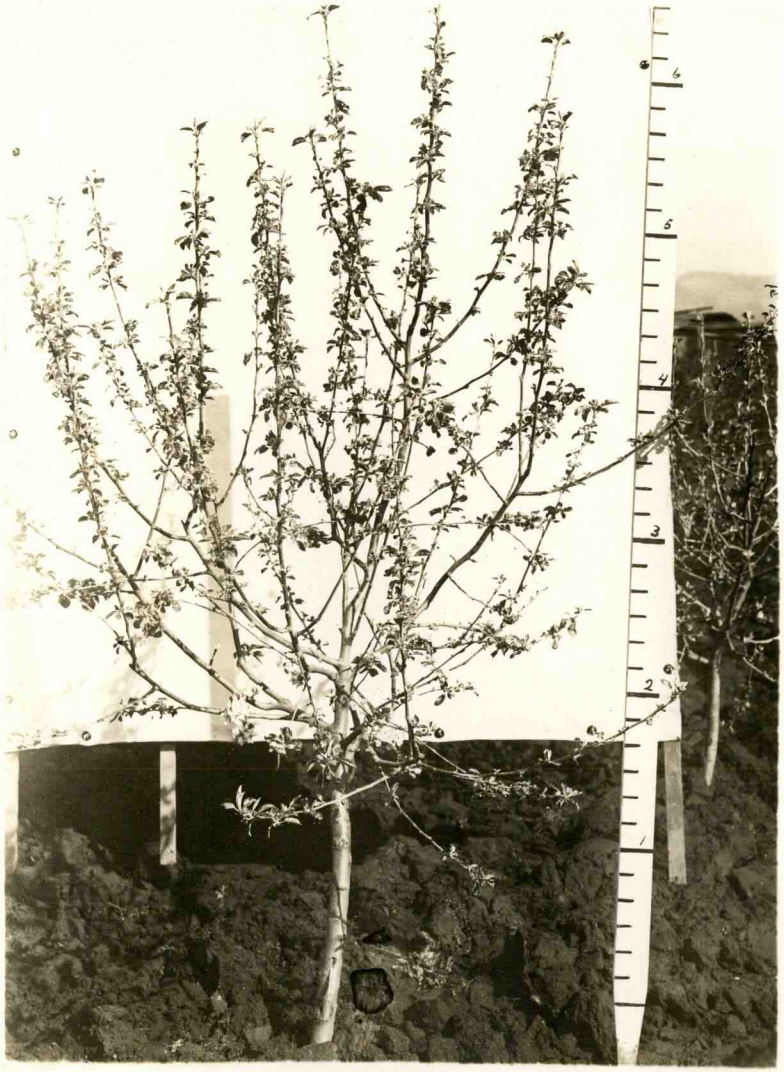

Fig. 1

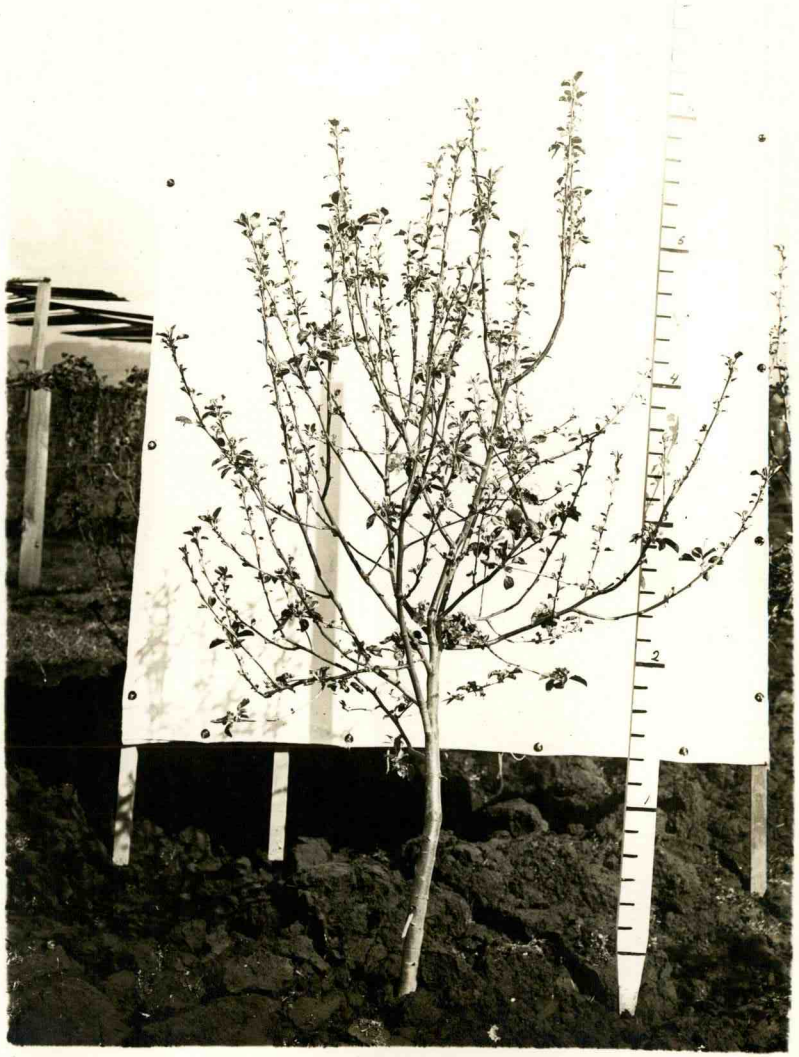

