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# AN INVESTIGATION IN TRANSPLANTING

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## COLLEGE OF AGRICULTURE

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# AN INVESTIGATION IN TRANSPLANTING

J. C. WHITTEN

## SUMMARY

A review of the existing literature, bearing upon the season at which fruit trees should be transplanted, shows that a majority of the authors recommend spring planting.

A classification of these expressed opinions based upon the climatic condition at the source of each, reveals the fact that for the most part those who recommend spring planting base their opinion upon experience in sections where winter conditions are trying, and those who recommend fall planting base their advice upon experience in the milder fruit-growing sections.

Those who express a preference for fall planting, emphasize the desirability of planting in very early autumn, for the alleged reason that it gives time for the roots of the trees to become better established before cold weather approaches. Experience at the Missouri Experiment Station shows that this does not hold true under Missouri conditions.

At the Missouri Experiment Station fall planting hardy fruit trees and most hardy deciduous trees and shrubs has given better results than spring planting.

Late fall planting has given better results than early fall planting.

Late spring planting has given as good results as early spring planting, providing the trees are kept dormant until they are planted.

Trees "heeled in" for planting may be held dormant until late spring, sometimes until early June, by lifting them out of the trench, turning them over, and again heeling them in in the same trench, as often as their buds show indication of starting.

Sour cherries usually suffer a mortality of one-third to one-half of the number of trees when planted in spring, but suffer no appreciable mortality when planted in late fall.

Peaches and most species which are subject to winter injury under Missouri conditions succeed best when planted in the spring.

Coniferous evergreens succeed best if transplanted just as their new growth is starting in the late spring. If the soil is moist and the weather is humid they may be transplanted in early autumn with satisfactory results.

Certain species of trees transplant best under special conditions mentioned in this bulletin.

Apple trees planted in the fall usually begin new root formation about the first of January, from the sides of the lower main roots, after the surface soil has frozen. Early fall-planted trees have begun root growth no earlier than late fall-planted trees. New root growth apparently proceeds slowly thruout the winter, below the frost line.

Apple trees planted in early fall dry out more during fall and winter than do those planted in late fall. The reason, apparently, is that their parts are less thoroly ripened or not fully at rest at the time of early planting. This date is followed by a period of high atmospheric temperatures and often by dry weather.

There is an obvious accumulation of soil warmth about the roots in early winter, beneath the frozen crust. New root formation may be stimulated by this "bottom heat" which passes upward in early winter. New root growth begins on the lower roots of fall-set trees and on the roots nearest the surface in the case of spring-set trees. New root growth apparently does not begin essentially earlier on early spring-planted trees than on those set later. In both cases new root growth starts with the advent of the leaves, or even later.

Fall-planted trees, mulched during the winter, have made slightly poorer growth than those not mulched. The soil about the mulched trees dries and warms more slowly, even where the mulch is removed in early spring.

Young apple trees having their branches pruned back in autumn make better growth the following season than do trees pruned back in spring. This holds true whether or not the trees are transplanted. Branches pruned back evaporate more water thru the wounds than do similar branches which are not pruned, for the first few days only. After the first few days the pruned branches lose less water thruout the winter than do those which are not pruned.

The wound made in pruning back a twig, or a slight wound anywhere on a twig, stimulates greater growth of adjacent buds. A wound made just above a bud stimulates greater growth than a similar wound made below or at the side of a bud. Wounds made in autumn stimulate greater growth the following season than do similar wounds made in the spring.

In transplanting fruit trees under Missouri conditions the roots, generally, should be set no deeper than they stood in the nursery. This is especially true if the trees are set in the spring, at which time the soil is slow in warming to the depth of the lower roots.

The tendency of trees in the orchards of this region to lean toward the northeast may be overcome in part by proper orientation of the trees at the time of transplanting, as explained in the text of the bulletin.

In setting fruit trees the soil should be pressed firmly about the roots to avoid drying out; the main roots should be set in their normal position without being bent or twisted. Digging large holes for the trees or shattering the subsoil is not necessary, except under certain conditions explained in the text.

The small, fibrous roots of transplanted fruit trees usually die, due to drying out or bending in setting, unless they can be dug and reset immediately with a mass of soil. The dead, fibrous roots should be pruned away at the time of transplanting, since they are an encumbrance and prevent pressing the soil into close contact with the larger essential roots.

The tops of young fruit trees should be pruned back at the time of transplanting, the degree of pruning differing with the character and habit of growth of the species.

The roots of fruit trees should not be allowed to freeze in handling. Tests show that while the tops of the trees may endure severe freezing without injury, the roots may be injured even by a few degrees of frost.

Garden vegetables such as cabbage, tomatoes, etc., will endure lower temperatures and greater extremes of drouth without injury, after transplanting, if grown more slowly in the forcing bed than is customary. Such vegetables grown in a seed bed of sandy soil, low in plant food, watered sparingly and ventilated freely have large fibrous root systems, short, stocky, firm, woody stems, and a concentrated sap of low freezing point. Vegetables grown in a seed bed of rich soil, highly manured, abundantly watered and in a high temperature with little ventilation, have scanty root systems, long stems, luxuriant leaves, succulence and a less concentrated sap of higher freezing point.

# Part I.—The Development of Fruit Trees as Influenced by Season of Transplanting

## INTRODUCTION

The season of transplanting, as a factor affecting the subsequent development of fruit trees, appears to have been the object of comparatively little experimental investigation. It is the usual custom of most fruit growers to transplant their trees in the spring. Possibly this custom may be the outgrowth of the opinion among early agriculturists that "the spring is Nature's time to plant." While spring transplanting is most largely practiced, practical experience has shown that most deciduous trees may be successfully planted at almost any time during their dormant period when soil and climatic conditions are at all favorable.

There is some conflict of opinion as to the most favorable season for transplanting fruit trees. Reference to the leading manuals on this subject shows that in both Europe and America a minority prefer fall planting. Some express no preference between fall and spring. Those who prefer fall planting usually emphasize the desirability of planting in very early autumn for the alleged reason that it gives time for the roots of the tree to become better established before cold weather approaches.

A careful classification of these expressed opinions, based upon the climatic conditions at the source of each, reveals a very interesting fact which apparently has not been adequately considered. It is found that those who recommend spring planting base their opinions upon experience in severer climates, while those who recommend fall planting base their advice upon experience in the milder fruit-growing sections. Careful consideration of the foregoing fact suggests that spring planting may perhaps be preferable toward the north and fall planting toward the south.

The abundant experience of practical fruit growers may seem to be an adequate basis upon which to decide this question for a given district. However, emphatic opinions differ, even among fruit growers of the same neighborhood. In view of these differences of opinion among practical growers, and in view of the fact that definite experimental data seem to be inadequate, the writer has been unable to satisfy the question as to the best season for transplanting for Missouri orchardists. For this reason, observations of the behavior of fall- and spring-planted trees were begun at the Missouri Experiment Station about twenty years ago. Frequent visits were also made to large commercial orchards which contained both fall- and spring-planted trees. These observations revealed evidences that fall planting was to be preferred. Consequently, definite experiments were begun in 1908 with a view to recording accurately the results of fall and spring planting, and, if possible, to determine the reason for any difference in the behavior of the trees. These experiments have yielded results that should prove of value to Missouri orchardists.

Additional questions in connection with transplanting, such as the depth to plant, orientation of the tree, mulching, shaping the tree at transplanting, etc., have arisen and have been given attention.

In view of these results it is of interest to review and to attempt to harmonize existing data and opinions in their relation to results secured at the Missouri Experiment Station.

## A BRIEF REVIEW OF LITERATURE REGARDING THE SEASON OF TRANSPLANTING

Lindley[34]* in "Horticulture" states that fruit trees may be transplanted successfully at almost any time during their dormant period. After a full discussion of the matter he finally concludes that "the earliest time at which planting can be effected after the leaves fall in autumn is, upon the whole, the best." He states that this allows the wounds a longer time to heal, thus resulting in less injury to the plant.

Downing[18] in "Fruits and Fruit Trees of America" concludes that "autumn planting is greatly to be preferred in all mild climates, on dry soils; and even for very hardy trees like the apple in colder climates; as the fixed position in the soil which the trees planted then get by the autumnal and spring rains, give them the advantage at the next season of growth over newly planted trees."

Bailey[1] in "The Principles of Fruit Growing" writes: "Fall planting is generally preferable to spring planting on thoroly drained and settled lands, particularly for hardy tree fruits like apples, pears and plums, and if the ground is in good condition and the stock well matured, peaches may be sometimes set in October, even in northern states with success." He states further that it is usually better to buy trees in the fall; "these trees must be kept until plant-

*The number, following the author's name, indicates reference to be found in the bibliography.

ing time, and it is about as cheap and fully as safe to plant them directly in the field as to heel them in until spring."

Thomas[48] in "The American Fruit Culturist" advises against removing the tree from the nursery too early, against planting when the soil conditions are unfavorable, and to prevent injury to heeled-in trees during winter. He concludes "it is a matter of small consequence at which season the trees are planted out, provided the work is well done."

Engler[20] in a paper on the root development of trees gives the following general rule: "In regions with well marked spring and fall rains, spring is the best time; in regions with dry summers and fall rains, fall planting is the time of the beginning of renewed activity of the roots which will vary with the species and locality between the end of September and the middle of October, and should be ascertained locally."

Brackett[9] expresses the belief in Farmers' Bulletin 11, that the season of transplanting is governed somewhat by latitude, and mentions as an objection to fall planting that "the roots of a tree do not take hold of the ground sufficiently to supply moisture to maintain a healthy, active circulation of the sap, which is required to prevent shriveling of the branches during winter's extreme cold and exhaustive evaporation from drying winds."

The six writers cited above are representative of widely separated sections of Europe and America. Three definitely committed themselves in favor of autumn transplanting. The other three express no decided preference between fall and spring. They mention, however, precautions necessary to avoid injury, provided planting is done in the fall. Each discusses the question broadly enough to indicate that the time for transplanting may vary with conditions in a particular section.

In order to throw further light upon the transplanting season which is perhaps most favorable in different districts of the United States it will be of interest to classify representative writings in accordance with the different fruit-growing regions of this country.

In making this classification the fact should be kept in mind that undoubtedly each author has considered the problem more widely than with reference to the locality in which he wrote. In a general way, however, this classification seems helpful in determining what are the conditions which favor or oppose transplanting under a given set of conditions.

## NORTHEASTERN DIVISION OF THE UNITED STATES

Sears[45] of Massachusetts states that fall planting is objectionable chiefly for the reason that the nurserymen may have to strip the leaves from the trees in order to take them from the nursery early enough for transplanting at this season. He expresses preference for transplanting fruit trees just as early in spring as the soil is in good condition to work. Jarvis[30] of Connecticut states that if soil and weather conditions are favorable after the stock arrives the trees may be safely and profitably planted in the fall. His entire discussion indicates apparently a slight preference for fall planting. Gourley of New Hampshire reports very favorable results from fall planting of apple trees. Wilkinson[53] of New York is quoted as follows: "If stock arrives in time [in the fall] it may be safely and profitably placed where they are to remain permanently. If conditions in fall are not right, spring planting is undoubtedly the safer course."

## NORTH-CENTRAL DIVISION OF THE UNITED STATES

White[50] of Michigan believes that in general the best season to plant depends upon the convenience of the planter but states the precaution: "If in any doubt as to the time to plant, leave it until spring." Erwin[21] of Iowa advises spring planting for the upper Mississippi valley and says that "trees which have been disturbed in the fall by transplanting are more subject to root killing the following winter. The work should be done in spring so that the roots may have time to become established before the hot dry weather of August." Green[27] of Minnesota likewise favors spring planting as a rule for the extreme north. He states further, however, that the very hardy fruit trees may be set in autumn provided they are afterward laid on the ground at the approach of winter and covered with earth and a little mulch to protect them from severe winter temperatures.

## CENTRAL AND SOUTHERN STATES

Whitten[51] of Missouri advises fall planting for all hardy, deciduous species, and spring planting for tender species. He observes that root growth will progress below the frost line during the winter in the case of fall-planted trees, but that the root growth of spring-planted trees is slow and uncertain and that the trees frequently come out in leaf before their new root growth becomes established. Chandler[21] of Missouri says: "In most of Missouri it is not best to plant peach trees in the fall on account of the danger from severe weather and dry winters, tho in a very favorable year the fall-planted trees will make better growth the first summer. In the extreme south if the ground is in good, moist condition very late in the fall or early in winter, it would be desirable to plant the trees then and a good mulch of some kind would be of great advantage."

Berchmans[8] of Georgia advises that where the soil is naturally dry and warm all hardy and deciduous trees should be planted as early in the fall as the growth ceases and the usual growth is well hardened off. He states further that in sections where the climate is mild, trees are inactive in their parts above ground during winter but remain active below ground in the formation of new roots.

## SEMI-ARID WESTERN STATES

Paddock[41] of Colorado recommends spring planting only, for the semi-arid fruit sections of the west. Shinn[46] of Idaho regards spring planting as safer for Idaho orchardists because of a drying out of fall-planted trees during their dry autumn and winter. He advises digging the trees in the fall and heeling them in, in order to give opportunity for callusing of the injured roots before spring, which he regards as "one of the main benefits of fall planting." Garcia[22] of New Mexico, for similar reasons advises spring planting for New Mexico orchardists.

## PACIFIC COAST STATES

Wickson[52] of California emphasizes two factors which should cover the season for transplanting fruit trees—the dormancy of the tree and the proper condition of the soil. He states that these factors are more apt to coincide in most parts of California about the first of January. He found that trees transplanted early had their wounds callused over and new rootlets considerably advanced before the buds begin to swell. Lanham[34] of Washington reports observations upon one thousand acres of apple trees planted from December 1, 1910, to April 1, 1911, and summarizes with the following comment: "The first planting made at least twice the growth of those set out last with a gradual gradation between."

Of horticulturists quoted from the northeastern states, three out of four prefer fall planting. The objection to fall planting raised by the fourth is that the trees may have to be lifted from the nursery before they are fully matured in order that the orchardist may be able to secure them before the ground freezes. This objection, therefore, applies to inconvenience of getting the trees to the orchard on time and does not necessarily indicate whether or not fall planting might be preferable if thoroly ripened trees could be secured sufficiently early. It should be observed in this connection that the northeastern section has a maritime climate in direct contrast to the dry winter climate of the north central states, the interior plains or the Rocky Mountain district.

Spring planting is generally recommended in the extreme north central states as well as prairie and Rocky Mountain states where the winters are dry and where the trees are subject to extreme winter desiccation.

It is apparent that in the central and southern states where rainfall is adequate and where the winters are mild, fall planting is preferred by the writers quoted.

In the Pacific Coast states where most of the rainfall occurs during their mild winter, December and January is recommended as the best planting season.

The advice summarized above no doubt represents a safe guide for general practice in the various districts of the United States. It is based upon the observation and wide experience of men who have given the general subject careful attention and who may be depended upon to represent an accurate judgment as to sound experience in their district.

A number of horticulturists have submitted definite data concerning the relative behavior of trees planted at different seasons. A consideration of these data is of interest. Koopman[33] reports the results of extensive experiments conducted at Potsdam giving the following summary:

I. Fall planting gave better results than spring planting in eighteen cases.

II. Fall planting gave the same results as spring planting in five cases.

III. Fall planting gave inferior results to spring planting in thirteen cases.

IV. Winter planting gave inferior results to fall planting in ten cases out of eleven.

V. Winter planting gave inferior results to spring planting in ten cases out of eleven.

VI. Early spring planting gave better results than late spring planting in all cases.

In Koopman's experiments the best results were in some cases secured with fall-planted trees and sometimes with spring-planted trees. After careful study and discussion of these results he recommends transplanting in the fall immediately after the leaves are shed or in the spring at the time the buds first begin to swell. He found either of these periods more favorable than very late fall or late spring.

Bedford and Pickering[2] in reports of the Woburn Experimental Fruit Farm, give the results of experiments dealing with the season of transplanting apple trees in England. They found that apple trees planted November 28, 1894, were, after one year's growth, decidedly less vigorous than the winter- or spring-planted trees. They state in this Report (2-1897) that "this would indicate that the generally received opinion as to the superiority of autumn as to the best time for planting is erroneous, but that the experiment must be repeated before drawing a positive conclusion." In a later experiment, 1905, five different plantings were made—one in early autumn, one in late autumn, one in winter, one in early spring and another in late spring. When the trees of these plantings were four years old they were carefully lifted and their weights compared with their weights when planted. The results showed that the percentage increased weight of the trees planted October 30 was nearly twice as great as that of those planted April 18, and was 75 per cent greater than the increase of the trees set in late fall or December 3. While their conclusions were in favor of early fall planting, they further state that, "unfortunately, it is rarely possible for growers to obtain their trees early enough to secure the advantages which very early autumn planting offers, unless the trees have been raised on the farm itself. Nevertheless, we should always advise planting as early as possible for the soil is more likely to be in a suitable condition than later on and the trees are less likely to be exposed to drying winds."

It was also found by Bedford and Pickering that apple, pear, plum and quince trees planted in autumn formed new roots in a majority of cases before January 15.

Card[10] in bulletin 56 of the Nebraska experiment station gives the results of an experiment in co-operation with the Missouri Botanical Garden in fall and spring planting of apple and peach trees. His results lead to the conclusion that fall planting was preferable for the vicinity of St. Louis, but that upon the plains of Nebraska spring planting was to be preferred, due to winter desiccation of fall-planted trees. He also determined that fall-planted trees can make growth of roots in the fall after planting and in early spring before growth of their tops begins.

Clement[15] of Vineland, Ontario, found that spring planting of cherry trees resulted in the death of a large proportion of the trees, while fall planting gave favorable results. Clement also made fall and spring plantings of pear and plum trees for three successive years. In each case the fall-planted trees made the better growth.

The foregoing review of experimental evidence indicates that the best season for transplanting probably depends upon environmental conditions of the tree in the district where it is grown.

## INVESTIGATIONS IN TRANSPLANTING AT THE MISSOURI EXPERIMENT STATION

In 1907, an experiment was begun at the Missouri Experiment Station with the object of determining whether fall or spring was the more favorable season for transplanting fruit trees, under Missouri conditions. Preliminary observations had been going on for more than a decade previous to 1907. In developing the horticultural grounds some fruit trees and deciduous shade trees had been planted in the fall and others in the spring, of nearly every year, since 1895. These trees were planted for other purposes than to determine the best season for transplanting. They afforded opportunity, however, for general observations upon this problem. Numerous large orchard plantings were then being made in the state. Trees were being set both in fall and spring. Many of these orchards were visited where fall and spring planting on a large scale could be observed.

Careful observation indicated that autumn was the more favorable season for transplanting hardy, deciduous trees in Missouri. These observations, however, were not sufficiently convincing. Often it was not possible to determine positively to what extent any difference in the growth of the trees might be due to the season of transplanting or to other causes. The fall- and spring-planted trees may have been grown in different nursery blocks; they may have been set and pruned by different workmen; soil conditions might vary; they may have been exposed to different influences during shipment; an autumn-set block might be given tillage or planted to a companion crop of vegetables just as the spring planting was going out; these and other causes arose to complicate the problem.

In order to secure more reliable data it was planned to grow trees in the Experiment Station nursery and give them uniform treatment, in every respect other than season of transplanting in the orchard.

