THE DEVELOPMENT OF THE FRUIT TREE AS INFLUENCED
BY THE SEASON OF TRANSPLANTING.

by

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INTRODUCTION

The season of transplanting, as a factor affecting the subsequent development of a fruit tree, appears to have been the object of comparatively little experimental investigation. It is probable that among the very early agriculturists the season of transplanting was governed by the opinion that "the spring is Nature's time to plant". Practical experience, however, has long since demonstrated that hardy species of deciduous trees may be safely transplanted, under reasonably favorable soil and climatic conditions, at any time during the dormant season. This practice seems justified in the light of our present scientific knowledge.

There seems to be a conflict of opinion as to that part of the dormant season in which fruit trees may be transplanted with the greatest assurance of success. There is perhaps not a month from October to May that has not been suggested by some writers as the best time to transplant. Some suggest early fall as soon as the leaves begin to ^{be} shed; others late fall, after the trees have ripened their tissues; even mid-winter, when the trees are in the midst of their resting period, is recommended; many advise early spring, just as the buds are beginning to swell; and still others suggest holding the trees until late spring, when soil con-

ditions may be more favorable for root growth.

The wide variation in the results obtained by transplanting at these different seasons indicate that the several recommendations may be largely a matter of general opinion based upon observations made under widely varying conditions. Unfortunately, horticultural literature contains records of very little experimental data from which to draw conclusions concerning the relative effect upon fruit trees of the season during which they are transplanted.

Since no common agreement seems to have been reached, it is of interest to review and attempt to harmonize existing opinions and to compare results obtained at the Missouri Agricultural Experiment Station with those obtained elsewhere.

REVIEW OF THE LITERATURE ON SEASON OF TRANSPLANTING

The earliest available record of experimental work bearing upon the problem of fall or winter versus spring transplanting of fruit trees occurs in Koopmann's "Grundlehren des Obstbaumschnittes" (33). Following is a summary of the results of the author's experiment conducted at Potsdam, Germany:

- I. Fall planting gave better results than spring planting in 18 cases.
- II. Fall planting gave the same results as spring planting in 5 cases.
- III. Fall planting gave inferior results to spring planting in 13 cases.
- IV. Winter planting gave inferior results to fall planting in 10 cases out of 11.
- V. Winter planting gave inferior results to spring planting in 10 cases out of 11.
- VI. Early spring planting gave better results than late spring planting in all cases.

Koopmann recommends as the best time for transplanting either the fall immediately after the leaves are shed, or the spring at the time the buds first begin to swell. He states further, that in the spring the temperature of the air usually rises so quickly that, for about the first fourteen days after transplanting, the new root development cannot offset the great detriment caused by the evaporation of water.

Bedford and Pickering, in the Reports of the Woburn Experimental Fruit Farm, give the results of experiments dealing with the season of transplanting apple trees in England. The authors 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 the best time for planting is erroneous, but the experiment must obviously be repeated before drawing such a conclusion." Measurements of leaf-size and growth of these trees at the end of three years showed practically nothing in favor of or against winter and spring planting as compared with autumn planting (2-1900). In a later experiment (8-1905), five different plantings were made. After being in the ground four years, the trees were lifted (Feb. 1905), and their weights compared with their weights when planted. The results showed that the percentage increase in weight of the trees planted October 30 was nearly twice as great as that of the trees planted April 18, and was 75 percent.greater than the increase of the trees set in late fall, or December 3. A comparison of late fall and early spring planting (March 13) shows a difference of six percent.in favor of the spring set trees. The increase in weight of trees planted March 30 was only 37 per cent as compared with 56 per cent for trees set

April 16. The authors state, that the comparatively small increase in weight of the trees set March 30 "is not sufficient to prove that such very late planting is preferable to moderately late planting, for the results must always be so largely dependent on what happens to the conditions of soil and weather at the moment." The authors also make the following comment, "Unfortunately, it is rarely possible for growers to obtain their trees early enough to secure the advantages which very early 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".

At the end of ten years, the difference between planting at different dates from November 28 to March 3 at Woburn was inappreciable. The trees planted October 30 were still ahead of those planted December 3 and later, "probably due to throwing out roots before winter" (2-1908).

It was also found by Bedford and Pickering that apple, pear, plum and quince trees planted in autumn formed new roots in the majority of cases before January 16. The authors also conclude from their experiments that where the planting cannot be done until spring it is best to leave the trees in the nursery until the ground is ready for receiving them; for if

the trees are lifted in the fall and heeled in until they can be planted, fresh roots may form while thus heeled in which will be destroyed during planting, thus tending to exhaust the trees by using up the stored food material, (2-1908).