Fig. 2

PLATE XI

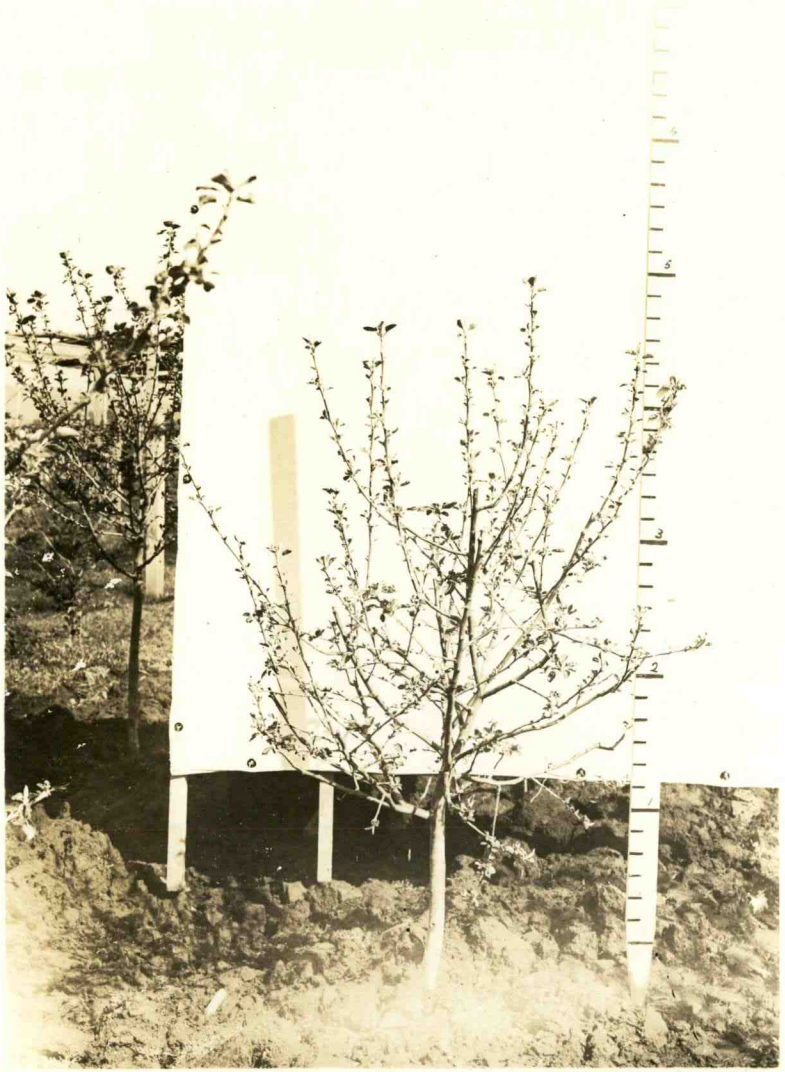

Fig. 1