In the spring of 1907, grafts of Jonathan apple were set in the nursery. Care was taken to select scions and roots of similar character. Several thousand trees were propagated from which to select for fall and spring planting in the orchard. By November, 1908, these trees were well matured, nicely branched, typical two-year-olds.

Forty trees were selected for the fall and spring transplanting experiment. They were selected in pairs, in order that each autumn-set tree might duplicate as nearly as possible a similar tree set in spring.

On November 12, 1908, twenty of these trees were transplanted to their permanent position. The site selected was adjacent to the nursery in order that the two sets of trees might winter under similar conditions except as to the season of transplanting. At the time of transplanting the trees in the fall their side branches were cut back in the usual manner, and on the same day the twenty duplicate trees remaining in the nursery for spring planting were similarly pruned.

On April 22, 1909, the twenty trees reserved for spring planting were set adjacent to those which had been set in November. The trees received good cultivation and similar treatment during the summer of 1909. A portion of them were dug up from time to time in order to observe the root development and other factors to be referred to later in this discussion.

At the close of their season's growth in 1909, careful measurement was made to determine the comparative length growth of new branches and trunk diameter of the fall- and spring-set trees. The results are shown in Table 1.

TABLE 1.—COMPARATIVE GROWTH IN 1909 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

| 10 trees set in fall, Nov. 12, '08 | | | 10 trees set in spring, Apr. 22, '09 | | |
|---|---|---|---|---|---|
| Tree No. | Length growth, inches | Caliper inches | Tree No. | Length growth, inches | Caliper inches |
| 1 | 247.0 | 12/16 | 1 | 170.7 | 11/16 |
| 2 | 377.5 | 12/16 | 2 | 185.0 | 12/16 |
| 3 | 324.0 | 12/16 | 3 | 99.5 | 10/16 |
| 4 | 16.0 | 15/16 | 4 | 42.0 | 10/16 |
| 5 | 260.0 | 12/16 | 5 | 133.0 | 9/16 |
| 6 | 411.5 | 13/16 | 6 | 105.0 | 9/16 |
| 7 | 195.0 | 13/16 | 7 | 173.5 | 15/16 |
| 8 | 210.0 | 13/16 | 8 | 190.5 | 11/16 |
| 9 | 104.0 | 12/16 | 9 | 21.0 | 10/16 |
| 10 | 294.0 | 15/16 | 10 | 124.0 | 12/16 |

It will be seen from Table 1 that the fall-transplanted trees made almost double the total length growth of new branches that was made by the trees planted in spring. The average total length growth of the former was a little over twenty feet, and of the latter a little over ten feet. Only one spring-planted tree (No. 4) made more growth than the comparable one (No. 4) planted in the fall.

The caliper of the trees, six inches from the ground, was thirteen-sixteenths inches for the fall-set trees and eleven-sixteenths inches for the spring-set trees. This greater diameter of trunk is of especial interest, especially for Missouri conditions. A "stocky" tree stands up straighter in this section where young trees tend to lean toward the northeast as a result of southwest winds in summer, and alternate thawing and freezing of their cells on the sunny side of the tree in winter.

On the spring-set trees the principal length growth was confined to twigs near the outer tips of the main limbs. Few of the buds near the base of the limbs made any growth and these were mainly short "rosettes." On the fall-planted trees the buds toward the base of the limbs started more freely and made length growth fairly comparable with that made at the periphery of the trees. Since length growth from the outer tips of the main limbs was fairly comparable in both fall- and spring-planted trees the former had but little wider spread than the latter. Casual observation failed to indicate the actual difference in growth which was revealed by measurement of all the branches. Possibly this may explain why fall planting has not been more emphasized by orchardists who have had extensive experience in both fall and spring planting in this section. The relative number of new twigs produced was not recorded as its possible significance was not fully appreciated until the trees had been pruned in winter following their first year's growth.

The subsequent growth during 1910 and 1911 of the same Jonathan trees is recorded in Tables 2 and 3. In these tables also are inserted columns which show the number of new branches which made a growth of more than one inch during the respective seasons. These tables show the autumn-set trees continued to make greater average growth than the spring-set trees, altho the difference was less marked as the trees became better established. The freer branching habit of the fall-set trees is also worthy of note. As will be subsequently observed, this bears a relation to the earlier and more abundant setting of fruit spurs on the fall-planted trees as they approached fruiting age.

TABLE 2.—COMPARATIVE GROWTH IN 1910 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

| 10 trees set in autumn, Nov. 12, '08 | | | | 10 trees set in spring Apr. 22, '09 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Length growth, feet | No. of branches | Caliper inches | Tree No. | Length growth, feet | No. of branches | Caliper inches |
| 1 | 84.1 | 52 | 1 4/16 | 1 | 80.7 | 50 | 1 4/16 |
| 2 | 106.2 | 63 | 1 5/16 | 2 | 73.4 | 50 | 1 5/16 |
| 3 | 99.6 | 58 | 1 5/16 | 3 | 56.5 | 42 | 1 2/16 |
| 4 | 40.3 | 42 | 1 1/16 | 4 | 42.6 | 40 | 1 |
| 5 | 78.7 | 49 | 1 4/16 | 5 | 69.1 | 56 | 1 3/16 |
| 6 | 99.8 | 60 | 1 5/16 | 6 | 58.0 | 45 | 1 4/16 |
| 7 | 102.3 | 52 | 1 3/16 | 7 | 95.1 | 80 | 1 7/16 |
| 8 | 109.0 | 69 | 1 6/16 | 8 | 54.3 | 45 | 1 5/16 |
| 9 | 60.0 | 53 | 1 4/16 | 9 | 46.1 | 36 | 1 3/16 |
| 10 | 112.4 | 69 | 1 8/16 | 10 | 58.1 | 37 | 1 4/16 |
| Average | 89.24 | 56.7 | 1 9/32 | Average | 63.6 | 48.1 | 1 8/32 |

TABLE 3.—COMPARATIVE GROWTH IN 1911 OF JONATHAN APPLE TREES SET IN NOVEMBER, 1908, AND APRIL, 1909

| 10 trees set in fall, Nov. 12, '08 | | | | 10 trees set in spring, Apr. 22, '09 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Length growth, feet | No. of branches | Caliper inches | Tree No. | Length growth, feet | No. of branches | Caliper inches |
| 1 | 85.20 | 104 | 1 21/32 | 1 | 138.04 | 128 | 1 9/32 |
| 2 | 114.87 | 136 | 1 18/32 | 2 | 108.95 | 108 | 1 9/32 |
| 3 | 107.37 | 104 | 1 19/32 | 3 | 102.45 | 72 | 1 6/32 |
| 4 | 83.62 | 77 | 1 12/32 | 4 | 30.62 | 65 | 1 3/32 |
| 5 | 77.39 | 127 | 1 19/32 | 5 | 47.79 | 74 | 1 3/32 |
| 6 | 119.29 | 131 | 1 16/32 | 6 | 72.56 | 79 | 1 14/32 |
| 7 | 128.79 | 142 | 1 16/32 | 7 | 121.35 | 165 | 1 22/32 |
| 8 | 98.41 | 151 | 1 16/32 | 8 | 80.08 | 77 | 1 12/32 |
| 9 | 93.41 | 115 | 1 14/32 | 9 | 52.79 | 75 | 1 5/32 |
| 10 | 107.45 | 155 | 1 28/32 | 10 | 90.77 | 114 | 1 16/32 |
| Average | 101.58 | 124.2 | 1.55 | Average | 84.54 | 95.7 | 1.31 |

A summary of the average length and diameter growth of the fall- and spring-set Jonathan trees, for the first three years, appears in Table 4.

TABLE 4.—COMPARISON OF AVERAGE LENGTH AND DIAMETER GROWTH OF AUTUMN- AND SPRING-SET JONATHAN APPLE TREES DURING 1909, 1910 AND 1911

| Autumn planted, Nov. 12, '08 | | | Spring planted, Apr. 22, '09 | | |
|---|---|---|---|---|---|
| Season | Length growth, feet | Diameter growth, inches | Season | growth, feet | Diameter growth, inches |
| 1909 | 20.3 | 0.81 | 1909 | 10.3 | 0.68 |
| 1910 | 89.24 | 1.28 | 1910 | 63.63 | 1.25 |
| 1911 | 101.58 | 1.56 | 1911 | 84.54 | 1.31 |

After their third year's growth in the orchard both the fall- and the spring-set trees had become so large that it did not seem feasible or desirable to attempt to keep further record of their entire twig growth. The trees were pruned to open, spreading heads each winter to admit light and encourage fruit spur formation. The more vigorous growth of the fall-set trees resulted in their producing a somewhat larger quantity of surplus growth which was removed in pruning. As a result there was no very visible difference in the size of the fall- and spring-set trees after the third year.

As previously noted, the fall-set trees made a larger number of secondary twigs in the body of the tree. They earlier began the differentiation of definite fruit spurs. In 1915, the fall-set trees produced their first crop of fruit, consisting of one peck of finely developed apples, distributed over six of the ten trees. One of the spring-set trees produced three apples. In 1916, the fall-set trees produced one and one-half bushels of fruit and the spring-set trees one peck of fruit. In 1917, a light crop was produced, about equally distributed on fall- and spring-set trees. In July, 1918, both sets of trees are carrying a good crop which appears to be about equally distributed. While the fall-set trees showed a tendency to form fruit spurs earlier and set more fruit the first two fruiting seasons, it is not apparent that their gain in fruitfulness is significant once the trees reach a fully established bearing habit.

In the fall of 1913, and spring of 1914, additional plantings were made. Additional types and varieties were included in order to determine whether the different sorts gave similar response with reference to the season of transplanting. This test also included one-year-old as well as two-year-old trees in order to determine whether the smaller trees, planted in autumn, would endure the winter as well as the larger trees.

A comparison of transplanting in early autumn as well as in late autumn and early spring and late spring was also made in order to determine when root growth begins after each planting. The summarized results appear in Tables 5 to 22.

Reference to Tables 5 and 6 shows that the average diameter of the fall-planted trees, at the end of the growing season, was 50/64 inches, as compared with 40/64 inches for the trees set in spring, which represents an annual increase in diameter for the season of 22/64 inches and 10/64 inches, respectively.

Further examination of these data shows that the fall-set trees made approximately two-thirds of their annual diameter growth previous to August 14, while the spring-set trees made approximately two-thirds of their annual diameter increment after August 14. Measurements taken August 14 show that the fall-planted trees had increased 12/64 inches in diameter and the spring-set trees only 3/64 inches in diameter on the same date. The average diameter increase during the remainder of the season was 10/64 and 7/64, respectively, for the fall- and spring-set trees.

TABLE 5.—GROWTH DURING SUMMER OF 1914 OF TRANSPARENT APPLE TREES
*Planted November 8, 1913*

| No. of trees | Diameter when set, inches | Diameter Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1* | 32/64 | 44/64 | 32/64 | 231 |
| 2 | 28/64 | 38/64 | 45/64 | 312 |
| 3* | 20/64 | 46/64 | 49/64 | 208.5 |
| 4 | 28/64 | 44/64 | 52/64 | 251 |
| 5* | 32/64 | 45/64 | 54/64 | 150 |
| 6 | 26/64 | 45/64 | 55/64 | 406 |
| 7* | 28/64 | 43/64 | 48/64 | 222 |
| 8 | 32/64 | 48/64 | 55/64 | 353.5 |
| 9* | 32/64 | 49/64 | 50/64 | 295 |
| 10 | 32/64 | 37/64 | 41/64 | 166 |
| 11* | 28/64 | 35/64 | 37/64 | 136.5 |
| 12 | 32/64 | 33/64 | 46/64 | 116 |
| 13* | 24/64 | 40/64 | 41/64 | 133 |
| 14 | 32/64 | 31/64 | 44/64 | 197 |
| 15* | 24/64 | 32/64 | 37/64 | 126 |
| 16 | 24/64 | 30/64 | 44/64 | 136 |
| 17* | 28/64 | 34/64 | 39/64 | 101.5 |
| 18 | 28/64 | 33/64 | 37/64 | 120 |
| 19 | 26/64 | 34/64 | 49/64 | 173 |
| Total | 540/64 | 741/64 | 855/64 | 3834 |
| Average | 28/64 | 39/64 | 45/64 | 201.8 |

*Mulched at time of planting.

TABLE 6.—GROWTH DURING SUMMER OF 1914 OF TRANSPARENT APPLE TREES
*Planted April 27, 1914*

| No. of trees | Diameter when set, inches | Diameter Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1 | 32/64 | 34/64 | 39/64 | 94 |
| 2 | 20/64 | 25/64 | 38/64 | 131 |
| 3 | 24/64 | 36/64 | 44/64 | 85 |
| 4 | 36/64 | 37/64 | 49/64 | 170 |
| 5 | 40/64 | 38/64 | 44/64 | 132 |
| 6 | 20/64 | 28/64 | 32/64 | 141 |
| 7 | 24/64 | 27/64 | 44/64 | 95 |
| 8 | 28/64 | 31/64 | 35/64 | 120 |
| 9 | 28/64 | 30/64 | 35/64 | 132 |
| 10 | 36/64 | 37/64 | 50/64 | 39 |
| 11 | 32/64 | 38/64 | 43/64 | 78 |
| 12 | 40/64 | 37/64 | 40/64 | 70 |
| 13* | ---------- | ---------- | ---------- | ---------- |
| 14* | ---------- | ---------- | ---------- | ---------- |
| 15 | 24/64 | 32/64 | 40/64 | 138 |
| Total | 384/64 | 430/64 | 533/64 | 1425 |
| Average | 30/64 | 32/64 | 40/64 | 104.2 |

*Trees died during the summer.

The slower growth of spring-set trees during the early part of the season has been observed in all the plantings, generally, where fall and spring planting has been compared at this Station. The spring-set trees put out their leaves and grow slowly, early in the season, as if leaf growth were waiting for the retarded root growth to catch up. If the early season is dry, any mortality of the trees usually takes place during this period, before their roots become well established. The fall-planted trees, on the contrary, make more rapid and continuous growth early in the season than they do later. This is no doubt due to the fact that their root growth is established early enough to support continuous rapid growth after they leaf out. The two spring-set trees which died, numbers 13 and 14 in Table 6, came out in leaf, persisted for a time with little added growth, and finally died as root growth failed to become established in time to support their tops.

The average total length growth of autumn- and spring-set trees, Tables 5 and 6, was 207.8 and 104.2 inches, respectively. These Transparent trees, like the Jonathan trees previously discussed, showed twice as much length growth of twigs on fall-set trees as was made by those set in spring. Their increase in diameter growth was more marked in favor of fall planting.

TABLE 7.—GROWTH DURING THE SUMMER OF 1914 OF AUTUMN PLANTED GRIMES APPPLE TREES

*Twelve trees planted in autumn, Dec. 6, 1913*

| No. of trees | Diameter when set, inches | Diameter Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1* | 20/64 | 24/64 | 24/64 | 52 |
| 2 | 16/64 | 25/64 | 24/64 | 74 |
| 3* | 28/64 | 38/64 | 44/64 | 90 |
| 4 | 28/64 | 34/64 | 55/64 | 149 |
| 5* | 20/64 | 38/64 | 48/64 | 333 |
| 6 | 32/64 | 37/64 | 44/64 | 191 |
| 7* | 24/64 | 30/64 | 34/64 | 187 |
| 8 | 20/64 | 27/64 | 32/64 | 171 |
| 9* | 20/64 | 37/64 | 48/64 | 161 |
| 10 | 20/64 | 30/64 | 40/64 | 111 |
| 11* | 32/64 | 37/64 | 42/64 | 119 |
| 12 | 28/64 | 34/64 | 35/64 | 110 |
| Total | 288/64 | 396/64 | 470/64 | 1748 |
| Average | 24/64 | 33/64 | 39/64 | 145.7 |

*Mulched at time of planting.

TABLE 8.—GROWTH DURING THE SUMMER OF 1914 OF SPRING PLANTED GRIMES APPLE TREES

*Transplanted April 8, 1914*

| No. of trees | Diameter when set, inches | Diameter Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1* | ........... | ........... | ........... | ........... |
| 2* | ........... | ........... | ........... | ........... |
| 3* | ........... | ........... | ........... | ........... |
| 4 | 28/64 | 31/64 | 31/64 | 52 |
| 5 | 28/64 | 30/64 | 34/64 | 22 |
| 6 | 32/64 | 34/64 | 38/64 | 203 |
| 7 | 24/64 | 28/64 | 34/64 | 144 |
| 8 | 24/64 | 30/64 | 34/64 | 152 |
| 9 | 12/64 | 28/64 | 28/64 | 29 |
| 10 | 24/64 | 32/64 | 41/64 | 234 |
| 11 | 24/64 | 31/64 | 33/64 | 33 |
| Total | 196/64 | 244/64 | 273/64 | 869 |
| Average | 24/64 | 30/64 | 34/64 | 108.6 |

*Died during the summer.

TABLE 9.—COMPARISON OF TWO-YEAR-OLD APPLE TREES TRANSPLANTED IN AUTUMN WITH TWO-YEAR-OLD TREES TRANSPLANTED IN SPRING

| | Autumn-planted, 1913 | | | Spring-planted, 1914 | | |
|---|---|---|---|---|---|---|
| Variety | Avg. Diam. growth prior to Aug. 14, '14, inches | Avg. for entire season, inches | Avg. length growth, inches | Avg. Diam. growth prior to Aug. 14, '14, inches | Avg. for entire season, inches | Avg. length growth, inches |
| Transparent | 12/64 | 22/64 | 207.8 | 3/64 | 10/64 | 104.2 |
| Grimes | 9/64 | 15/64 | 145.7 | 6/64 | 10/64 | 108.6 |
| Total | 21/64 | 37/64 | 353.5 | 9/64 | 20/64 | 212.8 |
| Average | 10/64 | 18/64 | 176.7 | 4/64 | 10/64 | 106.4 |

TABLE 10.—GROWTH DURING SUMMER OF 1914 OF EARLY AUTUMN PLANTED ONE-YEAR-OLD JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

*Fifteen trees planted in autumn, November 8, '13*

| No. of tree | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1* | 8/64 | 27/64 | 35/64 | 171 |
| 2* | 12/64 | 16/64 | 44/64 | 258 |
| 3* | 8/64 | 28/64 | 36/64 | 339.5 |
| 4 | 16/64 | 36/64 | 45/64 | 255 |
| Average | 11/64 | 27/64 | 40/64 | 255.9 |
| Winesap— | | | | |
| 5* | 8/64 | 29/64 | 41/64 | 184 |
| 6* | 16/64 | 32/64 | 36/64 | 292 |
| 7* | 8/64 | 20/64 | 22/64 | 78 |
| 8 | 16/64 | 28/64 | 36/64 | 130.5 |
| 9* | 8/64 | 25/64 | 36/64 | 181 |
| 10 | 12/64 | 29/64 | 40/64 | 181 |
| 11* | 12/64 | 29/64 | 38/64 | 156.5 |
| Average | 11/64 | 27/64 | 36/64 | 171.9 |
| Early Harvest— | | | | |
| 12 | 12/64 | 30/64 | 39/64 | 173 |
| 13* | 8/64 | 20/64 | 34/64 | 117 |
| 14 | 20/64 | 33/64 | 44/64 | 162 |
| 15* | 12/64 | 26/64 | 30/64 | 55 |
| Average | 13/64 | 27/64 | 37/64 | 126.7 |
| Total | 176/64 | 414/64 | 556/64 | 2733.5 |
| Average | 12/64 | 27/64 | 37/64 | 182.2 |

*Mulched at time of planting.