Card (10-1898), in Bulletin 56 of the Nebraska Experiment Station, gives the results of an experiment, carried on in cooperation with the Missouri Botanical Garden, regarding fall transplanting of apple and peach trees. He concludes that, in the locality of St. Louis, fall planting gives good results, while upon the plains it is usually found to be unsatisfactory, owing, largely, to the dry, open winters. It was also determined in this experiment that fall planted trees can make growth of roots in the fall after planting and in early spring while the tops are entirely dormant.

Clement (15), of Vineland, Ontario, was led by the loss in spring plantings of cherries to recommend fall planting for this tree. Before advising fall planting for other tree fruits which do not start as early in spring as the cherry, Clement conducted an experiment on pear and plum trees. Fall and spring plantings were made for three successive years and in every case there was a difference in favor of fall planting.

Observations have been made upon this problem by Whitten of the Missouri Agricultural Experiment Station. He found from measurements of the first three season's growth of fall

and spring plantings of Jonathan apple trees, that in each season those set in autumn made a much greater diameter growth and produced a larger number of branches and greater length of new wood than similar trees set in spring. The fall planted trees also came into bearing one year earlier than the spring set trees.

The foregoing review of the experimental evidence relating to the season of transplanting of fruit trees indicates that, in the majority of cases, better results have been obtained by planting in the autumn. It should be noted that the various tests were made under climatic conditions varying from the foggy, maritime climate of Germany and England to the drier, continental climate of the Central United States. They also extend over a wide range in latitude.

The Horticultural literature contains many expressed opinions regarding the season of transplanting, some of which may well be considered in this discussion.

In "Lindley's Horticulture", (36), the author states that the earliest time at which planting can be effected after the leaves fall in autumn is, upon the whole, the best; thus allowing the wounds a longer time to heal and causing less injury to the plant.

Downing (18) in "Fruits and Fruit Trees of America", makes the statement that "Autumn planting is greatly to be preferred in all mild climates, on dry soils; and even for very hardy trees as the apple in colder climates; as the fixed position in the soil which the trees planted then get by the

autumnal and spring rains, gives them the advantage, at the next season of growth over newly planted trees."

Bailey(1), in "The Principles of Fruit Growing" writes that "fall planting is generally preferable to spring planting on thoroughly 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." The author states further that it is usually better to buy trees in the fall; "these trees must be kept until planting 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", expresses the opinion that, having taken due precaution 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, "it is a matter of small consequence at which season the trees are put 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 summer rains, spring is the best time; in regions with dry summers and fall rains, fall planting at (of the roots) the time of the beginning of renewed activity 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 Farmer's Bulletin 113 that the season of transplanting is governed somewhat by latitude, and says that the objection to fall planting, is 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 shrivelling of the branches during winter's extreme cold and exhaustive evaporation from drying winds."

It will be seen that of the six writers cited above, three express themselves more or less strongly in favor of transplanting in autumn, while the other three are noncommittal in their statements. However, the latter state conditions under which fall planting would be preferable.

Since the authors quoted in the preceding pages have gained their views in widely separated localities, the question may arise as to their applicability to any particular section. In this connection it may be of interest to quote opinions of horticulturists representing distinct sections of the United States.

Northeastern Division of the United States:-

Sears (45), of Massachusetts, objects to fall planting chiefly for the reason that the nurseryman may have to strip the leaves from the trees in order to supply the trees early

enough for transplanting at this season. It is his opinion that the ideal time to set trees is 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. Gourley of New Hampshire, reports very favorable results from fall planting of apple trees. Wilkinson (53) of New York, makes the following statement: "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 the convenience of the season will determine, in the majority of cases, the time to plant, "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 and often dry weather of August". Green (27), of Minnesota, states that it is best, as a rule, in the extreme North to plant trees in the spring, Yet the hardy fruit trees may be set in autumn provided they

are afterwards laid on the ground at the approach of winter and covered with earth and a little mulch, which should be removed and the trees straightened up before growth starts in spring. It is of interest to note that Koopman also recommends this practice for the colder parts of Germany.

Central and Southern States:-

Whitten (51), of the University of Missouri, in the Garden Magazine and in his lecture courses, advises for Missouri, fall planting for all hardy species, and spring for tender species. He states that root growth will continue into winter because of the maximum store of heat in the soil at the time of fall planting, but that the root growth of spring planted trees is slow and uncertain since the soil then contains the minimum amount of heat and warms up slowly. At the same time the conditions in spring are such as to stimulate rapid top growth, which draws upon the reserve food supply before new roots can be formed. Chandler²(12) of Missouri writes as follows: "In most of Missouri it is not best to plant peach trees in the fall on account of the danger from severe winters and dry winters, though in a very favorable year the fall planted trees would make a better growth the first summer. In extreme southern Missouri 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."