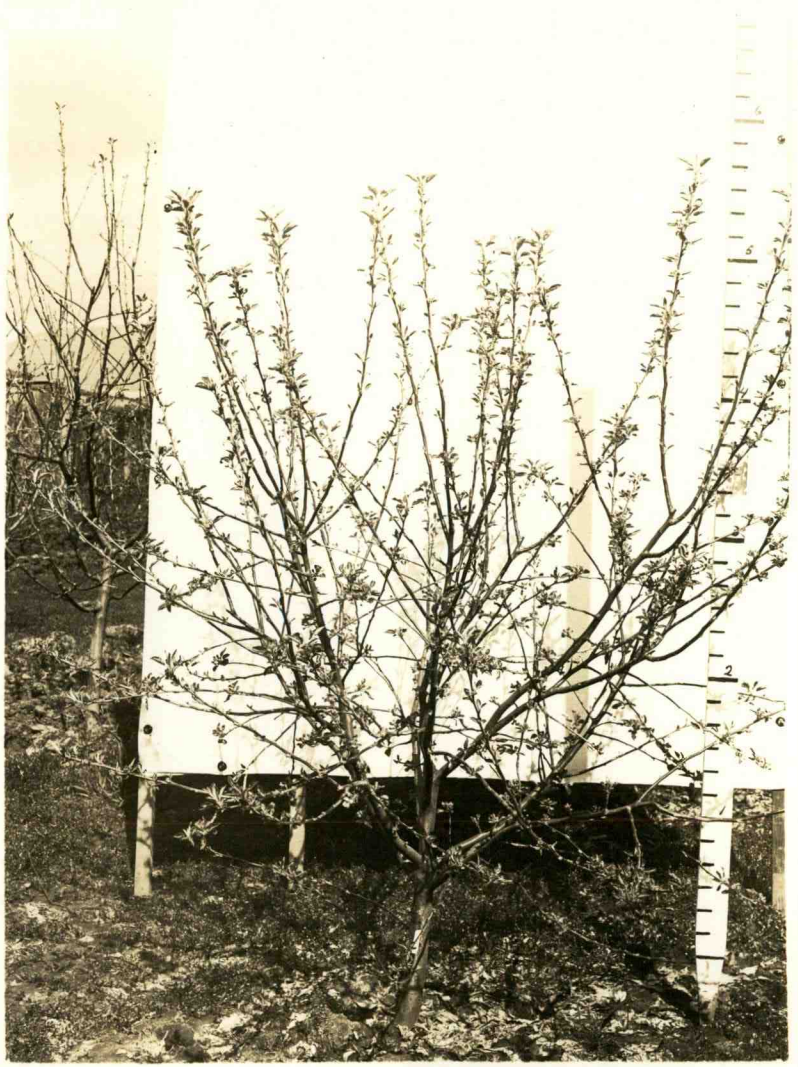

Fig. 2

PLATE XII

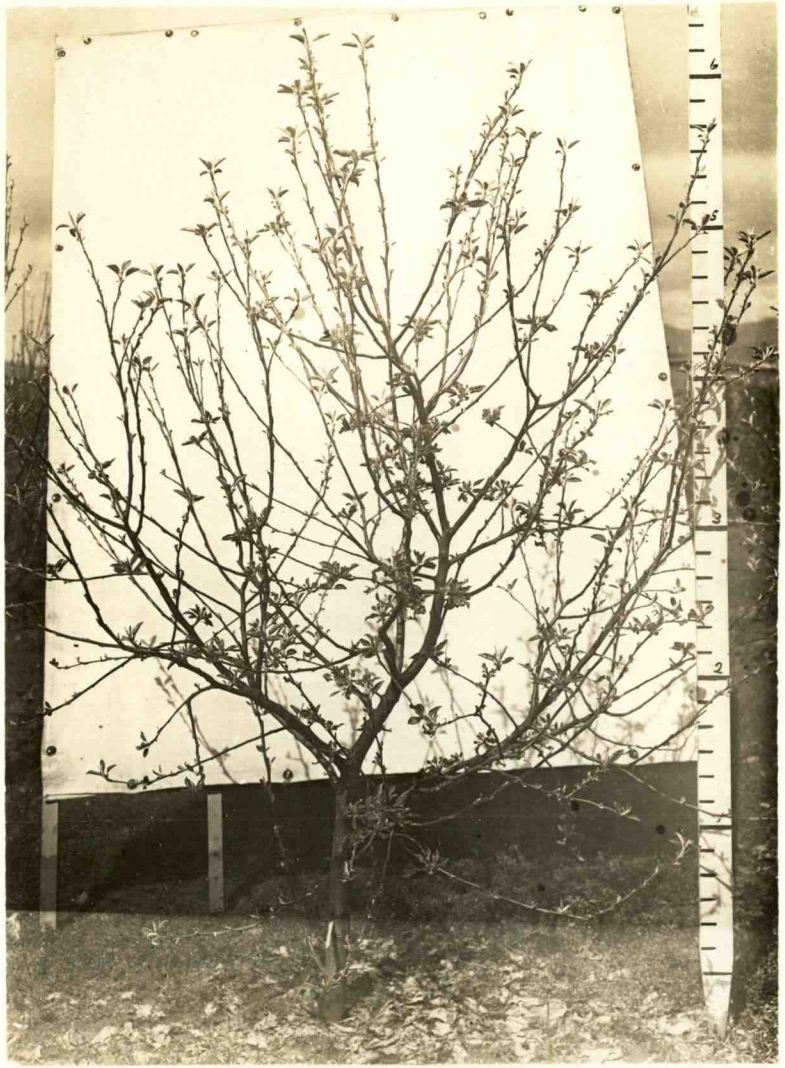