TABLE 11.—GROWTH DURING SUMMER OF 1914 OF LATE AUTUMN PLANTED ONE-YEAR-OLD JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

*15 trees planted in autumn, December 6, 1913*

| No. of trees | Diameter when set, inches | Diameter Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| Jonathan— | | | | |
| 1 | 8/64 | 26/64 | 34/64 | 135 |
| 2 | 12/64 | 33/64 | 43/64 | 277 |
| 3 M | 8/64 | 27/64 | 34/64 | 183 |
| 4 M | 12/64 | 33/64 | 44/64 | 262 |
| Average | 10/64 | 30/64 | 39/64 | 214 |
| Winesap— | | | | |
| 5 M | 12/64 | 35/64 | 39/64 | 251 |
| 6 | 12/64 | 34/64 | 44/64 | 352 |
| 7 M | 8/64 | 31/64 | 46/64 | 287 |
| 8 | 12/64 | 31/64 | 45/64 | 218 |
| 9 M | 8/64 | 29/64 | 41/64 | 264 |
| 10 | 12/64 | 34/64 | 43/64 | 340 |
| 11 M | 12/64 | 30/64 | 40/64 | 131 |
| Average | 11/64 | 32/64 | 44/64 | 265.7 |
| Early Harvest— | | | | |
| 12 | 12/64 | 30/64 | 42/64 | 92 |
| 13 M | 8/64 | 30/64 | 29/64 | 132 |
| 14 | 20/64 | 36/64 | 43/64 | 193 |
| 15 M | 12/64 | 34/64 | 40/64 | 163 |
| Average | 13/64 | 32/64 | 33/64 | 137.5 |
| Total | 160/64 | 473/64 | 567/64 | 3280 |
| Average | 11/64 | 31/64 | 42/64 | 218.6 |

M—mulched at time of planting.

TABLE 12.—GROWTH DURING SUMMER OF 1914 OF SPRING PLANTED ONE-YEAR-OLD JONATHAN, WINESAP, AND EARLY HARVEST TREES

*Fifteen trees planted April 18, 1914*

| No. of tree | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| Jonathan— | | | | |
| 1 | 12/64 | 21/64 | 27/64 | 110 |
| 2 | 12/64 | 21/64 | 30/64 | 185 |
| 3 | 16/64 | 21/64 | 28/64 | 135 |
| 4 | 16/64 | 27/64 | 27/64 | 272 |
| Average | 14/64 | 23/64 | 24/64 | 175.5 |
| Winesap— | | | | |
| 5 | 12/64 | 25/64 | 30/64 | 102 |
| 6 | 12/64 | 23/64 | 26/64 | 62.5 |
| 7 | 12/64 | 15/64 | 24/64 | 14 |
| 8 | 12/64 | 25/64 | 31/64 | 128 |
| 9 | 12/64 | 22/64 | 28/64 | 100 |
| 10 | 12/64 | 21/64 | 26/64 | 75 |
| 11 | 16/64 | 20/64 | 24/64 | 51 |
| Average | 13/64 | 22/64 | 27/64 | 75.5 |
| Early Harvest— | | | | |
| 12 | 16/64 | 22/64 | 23/64 | 44 |
| 13 | 12/64 | 23/64 | 28/64 | 88.5 |
| 14 | 20/64 | 24/64 | 27/64 | 47 |
| 15 | 16/64 | 21/64 | 24/64 | 97.5 |
| Average | 16/64 | 23/64 | 26/64 | 68.7 |
| Total | 204/64 | 331/64 | 403/64 | 1511.5 |
| Average | 14/64 | 22/64 | 27/64 | 100.7 |

TABLE 13.—COMPARATIVE GROWTH DURING THE SUMMER OF 1914. ALL AUTUMN AND SPRING PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

| Time of planting | Avg. Diam. when set, inches | Avg. Diam. Aug. 14. 1914, inches | Avg. Diam Nov. 20, '14, inches | Avg. Length growth, inches |
|---|---|---|---|---|
| Nov. 8, '13 | 12/64 | 27/64 | 37/64 | 182.2 |
| Dec. 6, '13 | 11/64 | 31/64 | 42/64 | 219.3 |
| Average | 11/64 | 29/64 | 39/64 | 200.7 |
| Apr. 18, '14 | 14/64 | 22/64 | 28/64 | 100.7 |

TABLE 14.—COMPARATIVE AVERAGE GROWTH DURING THE SUMMER OF 1914, OF ALL AUTUMN- AND SPRING-PLANTED TRANSPARENT, GRIMES, JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

| Time of planting | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of length growth, inches |
|---|---|---|---|---|
| Fall | 16/64 | 33/64 | 41/64 | 188.7 |
| Spring | 23/64 | 28/64 | 34/64 | 106.2 |

Tables 7 and 8 show that fall-set Grimes trees made better growth than Grimes set in spring but that these differences were less marked than in the case of the Jonathan and Transparent trees heretofore discussed. In diameter growth, previous to August 14, the fall-planted trees made about two-thirds of their total annual increment while the spring-set trees made more than one-half their annual increase. At the close of the growing season the increase in diameter of the fall-set trees exceeded that of the spring-set trees by 14 per cent. In total annual twig growth, the fall-set trees exceeded that of the spring-planted trees in the relation of 145.7 inches, for the former, to 108.6 inches for the latter. These data, taken in connection with general observations that have been made upon numerous other fall and spring plantings of Grimes, indicate that this variety profits less by fall planting than do some of the other varieties.

The Grimes has a weak trunk, however, and suffers larger mortality due to transplanting than do most varieties of apples grown in this region. It will be observed that three of the Grimes trees planted in spring died in early summer. Perhaps fall planting may be of sufficient importance in lessening mortality in this variety to be reckoned as an important factor.

Comparing Tables 10 and 11 it will be seen that the average diameter growth and twig growth of trees planted December 6, exceeded the growth made by trees planted November 8. This difference was most marked in the case of the Winesap. The Jonathan trees seem to be an exception. It should be borne in mind, however, that this variation is due to tree No. 3, Table 10, which made very exceptional growth, no doubt due to individual variation.

In addition to the trees recorded in the foregoing tables, repeated early and late fall-plantings have been made and observed on the Experiment Station grounds as well as in commercial orchards. These observations indicate uniformly that late fall planting is preferable to early fall planting for this region.

Comparing Tables 10 and 11 with Table 12, it is shown that either early or late fall-planting gave better results than spring planting; thus confirming the results shown in previous tables.

A comparison of the growth of early spring- and late spring-planted apple trees is made in Table 22. It will be seen that the trees planted on March 29 made far better growth than those planted April 28. In the same table it will also be seen that the early spring-planted trees outgrew those planted in the fall, while the latter made far better growth than those planted in late spring. This is the only instance, at the Missouri Experiment Station, in a series of years, in which apple trees planted at any time in spring have outgrown similar trees planted in the fall. The exceptional results recorded in this table are probably due to unusual conditions. The fall of 1916 was exceptionally dry. There was very little winter precipitation. The soil was very dry during the autumn and winter. Unfavorable conditions for fall-planted trees are further emphasized by the fact that winter wheat suffered to an unusual degree, large areas being so badly winter killed that they were plowed up and planted to other crops in the spring of 1917. Fall-planted trees dried out far worse than usual during the winter. By the last of March the soil was just moist enough for ideal planting conditions. These conditions prevailed for a month after the trees were set on March 29. The soil was not too wet and cold, as is often the case in early spring, but was sufficiently moist for the early spring-planted trees to make a most favorable start. Since these trees had stood with their roots undisturbed in the nursery during the winter, they had not dried out as did the fall-planted trees.

Conditions were far less favorable than usual for the late spring-planted trees. The weather was warm and dry at the time they were set. Their leaves appeared before their roots became established in the soil. The summer was dry, affecting them more unfavorably than it did the trees which were planted under the more favorable conditions of the previous month.

Additional early and late spring plantings have been made, altho not located where they could be given frequent observation or where detailed records could be made. The results have been observed, however, in numerous seasons.

TABLE 15.—COMPARATIVE GROWTH DURING THEIR SECOND SUMMER (1915) OF AUTUMN- AND SPRING-PLANTED TRANSPARENT APPLE TREES

| Nineteen trees set November 8, 1913 | | | | Fifteen trees set April 27, 1914 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches | Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches |
| 1 | 1 23/64 | 44 | 1081 | 1 | 46/64 | ........ | 25 |
| 2 | 1 6/64 | 17 | 660 | 2 | 66/64 | 22 | 536 |
| 3 | 1 10/64 | 16 | 343 | 3 | 56/64 | 14 | 168 |
| 4 | ........ | ........ | ........ | 4 | 1 16/64 | 37 | 808 |
| 5 | 1 | 10 | 198 | 5 | 1 12/64 | 26 | 628 |
| 6 | 1 10/64 | 24 | 369 | 6 | 49/64 | ........ | 60 |
| 7 | 1 14/64 | 36 | 830 | 7 | 52/64 | 6 | 84 |
| 8 | 1 34/64 | 55 | 863 | 8 | 62/64 | 23 | 606 |
| 9 | 1 11/64 | 27 | 589 | 9 | 1 3/64 | 33 | 656 |
| 10* | ........ | ........ | ........ | 10 | 1 22/64 | 33 | 795 |
| 11 | 1 1/64 | 19 | 485 | 11* | ........ | ........ | ........ |
| 12 | 1 12/64 | 27 | 689 | 12* | ........ | ........ | ........ |
| 13 | 1 12/64 | 36 | 774 | 13† | ........ | ........ | ........ |
| 14 | 59/64 | 32 | 532 | 14† | ........ | ........ | ........ |
| 15 | 1 | 40 | 542 | 15 | 1 18/64 | 42 | 940 |
| 16 | 51/64 | 18 | 294 | 16 | ........ | ........ | ........ |
| 17 | 61/64 | 28 | 529 | ........ | ........ | ........ | ........ |
| 18 | 78/64 | 13 | 198 | ........ | ........ | ........ | ........ |
| 19 | 56/64 | 27 | 425 | ........ | ........ | ........ | ........ |
| Total | 18 16/64 | 469 | 9401 | Total | 11 | 236 | 5306 |
| Average | 1 4/64 | 27.5 | 553 | Average | 1.1 | 26.2 | 482.4 |

*Blight and canker.
†Died during summer 1914.

TABLE 16.—COMPARATIVE GROWTH DURING THEIR SECOND SUMMER (1915) OF AUTUMN AND SPRING-PLANTED GRIMES APPLE TREES

| Twelve trees set December 6, 1913 | | | | Eleven trees set April 18, 1914 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches | Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches |
| 1 | ........ | 16 | 242 | 1* | ........ | ........ | ........ |
| 2 | ........ | 16 | 288 | 2* | ........ | ........ | ........ |
| 3 | 1 19/64 | 29 | 649 | 3* | ........ | ........ | ........ |
| 4 | 1 17/64 | 28 | 686 | 4† | ........ | ........ | ........ |
| 5 | 1 44/64 | 59 | 1311 | 5 | 56/64 | 23 | 370 |
| 6 | 1 12/64 | 27 | 460 | 6 | 1 7/64 | 27 | 533 |
| 7 | ........ | 38 | 748 | 7 | 48/64 | 22 | 193 |
| 8 | 1 14/64 | 25 | 345 | 8 | 53/64 | 22 | 213 |
| 9 | 1 19/64 | 23 | 526 | 9† | ........ | ........ | ........ |
| 10 | 1 7/64 | 31 | 505 | 10 | 1 12/64 | 38 | 590 |
| 11 | 1 14/64 | 26 | 468 | 11† | ........ | ........ | ........ |
| 12 | 1 7/64 | 23 | 404 | ........ | ........ | ........ | ........ |
| Total | 11 25/64 | 341 | 6682 | Total | 4 50/64 | 132 | 1899 |
| Average | 1 17/64 | 28.4 | 556.8 | Average | 61/64 | 26.4 | 375.8 |

*Trees died during the summer of 1914.
†Killed by blight and canker infection.

TABLE 17.—SHOWING GROWTH DURING THEIR SECOND SUMMER (1915) OF EARLY AND LATE AUTUMN-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

| Fifteen trees planted Nov. 8, 1913 | | | | Fifteen trees planted Dec. 6, 1913 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches | Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches |
| Jonathan— | | | | Jonathan— | | | |
| 1* | ...... | ...... | ...... | 1* | ...... | ...... | ...... |
| 2* | ...... | ...... | ...... | 2* | ...... | ...... | ...... |
| 3* | ...... | ...... | ...... | 3* | ...... | ...... | ...... |
| 4* | ...... | ...... | ...... | 4* | ...... | ...... | ...... |
| Winesap— | | | | Winesap— | | | |
| 5 | 15/64 | 33 | 785 | 5 | 1 18/64 | 43 | 790 |
| 6 | 48/64 | ...... | ...... | 6 | 60/64 | 24 | 407 |
| 7 | 48/64 | 15 | 285 | 7 | 1 24/64 | 56 | 1374 |
| 8 | 1 1/64 | 25 | 573 | 8 | 1 22/64 | 45 | 1026 |
| 9 | 58/64 | 20 | 422 | 9 | ...... | ...... | ...... |
| 10 | 60/64 | 15 | 374 | 10 | ...... | ...... | ...... |
| 11 | 62/64 | 14 | 391 | 11 | 59/64 | 18 | 293 |
| Average | ...... | 20 | 471.6 | Average | ...... | 37 | 778 |
| Early Harvest- | | | | | | | |
| 12 | 54/64 | 17 | 374 | 12 | 55/64 | 17 | 342 |
| 13 | 44/64 | 7 | 161 | 13 | 56/64 | 18 | 442 |
| 14 | 1 1/64 | 21 | 467 | 14 | 60/64 | 10 | 201 |
| 15 | 52/64 | 15 | 225 | 15 | 57/64 | 13 | 280 |
| Average | ...... | 15 | 307 | Average | ...... | 15 | 316.2 |
| Total | 9 59/64 | 182 | 4051 | Total | 9 27/64 | 243 | 5155 |
| Average | 57/64 | 18.2 | 405.7 | Average | 1 3/64 | 27 | 572.7 |

*Trees cut back severely because of blight and canker infection.

TABLE 18.—GROWTH DURING THE SUMMER OF 1915 OF SPRING-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

| Tree No. | Diameter, Nov. 30, 1915, inches | Branches | Length growth, inches |
|---|---|---|---|
| 1* | ...... | ...... | ...... |
| 2* | ...... | ...... | ...... |
| 4* | ...... | ...... | ...... |
| 4* | ...... | ...... | ...... |
| Winesap— | | | |
| 5 | 55/64 | 15 | 246 |
| 6 | 50/64 | 14 | 341 |
| 7 | 45/64 | 17 | 267 |
| 8* | 55/64 | ...... | ...... |
| 9 | 52/64 | 14 | 409 |
| 10 | 45/64 | 20 | 711 |
| 11 | 33/64 | 7 | 163 |
| Average | ...... | 15 | 356 |
| Early Harvest— | | | |
| 12 | 34/64 | 13 | 126 |
| 13 | ...... | 8 | 199 |
| 14 | 44/64 | 13 | 173 |
| 15* | ...... | ...... | ...... |
| Average | ...... | ...... | 166 |
| Total | 6 34/64 | 121 | 2635 |
| Average | 46/64 | 13.4 | 292.7 |

*Trees cut back severely on account of blight and canker infection.

TABLE 19.—COMPARISON OF THE AVERAGE GROWTH DURING THE SUMMER OF 1915 OF ALL AUTUMN AND SPRING-PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

| Time of Planting | Avg. Diam. Nov. 30, 1915, inches | No. of Branches | Avg. Length growth, inches |
|---|---|---|---|
| Nov. 8, 1913 | 57/64 | 18.2 | 405.7 |
| Dec. 6, 1913 | 1 3/64 | 27 | 572.7 |
| Average | 62/64 | 22.6 | 489.2 |
| April 18, 1914 | 46/64 | 13.4 | 292.7 |

TABLE 20.—COMPARATIVE INCREASE IN GROWTH DURING THE SEASONS OF 1914 AND 1915 OF APPLE TREES SET NOVEMBER 8, 1913, AND SET DECEMBER 6, 1913

| Trees set November 8, 1913 | | | Trees set December 6, 1913 | | |
|---|---|---|---|---|---|
| Year | Average increase in growth in inches | | Year | Average increase in growth in inches | |
| | Diameter | Length | | Diameter | Length |
| 1914 | 25/64 | 207.8 | 1914 | 31/64 | 219.3 |
| 1915 | 20/64 | 405.7 | 1915 | 25/64 | 572.7 |

TABLE 21.—COMPARISON OF THE AVERAGE GROWTH DURING THE SUMMER OF 1915 OF ALL AUTUMN AND SPRING-PLANTED TRANSPARENT, GRIMES, JONATHAN, WINESAP AND EARLY HARVEST TREES

| Time of Planting | Avg. Diam. Nov. 30, 1915, inches | No. of Branches | Avg. length growth, inches |
|---|---|---|---|
| Fall | 1 21/64 | 25.2 | 507.3 |
| Spring | 1 16/64 | 22.0 | 382.1 |

TABLE 22.—GROWTH DURING SUMMER OF 1917 OF LATE AUTUMN, EARLY SPRING AND LATE SPRING-PLANTED APPLE TREES

| Fall-planted Dec. 2, '16 | | | | Spring-planted March 29, '17 | | | | Spring-planted April 28, '17 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree No. | No. of twigs | Length inches | Wt. of Prunings, grams | Tree No. | No. of twigs | Length inches | Wt. of Prunings, grams | Tree No. | No. of twigs | Length inches | Wt. of Prunings, grams |
| Winesap— | | | | | | | | | | | |
| 1341 | 7 | 132 | 20 | 1381 | 12 | 168 | 35 | 1421 | 8 | 96 | 22 |
| 1342 | 10 | 139 | 22 | 1382 | 8 | 112 | 25 | 1422 | 11 | 86 | 14 |
| 1343 | 11 | 125 | 22 | 1383 | 11 | 151 | 27 | 1423 | 4 | 6 | 0 |
| 1344 | 8 | 68 | 9 | 1384 | 10 | 156 | 29 | 1424 | 8 | 86 | 10 |
| 1345 | 9 | 139 | 23 | 1385 | 6 | 84 | 13 | 1425 | 11 | 46 | 8 |
| Average | 9.0 | 120.6 | 19.4 | Average | 9.0 | 134.2 | 23.8 | Average | 6.4 | 64 | 10.8 |
| Gano— | | | | | | | | | | | |
| 1346 | 12 | 80 | 10 | 1386 | 12 | 66 | 8 | 1426 | 6 | 65 | 20 |
| 1347 | 11 | 84 | 15 | 1387 | 10 | 74 | 10 | 1427 | 4 | 54 | 9 |
| 1348 | 10 | 72 | 15 | 1388 | 10 | 129 | 18 | 1428 | 8 | 6 | 0 |
| 1349 | 14 | 139 | 27 | 1389 | 8 | 42 | 6 | 1429 | 6 | 78 | 9 |
| 1350 | 7 | 60 | 10 | 1390 | 6 | 102 | 16 | 1430 | 10 | 111 | 10 |
| Average | 10.8 | 87.0 | 15.4 | Average | 9.2 | 84.6 | 11.6 | Average | 6.8 | 60.8 | 9.6 |
| Jonathan— | | | | | | | | | | | |
| 1351 | 8 | 139 | 18 | 1391 | 7 | 80 | 11 | 1431 | 7 | 60 | 5 |
| 1352 | 7 | 146 | 19 | 1392 | 11 | 154 | 30 | 1432 | 7 | 98 | 13 |
| 1353 | 6 | 98 | 20 | 1393 | 5 | 64 | 9 | 1433 | 6 | 76 | 13 |
| 1354 | 8 | 110 | 15 | 1394 | 7 | 56 | 7 | 1434 | 4 | 9 | 0 |
| 1355 | 8 | 173 | 32 | 1395 | 4 | 96 | 12 | 1435 | 2 | 12 | 5 |
| Average | 7.4 | 133.2 | 20.8 | Average | 6.8 | 90.0 | 13.8 | Average | 5.1 | 51.0 | 7.2 |

Early spring planting is probably to be preferred to late spring planting if the soil is dry enough to be worked nicely in March, and especially if the trees to be transplanted are standing in the nursery where their buds are likely to start early. Early spring planting usually proves better than later planting if the following summer proves to be dry and hot.