Berckmans (8), of Georgia, expresses the opinion that where the soil is naturally dry and warm all hardy and deciduous trees should be transplanted as early in the fall as the growth ceases and the young wood is well hardened off. He states further that, in sections where the climate is mild, trees are inactive in winter as far as the formation of leaves and new wood is concerned, but are not so in regard to 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 the safer rule for Idaho orchardists because of the dry falls and dry winters. He also adds that "one of the main benefits of fall planting", the callousing of the injured roots, may be obtained by heel-ing-in the trees over winter. Garcia(22), of New Mexico, is of the opinion that, taking everything into consideration, spring planting is better for New Mexico conditions.

Pacific Coast States:-

Wickson (52), of California, cites two factors governing the season of transplanting fruit trees; the dormancy of the trees, and the proper condition of the soil. These factors are most apt to coincide in most parts of California about the first of January. Wickson found that the trees transplanted early had their wounds calloused over and new rootlets considerably advanced before the buds began to swell. Observations

made by Lanham (34), in Washington, upon 1,000 acres of apple trees planted from December 1, 1910 to April 1, 1911 indicated that "the first planted made at least twice the growth of those set out last, with a gradual gradation between."

Reference to the opinions stated above, shows that three out of four of the recommendations from the northeastern states favor fall planting. The objection to fall planting raised by the fourth writer is that the trees may have to be lifted from the nursery before they are fully mature. This objection, therefore, is concerned with the convenience of planting at this season and does not show that fall planting would not be better, provided the trees could be secured sufficiently early. Spring planting is generally recommended by those representing the extreme north-central states, and the prairie states where trees transplanted in the fall are subjected to extreme winter desiccation. Those representing the central and southern states prefer fall planting as giving better results than setting in spring. In the semi-arid states of the West, spring planting only is advised, regardless of latitude. On the Pacific Coast, however, conditions seem to be better adapted to transplanting in autumn or mid-winter.

The foregoing resume' of the expressed opinions regarding the comparative merits of transplanting at the different seasons shows that these opinions are based mainly upon practical field experience rather than upon experimental data. It is also evident that there is a lack of entire agreement up-

on this question, among horticulturists, even in quite restricted areas, having uniform climatic conditions. Casual observations which are the result of actual orchard experience are very valuable. Yet, certain practical questions arise, the answer to which must be sought by close observation of the development of plantings made at different seasons, and a consideration of the factors which may affect their growth.

Since, among the horticulturists representing a given locality, there is a more or less general agreement as to the best season for transplanting, it would seem that the problem would have to be worked out for each section separately.

FALL AND SPRING TRANSPLANTING AT THE MISSOURI
EXPERIMENT STATION.

An experiment calculated to throw light on the best season for transplanting in this state was begun at the Missouri Experiment Station in the fall of 1908. Ten Jonathan apple trees were planted on the horticultural grounds, and, for comparison, ten similar trees were set in the spring of 1909. The twenty trees were very carefully selected from several thousand trees grown in the station nursery. They were selected in pairs, in order that each autumn set tree might duplicate as nearly as possible, a similar tree set in spring. The ten trees for the spring planting were allowed to remain in the nursery until time of planting closely adjacent to the fall planted trees, in order that the two sets of trees might winter under the same conditions. At the time of planting the trees in the fall, their side branches were cut back in the usual manner, and on the same day the ten trees selected for the spring planting were similarly pruned.

Similar fall and spring plantings, including different varieties, have subsequently been made. The present investigation has consisted of tabulating and correlating the resulting growth of these trees. In addition, the writer has made plantings of apple trees in early and late fall and early and late spring.

Further objects of this investigation have been as fol-

lows: (1) To observe the time of formation of new roots after each fall and spring planting mentioned above; (2) to determine the relative loss of water, during winter, of twigs from trees transplanted in the fall and those not transplanted; also whether water is lost more rapidly during periods of cold when the ground is frozen, and whether water is taken up again during warm periods when all or part of the frost may leave the ground; (3) To record the relative amounts of growth in the case of trees planted in the fall and mulched and those not mulched; (4) to observe whether or not it is possible to retard the growth of trees that are heeled in for spring transplanting by lifting and re-heeling as often as evidences of growth appear; (5) To determine the relation of a wound made in the pruning back of a limb, to the development of an adjacent bud; (6) To obtain a continuous record of the temperature of the soil at the average depth of the root system of a transplanted tree.