Fig. 1

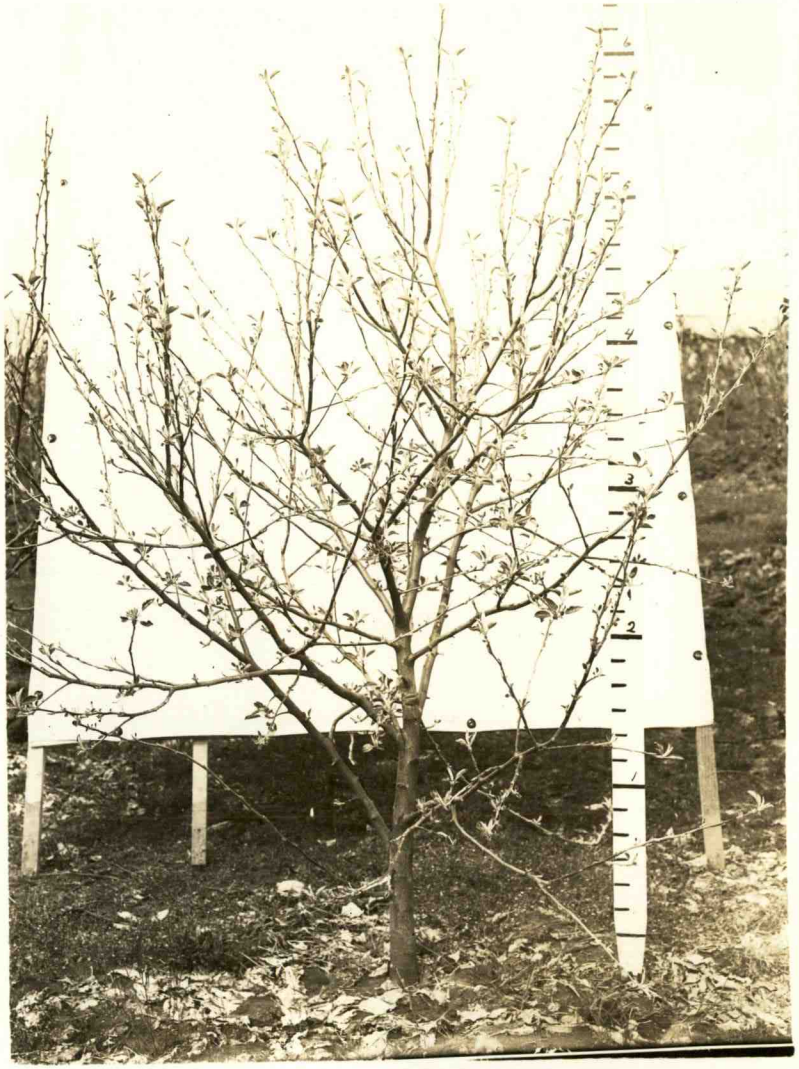

Fig. 2