There is perhaps no advantage in early spring planting if the soil is wet and cold and especially if the trees are stored where they can be kept dormant. Most Missouri soils are fine, clay loams rather than sandy and well drained. Frequently these soils are too wet to work to the best advantage in very early spring.

## FALL AND SPRING PLANTING OF SOUR CHERRIES

In Missouri it has been customary to plant sour cherries (sweet cherries are not generally grown in the state) and other stone fruits, in the spring. They are regarded as being the most difficult of our orchard fruits to transplant successfully. Planted in the spring, often from one-third to two-thirds of the trees die. This large mortality of cherry trees necessitates repeated replanting before a full stand of trees is secured in the orchard.

Repeated spring plantings of sour cherries at the Experiment Station have usually resulted in similar mortality of the trees. Only in occasional seasons, when soil and weather conditions were favorable at the time of planting, and when well-distributed rainfall kept the soil neither too wet nor too dry thruout the summer, has spring planting resulted in a good stand of trees. If the summer is too wet, the trees seem to thrive no more successfully than during summer drouth. The roots of sour cherries apparently require a moderate but constant supply of moisture in a well-aired soil but suffer when the soil is saturated with water, which shuts out air for any great length of time. This is especially true of young cherry trees recently transplanted.

TABLE 23.—GROWTH IN 1914 OF AUTUMN-PLANTED MONTMORENCY CHERRY TREES

*Six trees set in autumn, Nov. 20, 1913*

| No. of Trees | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1 | 32/64 | 33/64 | 33/64 | 50.75 |
| 2 | 32/64 | 33/64 | 35/64 | 89.0 |
| 3 | 28/64 | 33/64 | 37/64 | 97.0 |
| 4 | 36/64 | 36/64 | 40/64 | 31.5 |
| 5 | 28/64 | 37/64 | 39/64 | 101.5 |
| 6 | 32/64 | 36/64 | 37/64 | 80.0 |
| Total | 188/64 | 207/64 | 227/64 | 449.75 |
| Average | 31/64 | 35/64 | 38/64 | 74.8 |

TABLE 24.—GROWTH IN 1914 OF SPRING-PLANTED MONTMORENCY CHERRY TREES

*Six trees set in spring April 14, 1914*

| No. of Trees | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of twig growth, inches |
|---|---|---|---|---|
| 1* | 32/64 | ---------- | ---------- | ---------- |
| 2* | 32/64 | ---------- | ---------- | ---------- |
| 3 | 28/64 | 32/64 | 33/64 | 33.5 |
| 4* | 32/64 | ---------- | ---------- | ---------- |
| 5* | 24/64 | ---------- | ---------- | ---------- |
| 6 | 32/64 | 35/64 | 36/64 | 32 |
| Total | 180/64 | 67/64 | 69/64 | 65.5 |
| Average | 30/64 | 33/64 | 34/64 | 32.7 |

*Trees died during summer of 1914.

TABLE 25.—COMPARATIVE GROWTH DURING THE SUMMER OF 1915 OF AUTUMN AND SPRING-PLANTED MONTMORENCY CHERRY TREES

| Six trees set in autumn, Nov. 20, 1913 | | | | Six trees set in spring, April 14, 1914 | | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches | Tree No. | Diam. Nov. 30, 1915, inches | Branches | Length growth, inches |
| 1 | 1 4/64 | 36 | 401.5 | 1* | ---------- | ------- | ----- |
| 2 | 1 16/64 | 47 | 656.5 | 2* | ---------- | ------- | ----- |
| 3 | 1 11/64 | 48 | 576 | 3 | 1 | 42 | 434 |
| 4 | 62/64 | 31 | 280 | 4* | ---------- | ------- | ----- |
| 5 | 1 6/64 | 90 | 585 | 5* | ---------- | ------- | ----- |
| 6 | 62/64 | 24 | 190 | 6 | 1 6/64 | 39 | 418 |
| Total | 6 33/64 | 276 | 2689 | Total | 2 6/64 | 81 | 852 |
| Average | 1 5/64 | 46 | 248.1 | Average | 1 3/64 | 40.5 | 426 |

*Died during summer of 1914.

The occasional fall plantings of sour cherry trees, made at the Experiment Station, have uniformly resulted in a good stand of trees. Sour cherries set in the fall have uniformly transplanted as successfully as apples or other fruits.

Tables 23, 24, and 25 show results which are quite typical as a comparison of spring and fall planting of sour cherries. The trees set in the fall of 1913, transplanted successfully, all of them made fine growth the following summer and, at this writing, July, 1918, all of them are in vigorous and healthy condition. They produced a good crop of fruit this year. Two-thirds of the trees set in the spring of 1914, started growth but died before midsummer. The trees which lived thru the first summer are now doing well but have not quite caught up with the fall-planted trees.

The average annual twig growth of the fall-set trees exceeded that of the spring-set trees which lived, in the proportion of 74.8 inches to 32.7 inches. Since two-thirds of the spring-set trees died before they made appreciable growth it is evident that the one-third which lived were the strongest growing specimens of the spring-set lot. If these are compared with the one-third of the fall-set trees which made the strongest growth the relation is 99 inches average length of twig growth, and 10/64 inches average diameter increase, for fall-set trees, and 32.7 inches length growth and 4/64 diameter increase, for spring-set trees.

A detailed record of the growth of these cherry trees is shown in Table 25. If the spring-set trees which died are disregarded, it is apparent that those which lived partly overtook the average of the entire number planted in the fall. If the living spring-set trees are compared with the strongest of the fall-set trees a marked advantage is shown in the latter.

## FALL AND SPRING PLANTING OF VARIOUS SPECIES OF TREES

Peach trees prove to be planted more safely in spring than in the fall, in central Missouri. If a severe winter follows autumn planting of the peach, often the trees are killed. Even in milder winters the wood is usually injured sufficiently to turn brown within. With such injury the trees frequently die and at best make poor growth.

Peach trees which have a well-established root system usually recover from such winter injury if their roots remain undisturbed and if they are properly cut back. The root system of young peach trees, even in the nursery, is rarely injured by the coldest winters in central Missouri, providing it is allowed to remain undisturbed. Fall-transplanted peach trees do not establish sufficient root system to winter safely. Even their root system is usually injured and if the winter is severe both tops and roots are usually injured beyond recovery. In the southern counties of the state, however, peach trees are frequently transplanted in the fall with good results.

Japanese plums and other slightly tender species subject to winter injury in this section are more safely planted in the spring.

Pears and hardy plums apparently profit by fall planting to about the same degree as do apples.

Persimmons, native walnuts, chestnuts, hickories, and pecans have been transplanted at various seasons of the year. The best results have been secured by planting these species just as their new leaves are pushing out in spring. They do not transplant successfully when fully dormant, either in fall or early spring.

In the development of the grounds, during the last twenty years, large numbers of ornamental trees and shrubs—both deciduous and evergreen—have been set at various seasons of the year. They have been set when and where they were needed for ornamental purposes rather than to determine the most favorable season for transplanting. The results of this general experience, however, may have some value, especially to those who have not had opportunity for extensive observation of the results of planting at different seasons.

Thoroly hardy deciduous trees and shrubs (with the exception of persimmons and nut trees previously discussed) have usually made better growth when transplanted in late autumn. If the soil is very dry in autumn, as occasionally happens in this section, transplanting may be more safely postponed until early spring.

Slightly tender deciduous species including magnolia, tulip (or yellow poplar), Vitex, sweet gum, and some of the soft wood species whose twigs tend to shrivel and dry out in severe winters, are safer planted in the spring. The best time in spring is not yet fully determined. It may vary with the individual species. Magnolias have done best if transplanted during their early blossoming period; the tulip trees and sweet gum just as their buds were bursting; and most other species before their buds start growth.

The best season for transplanting coniferous evergreens is a vexed question, especially in the central west where fluctuations in

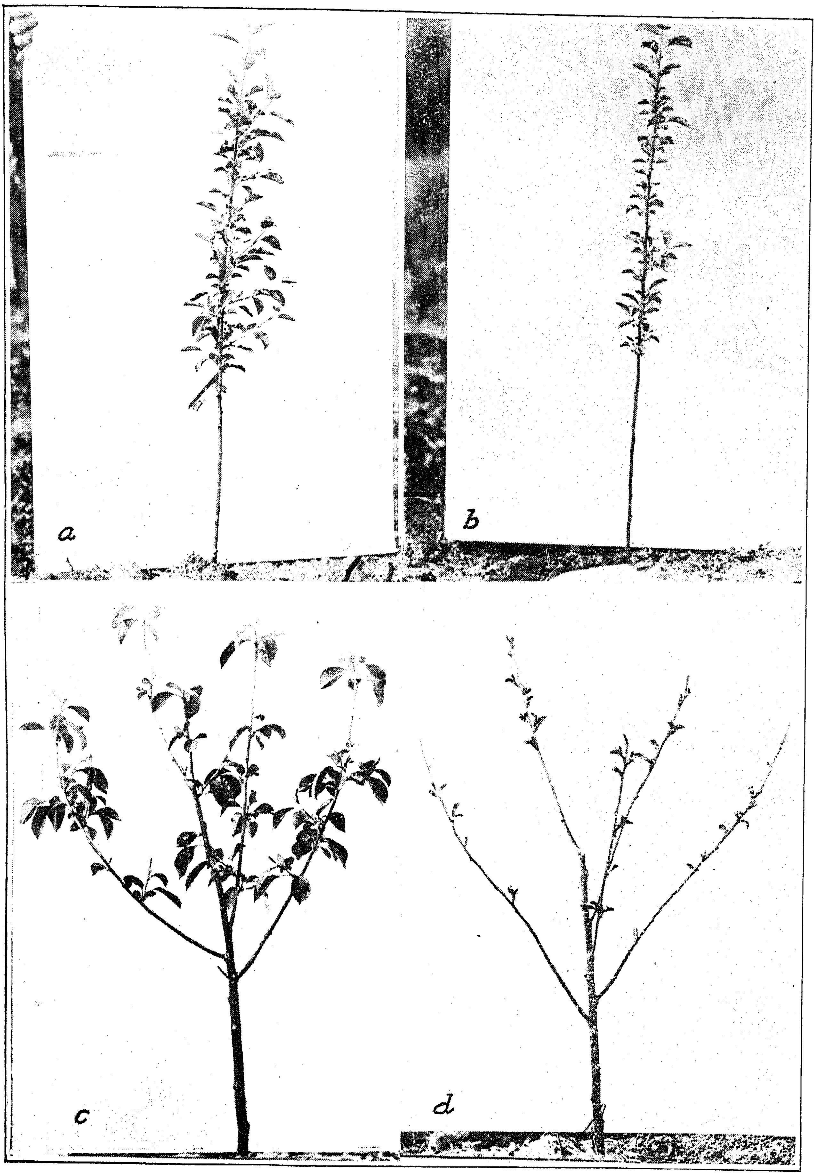



PLATE 1.—Showing the greater average growth on May 11, 1914, on Jonathan apple trees planted December 8, 1913, (*a*), and planted April 18, 1914 (*b*). Also showing the average difference in growth on May 11, 1914, of Montmorency cherry trees transplanted November 20, 1913 (*c*), and transplanted April 14, 1914 (*d*).

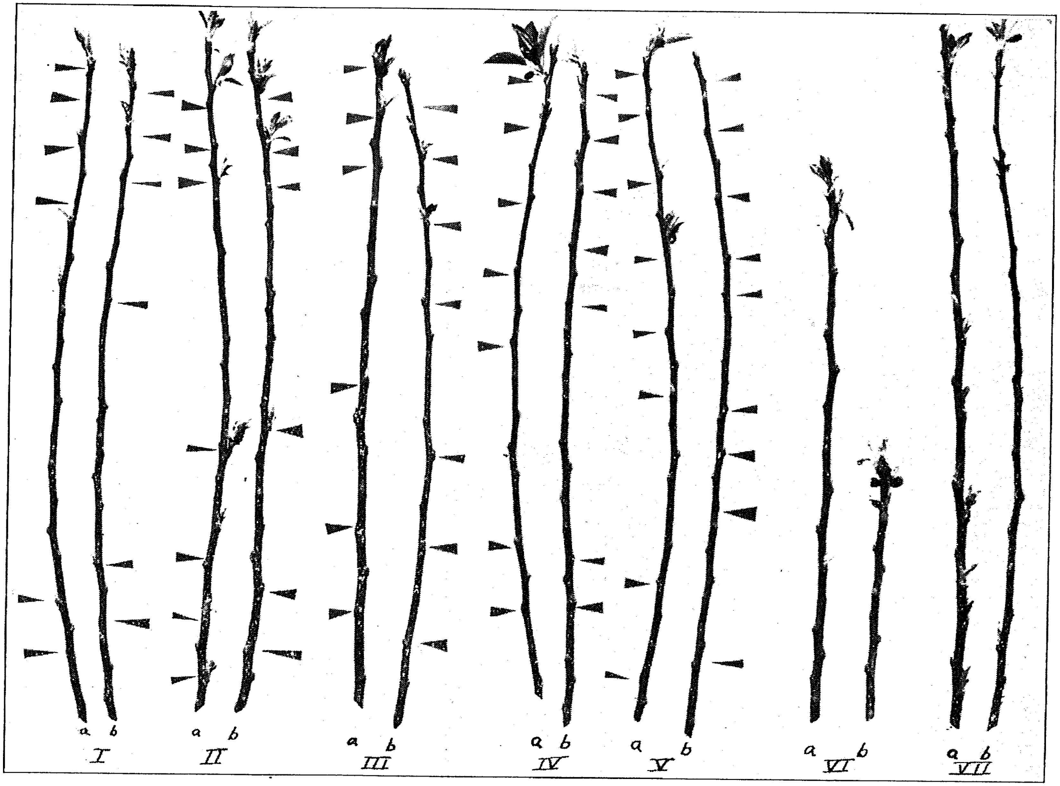



PLATE II.—The effect of wounding upon the activity of dormant buds. Twigs from Delicious apple treated February 22, 1916, in the following manner: Group I, wounded below the alternate buds; Group II, wounded above alternate buds; Group III, wounded above and below alternate buds; Group IV, wounded on one side of alternate buds; Group V, wounded on both sides of alternate buds; Group VI, pruned to different lengths; Group VII, checks. Arrows indicate some of the wounded buds. "*a*" indicates wounding by incision thru the cortex; "*b*" indicates wounding by notching, a small portion of the cortex peing removed.

weather conditions are often extreme. The evergreens are difficult to transplant. This is no doubt due to the fact that they carry their leaves thruout the year and consequently evaporate water thru these leaves, as opposed to deciduous trees in which evaporation is greatly reduced during the dormant period. The roots of evergreens cannot endure even brief exposure to the air without severe injury. For that reason their roots should be protected with moist soil, wet burlap, or other moist packing, at all times while being handled.

There is perhaps not a month in the year that has not been recommended as the best time to transplant evergreens for certain localities. At the Missouri Experiment Station a larger or smaller number of evergreens have been transplanted at various seasons every year for a quarter of a century. In nearly every season the best results have been secured with trees transplanted in late spring, just as new growth was beginning. The next most favorable time has proved to be in early fall, after growth has ceased, but before the trees have matured their growth for winter.

The resin in the ducts of evergreens appears to be very thick during the winter. If the trees are handled in very late fall, during the winter, or in late spring, this resin hardens quickly, the cut ends of the roots become covered with a hard resinous coat which does not emit new roots, and even the twigs, leaves and main roots appear to be so hardened with resin as to obstruct the passage of water. There are two periods, one just after growth ceases in the fall, and the other just after growth begins in spring when sap movement appears not to be obstructed by hardening of the resin.

If the soil is moist and the atmosphere is humid, early autumn planting gives good results under Missouri conditions. If the soil and air are dry in early autumn, as is often the case, planting should be delayed until growth starts in spring.

## ROOT FORMATION OF EARLY AND LATE FALL-PLANTED APPLE TREES

The chief advantages ascribed to fall transplanting of deciduous trees are that the soil becomes thoroly settled about their roots, that the wounds at the ends of the cut-back roots become calloused over, and that the new roots may be formed before the trees leaf out in spring. Practically all of those who favor fall transplanting have advised that the work be done as early in autumn as the trees are in condition to move from the nursery, in order that their roots may become reëstablished before the ground freezes. It seems to have remained an unsettled question, however, as to what extent the success of fall planting may depend upon callousing of the wounds or the formation of new roots before winter sets in. To just what extent the new root system does become "newly established" in the fall has been a matter of doubt. In view of the fact that late fall planting has given better results than early fall planting at the Missouri Experiment Station it is of interest to compare the root development of early and late fall-set trees.

Referring to the available literature on the root growth of trees, this statement by Jost[31] is of interest, "Owing to the obvious difficulties of research, the problems with root growth have been as yet little elucidated." Sorauer[47] states that "the shedding of the leaves ushers in a period of rest. As this partly depends upon the gradual decrease of temperature, the upper portions of the stem, which are exposed to the atmosphere, may have completely entered the period of rest, while the roots which lie in the warmer layers of the soil, are still continuing their growth in thickness. This activity may sometimes last until January, and then only can we say that the plant is entirely at rest."

With respect to callousing of the wounds on the roots in autumn after trees are transplanted, Lindley[36] states, "If at that time [after shedding of the leaves] a root is wounded, a process of granulation or cicatrication will commence, just as it does in cuttings; and from that granulation, which is a mere development of the horizontal cellular system, roots will eventually proceed—the sooner the wound is made the better, because it has the longer time to heal; and therefore the earlier in autumn transplanting is effected, the less injury will be sustained." Koopman[33] also evidently regards the callousing of the roots of early fall-planted trees as being an important factor when he warns against their exposure in this statement, "Once dried out, the cut surfaces do not heal themselves again." Others believe, however, that new root growth does not start from the callous but that new rootlets push out from the sides of the essential roots. Bedford and Pickering[1] (1908, pp. 3-4) make the following statement, "The whole subject to be sought in planting a tree is to secure the formation of fresh rootlets from the main roots, and not to preserve the fibrous roots, which, having lost their root tips are little better than dead encumbrance to the tree." They also further state that if the tree is lifted a few weeks after transplanting, it will be seen "that, in the case of a main root which has been trimmed back rather short, there will be considerable development of new rootlets close to the cut end, tho not actually from the cut end itself."