Table I

COMPARATIVE GROWTH IN 1909 OF AUTUMN AND SPRING

SET JONATHAN APPLE TREES

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	153.0	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
Avg	243.7	13/16	Avg	124.0	10/16

It will be seen from the above table that the fall transplanted trees made almost double the total length growth of their branches that was made by trees transplanted in spring. The average total length growth of the branches on each fall planted tree was a little over twenty feet as compared with an average of a little over ten feet on each spring set tree. The caliper of the trees six inches from the ground was 13/16 inches for the fall set trees, and 10/16 inches for the spring

set trees. Thus, the trees set in autumn not only made greater length growth of their branches, but also made a greater diameter growth than the spring set trees. Observations on the autumn set trees showed that they established root growth before cold weather of winter. Only one spring set tree outgrew the corresponding autumn set tree (No. 4). This, no doubt, was due to individual variation.

Table II
COMPARATIVE GROWTH IN 1910 OF AUTUMN AND SPRING SET
JONATHAN APPLE TREES

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
Avg: 80.25: 56.5 : 1 9/32				:: Avg: 63.4 : 47.8 : 1 8/32			

The above record of the growth made by the trees in this experiment during the second season after transplanting, shows that the average total length growth of branches of the autumn set trees was 26 per cent greater than that of the spring set trees or 80 1/4 feet as compared with 63.4 feet. The caliper of the fall planted trees was 1 9/32 inches, and of the spring planted trees 1 8/32 inches, which represents only a slight difference in favor of the autumn set trees. It will also be noted that the fall planted trees averaged 56.5 branches as compared with 47.8 branches for the spring planted trees. The autumn planted trees, therefore, at the end of the second year's growth, still exhibited an advantage over their spring planted companions, although the difference is less marked than during the previous season.

Table III

COMPARATIVE GROWTH IN 1911 OF AUTUMN AND SPRING

SET JONATHAN APPLE TREES

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
Avg: 101.38: 124.2 : 1.55 ::				Avg: 84.54 : 95.1 : 1.33			

Examination of the above table shows that the average total length growth during the third season after transplanting was 101.38 and 84.54 feet for the fall and spring set trees, respectively, which is 19.9 per cent in favor of the trees set in the autumn. The average diameter of the fall planted trees was 1.55 inches as compared with 1.33 inches for the spring set

trees. The length growth of the fall planted trees was produced on an average of 124.2 branches per tree, while the new growth of the spring set trees was produced on an average of 95.1 branches per tree. As is indicated by these figures, the fall planted trees were still in advance of the spring planted ones in length growth, diameter of trunk, and number of branches. The difference in length growth in favor of the fall planted trees was slightly less than at the end of the second season, however.

Examination of the data presented in Tables I, II and III shows that the length growth of the fall planted trees exceeded that of the trees set in spring by 10 feet the first year, 16.63 feet the second year, and 16.74 feet the third year. Expressed in per cent, these differences are 100%, 26%, and 19% for the first, second and third seasons, respectively. The diameter growth, also of the fall set trees exceeded that of their spring set neighbors by .18, .03, and .22 inches, or 30%, 2.5% and 16.5% for the respective seasons. The length and diameter growth of these trees during the three seasons may be tabulated as follows:

Table IV
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	: Length : : growth : (feet) :	Diameter : : growth : (inches)
1909	: 20.3	: 0.81	1909	: 10.3	: 0.63
1910	: 80.23	: 1.28	1910	: 63.63	: 1.25
1911	:101.38	: 1.55	1911	: 84.54	: 1.33

For the purpose of obtaining further data upon the problem of fall versus spring transplanting, additional plantings of apple and cherry trees were made on the horticultural grounds in the autumn of 1913 and the spring of 1914. The chief object of this experiment was to compare early and late fall planting, and early and late spring planting. These trees were selected and planted in the same careful manner as has been previously described. On August 14, 1914, diameter measurements were taken one foot above the ground on all trees. On November 20, 1914, the trees were calipered in the same manner as before, and at the same time accurate measurements of wood growth during the past season were also taken. Measurements were made by the writer of the diameter and length growth of these trees during the season of 1915. The apple trees were planted

close together, 2 x 6 feet, in order to eliminate soil difference. The cherry trees were planted 18 feet apart each way.

The data obtained from the cherry trees are presented in Tables V and VI.

Table V
GROWTH IN 1914 OF AUTUMN PLANTED MONTMORENCY
CHERRY TREES

6 trees set in autumn, Nov.20,1913.				
No. of tree.	Diam.when set. (inches)	Diam.Aug. 14,1914. (inches)	Diam.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	35/64	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	37/64	74.8

Table VI
GROWTH IN 1914 OF SPRING PLANTED MONTMORENCY
CHERRY TREES.