PLATE XLII

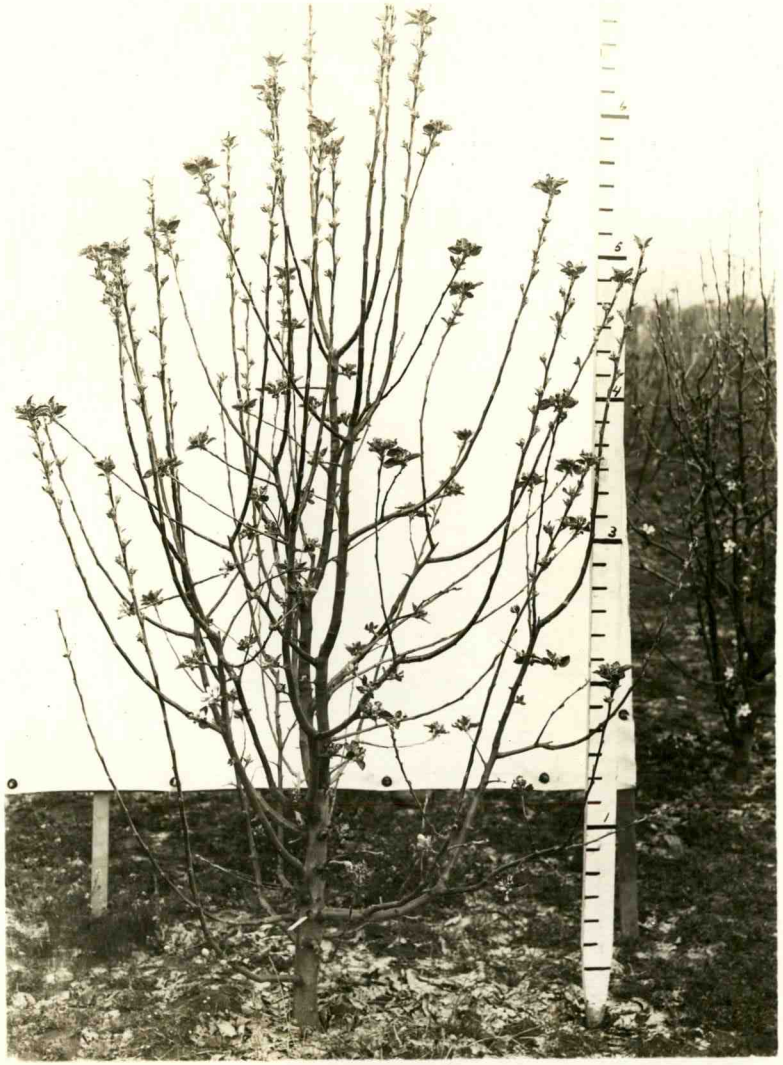

Fig. 1

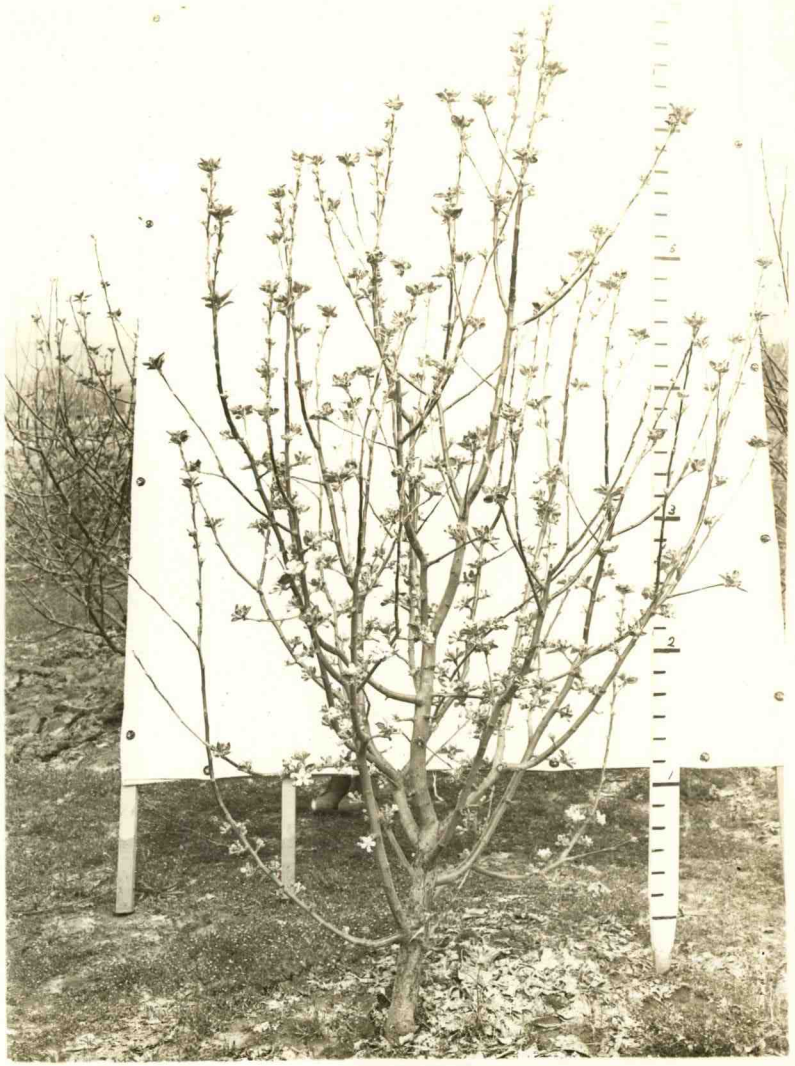