Card[10] (1898) found that apple trees planted at the Nebraska experiment station October 22, 1897, formed a few short root tips before November 16 of the same fall. Peach trees planted at the same time showed no root growth on the latter date, altho root growth was still active on peach trees which had not been transplanted. An examination of the fall-transplanted apple and peach trees April, 1898, showed that root growth was progressing from the sides of the main roots and that "the cut surfaces were beginning to callous, none having apparently taken place during the fall and winter." He found that at the Missouri Botanical Garden apple trees which were transplanted November 3, had formed roots one to two inches long by December 14, but that no calluses had formed. Peach trees transplanted on the former date had formed no roots but the callusing of the wounds had begun.

At the Missouri Experiment Station observations on the root development of fall-planted apple trees were made in 1895. During the last week in October, two-year-old trees of several representative varieties were transplanted from the Experiment Station nursery. Specimen trees were taken up from time to time and their roots examined. During the first part of December there were no evidences of the starting of new roots on any of the trees examined up to that time. During the last part of December a few new roots were observed on a part of the trees. When the ground thawed in early spring a liberal number of new roots were observed on all the trees examined. Those transplanted in spring put out their leaves before their new root growth started. It was observed that once the spring-planted trees started new leaf growth they then made no more progress for a time, leaf growth apparently being at a standstill until new roots became established. The fall-planted trees had numerous new roots before they came into leaf, and made steady growth after their first spring start.

Similar observations have been repeated, from time to time, in subsequent years. The first new root growth, on fall-transplanted apple trees, was observed from late December to early January in different years. In each case the new growth has occurred on the roots below the frost line, after the surface soil was frozen to a depth of a few inches. Spring-transplanted apple trees have repeatedly been observed to put out leaves ahead of new root formation. Once this new leaf growth was formed, further progress was usually observed to be delayed until new root growth became established later in the spring. Mortality of spring-planted trees has apparently been due to loss of water thru their leaves which started ahead of their roots.

Perhaps the most thoro study of this matter at the Missouri Experiment Station was made during 1915-16 by Mr. L. E. Jesseman, graduate scholar in the department of horticulture. His work was done under the writer's direction, as part of a problem for his Master's thesis. Mr. Jesseman's statement follows:

On October 30, 1915, or as soon as ninety per cent of the leaves were shed, the writer transplanted several one-year-old trees representing the varieties, Jonathan, Winesap, and Gano. On December 2, more than a month later, when it was apparent that the ground would soon be frozen, an additional planting was made, comprising five Jonathans, five Ganos and five Winesaps. These trees were one-year cut-backs; that is, one-year-old tops on three-year-old roots. The trees in each set were lifted from the nursery and replanted immediately without undue exposure of the roots. The roots were pruned where necessary.

The first examination of the root systems of these trees was made December 1. Tree No. 3 of each variety planted October 30, was carefully lifted and the soil washed from the roots with a gentle stream of water. It was found that no new roots had formed, neither had any callusing of the cut surfaces taken place. The numerous root hairs and many of the finer rootlets, which were observed when the trees were planted, had died or become brown and shriveled in appearance. These trees were replanted for further observation. Examination of a tree in the nursery which had not been disturbed showed the root growth was still active.

The time of the next observation was January 22, following a warm period of several days duration. The ground was free from frost for approximately five inches below the surface, the frost extending to a depth of nine inches. This time trees No. 2 and 3 of each variety of the early planting were lifted, and their roots examined. It was found that there were thirteen new root tips on the Gano, six on the Jonathan and five on the Winesap. The roots varied in length from 1/16 to 1/2 inch. It was noted at the time of planting that on the No. 2 Jonathan there were large, fleshy root tips growing from the stem. When examined in January, one of these roots was missing, and three had lengthened considerably, one of them being 1 1/8 inches long. Trees No. 3 of each variety, which were lifted and replanted December 1, still showed no evidence of new root growth.

A specimen tree from the late fall planting, December 2, was taken up January 29. It was seen that there were two large root tips, 1/4 to 1/2 inch long, about two inches from the end of one of the main roots. There was a very vigorous growth of root hairs taking place on all of the fibrous roots. Root growth seemed to be more active than in the case of trees transplanted October 30. No callouses were observed on either the early- or the late-planted trees.

Upon examining the tree which had remained undisturbed in the nursery, it was found that root growth was still active below the frost line.

It was determined, therefore, from the above observations that no new growth of roots or callusing of wounds occurred before December 1 on trees transplanted October 30. It was evident, however, that formation of new roots had been going on for a sufficient length of time previous to January 22 to form roots 1/2 inch in length. It appeared that trees transplanted in late autumn, December 2, began new root growth at approximately the same time as those set 33 days earlier. It was also clearly shown that root formation is not necessarily preceded by callusing of the cut surfaces of the roots.

## ROOT FORMATION OF SPRING-TRANSPLANTED APPLE TREES

A study of the resumption of root growth of spring-transplanted trees should be associated with what is known of the normal root growth of established trees whose roots have not been disturbed by transplanting. With reference to the resumption of root growth in spring, Engler[20] states, "It is found that various species begin root activity before bud development; namely, Zurich in March and April, a few days to four weeks before buds open. In high altitudes the time difference becomes smaller and in some cases vanished entirely." Goff[26] in Wisconsin observed root growth of the apple and other trees starting about March 31, before the buds had preceptibly swollen. He also found the root growth in early spring is most active near the surface of the soil and that it starts where it left off in autumn, at the tips of the finer roots. Card[10] has made similar observations upon the root growth of established trees in Nebraska.

Observations at the Missouri Experiment Station indicate that the root systems of established fruit trees have no such definite rest period as do their tops. Repeated observations of fruit trees taken up at intervals from the time they shed their leaves in the fall until they leaf out in spring indicate that root growth continues after the trees shed their leaves; that it may progress slowly, below the frost line, at any time during the winter and that rapid root growth begins in spring, especially on roots near the surface, before the buds begin growth. On undisturbed trees this growth progresses mainly from the tips of the finer roots.

Observation of transplanted trees shows that the operation of transplanting is followed by a cessation of root growth which lasts over a considerable period, no matter how carefully the work is done. On fall-planted trees root growth is resumed before midwinter, below the frost line, from the deeper main roots, and may continue all winter below the frost line. On spring-planted trees root growth is delayed until after the buds start and is resumed mainly from the larger roots which first receive warmth, nearest the surface of the soil. Regardless of the season of transplanting, the small fibrous roots rarely resume growth but for the most part wither away and, as Bedford and Pickering[3] have said, they are an incumbrance to the transplanted tree.

It is an interesting fact that trees which have been dug in the fall and "heeled in" over winter, or trees which have been received from distant nurseries, usually have started leaf growth and root growth at about the same time when spring-planted. Trees that are handled enough to lose some of the water content, between the time of lifting from the nursery and setting in the orchard, are usually delayed somewhat in putting out their leaves. In some cases leaf growth has not begun until new root growth is underway.

In the spring of 1916 this proved true of trees transplanted from the Station nursery in which they were handled with the least possible exposure. These trees were set and observed by Mr. Jesseman as a part of his work, referred to previously. It is of interest to quote his record of these trees:

On March 25, 1916, five trees each of the Jonathan, Winesap and Gano varieties were transplanted. (These trees had been selected in the fall to duplicate the fall-set trees and were allowed to remain in the nursery during the winter.) Four days later, an equal number of trees of the same varieties were transplanted. (These were the trees selected for comparison with those planted December 2, 1915. Root growth was progressing rapidly upon these trees when lifted from the nursery.)

Specimen trees of the two spring plantings were carefully lifted from time to time and the root systems examined. For purposes of comparison, fall-transplanted trees which had remained in the nursery were also lifted.

An examination, on April 11, of a tree planted March 25 showed that no new roots had formed. The numerous new root tips and root hairs which were observed at the time of planting had either disappeared or turned brown in color, indicating that they had probably ceased to function. April 19, or twenty-five days after planting, another tree was lifted. A new root one inch long was observed, as well as several other root tips which were from one-eighth to one-half inch in length. These roots were all near the ends of fibrous roots. No callous formation had taken place. On the same day, a tree transplanted October 30, 1915, was removed for the purpose of comparing its root development with that of the spring-set tree. A very vigorous new root system was observed. The new roots were from one-half to four inches in length and proceeded from the shorter main roots. Eight roots three-fourths and one and one-half inches long were growing from the end of a root one-eighth inch in diameter. New root tips were forming near the end of all the smaller roots, and, in addition, each root was well supplied with root hairs. This tree, therefore, was well prepared to supply water and food to the expanding leaves, which were at this time approximately three-fourths inch in width. The leaves on the spring-set tree were not quite so far advanced as those planted in autumn.

Examination, on April 22, of a Winesap tree which was transplanted March 29, showed that three new root tips one-eighth inch in length, had formed near the ends of main roots. A few new root hairs were observed. The leaves upon this tree were just unfolding. For comparison, the neighboring tree which was transplanted December 2, 1915, was removed. The new root development was found to be even more extensive than that observed on the trees which were planted October 30. The later planted trees, however, were placed in a soil more favorable for root growth than were the earlier planted trees.

Observations made May 3 on a specimen of the spring-planted trees indicated that the roots were not over two inches in length and were few in number. Since this was nearly forty days after planting, it would appear that root growth was progressing rather slowly as compared with that of autumn set trees.

Very little difference has been observed at this Station between the results of early and late spring planting, providing the trees are equally dormant when planted. Dormant fruit trees from cold storage have been planted out with good results as late as June 3. Trees should be dug from the nursery before their buds start and kept dormant until they can be set in the orchard. The writer has observed no advantage in very early spring setting except that of getting the work out of the way. If the soil is too wet to work well in early spring setting may be delayed, if the trees can be kept dormant.

## A METHOD OF HOLDING TREES DORMANT FOR LATE SPRING PLANTING

Most nurserymen have storage facilities in which they are able to hold trees dormant until they are shipped for planting. Once they are received by the orchardist they are usually "heeled-in" unless conditions admit of setting them as soon as they are received. If wet soil or other circumstance delays planting, the trees may put out their leaves while heeled-in. If the trees start growth while heeled-in in the trench they are likely to suffer when transplanted, due to loss of water thru the leaves, before the roots become established.

If it becomes necessary to hold trees in the trench for late spring planting, the writer has found they may quite readily be kept dormant by rehandling as often as the buds show sign of starting into growth. As the buds begin to swell the trees may be lifted from the trench, turned over to expose their opposite sides to the sun, and heeled-in again in the same trench. This lifting and turning and heeling-in usually delays the growth of the buds from ten days to two weeks. If trees are handled in this way as often as is necessary, they may be held dormant for planting until very late spring, when the soil becomes dry and warm enough to induce the roots to start simultaneously with the leaves after they are set.

Since the terminal buds normally start growth more promptly than do the lower lateral buds it is advisable to prune the trees back properly for setting, at the time they are first heeled-in. The more dormant, lateral buds remaining on the shortened branches start new growth slowly. Furthermore, removal of the surplus growth reduces the evaporating surface and saves the trees from undue drying out.

## RELATIVE TRANSPIRATION FROM DORMANT BRANCHES OF ESTABLISHED AND TRANSPLANTED APPLE TREES

Earlier in this bulletin it has been shown that late fall-planted trees made better growth than early fall-planted trees. It was observed that the twigs of trees planted in very early autumn appeared to shrivel slightly, indicating that they dried out somewhat more than trees planted in late autumn.

During the season of 1915-16 Mr. Jesseman, graduate student, previously quoted in this bulletin, made some very interesting observations upon this point under the writer's direction. Mr. Jesseman's discussion of his results follows:

Transpiration takes place from dormant twigs even on the cold days in winter. This loss of water, even tho very small in amount, must be supplied by movement of water upward from the roots of the tree. If sufficient water cannot be supplied desiccation or winter killing results. This winter injury is one of the factors limiting the success of autumn planting in sections of the country where cold drying winds prevail in winter. It is the general opinion that moisture is lost more rapidly during prolonged periods of cold in winter and that water is taken up again by the roots during subsequent warm periods. It is also believed that fall-planted trees experience considerable loss of water before the root system becomes reëstablished in the soil, and are likely to be in a weakened condition when growth begins in spring.

In order to shed further light upon these questions, the writer has made moisture determination of dormant twigs from undisturbed and from autumn-transplanted apple trees. Four determinations were made as follows: Before and after a cold period of three days duration; again after several days of rain; and finally, at the beginning of growth in spring. The results of these determinations are given in the following table:

TABLE 26.—MOISTURE CONTENT OF DORMANT BRANCHES FROM UNDISTURBED TREES AND FROM TREES TRANSPLANTED IN AUTUMN

| Trees | Percentage of moisture | | | |
|---|---|---|---|---|
| | Jan. 16, 1916 | Jan. 20, 1916 | Jan. 27, 1916 | Mar. 27, 1916 |
| Undisturbed | 52.74 | 51.66 | 52.03 | 50.73 |
| | 50.57 | 51.26 | 53.64 | 52.59 |
| Average | 51.65 | 51.37 | 52.83 | 51.67 |
| Transplanted Dec. 7, 1915 | 50.99 | 51.24 | 51.80 | 48.37 |
| | 51.28 | 51.18 | 51.74 | 50.27 |
| Average | 51.13 | 51.23 | 51.77 | 49.32 |
| Transplanted Nov. 1, 1915 | 48.67 | ------- | ------- | ------- |

The trees from which the data were obtained were three years old and of the Early Harvest variety. They were standing six feet apart in the nursery row, and on December 7 two of them were lifted and immediately replanted in their original positions. Hence the conditions were the same for all these trees except for the disturbance due to transplanting two of them. The soil is heavy clay loam. Twigs in a healthy condition and from the corresponding portions of the different trees were removed for analysis on the dates indicated in Table 26. These were heated in a desiccating oven at a temperature of from 100 to 110 degrees Centigrade until they reached constant weight. The few trees which were transplanted November 1 were cut back at the time of planting and hence afforded material for only one determination.

As will be seen from Table 26, the average percentage of moisture in the twigs of trees under normal conditions on January 15 was 51.65, as compared with 51.13 per cent for the trees transplanted December 7. Thus, trees which had been transplanted over a month contained only 0.52 percent less water than undisturbed trees. It should be noted that just previous to this date the lowest temperatures of the winter occurred; namely -6, -11, -2 degrees F., January 12, 13, and 14, respectively. January 19, after three days of continued cold, when the minimum temperature was 0 degrees and the maximum 32 degrees F., another analysis was made. The undisturbed trees showed a slight loss of water. It is probable that the undisturbed trees showed a larger amount of evaporation because they possessed a larger amount of water when cold weather came on and therefore had more water to lose.

In the interval between January 20 and January 27, temperatures as high as 63 degrees F., and much rain occurred. Analyses made at the close of this period, indicated that the average moisture content of the normal trees was 52.83 per cent, and of the transplanted trees 51.77 per cent. The former trees gained 1.46 per cent and the latter 0.54 per cent. This appears to confirm the opinion that trees tend to become more turgid during warm periods in winter. Also, that trees whose root systems have been mutilated by transplanting in autumn are not able to recover their turgidity as rapidly as trees which have not been disturbed in this manner.

It might be concluded from the foregoing paragraph that the autumn-planted trees would suffer during the winter a marked deficit in water content. Reference to the table shows that, on March 27, when the buds were beginning to open, the average moisture content of the fall-planted trees was 2.35 per cent lower than that of the undisturbed trees. This deficiency in moisture apparently had no injurious effect upon the trees in question. It is probable that fall-planted trees can withstand a greater loss of water than the above-named amount without serious injury. The following statement by Sorauer[47] (p. 91) is of interest in this connection: "Freshly transplanted trees and shrubs are more sensitive than the untouched ones; generally speaking, the roots are more sensitive than the stem and branches, owing to their more delicate tissues and the larger percentage of water of the former. The branches of fruit-trees where transplanted in the autumn were less damaged by frost than those which had remained in their original positions."

Such a phenomenon is, in all probability, due to the fact that the branches contained less water, as the transplanting, by damaging the many root tips, consequently stops the growth of the branches, and accelerates the ripening of the wood. Chandler[13] concluded also that greater concentration of sap which results from usual evaporation of water from trees during the winter would, by lowering the freezing point of their sap, render plants less liable to injury by low winter temperatures.

In addition to the analyses already discussed, the moisture content was determined on January 16, of trees which had been transplanted November 1. It was found to be 48.67 per cent, or 2.46 per cent lower than the average of the trees which had remained in their original position. On the other hand, the average water content of trees planted December 7, or over a month later, was 51.13 per cent, or only 0.52 per cent less than the normal trees. This would seem to indicate that the rate of evaporation was much higher during the month of November than during December and early part of January, as might be expected. While in this comparison the results may have been influenced by the individual variation of the trees, or may be within the limits of experimental error, it is of interest to consider it in connection with the fact brought out earlier in this paper; namely, that apple trees planted in the late fall of 1913 (December 6) at this Station, made much better growth during the next two seasons than similar trees set a month earlier, or November 8, 1913. These two facts, considered together, may be a confirmation of the opinion expressed by Whitten that the high temperature and bright sunlight of this interior climate, which often prevail until late autumn in this section, may serve to keep up the activity and a high rate of evaporation in the early-transplanted tree until late in November. Under such conditions it would undoubtedly be wiser to transplant in late autumn when the functions of the aerial portions of the trees have become practically dormant, and while a sufficient store of heat still remains in the soil to stimulate new root growth, before severe weather of winter.

# Part II—Minor Studies Relating to Transplanting

## RELATION OF MULCHING TO THE DEVELOPMENT OF FALL-PLANTED APPLE TREES

The opinion is quite general among horticulturists that fruit trees should be mulched when transplanted in autumn. The benefits of a mulch, sometimes suggested, are that it delays freezing of the soil in autumn, giving the roots a longer time in which to heal, callous or make growth; prevents heaving of the soil by alternate freezing and thawing in winter; prevents deep freezing in severe climates, and protects the roots of the trees from drying out in dry climates. Clement[15] advised banking up around fall-transplanted trees with soil and then mulching with manure. Wickson[52], referring to California conditions, states that "even in localities of light rainfall, if the trees are well mulched early in the winter, irrigation may be unnecessary for the young, deciduous trees." Oskamp[40] found that the soil beneath a mulch of straw and grass cooled off less quickly in autumn than where clean cultivation was practiced, and that it retained a higher minimum temperature until spring. In spring, however, the soil warmed up less where the mulch was maintained, than where clean cultivation was practiced.

There can be little doubt that a mulch may be beneficial to autumn-transplanted trees in climates where the roots are subject to injury from severe freezing, or in very dry climates where the roots may suffer from lack of soil moisture. A mulch applied in summer may also be beneficial in preventing drying out if a dry hot summer follows fall planting. There is some question, however, as to whether fall and winter mulch is desirable under Missouri conditions, where winter freezing is not severe and where soil moisture is usually adequate, and sometimes excessive, during winter and spring.

The question also arises as to whether a mulch may not even retard growth of the roots, if it is retained in spring, by preventing the soil from warming up rapidly. Even if the mulch is removed in early spring, may not the soil retain water enough to keep the soil cool and delay root action?