6 trees set in spring Apr.14,1914.				
No.of tree.	Diam.when set (inches)	Diam.Aug. 14,1914 (inches)	Diam.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	64/64	65.5
Average	30/64	33/64	34/64	32.7

* Trees died during summer of 1914.

From Table V it will be seen that the autumn planted cherry trees made an average total length growth in 1914 of 74.8 inches, and an average increase in diameter of trunk of 6/64 inches. The spring planted trees, recorded in Table VI, made an average total length growth of branches of 32.7 inches, and an average increase in diameter of 4/64 inches. Thus, the average length of new wood produced by the fall set cherry trees was 42 inches, or 128 per cent

greater than that produced by the spring set trees. The average increase in diameter of trunk of the fall planted trees was 50 per cent greater than that of the spring set trees. It will also be noted that, on August 14, the diameter of the autumn set trees was slightly greater than the diameter of the spring set trees at that time. While the difference is very small ($1/64$ inch), it may indicate a poorer root development of the spring planted trees.

At the end of the growing season of 1914, the six fall transplanted cherry trees were in a healthy condition, while four, or $66 \frac{2}{3}$ per cent, of the trees planted in April had died during the exceedingly dry and hot summer. This fact is of particular interest because of the great mortality of spring planted sour cherries in this state. The general experience in experimental plots at this station has been that there is a great mortality among spring set sour cherries. It is also true that growers who practice fall planting for pome fruits, set cherries in spring like other stone fruits. It is probably true that fall planting is more essential for success with sour cherries in Missouri than with the other tree fruits.

Table VII
GROWTH DURING SUMMER OF 1914 OF AUTUMN PLANTED
TRANSPARENT APPLE TREES

No. of tree.	of:	Diam. when set.	Diam. Aug. 14, 1914.	Diam. Nov. 20, 1914.	Amount of twig growth.
		(inches)	(inches)	(inches)	(inches)
1	M	32/64	44/64	52/64	231
2		28/64	38/64	45/64	312
3	M	20/64	46/64	49/64	208.5
4		28/64	44/64	52/64	251
5	M	32/64	45/64	54/64	150
6		26/64	45/64	55/64	406
7	M	28/64	43/64	48/64	222
8		32/64	48/64	55/64	353.5
9	M	32/64	49/64	50/64	295.
10		32/64	37/64	41/64	166
11	M	28/64	36/64	37/64	136.5
12		32/64	35/64	46/64	116
13		24/64	40/64	41/64	133
14	M	32/64	31/64	44/64	197
15		24/64	32/64	37/64	126
16	M	24/64	30/64	40/64	136
17		28/64	34/64	39/64	101.5
18	M	28/64	33/64	37/64	120
19		26/64	34/64	49/64	173
<hr/>					
Total	:	540/64	764/64	953/64	3948
Average	:	28/64	40/64	50/64	207.8

M - mulched at time of planting.

Table VIII.

GROWTH DURING SUMMER OF 1914 OF SPRING PLANTED
TRANSPARENT APPLE TREES

15 trees set in spring, April 27, '14.				
No. of tree.	Diam. when set (inches)	Diam. Aug. 14, 1914 (inches)	Diam. 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 summer.

From Tables VII and VIII it will be seen that the average diameter of the fall planted trees at the end of the growing season was 50/65 inches, as compared with 40/64 inches for the trees set in spring, which was an increase during the season of 22/64 and 10/64 inches, respectively. Measurements taken August 14. showed that the fall planted trees had increased 12/64 inches, and the spring set trees only 3/64 inches in diameter. The average increase in diameter during the remainder of the season was 10/64 inches and 7/64 inches, respectively, for the fall and spring set trees. The greatly inferior growth during the earlier part of the season of the spring planted trees would seem to indicate a very slow development of their root systems as compared with their fall planted neighbors. Two-thirds of the entire season's diameter growth was made by the fall planted trees before August 14, while approximately the same proportion of the total increase in diameter of the spring set trees occurred after this date.

The average total length growth of autumn and spring set trees was 207.8 and 104.2 inches, respectively. The fall planted trees, therefore, made practically double the growth of branches that occurred on the trees set in the spring. In addition to the inferior diameter and length growth of the spring transplanted trees, it will be seen from Table VIII that two specimens died during the summer.