Fig. 2

PLATE XIV

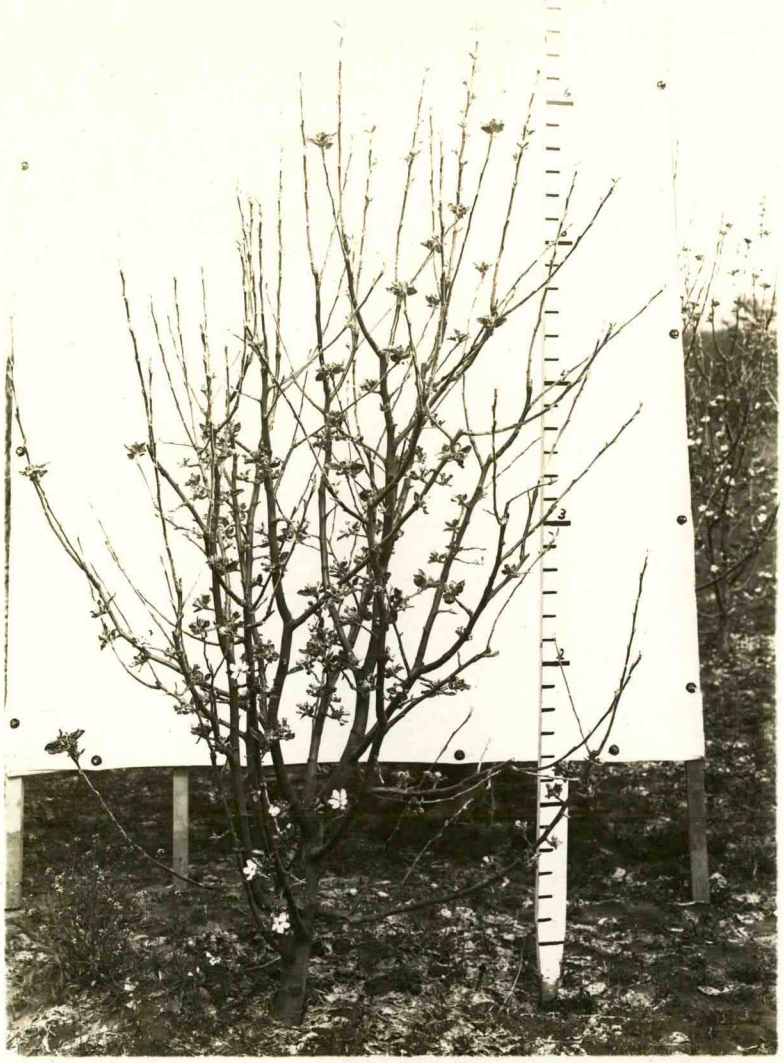