In order to throw light on this subject, for Missouri conditions, observations were made in 1914 upon trees mulched and not mulched, which were planted the previous season. The apple trees under observation were Transparent, Grimes, Jonathan, Winesap and Early Harvest. The trees of the former two varieties were two years old and the latter three were one year old when transplanted.

TABLE 27.—GROWTH DURING THE SUMMER OF 1914 OF APPLE TREES MULCHED AT THE TIME OF TRANSPLANTING IN AUTUMN

| Variety and date of planting | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of length growth, inches |
|---|---|---|---|---|
| Transparent— | | | | |
| Nov. 8, 1913 | 32/64 | 42/64 | 52/64 | 237 |
| | 20/64 | 46/64 | 49/64 | 208.5 |
| | 32/64 | 45/64 | 54/64 | 150 |
| | 28/64 | 43/64 | 48/64 | 222 |
| | 32/64 | 42/64 | 50/64 | 295 |
| | 28/64 | 35/64 | 37/64 | 136.5 |
| | 28/64 | 40/64 | 41/64 | 133 |
| | 24/64 | 32/64 | 37/64 | 126 |
| | 28/64 | 34/64 | 39/64 | 101.5 |
| | 28/64 | 34/64 | 49/64 | 173 |
| Average | 28/64 | 39/64 | 46/64 | 178.3 |
| Grimes— | | | | |
| Dec. 6, 1913 | 20/64 | 29/64 | 29/64 | 52 |
| | 28/64 | 38/64 | 44/64 | 90 |
| | 20/64 | 28/64 | 40/64 | 333 |
| | 24/64 | 34/64 | 34/64 | 187 |
| | 20/64 | 37/64 | 48/64 | 161 |
| | 32/64 | 37/64 | 42/64 | 119 |
| Average | 24/64 | 34/64 | 40/64 | 157 |
| Jonathan— | | | | |
| Nov. 8, 1913 | 18/64 | 27/64 | 35/64 | 171 |
| | 8/64 | 28/64 | 36/64 | 339.5 |
| Average | 13/64 | 28/64 | 36/64 | 255.2 |
| Winesap— | | | | |
| Nov. 8, 1913 | 8/64 | 29/64 | 41/64 | 184 |
| | 8/64 | 20/64 | 22/64 | 78 |
| | 8/64 | 25/64 | 36/64 | 181 |
| | 12/64 | 29/64 | 38/64 | 136.5 |
| Average | 9/64 | 26/64 | 34/64 | 145.0 |
| Early Harvest— | | | | |
| Nov. 8, 1913 | 8/64 | 26/64 | 34/64 | 117 |
| | 12/64 | 26/64 | 30/64 | 55 |
| Average | 10/64 | 26/64 | 32/64 | 86 |
| Jonathan— | | | | |
| Dec. 6, 1913 | 8/64 | 26/64 | 34/64 | 135 |
| | 8/64 | 27/64 | 34/64 | 183 |
| Average | 8/64 | 27/64 | 34/64 | 159 |
| Winesap— | | | | |
| Dec. 6, 1913 | 12/64 | 35/64 | 49/64 | 251 |
| | 8/64 | 31/64 | 46/64 | 287 |
| | 8/64 | 29/64 | 41/64 | 264 |
| | 12/64 | 30/64 | 40/64 | 141 |
| Average | 10/64 | 31/64 | 44/64 | 235.7 |
| Early Harvest— | | | | |
| Dec. 6, 1913 | 8/64 | 34/64 | 39/64 | 132 |
| | 12/64 | 34/64 | 40/64 | 174.0 |
| Average | 10/64 | 34/64 | 40/64 | 153.0 |
| Total | 572/64 | 1058/64 | 1296/64 | 5553.5 |
| Average | 17/64 | 33/64 | 40/64 | 174.0 |

TABLE 28.—THE GROWTH DURING THE SUMMER OF 1914 OF APPLE TREES NOT MULCHED AT THE TIME OF TRANSPLANTING IN AUTUMN

| Variety and date of planting | Diameter when set, inches | Diameter, Aug. 14, 1914, inches | Diameter, Nov. 20, 1914, inches | Amount of length growth, inches |
|---|---|---|---|---|
| Transparent— | | | | |
| Nov. 8, 1913 | 28/64 | 36/64 | 45/64 | 312 |
| | 28/64 | 44/64 | 52/64 | 253 |
| | 28/64 | 45/64 | 55/64 | 406 |
| | 32/64 | 48/64 | 41/64 | 355.5 |
| | 32/64 | 37/64 | 37/64 | 166 |
| | 28/64 | 33/64 | 42/64 | 120 |
| | 24/64 | 36/64 | 55/64 | 136 |
| Average | 29/64 | 40/64 | 47/64 | 249.5 |
| Grimes— | | | | |
| Dec. 6, 1913 | 16/64 | 25/64 | 29/64 | 74 |
| | 28/64 | 34/64 | 35/64 | 149 |
| | 32/64 | 37/64 | 44/64 | 191 |
| | 20/64 | 27/64 | 32/64 | 171 |
| | 20/64 | 30/64 | 40/64 | 111 |
| | 28/64 | 34/64 | 35/64 | 110 |
| Average | 24/64 | 31/64 | 36/64 | 134.3 |
| Jonathan— | | | | |
| Nov. 8, 1913 | 12/64 | 16/64 | 44/64 | 258 |
| | 16/64 | 36/64 | 45/64 | 255 |
| Average | 14/64 | 26/64 | 45/64 | 257 |
| Winesap— | | | | |
| Nov. 8, 1913 | 16/64 | 32/64 | 36/64 | 292 |
| | 16/64 | 28/64 | 36/64 | 130.5 |
| | 12/64 | 29/64 | 40/64 | 181 |
| Average | 15/64 | 30/64 | 37/64 | 201.0 |
| Early Harvest— | | | | |
| Nov. 8, 1913 | 12/64 | 30/64 | 34/64 | 173 |
| | 20/64 | 33/64 | 44/64 | 162 |
| Average | 16/64 | 32/64 | 39/64 | 167.5 |
| Jonathan— | | | | |
| Dec. 6, 1913 | 12/64 | 33/64 | 43/64 | 277 |
| | 12/64 | 31/64 | 45/64 | 262 |
| Average | 12/64 | 32/64 | 44/64 | 169.5 |
| Winesap— | | | | |
| Dec. 6, 1913 | 12/64 | 54/64 | 44/64 | 352 |
| | 12/64 | 31/64 | 45/64 | 218 |
| Average | 12/64 | 43/64 | 45/64 | 285.0 |
| Early Harvest— | | | | |
| Dec. 6, 1913 | 12/64 | 30/64 | 42/64 | 92 |
| | 20/64 | 36/64 | 43/64 | 193 |
| Average | 16/64 | 33/64 | 43/64 | 142.5 |
| Total | 528/64 | 885/64 | 1083/64 | 5400.0 |
| Average | 20/64 | 34/64 | 42/64 | 207.7 |

Immediately after planting in the fall, alternate trees in each row were mulched with straw, as shown in previous tables in which the growth of these varieties is recorded. The mulch was allowed to remain about the trees until time to begin spring cultivation, when it was removed in early April. The trees mulched and not mulched were given similar treatment and clean cultivation during the summer.

The resulting growth of the trees which were mulched and those which were not mulched is recorded in Tables 27 and 28. The mulched trees made a somewhat smaller average increase in diameter of trunk than did the trees which were not mulched. The mulched trees made an average total length growth of twigs amounting to 174 inches and the trees not mulched averaged a length growth of 212.5 inches, or an average of 36.5 inches per tree, which is 21 per cent in favor of the latter.

It is apparent that the mulch was somewhat detrimental rather than beneficial in this instance, apparently due to its retarding the warming of the soil about the roots of the mulched trees, even tho it was removed in early April. In cultivating the soil about the trees, after the mulch was removed, it was evident that more moisture was retained in the soil where the mulch had lain over winter than in the soil about the trees that had no mulch.

There was no visible difference in the time at which growth above ground began on the mulched and unmulched trees. This fact was to be expected as it has been shown repeatedly at this Station and elsewhere that a mulch about the roots of a tree does not retard the spring growth of its buds above the mulch. Spring growth of the buds is governed by the temperature of the twigs and buds themselves and is practically uninfluenced by the temperature of the roots.

Additional trees were reserved for examination as to comparative root growth as influenced by mulching. Specimens were examined from time to time. Roots began to form on mulched and unmulched trees in early January, following fall transplanting. At that time the ground was frozen to a shallow depth beneath the mulch tho not so deep as where no mulch was applied. There was no marked difference in the amount of root growth of mulched and unmulched trees up to the time the mulch was removed in spring. Unfortunately facilities were not available for recording comparative soil temperatures.

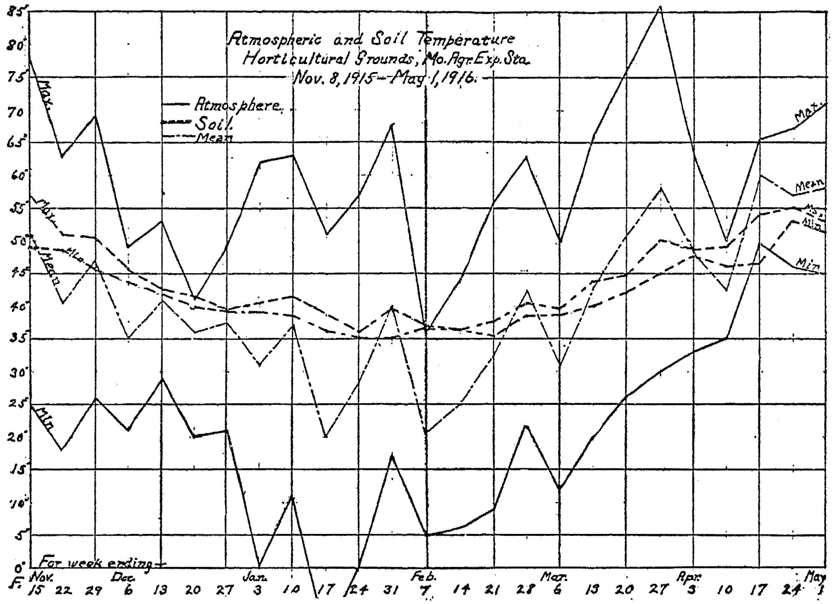
The foregoing record, combined with general observations made in other seasons on results due to the presence or absence of a mulch about fall-planted trees, at this Station, indicate that there is no advantage in a winter and spring mulch under Missouri conditions. Whenever there is an abundance of soil moisture in the spring the mulch appears to be slightly disadvantageous and in no instance has it proved to be beneficial.

## RELATION OF SOIL AND ATMOSPHERIC TEMPERATURES TO FALL AND SPRING PLANTING

The growth of any part of a plant is profoundly influenced by temperature. The soil temperature about the roots and the atmospheric temperature surrounding the twigs and buds must be regarded as important factors in determining the root and twig development of transplanted trees. It has been previously noted in this bulletin that trees transplanted in early autumn, at the Missouri Experiment Station, have not started new root growth ahead of similar trees planted in late autumn or early winter. It has also been noted that trees transplanted in very early spring do not renew their root growth promptly; usually it starts no earlier than on trees planted later in spring. In the case of both early and late spring-planted trees new root growth is usually delayed until the leaves appear. On the other hand, both early and late fall-planted trees begin new root growth after the surface of the earth freezes (usually in early January), and it apparently continues below the frost line during winter and is well advanced when the trees put out their leaves in spring. The new roots of undisturbed trees apparently have no very definite rest period, but may make new growth after the trees shed their leaves in autumn. This growth may continue slowly below the frost line in winter and somewhat rapid new root growth formation may begin in advance of leaf formation. Fall and winter root growth is made well below the surface of the soil; early spring root growth is most marked near the surface, where the soil warms first.

With the hope of throwing some light upon the reasons for the behavior of the trees, a continuous record of soil temperature from November 8, 1915, to May 1, 1916 was made. This record, together with a record of atmospheric temperature, is shown in the accompanying chart. The weather record was obtained from the Columbia, Missouri, office of the United States Weather Bureau. The soil temperature was taken by a Julien P. Freiz & Sons thermograph. The bulb was placed at a depth of fifteen inches, which was the average depth of the lower roots of transplanted trees. The reading of the thermograph was checked by comparison with standard thermometers. The data were taken and the chart prepared by Mr. Jesseman, graduate student in the department.

The chart shows comparative uniformity of soil temperature as compared with extreme fluctuations of the atmospheric temperature. It is of interest to note that at one time the temperature of the air was 47 degrees below that of the soil, while on another occasion it was 45 degres above the soil temperature at a depth of fifteen inches. Further examination of the chart shows that there was a gradual depression of soil temperature until January 24, when a gradual rise began. The soil temperature during the week ending




November 15 was practically the same as the temperature on May 1. The mean temperature of the air dropped below that of the soil by the first of December and continued so, with one minor exception, until the last of February, when a rapid rise of temperature began.

The weather record shown in the chart, from November 15, 1915, to May 1, 1916, is found to vary but little from the twenty-year average at Columbia, Missouri. While the soil temperature record covers but a single winter, it is probable that it also conforms closely to the seasonal average, since the soil temperature curve is shown to follow a close relation to the mean of the atmospheric temperature. It is known that in exceptional seasons, however, soil at Columbia may freeze to a greater depth than fifteen inches, altho the minimum shown by the chart is 35 degrees at that depth.

These data, considered in connection with the known habits of growth of fruit trees, are of great interest in studying the results of transplanting at different seasons. Young, deciduous fruit trees usually continue their growth in central Missouri until moderately late autumn. The average first killing frost occurs October 15. With the first hard frost the lower leaves begin to fall. By the last of October the leaves are largely shed, or in condition to be stripped and the trees dug. If, however, the trees are allowed to stand in the nursery, a few leaves usually remain green toward the younger tips of the limbs until the middle of November. Cork formation about the lenticels and leaf scars and general ripening of the wood goes on so the twigs cannot be said to have their activity checked sufficiently to be fully in their winter rest before November 15.

If trees are transplanted in early autumn they are still in a condition to transpire and dry out somewhat, during the warm, often dry, sunny days of early November. Reference to the chart shows that on November 15 the maximum air temperature was 78 degrees but that it fell rapidly after that date. That transplanting after the trees are fully ripe and the days become cool gives better results, is shown by the tests at this Station and previously discussed in this bulletin.

It is shown by the chart that soil temperatures remain favorable for root growth long after top growth has ceased and the trees are fully ripe and at rest above ground. The fact that trees transplanted in late fall begin root growth as soon as do those planted earlier in autumn, has previously been shown. It has also been shown that late-planted trees dry out less during the winter. There is no special advantage in early planting since the soil ordinarily does not freeze sufficiently to interefere with the work until about December 10, and new root growth does not usually begin until about the first of January.

In central Missouri, it is probable that the soil attains its maximum store of summer heat in October altho we have no local data by which to prove at what date or what distance this heat extends to its greatest depth. This heat, passing out of the soil, in early winter, apparently stimulates root growth of the trees, very much as mild bottom heat from a hot bed might do, long after the atmosphere is cold enough that the twigs above ground are in their most complete rest. It has been observed repeatedly at the Missouri Experiment Station that the lower roots of fall-transplanted trees begin new root growth, and that cuttings of grapes and other woody plants begin to callous and often make roots, in early January, after the surface of the soil is closed in by a frozen layer or "frost shell' several inches in thickness. At this time there is usually a considerable period in which the trees or cuttings are very turgid. Evaporation from their parts above ground is apparently reduced, due to the low atmospheric temperature, while they are amply supplied with water from the warmer moist soil surrounding their parts that extend below the frost line. This should not be confused with the fact that the twigs may shrivel somewhat later on if periods of dry cold weather prevail and the soil freezes so deep as to oppose taking in water by the roots.

Apparently there is an accumulation of "bottom heat" below the frost layer, once the layer has formed to a depth of a few inches. It will be observed that there is an upward tendency of the soil temperature curves in the chart, from December 27, to January 10, in marked opposition to the general downward tendency of the curves of the atmospheric minimum and mean. While the soil temperature at this time was about 40 degrees at a depth of fifteen inches, the surface of the soil was frozen to a depth of about four inches, the expanding ice crystals in the surface soil thus forming a tight shell of earth.

Apparently, also, there is a tendency toward the movement of surplus water to the frozen surface layer from the warmer soil immediately below, thus allowing the soil about the roots below the frost line to become more flocculent, when at the same time the frozen surface layer is becoming more impervious by its accumulation of ice formed of the water from below. No very definite data are available with which to substantiate this suggestion, but the following observations seem pertinent.

Often the surface soil is dry enough to work well about trees or cuttings just before it freezes. As it begins to freeze abundant ice crystals appear on the surface, even if the air is relatively dry. Soon a network of ice may cover the ground. This does not occur unless there is a liberal supply of soil moisture below the surface. If the warm weather occurs to thaw the surface soil it is found too wet to work until the entire frost layer thaws so that the accumulation of surface water can drain downward. The action, during the early winter, of heat stored in the soil during the previous summer is well illustrated by the following observation. In cold climates a heavy snowfall may cover the ground in early winter. If the ground is not frozen it may not freeze under the snow during the winter. If the surface soil is frozen previous to a very heavy snowfall the frost layer may be thawed, from *below,* owing to the influence of the heat below the frost line. If the snowfall covers frozen ground in late winter the soil thaws from *above* with the melting of the snow, while frost may remain below even after spring crops are planted.

If trees are planted in very early spring the soil about their roots is warmed slowly, while the air above warms rapidly. As a result the buds of early spring-planted trees tend to start growth in advance of the roots. If planted in late spring after the soil has become warm, root growth and top growth are more nearly simultaneous, providing the buds are fully dormant when the trees are planted.

## RELATION OF WOUNDS TO THE ACTIVITY OF ADJACENT BUDS

It is a matter of common observation that the terminal bud of a branch normally starts growth in spring in advance of the lateral buds lower down. If the terminal bud is removed in pruning back the branch, the buds which remain near the cut end tend to start in advance of those lower on the twig. Insect punctures on the side of the twig often stimulate the growth of the adjacent buds in advance of those more remote from the wound. In forcing twigs into growth in vases of water in the greenhouse during winter, the writer has often observed that the lower bud adjacent to the cut end of a twig may start growth in advance of the others. Uninjured buds near a wound of any kind tend to make an earlier start.

In this connection McDougal[39] says "intense mechanical forces which cut, tear or crush the protoplasts or their membranes, exert a stimulating effect upon the neighboring uninjured elements as well as the entire organism in some instances." In the writer's experience, if the wound is made the previous autumn the stimulus appears to be greater than if made shortly before the buds start growth. Trees transplanted in the fall make stronger growth if cut back when transplanted than if the pruning is delayed until spring. The same is also true of trees which are not transplanted. This may be due in part to greater desiccation from the twig surface of unpruned trees and also the fact that there is rapid loss of water from the pruning wound made in spring, before the ducts are closed by the normal process. The belief that it is also due in part to the greater stimulus of wounds made in autumn is supported by the following evidence:

On three separate occasions the writer has grown deciduous fruit frees in greenhouse benches for a period of years. Under these conditions a moist atmosphere and temperature suitable to growing plants was maintained thruout the winter. The trees were not subjected to drying out or to cold weather. The rest period of the trees was shorter than that of trees subjected to open field conditions. Twigs were pruned back at the time they shed their leaves in December and similar twigs were pruned just before growth was resumed in late February or March. A part of the wounds were paraffined as soon as they were cut to prevent drying out. Stronger average growth was made by the buds adjacent to wounds made at the beginning of the rest period. Similar results have been secured in the case of a still larger number of trees, grown in open ground, even in seasons when winter desiccation was least marked.