Table IX
GROWTH DURING THE SUMMER OF 1914 OF AUTUMN
PLANTED GRIMES APPLE TREES

12 trees planted in the autumn, Dec.6, '13.				
No. of tree.	Diam. when set. : (inches)	Diam. Aug. 14 1914. : (inches)	Diam. Nov. 20, 1914. : (inches)	Amount of twig growth : (inches)
1M	20/64	24/64	24/64	52
2	16/64	25/64	24/64	74
3M	28/64	38/64	44/64	90
4	28/64	34/64	55/64	149
5M	20/64	38/64	48/64	333
6	32/64	37/64	44/64	191
7M	24/64	30/64	34/64	187
8M	20/64	27/64	32/64	171
9M	20/64	37/64	48/64	161
10	20/64	30/64	40/64	111
11M	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

M - mulched at time of planting.

Table X

GROWTH DURING THE SUMMER OF 1914 OF SPRING

PLANTED GRIMES APPLE TREES

No. of tree	Diam. when set. (inches)	Diam Aug. 14, 1914. (inches)	Diam 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.

An examination of data presented in tables IX and X shows that the fall and spring set trees averaged 24/64 inches in diameter of trunk at the time of planting. The respective

diameters of these trees after growth had ceased in 1914 was $39/64$ and $34/64$ inches, a difference of $5/64$ inches or 14 per cent, in favor of the autumn planted trees. The trunk growth of the autumn set trees previous to August 14 was $9/64$ inches as compared with $6/64$ inches in the case of the spring set trees. The respective increments in diameter after August 14 were $6/64$ and $4/64$ inches. Again, we find that the autumn planted trees accomplished approximately two-thirds of their total diameter growth before August 14, 1914. The spring planted trees also made slightly more than half their entire season's diameter growth before this date. It will be noted, however, that the date of the spring planting in this instance was April 8, or 19 days earlier than the Transparent trees recorded in Table VIII, were transplanted. It will be remembered that the latter trees made only one-third of their entire season's diameter growth before August 14. It is probable that the advantage of these few days was more significant in 1914 than would ordinarily be true, because of the unusually dry spring and summer of that year.

A comparison of length growth of branches shows that 145.7 inches of new wood were produced by the autumn set trees and 108.6 inches by those set in spring. The fall planted trees exceeded the spring set trees by 33 per cent in

length growth.

The Transparent and Grimes trees under consideration in Tables VII to X were two years old when transplanted. Furthermore, the two varieties were not planted upon the same date in autumn and in spring. Hence, in comparing the merits of fall planting with planting in spring, it would be necessary to consider together the results of the two plantings in each season.

Table XI

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.	Avg.for:	Avg.	:	Avg.diam.	Avg.for:	Avg.	:
	:growth prior	:entire	:length:	:	:growth prior	:entire	:length	:
	:to Aug.14 '14	:season	:growth:	:	:to Aug.14 '14	:season	:growth	:
	: (inches)	:inches	:inches:	:	: (inches)	:inches	:inches	:
Trans-	: 12/64	:22/64	:207.8	:	3/64	: 10/64	:104.2	:
parent	:	:	:	:	:	:	:	:
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	:

The average increment in diameter of all the fall planted trees prior to August 14, was more than double that of the spring set trees. The average diameter growth of fall planted trees for the entire season was 80 per cent greater than the

growth of the spring set trees. The average length growth of branches of autumn set trees was 176.7 inches as compared with 106.4 inches for the spring planted trees. The excess in this respect of the fall planted trees was 66 per cent.

Table XII

GROWTH DURING SUMMER OF 1914 OF EARLY AUTUMN
PLANTED JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

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

M - Mulched at time of planting.

Table XIII

GROWTH DURING SUMMER OF 1914 OF ^{LATE}~~EARLY~~ AUTUMN
PLANTED JONATHAN WINESAP AND EARLY HARVEST APPLE TREES

15 trees planted in Autumn, Dec. 6, 1913.				
No. of tree	Diam. when set (inches)	Diam. Aug. 14, 1914. (inches)	Diam. 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
Winesap				
5 M	12/64	35/64	49/64	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	141
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
Total	160/64	473/64	567/64	3290
Average	11/64	31/64	42/64	2193

M - mulched at time of planting.

Table XIV

GROWTH DURING SUMMER OF 1914 OF SPRING PLANTED
JONATHAN, WINESAP AND EARLY HARVEST TREES

15 trees planted April 18, 1914.				
No. of tree	Diam. when set. (inches)	Diam. Aug. 14, 1914. (inches)	Diam. 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	12/64	21/64	28/64	135
4	16/64	27/14	37/64	272
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
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
Total	204/64	331/64	413/64	1511.5
Average	14/64	22/64	28/64	100.7

Table XV.