Fig. 1

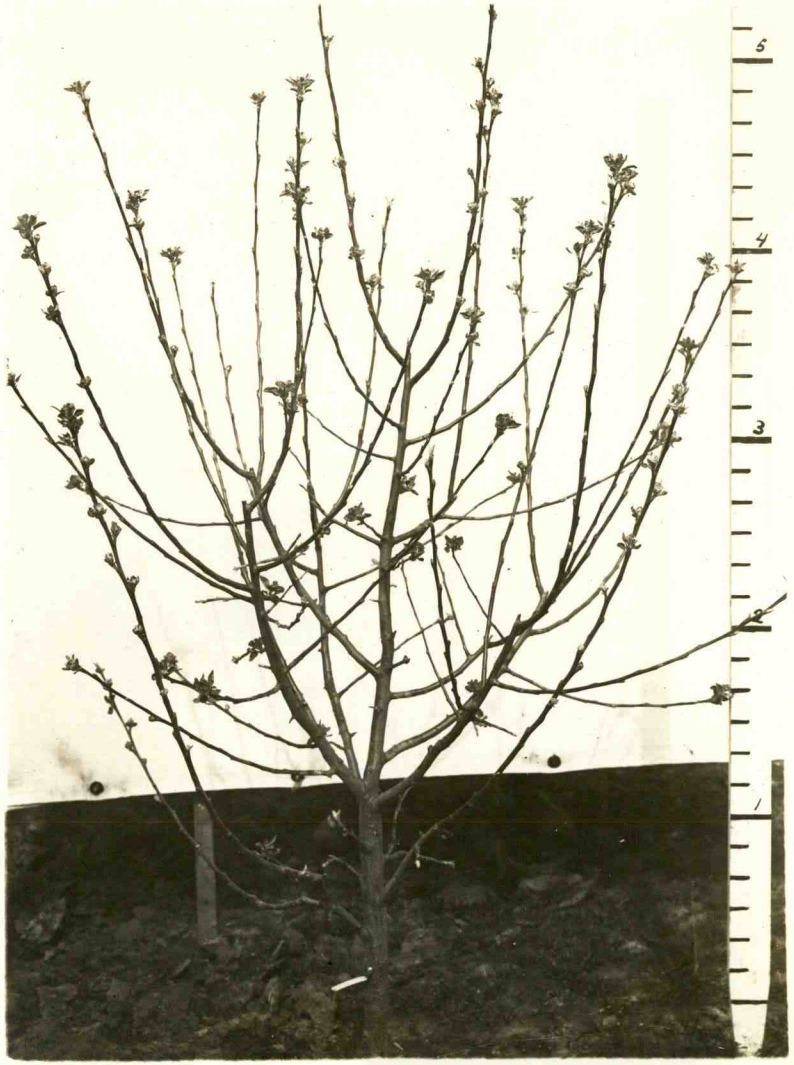

Fig. 2

PLATE XV