Typical results, showing the relation of wounds to growth of the adjacent buds were secured by Mr. Jesseman. The following quotation from his discussion is of interest, in connection with Plate II.

The effect of wounding upon the activity of dormant buds may be shown more directly by the following experiment, in which a wound is made thru the cortex closely adjacent to the buds themselves.

The material used in this experiment was one-year-old wood from a Delicious apple tree. These branches were removed February 22, 1916, while the buds were still dormant. They were cut into equal lengths and divided into seven groups of six twigs each. The character of the wound made on half of the twigs in each group was an incision with a knife thru the cortex across the axis of the twig. On the other half a small notch about one-sixth inch wide was made, removing a portion of the cortex. Alternate buds were wounded. The position of the wounds was varied for each group, as follows: No. 1, below the bud; No. 2, above the bud; No. 3, above and below the bud; No. 4, lateral and longitudinal on one side only; No. 5, same as No. 4 on both sides of bud. Twigs in No. 6 were pruned to different lengths, and those in group No. 7 were checks.

The accompanying photograph [Plate II] taken March 7 shows two average specimens from each group. It will be noticed that the wound was not effective in all cases in stimulating a bud into making greater growth than the adjacent unwounded buds. These results are influenced to some extent by the variation in the buds.

It was found by counting the number of buds which had burst that the second treatment, or wounding above the bud, appeared to afford the greatest stimulus. Wounding above and below the buds was effective in a nearly equal number of cases. A lateral wound on one side only was apparently less effective than transverse wounds above or below the bud, with the exception of the excessive growth of the bud near the terminal of III, *a* [Plate II]. [In the same figure] IV, *b* shows that notching on both sides was too severe a treatment. The buds on the twigs in this group dried up before they had started appreciably. It will be noted that whether a branch is pruned short or long that the outermost bud makes an earlier and more vigorous growth than the remaining buds on the branch. The normal twigs in Group 7 indicate that the terminal buds are much in advance of the laterals, and that the latter started quite uniformly. The relative effect of two forms of wounds was noticeable. The notched buds seemed to start earlier, but they soon appeared to suffer from desiccation. A simple knife-cut thru the cortex was sufficient to produce marked results.

These results show, therefore, that dormant lateral buds may be stimulated into abnormally early growth by means of a wound in close proximity of the bud. The greatest stimulus is afforded by an incision thru the cortex immediately above the bud. Lateral wounding is a less effective stimulus. Removing a portion of the cortex in making a notch may be too severe a wound, causing loss of water from the bud.

These results are in accord with statements made by Gaucher[26], Gressents[28], Lauche[35], and Lucas[37]. Weber[49], in an experiment on shortening the rest period of shoots, found that injured buds in almost every case preceded in opening and rapidly outgrew untreated buds on the same sprout.

The practical suggestions might be made in connection with this experiment that it may be advisable to prune back in autumn trees that are to be transplanted in spring; also that branching may be induced on poorly headed trees."

## THE TIME TO PRUNE TRANSPLANTED TREES

The time to prune transplanted trees, and young trees not to be transplanted, has been much discussed. Early spring has been most generally recommended for pruning. It is the usual custom to prune back the branches of young trees when they are transplanted. Some writers have recommended delaying pruning back fall transplanted trees until spring. The precaution often urged against cutting back the branches in the fall is that the tree loses too much moisture thru the cut surfaces of the twigs. Fear has been expressed that the cut-back branches will dry out sufficiently to kill back badly during winter. The question naturally arises as to whether more water will be lost thru the wounds of the cut twigs than would be transpired from the branches were they left intact.

In order to answer this question for Missouri conditions, general observations have been made on young trees pruned at different seasons at the Missouri Experiment Station in the last twenty years. The results uniformly indicate that better growth results if the branches are cut back in the fall. This holds true for young trees generally, whether they are transplanted in the fall or spring or whether they are not transplanted.

Mr. Ed. Kemper, a skillful grape propagator and grower of Hermann, Missouri became interested in the writer's observations on this subject, when he was a student at the University of Missouri. He has since assured the writer that grapes, especially, make better growth if pruned back in the fall. He sets his cuttings in autumn as soon as the vines shed their leaves and thereby successfully roots Norton, Cynthiana and other varieties found to root with difficulty if the cuttings are made and set in early spring. He further says that one-year-old grapes, designed to stand a second year in the nursery, make much better growth if pruned back in the fall; also that bearing grape vines make stronger growth if pruned in autumn as soon as their leaves are shed. He emphasizes this particularly in the case of varieties that tend to make poor renewal growth from the lower spurs. These, according to his experience, make better growth from renewal spurs if pruned in autumn.

Tests made at the Missouri Experiment Station in 1900 and 1901 are typical of the results secured generally with apples. The details of this season's work shown in Tables 29, 30 and 31, were carried out by Mr. W. L. Howard, who at that time was a graduate student in this department.

From the tables it will be seen that there was very little difference between the water content at the periods when tests were made of apple trees transplanted in late fall and those which were not transplanted. The fact is also indicated that the trees whose branches were pruned back in late autumn contained, on the average, slightly more water than those which retained their branches. While this difference is not great it at least indicates that the pruned branches did not suffer from drying out thru the wounds, but that on the contrary the pruned trees dried out slightly less than did those which were not pruned.

TABLE 29.—SHOWING THE AMOUNT OF WATER ON MARCH 6, 1901, IN TREES TRANSPLANTED AND NOT TRANSPLANTED, AND PRUNED AND NOT PRUNED

| Portion of tree | Two-year-old Ben Davis | | | | One-year-old Ben Davis | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Transplanted Nov. 19, 1900 | | Not Transplanted | |
| | Lot 1 Fall pruned | Lot 2 Not pruned | Lot 3 Fall pruned | Lot 4 Not pruned | Lot 5 Fall pruned | Lot 6 Not pruned | Lot 7 Fall pruned | Lot 8 Not pruned |
| Branches | 46.25 | 47.21 | 47.19 | 50.04 | 45.51 | 44.44 | ------- | ------- |
| Trunk | 42.73 | 42.08 | 43.12 | 46.49 | 57.93 | 56.40 | 47.48 | 50.00 |
| Roots | 50.00 | 48.82 | 53.76 | 52.84 | 54.77 | 52.80 | 53.92 | 59.15 |
| Average for trunks and branches | 44.49 | 44.64 | 45.15 | 48.26 | 52.72 | 50.42 | 47.48 | 50.00 |
| Average for whole trees | 46.32 | 46.03 | 48.02 | 47.12 | 52.73 | 51.21 | 50.70 | 36.38 |

| Portion of tree | One-year-old Jonathan | | | | One-year-old seedling peach | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Transplanted Nov. 19, 1900 | | Not Transplanted | |
| | Lot 9 Fall pruned | Lot 10 Not pruned | Lot 11 Fall pruned | Lot 12 Not pruned | Lot 13 Fall pruned | Lot 14 Not pruned | Lot 15 Fall pruned | Lot 16 Not pruned |
| Branches | 44.23 | 33.38 | 45.69 | 40.00 | 42.23 | 41.88 | 44.70 | 45.71 |
| Trunk | 46.30 | 53.26 | ------- | 42.35 | ------- | 41.77 | ------- | 43.39 |
| Roots | 56.56 | 49.06 | 58.86 | 56.00 | 52.31 | 55.45 | 59.75 | 51.14 |
| Average for trunks and branches | 45.26 | 43.32 | 45.69 | 41.17 | 42.23 | 41.81 | 44.70 | 44.55 |
| Average for whole tree | 49.00 | 45.23 | 52.27 | 46.11 | 47.27 | 46.36 | 52.22 | 47.75 |

TABLE 30.—SHOWING THE AMOUNT OF WATER ON APRIL 6, 1901, IN TREES TRANSPLANTED AND NOT TRANSPLANTED, PRUNED AND NOT PRUNED

| Portion of tree | Two-year-old Ben Davis | | | | One-year-old Ben Davis | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Transplanted Nov. 19, 1900 | | Not Transplanted | |
| | Lot 1 Fall pruned | Lot 2 Not pruned | Lot 3 Fall pruned | Lot 4 Not pruned | Lot 5 Fall pruned | Lot 6 Not pruned | Lot 7 Fall pruned | Lot 8 Not pruned |
| Branches | 47.80 | 49.60 | 49.38 | 51.80 | 48.80 | 50.38 | ------- | 52.31 |
| Trunk | ------- | 42.21 | 48.61 | 48.46 | 46.15 | 47.20 | 47.20 | 49.60 |
| Roots | 55.52 | 50.54 | 53.23 | 55.29 | 52.40 | 58.64 | 56.06 | 57.50 |
| Average for trunks and branches | 47.80 | 45.90 | 48.99 | 50.13 | 47.47 | 48.79 | 47.20 | 50.95 |
| Average for whole trees | 51.66 | 47.45 | 50.41 | 51.85 | 49.11 | 52.07 | 51.63 | 53.13 |

| Portion of tree | One-year-old Jonathan | | | | One-year-old seedling peach | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Transplanted Nov. 19, 1900 | | Not Transplanted | |
| | Lot 9 Fall pruned | Lot 10 Not pruned | Lot 11 Fall pruned | Lot 12 Not pruned | Lot 13 Fall pruned | Lot 14 Not pruned | Lot 15 Fall pruned | Lot 16 Not pruned |
| Branches | 48.97 | 48.05 | 48.07 | 49.41 | 46.15 | 48.24 | 50.00 | 50.12 |
| Trunk | 45.63 | 41.54 | 47.61 | 47.05 | 46.35 | 46.87 | 46.85 | 44.60 |
| Roots | 51.53 | 55.00 | 56.14 | 58.05 | 56.26 | 58.87 | 55.26 | 59.19 |
| Average for trunks and branches | 47.30 | 44.79 | 47.84 | 48.23 | 46.25 | 47.55 | 48.42 | 47.36 |
| Average for whole trees | 48.71 | 48.20 | 50.61 | 51.50 | 49.59 | 51.33 | 50.70 | 51.63 |

TABLE 31.—SHOWING THE AMOUNT OF WATER ON APRIL 22, 1901, IN TREES TRANSPLANTED AND NOT TRANSPLANTED, PRUNED AND NOT PRUNED

| Portion of tree | Two-year-old Ben Davis | | | | Two-year-old Ben Davis | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Nov. 19, 1900 Transplanted | | Not Transplanted | |
| | Lot 1 Fall pruned | Lot 2 Not pruned | Lot 3 Fall pruned | Lot 4 Not pruned | Lot 5 Fall pruned | Lot 6 Not pruned | Lot 7 Fall pruned | Lot 8 Not pruned |
| Branches | 49.35 | 45.92 | 53.75 | 53.64 | 53.19 | 50.00 | 52.50 | 50.00 |
| Trunk | 49.05 | 46.16 | 50.24 | 50.00 | 48.17 | 46.96 | 52.80 | 53.16 |
| Roots | 49.70 | 50.34 | ....... | 55.80 | 52.68 | 56.73 | 43.91 | 56.41 |
| Average for trunks and branches | 49.20 | 46.04 | 51.99 | 51.82 | 50.68 | 48.48 | 52.65 | 51.58 |
| Average for whole tree | 49.37 | 47.47 | 51.99 | 53.15 | 51.35 | 51.23 | 49.74 | 53.19 |

| Portion of tree | One-year-old Jonathan | | | | One-year-old Seedling peach | | | |
|---|---|---|---|---|---|---|---|---|
| | Transplanted Nov. 19, 1900 | | Not Transplanted | | Transplanted Nov. 19, 1900 | | Not Transplanted | |
| | Lot 9 Fall pruned | Lot 10 Not pruned | Lot 11 Fall pruned | Lot 12 Not pruned | Lot 13 Fall pruned | Lot 14 Not pruned | Lot 15 Fall pruned | Lot 16 Not pruned |
| Branches | 52.17 | 55.55 | 58.33 | 55.55 | ....... | ....... | ....... | ....... |
| Trunk | 46.55 | 49.42 | 52.77 | 50.00 | 44.51 | 50.00 | 51.76 | 47.36 |
| Roots | 53.44 | 60.00 | 59.39 | 59.09 | 53.70 | 49.84 | 59.95 | 58.76 |
| Average for trunks and branches | 49.36 | 52.48 | 55.50 | 52.77 | ....... | ....... | ....... | ....... |
| Average for whole tree | 50.72 | 54.99 | 56.83 | 54.88 | 49.20 | 49.92 | 55.85 | 53.06 |

An additional test for the amount of water evaporated from trees pruned and not pruned was made as follows: On November 12, 1900, well-branched, two-year-old apple trees were dug from the

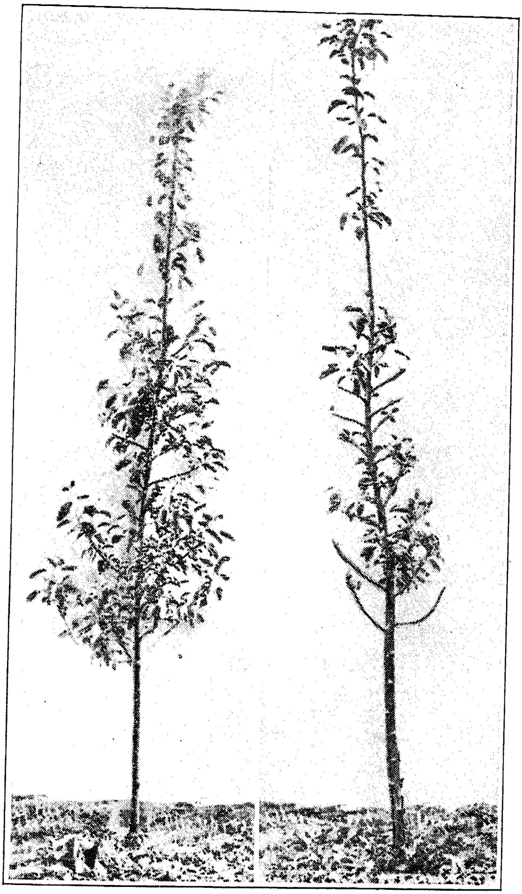


PLATE III.—Average difference in growth on May 15, 1901, of Ben Davis apple trees planted and pruned back on November 19, 1900 (left); and planted November 19, 1900, but pruned back in early April, 1901 (right).

PLATE IV.—The greater growth on May 15, 1901, of side branches pruned back November 19, 1900, and those pruned back in early April, 1901; either tree transplanted. The central stems not cut back made more growth on trees which had side branches pruned in the fall.

nursery and their roots placed in glass museum jars with the tops of the trees extending above the jars. The jars were then sealed above the water, around the trunks of the trees, to prevent evaporation except thru the tops of the trees which grew normally above the ground. One-half the number of trees were pruned and the other half retained their branches. The trees and jars were then placed so as to leave the tops of the trees exposed to outside air during the fall and winter, the jars containing their roots in water being protected from freezing. Each jar, with the trees and water contained, was weighed daily in order to determine the relative weight of water lost by evaporation thru the pruned and unpruned trees.

For the first few days slightly more water was evaporated from the pruned trees, as indicated by their slightly more rapidly diminishing weight. At the end of ten days the trees which were not pruned began to diminish in weight the more rapidly. This indicated that water was lost thru the cut surfaces somewhat more rapidly, at first, until the wounds were closed. As soon as the cuts at the ends of the pruned branches had a little time for their ducts to become plugged in the normal way the unpruned trees lost the greater quantity of water.

While these determinations did not show any very significant difference in the amount of water evaporated from fall-pruned apple trees and those which were not pruned, the following spring growth of the trees set in the orchard did show a marked difference in favor of fall pruning. Plate III shows the average difference, on May 15, 1901 of the trees transplanted, and pruned back on November 19, 1900 and pruned back in early April, 1901. The difference in the growth of the trees showed emphatically that fall-transplanted trees should be pruned at the time they are transplanted.

The advantage of fall pruning over spring pruning was quite as emphatically shown in the case of the apple trees which were not transplanted. Plate IV shows the corresponding growth on May 15, 1901, of representative trees, pruned November 19, 1900, and in early April, 1901.

Attention is called to the fact that the central stem of each tree was left intact, instead of cutting it back, as would be done in shaping trees for an orchard. Growth from the main stems which were not cut back was greater on the trees which had their lateral branches pruned in fall, than on those which were pruned in spring. The greater growth made by fall-pruned trees may be due in part to the greater stimulus of wounds made in the fall as compared with those made in spring. Also, it may in part be accounted for by the fact that the cuts made in the fall do not lose water in spring when growth begins, while those made in spring lose water and reduce the turgidity of the tree as growth is about to be resumed.

Peach trees pruned in the fall dried out to about the same degree as those which retained their branches during winter. This was true of trees whether or not they were transplanted. Fall transplanting of the peach has proved so unsuccessful in this section that it is recommended that peach trees be transplanted in the spring and pruned back as soon as they are set.

## THE DEPTH TO PLANT

The character of the soil and climate of a region should no doubt govern the depth to which the roots of a fruit tree should be set. For most sections it is generally recommended that the roots be set a little deeper than they stood in the nursery. Very deep planting has been emphasized in the prairie states of the northwest, where there is danger of root injury by severe winters. Deep planting is also preferred in the plains where winter desiccation is marked and where rainfall is very limited. No doubt the roots should be set deeper in loose, sandy soils than in heavier soils. Most Missouri growers of long experience advocate setting a little deeper than the trees stood in the nursery. Many who have had limited experience set their trees much deeper than this, with the idea that the trees will stand straighter and firmer and that the roots are thus secured against drying out.

At this Station shallow planting has given better results than deep planting. This point has been repeatedly tested in different years and the results of deep and shallow planting have also been observed in many of the orchards of the state. The results indicate that a majority of the trees set in the state are planted too deep. Deep set roots, especially if spring planted, start growth slowly. The trees usually sway in the wind until a funnel-shaped cavity is formed in the moist soil around the base of the trunk. Borers enter the trunk below ground more readily where such a cavity is formed than in shallow planted trees around which a dust mulch may be retained in close contact with the base of the trunk. Mice find shelter in the soil cavity about a deep-set tree and often girdle it. They rarely girdle trees where the soil is bare and settled in winter, so as to afford no shelter about the base of the trunk. "Root rot" occurs much more frequently in trees set deep.

If trees are set in autumn they may be set an inch or so deeper than they stood in the nursery. The soil at this season is aired and warmed to a greater depth. New root growth starts, in early winter, on the lower roots which become established for early spring growth. If trees are transplanted in spring they should be set no deeper than they stood in the nursery. If the soil is heavy, spring-set trees should stand a little shallower than they stood in the nursery. In the case of spring-set trees, new root growth starts first on the roots nearest the surface of the soil, which is better aired and which warms up first.

In order to stand straight and firm a newly set tree depends largely upon speedy, new root growth to anchor it in the soil.

## PROPER ORIENTATION OF THE TREES

In the central west fruit trees tend to lean more or less to the northeast. This is particularly marked in prairie districts. It is also more marked in some varieties of trees than in others. This tendency is largely established while the tree is young, or during the first few years after it is planted in the orchard.