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	: Avg.diam. : Aug.14 '14.	: Avg. diam. : Nov.20 '14	: Avg.length growth.
	: (inches)	: (inches)	: (inches)	: (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

It is evident from inspection of Tables XII and XIII that the growth of the trees transplanted December 6, 1913, was much superior to the growth of the trees planted November 8, or nearly a month earlier. The results of early and late fall planting will be compared later in this paper. Hence, the average growth of the trees planted on these two dates will be used in comparison with the average growth of the companion trees set in the following spring.

Reference to Table XV shows the average growth of the 30 trees transplanted in fall to be 200.7 inches in length of branches and 28/64 inches in diameter of trunk, as compared with 100.7 inches of twig growth and 14/64 inches diameter growth of the trees set in the spring. The autumn set

trees, therefore, exceed those set in spring by 100 per cent in both length and diameter growth. The increase in diameter which occurred on the average fall planted tree prior to August 14, was more than double that occurring on the spring planted trees. This is a decided confirmation of the general supposition among growers who practice fall planting that trees which are transplanted in autumn become established and capable of making a vigorous growth early in the next season.

It should also be noted that ten or 21.7 per cent of the 46 trees transplanted in spring died, while none of the fall planted trees failed to survive the summer.

The Jonathan, Winesap and Early Harvest trees here considered, were one year old at the time of planting. The resulting growth of these trees parallels quite closely the growth made by the Transparent and Grimes trees recorded in Tables VII to X, with one exception. It was found that the growth of the Grimes trees which were transplanted December 6, 1913 was much inferior to the growth of Transparent trees transplanted November 8. A comparison of these results will be considered in the discussion of early versus late fall planting. A further comparison of the two seasons of transplanting should be made, including all the trees of different ages and varieties. Such a comparison is given in the table which follows.

Table XVI

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	: Diam. when : set : (inches)	: Diam. Aug. : 14, 1914. : (inches)	: Diam. 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

It will be noted that the trees, from which the data in the above table were collected, represent 5 varieties, one and two year old transplants, and that the dates of planting were varied in each season.

The fall planted trees made an average length growth of 188.7 inches and diameter growth of 25/64 inches, while the average spring set tree increased 106.2 inches in length of branches and 11/64 inches in diameter of trunk. Thus, the autumn set trees made over twice as much diameter growth and nearly 50 per cent more twig growth than the spring set trees.

Table XVII

COMPARATIVE GROWTH DURING THE SUMMER OF 1915
OF AUTUMN AND SPRING PLANTED MONTMORENCY CHERRY TREES.

6 trees set in autumn Nov. 20, 1913				6 trees set in spring April 14, 1914			
Tree No.	Diam. Nov. 30, 1915. (inches)	Bran-ches	Length: growth (inches)	Tree No.	Diam. Nov. 30, 1915. (inches)	Bran-ches	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			
Aver. 1 5/64 : 46 : 448.1				Aver.: 1 3/64 : 40.5 : 426			
* Died during summer of 1914.							

It appears from the above table that the two cherry trees from the spring planting which survived the summer of 1914 have nearly overtaken their fall planted neighbors. It would be of interest to know if further and more extensive trials would show similar results in the second season after transplanting.

It is clearly shown by this experiment, however, that the grower is warranted in violating the generally accepted rule of transplanting stone fruits in spring. Sour cherries

planted in autumn pass the winter successfully and make a vigorous growth the following season. And, what is more important, the high mortality among specimens of this species when transplanted in spring may be hereby avoided.

Plate I

Montmorency Cherry Trees
Fall planted at left and spring planted at right
of picture (May 15, 1915)

Planted Nov. 20, 1913

Specimens of Cherry Trees Shown in Plate I (May 11, 1914)

Planted Apr. 14, 1914

Table XVIII

COMPARATIVE GROWTH DURING THE SUMMER OF 1915 OF AUTUMN
AND SPRING PLANTED TRANSPARENT APPLE TREES

19 trees set November 8, 1913:				15 trees set April 27, 1914.			
Tree: No.	Diam. Nov. :30, 1915 :(inches)	Bran- :ches. :	Length :growth :(inches):	Tree: No.	Diam. Nov. :30, 1915 :(inches):	Bran- :ches. :	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	::	:	:	:
17	: 61/64	: 28	: 529	::	:	:	:
18	: 78/64	: 13	: 198	::	:	:	:
19	: 56/64	: 27	: 425	::	:	:	:
Total 18	16/64	: 469	: 8401	:: Total 11	-	: 236	: 52.56
Avg.:	1 4/64	: 27.5	: 494.1	:: Avg.:	1.1	: 26.2	: 477.8
* Blight and canker.				# Died during summer 1914.			