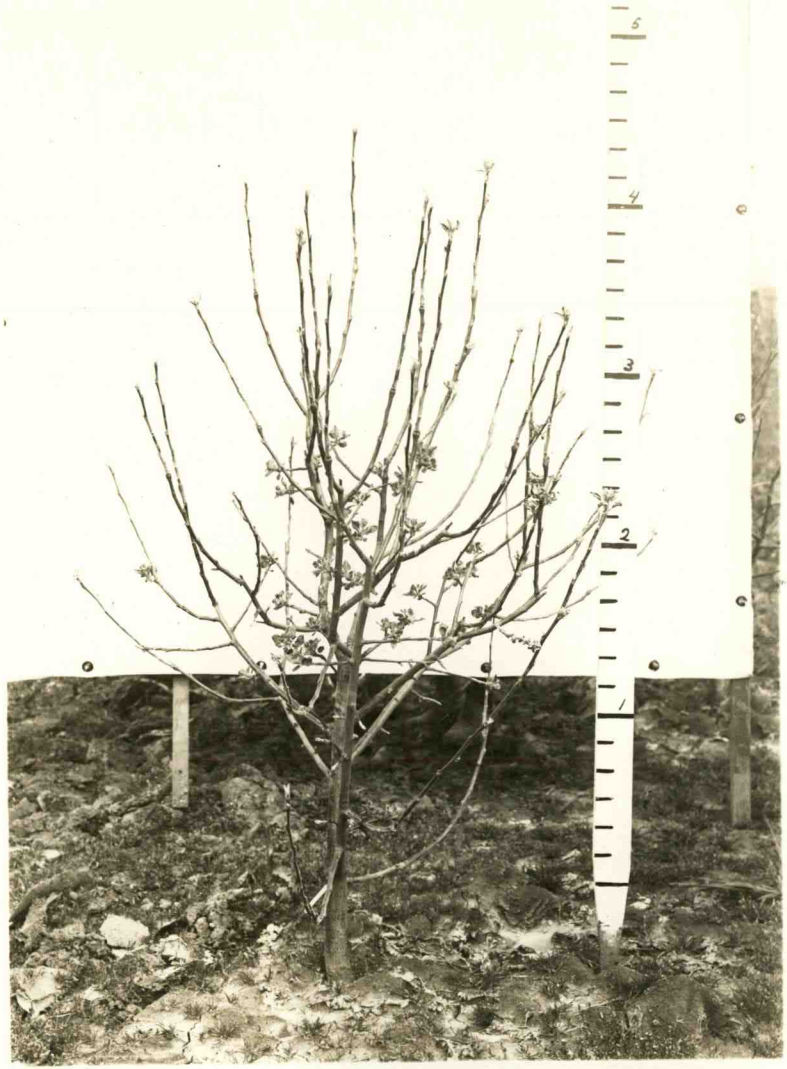

Fig. 1

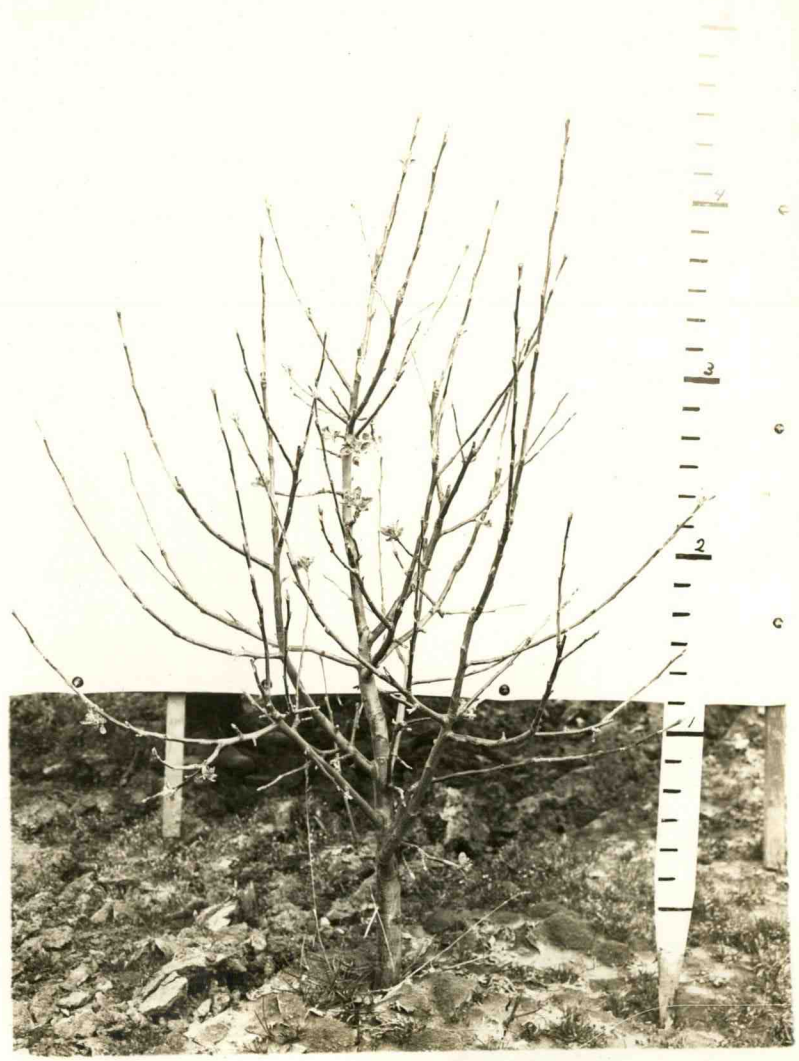

Fig. 2