The tendency of fruit trees to lean toward the northeast is due apparently to two causes: The fact that the prevailing winds are from the southwest during the growing season, and the fact that the tissues of the southwest side of the tree tend to "scald" more or less, due to extreme fluctuations of temperature of the sunny side of the tree, especially in late winter and early spring.

Sunscald, on the southwest sides of the trees in this section has been supposed to occur in summer due to the influence of the hot sun and dry southwest winds during the heat of the summer. That it occurs in late winter has been shown by observations covering a series of years at the Missouri Experiment Station.

In the winter of 1896-7 it was found that the tissues, under the bark, may rise to a temperature of 25 degrees Fah. above atmospheric temperature on sunny days in late winter; also that the tissues on the shady side of the tree remain at atmospheric temperature, or a degree or two lower. These comparative temperatures were secured by inserting thermometers into the sap wood of the opposite sides of the tree. The thermometer bulbs were inserted downward a distance of about two inches below the entrance of the drill holes in which they were placed, the thermometer stems extending upward as nearly parallel with the trunk of the tree as possible.

While the south side of the tree was warmed much above atmospheric temperature during bright sunlight, it cooled rapidly to atmospheric temperature when the rays of the sun were excluded. As an example, on one day in February the atmospheric temperature registered 32 degrees Fah., or freezing, at 1:00 P. M.; the temperature of the shady side of the tree 31 degrees, or one degree colder than the air. The sunny side of the tree showed a temperature of 67 degrees, or 35 degrees above that of the atmosphere. At sunset the temperature of both sides of the tree corresponded to the atmospheric temperature and during the night the atmospheric and tree temperatures were lowered to -12 degrees.

The fluctuations of day temperatures of the south side of the tree were most marked on cold, clear sunny days, when the roots of the tree were frozen, so water could not be taken up by the roots to cool the trunk. Examinations showed that the cells of the south side of the tree trunk were injured by the fluctuations of temperature between day and night.

Similar temperature studies made during the hot weather of summer, showed no essential difference between the temperature of the opposite sides of the tree trunks, but the tree temperatures usually registered 10 degrees to 12 degrees lower than the atmospheric temperature on hot days. This was no doubt due to the cooling of the trunk of the tree by water brought up from below when evaporation from the leaves was rapid.

That the temperature of the tree is lowered by evaporation on hot summer days, is further shown by the following observation. On a hot day in July the atmosphere registered a temperature of 102 degrees. The temperature of the young tree trunk was 90 degrees, just beneath the growing layer. The leaves were then removed from the tree to reduce evaporation. The temperature of the tree soon rose to 103 degrees, or one degree above atmosphere.

Shading the sunny side of a tree trunk or covering it with lime white-wash reflects the rays of the sun, thus enabling the trunk to remain at atmospheric temperature, or a little below, and avoid sunscald.

This injury to the tissues, to the sunny side of a tree in winter, combined with the prevailing southwest winds, accounts for the fact that young trees make stronger growth on the northeast side and tend to lean toward the northeast during the growing season.

The tendency of young trees to lean toward the northeast may be largely avoided by proper orientation of the tree when it is set in the orchard. No matter how symmetrical the young tree may appear, it will be found to possess a "heavy" side. One side has a heavier growth. This may be influenced by the sunlight or by the relation of the tree to its neighbors, growing in the nursery row. The pith is not generally in the center of the stem due to unequal thickness of the growing layers on the opposite sides. The roots, branches and tissue development are heavier on one side than on the other.

In planting the tree the heavier side should be set toward the southwest in this interior section. To orient the tree, it should be caught so it will balance, and come to rest, across the palm of the hand. Its heavy side wil turn toward the palm. That side should face the southwest in setting. It will be found that the tree will resist bending toward the northeast.

## SETTING THE ROOTS IN THE SOIL

The holes which are to receive the roots of fruit trees should be dug just deep and broad enough to accommodate the natural spread of the roots. This general statement is based upon observation of the growth of trees in various soil formations in the state and in which various soil treatments have been tested. The questions of digging larger holes, and of shattering the subsoil with dynamite below the bottom of the tree, have been given attention.

On all well-drained, typical fruit soils, deep plowing, thoro harrowing, and digging the holes of sufficient size to accommodate the roots has proved to be the only treatment necessary to secure the maximum growth of trees. Digging large holes or dynamiting the subsoil has not resulted in any advantage to the trees in such soils. Where trees have been set in sod, as in a lawn, or where replanting has been done between established trees in an orchard, the newly set trees have made much better growth if the holes were dug deep enough and broad enough to kill back the competing roots of the surrounding grass or trees to a distance of several feet. It has been found difficult to get replants in an established orchard to live unless the holes were dug about eighteen inches deep and at least four or five feet wide. This gives opportunity for the replant to become established before the roots of the surrounding trees grow in and compete with the replanted tree.

In doing this work the writer has found that the roots of established fruit trees spread laterally to a much greater distance than do their branches. Often the roots of the older trees permeate the soil prepared for the replant before the end of the first season. This emphasizes the need of frequently cutting back the roots of the surrounding trees while tilling about the replant until it becomes well established.

In 1914, the use of dynamite to shatter the subsoil was tested on the horticultural grounds at Columbia. This soil is a moderately heavy loam. The dark surface loam is about fifteen inches deep and is underlaid with a heavy, clay subsoil, which becomes more and more impervious, to a depth of twenty feet. The soil and subsoil are too heavy to be well adapted to fruit trees, altho orchards on it have proved fairly profitable if well managed. Apple trees were set, part of the rows having the holes dug just deep enough to accommodate the roots. The alternate rows were set after shattering the subsoil with dynamite below each tree hole to depths varying from four to five feet. The work was done when the subsoil was dry enough to work well.

The first season the trees where dynamite was not used made better growth. Water aparently collected, as in a jug, in the dynamited pockets and did not drain out well below. In three subsequent years no difference could be observed in the growth of the trees where dynamite was or was not used. Each year a study of the root growth of a few of the trees has been made. There is no evidence that the use of dynamite has either favored or opposed root growth. Evidently there is no advantage in loosening a pocket in subsoil so thick that it cannot be shattered deep enough to afford drainage into a porous layer below.

In one region of the state occurs deep, red, clay loam and subsoil mixed with enough sand to give good under drainage. This formation has proved to be an excellent fruit soil except in certain areas in which occurs a layer of pale gray hardpan twelve to eighteen inches thick and lying twelve to twenty inches below the surface. Below this hardpan layer the red clay subsoil is sandy and porous to a good depth. Shattering this layer of hardpan with dynamite under each tree hole has resulted in far better growth of fruit trees. In this case good under drainage is secured once the hardpan is broken thru.

In setting, the soil should be tramped firmly about the roots from the bottom of the hole upward, and an inch of loose soil spread over the tramped surface to prevent the soil from baking and drying out. Much of the mortality of fruit trees is due to bending the roots and failure to compact the soil about the roots in planting.

The roots should be set so as to stand in their normal position. Avoid twisting or bending them. Bending a main root greatly lessens its capacity to take up water and prevents its making normal growth. The roots may be kept in their normal position and the soil compacted about them by observing the following suggestions: Shake the tree vigorously with one hand while the earth is being shaken from the shovel with the other hand. In this way the soil sifts among the roots instead of bending them down, as will be the case if the soil is scraped into the hole in masses. Each layer of soil shaken in should be tramped firmly, from the bottom of the hole upward. It is impossible properly to compact the soil if the hole is filled before it is tramped.

## SHAPING THE TREE AT TIME OF TRANSPLANTING

Since 1895, the writer has put out many plantings of young trees to test methods of shaping, ranging from the Stringfellow system, in which the tree is reduced to a short trunk or stub above ground and a single tap root below, to no pruning of either top or root. An intermediate degree of pruning, the severity differing with the species, has given best results under central Missouri conditions. The following sugestions are based upon these results.

The root system of the tree should be pruned just before setting. The tap root should be preserved. The main lateral roots should be shortened to about six inches in length. The small, fibrous roots should be pruned off. This is very important, since if they remain intact they are an incumbrance to the tree. These fibrous roots not only die, for the most part, but they prevent getting the soil in close contact with the essential, larger roots. As trees are ordinarily handled the small fibrous roots dry out and die before the tree is set. They coil more or less around the larger roots like a mass of curled hair. Even if the tree can be dug and planted immediately, the fibrous roots cannot be depended upon to start new growth unless a mass of moist soil can be moved with the roots so as not to disturb the fibrous roots in the soil. Even the naked fibrous roots, if not dried out, are bent so much in setting that they cannot function.

If a main root is more than six or eight inches long it should be shortened. Long roots cannot well be set without bending. A bent or twisted root does not function so well as a shorter root which lies in its normal position. If the end of an essential root has a ragged wound it should be cut back to fresh, healthy tissue, with a clean, smooth cut. If, however, the end of an essential root has calloused and is healthy it should not be cut, unless the root is too long to plant without bending. Many observations made at this Station since 1895, show that new root growth starts, for the most part, from the sides of the larger main roots where they come in close contact with thoroly settled soil. The small, fibrous roots die unless a large ball of earth is moved with the tree.

The top of the young tree should be pruned as soon as it is set. Experiments recorded elsewhere in this bulletin show that trees make better growth if pruned in the fall as soon as their leaves are shed, regardless of when they are transplanted. Where trees are shipped from a nursery this may not be practicable.

Pruning the newly set tree is primarily for the purpose of reducing the evaporating surface of the tree until new root growth becomes established to supply adequate water. Incidentally, also, it may serve in starting a proper framework, or branching system. The degree of pruning which is desirable differs with the species. Trees like the peach, which start new branches readily from the central trunk but the twigs of which tend to dry out badly, should be cut back most severely. Trees like the sour cherry, which does not start growth readily from the dormant buds on the older parts but which makes its new growth from the active buds near the terminals of its branches, should be pruned least.

After careful study the different species are arranged in the following order, from those which should be pruned most to those which should be pruned least, at the time of transplanting: Peach, nectarine, Japanese plum, apricot, pear, apple, European plum, American plum, and sour cherry.

The peach should be pruned to a single whip by removing the side branches and shortening the main stem to two or three feet in height. The nectarine and Japanese plum should be pruned in a similar way, except that the latter may retain stubs, a few inches long, of three to five main limbs if the branches are large and well established. These species start new growth most readily from the main trunk or the base of the limbs.

The pear and apple should be cut back to a medium degree. The side branches should be cut back so as to reduce them one-half to three-fourths. The central stem should be shortened. At the end of the first season's growth the permanent framework may be established by removing all but from three to five well distributed, outward spreading limbs to secure an open center. If the tree is large, so permanent limbs may be chosen at the time of transplanting, this permanent framework may be established then. If the tree is a one-year-old whip having no branches it should be shortened to a height of about two and one-half or three feet, with the view to securing a good branching system below the point of cutting back.

The American plum should be cut back somewhat less severely than the apple. If the tree is well branched three or four main limbs may be left intact to form a permanent head and the remaining stem and branches removed. The side branches remaining may be shortened one-third to one-half.

The sour cherry should not have its permanent branches cut back, as it starts new growth most readily from the larger, active buds at the terminals. Three to five main limbs should be chosen for the permanent framework and the remaining limbs and central stem should be removed. The limbs which remain should have their terminals left intact.

## PROTECT YOUNG TREE ROOTS FROM FREEZING AND DRYING

The roots of young, dormant fruit trees are easily killed by freezing. The roots will not endure the low temperatures to which the tops may be exposed without injury. The writer's attention was first called to this matter by the following incident:

Two-year-old apple trees were sent to this department in June from an adjacent state, with the statement that they had been held dormant during the winter in cold storage. There was no indication of injury when they came out of storage as the bark and limbs were fresh and bright and the wood of the stem and twigs was of normal color, showing no discoloration such as results from winter injury. Nevertheless, when these storage trees were planted in various orchards they failed to grow. They continued to look perfectly healthy for a time, but remained dormant, and after some weeks began to shrivel and die without having pushed their buds into growth. An examination of the trees sent for the purpose revealed the fact that there was no indication of injury to their buds, branches or trunks. An examination of the roots, however, showed that the inner bark and growing layer was dead and the wood so brown as to show complete winter killing of the root systems. Evidently the roots had been killed by a temperature not low enough to injure the tops.

On several occasions trees have been received for examination, after freezing during shipment. Frequently the roots have been found killed by freezing when the tops were uninjured. As a result tests have been made to determine if possible at what temperature the roots of various species of fruit trees are killed.

As a result of these tests it appears that roots of dormant peaches are killed at about 26 degrees or 27 degrees, pears and apples at about 24 degrees to 26 degrees, and American plums at about 22 degrees Fah. They may be injured more or less by a somewhat higher temperature if exposure is prolonged. None of the roots of fruit trees tested have endured ten degrees below the freezing point of water for any great length of time without being killed.

No doubt the temperature which the roots safely endure varies somewhat with their maturity and the suddenness with which the temperature is lowered. The roots may adapt themselves somewhat to low winter temperatures much as the tops of the trees, but to a less degree. Large roots laid bare by tillage or by erosion in summer often adapt so as to endure the subsequent winter without injury.

It is apparent, however, that the roots of young, dormant fruit trees are far more liable to injury from freezing than heretofore has been recognized and that care should be exercised to protect them from freezing while being handled.

It is a fact generally recognized that trees are easily injured if the roots are allowed to dry out in handling. Apparently, however, this is not always sufficiently borne in mind. The fact that the roots may be handled without cover for a time in a moist packing shed, or in the field during a moist still day, should not encourage the belief that exposure to winds and a dry air may not speedily result in injury. In planting large orchard areas the trees are frequently distributed ahead of the planters where the roots are exposed to the drying influence of sun and wind until they are injured.

At the Missouri Experiment Station tests have been made to determine the amount of injury to the roots occasioned by different periods of exposure under various conditions. Trees were dug from the nursery, on the horticultural grounds, where they could be handled without previous handling, shipping or exposure. A part of the trees. in each instance, were dug and reset as quickly as possible in adjacent ground. Corresponding trees, at each planting were dug and allowed to lie on the ground for various periods of exposure before planting. Tests were made, at different times, when the atmospheric conditions varied from dry, windy days to still days when the air was humid and the sun overcast with clouds.

On dry, sunny, windy days exposure of the roots for fifteen minutes caused injury, evidenced by the fact that the trees so exposed made less growth than did those which were planted as soon as they were dug. On a day of partial sunshine, with no wind and of fairly high humidity, exposure for thirty minutes did not result in evident injury. Trees exposed for a longer time under these conditions were visibly injured, as was apparent from the poorer growth which they subsequently made. Trees exposed under the same conditions for one hour were so much injured that a majority of them died. On a cloudy day, with sufficient mist to indicate a saturated atmosphere, trees were exposed for two hours without evidence of injury.

Trees have been kept in an unheated room in the basement of the horticulture building, in an atmosphere kept saturated by means of jets of water sprayed into the air, with no packing about their roots, thruout the winter. The roots were not visibly injured. The branches, however, pushed out excresences of adventitious tissue about their lenticels which appeared like the beginning of aerial root growth. These trees made only moderately satisfactory growth when planted in the spring, their spongy twigs shriveling somewhat before they adapted themselves to field conditions and growth began.

The roots of fruit trees must, of necessity, be exposed more or less in digging, baling and shipping from the nursery. After they are received they must be subjected to additional exposure before they are set in the ground. Since exposure of freshly dug trees for fifteen minutes, if the day is dry and windy, and for more than thirty minutes on an average spring day results in injury to the roots, it is safe to advise that all possible care be exercised to avoid unnecessary exposure in planting.

## TRANSPLANTING GARDEN VEGETABLES

Certain garden vegetables such as the tomato, cabbage, cauliflower, pepper, eggplant and sweet potato are usually started in a hot bed or cold frame and later transplanted to an open field.

Often these vegetables are transplanted with less assurance of success in the continental climate of the central west than in the maritime climate of the coast states. In the west, weather changes are often marked by extremes with reference to temperature and moisture, which are essential factors governing successful transplanting. Transplanted vegetables are sometimes subjected to injury or death by late spring frosts or by dry, windy weather following transplanting.

Injury by late frosts in part may be obviated by covering the plants during a cold spell with newspapers, inverted boxes or other covers or even with dry soil, if the form of the plants admits. Injury from drouth and dry winds may be lessened, tho not fully overcome, by watering or shading the plants until their roots are established. These are expedients which entail labor and expense. Any more feasible method of preventing injury becomes of interest.

At the Missouri Experiment Station it has been found that the condition of the plant, as influenced by the surroundings in which it is grown, may greatly favor or oppose success in transplanting. Plants grown in a sandy soil, low in plant food, watered sparingly and ventilated freely are far less subject to injury from dry or cold weather than are succulent plants, grown rapidly under opposite conditions.

The usual custom is to grow these plants as rapidly as they can be forced, in a rich soil, with abundant bottom heat and with copious watering and a moist atmosphere. Plants thus grown are large and succulent, and luxuriant so long as they remain in the forcing bed. The plants are usually "hardened off" by withholding water for a day or two, until the plants wilt slightly. They are then copiously watered and transplanted as soon as they become turgid.

The writer has found by experience covering a number of years, that smaller plants grown under conditions less favorable to succulent development transplant with less loss. In 1915, tomato plants were grown in a thin, sandy seedbed, watered sparingly and ventilated abundantly. By the middle of May they averaged eight inches in height, had thick, stout, hard, woody stems and short joints. Their leaves were relatively small but abundant. They had enormously developed, fibrous root systems, due to thin loose soil and scanty water.

From the same seed packet other plants were grown in the usual rich potting soil, abundantly watered and not ventilated enough to reduce rapid growth. By the middle of May they were eighteen inches high, had succulent stems, large leaves and longer joints altho they were not what the gardener would call "stringy." They were in bloom. They were repotted often enough to avoid checking their growth.

Both lots were transplanted to the field the middle of May. The soil had been kept in fine condition but the weather was dry, hot and windy following the transplanting. The smaller, firm, woody plants did well without shading, watering or other care except good cultivation. The larger plants died, where they were neither shaded nor watered. Those shaded during the day eventually became established for the most part altho a few died. Those watered but not shaded did a little better. Those watered freely and shaded during the day all lived and eventually became established. The smaller plants came into fruiting slightly ahead of the larger plants which were shaded and watered. They gave better results during the season.

Similar tests have been made during each subsequent season, with various vegetables. It has been found that early cabbage and cauliflower endure low temperatures with less injury if grown dry and less succulent. They may safely be planted to an open field much earlier. They wilt less, following transplanting.

In 1917, a frost followed the transplanting of firm and succulent tomato plants. The luxuriant plants were badly injured while the firm, smaller ones escaped serious injury.

All vegetables mentioned in the foregoing list transplant more readily and better endure cold or drouth if grown slowly as outlined above, with the exception of eggplants. Eggplants are easily "stunted" and develop better if luxuriant growth can be maintained thruout their life history. Cauliflower, if grown too slowly, or checked too suddenly, heads out prematurely and makes small heads. While it is not desirable to grow them too succulent care should be taken not to check their growth to a point where their product will be too small. Earliness to a marked degree may be secured, but at the expense of size of the product.

This matter is only briefly discussed here, giving the results of the preliminary work. Further work has now been planned as a definte Experiment Station project.

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