In the above table, is recorded the growth of autumn and spring set Transparent trees during the second season after transplanting. It will be seen that the advantage exhibited by the fall planted trees during their first season's growth has become much less pronounced at the end of the second year.

Two trees from each planting were eliminated from the experiment in 1915 by blight and canker infection.

Table XIX

COMPARATIVE GROWTH DURING THE SUMMER OF 1915 OF AUTUMN
AND SPRING PLANTED GRIMES APPLE TREES

12 trees set December 6, 1913::				11 trees set April 18, 1914.			
Tree No.	:Diam. Nov. :30, 1915. :(inches)	:Bran; :ches	:Length :growth :(inches)	Tree No.	:Diam. Nov. :30, 1915. :(inches)	:Bran; :ches	: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				:	Total: 4 50/64 :132		
Avg. : 1 17/64:28.4				:	Avg.: 61/64 :26.4		

* Trees died during summer of 1914.

Killed by blight and canker infection.

The superior growth of the Grimes trees transplanted December 6, 1913, is more pronounced during the second year than at the end of the first season's growth. The average growth of the autumn planted trees for the season of 1915 was $42/64$ inches in diameter and 556.8 inches of twig growth, as compared with $27/64$ inches increase in diameter and 375.8 inches of length growth of spring planted trees. The difference in favor of the trees set December 6 is 55 per cent and 48 per cent in diameter and length growth, respectively.

In addition to the death in 1914 of the three spring planted trees, three others succumbed in 1915 to attacks by disease.

From an examination of Tables XVIII and XIX, it will be found that the autumn set trees attained an average diameter in 1915 of $1\ 10/64$ inches and averaged 525.4 inches of twig growth, as compared with $1\ 1/64$ inches in diameter of stem and 425.8 inches length growth of the average spring set tree. It is evident, therefore, that the effect of the season of transplanting upon the two year old transplants, considered in the above discussion, was plainly apparent during at least two season's growth.

Table XX.

SHOWING GROWTH DURING THE SUMMER OF 1915
OF EARLY AND LATE AUTUMN PLANTED JONATHAN, WINESAP
AND EARLY HARVEST APPLE TREES

15 trees planted Nov. 8, 1913::15 trees planted Dec. 6, 1913.					
::					
Tree:Diam. Nov.:Bran-:Length ::Tree:Diam. Nov.:Bran-:Length					
No. : 30, 1915.:ches :growth ::No. : 30, 1915 :ches :growth					
: (inches) : : (inches:: : (inches) : : (inches)					
<hr/>					
Jonathan	:	:	::Jonathan	:	:
1*:	:	:	:: 1*:	:	:
2*:	:	:	:: 2*:	:	:
3*:	:	:	:: 3*:	:	:
4*:	:	:	:: 4*:	:	:
<hr/>					
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
<hr/>					
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
<hr/>					
Total 9 59/64	:182	:4051	::Total 9 27/64	: 243	: 5155
Avg. 57/64	: 18.2	405.7	::Avg. 1 3/64	: 27	: 572.7
* Trees cut back severely because of blight and canker infection					

Table XXI

GROWTH DURING THE SUMMER OF 1915 OF SPRING PLANTED
JONATHAN, WINESAP AND EARLY HARVEST APPLE TREES

15 trees set in spring, April 18, 1914.						
Tree No.	:	Diam. Nov.	:	Bran-	:	Length
	:	30, 1915	:	ches	:	growth
	:	(inches)	:		:	(inches)
<hr/>						
Jonathan	:		:		:	
1*	:		:		:	
2*	:		:		:	
3*	:		:		:	
4*	:		:		:	
Winesap	:		:		:	
45	:	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
Early Harvest	:		:		:	
12	:	39/64	:	13	:	126
13	:		:	8	:	199
14	:	44/64	:	13	:	173
15*	:		:		:	
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 XXII

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, '13:	57/64	: 18.2	: 405.7
Dec. 6, '13: 1	3/64	: 27	: 572.7
Average	: 62/64	: 22.6	: 489.2
Apr. 18, '14:	46/64	: 13.4	: 292.7

Reference to Table XX shows that the later fall transplanted trees still exhibit at the end of the second season's growth, a distinct advantage over the earlier planted trees. The average results of these two plantings is given in Table XXII and will be used in comparison with the results of the spring planting. The autumn and spring set trees averaged 62/64 and 46/64 inches, respectively, in diameter of stem, and their respective length growth of branches during the second season was 489.2 and 292.7 inches. In other words, the fall planted trees exceeded their spring set neighbors by 34 per cent in diameter, and by 69 per cent in length of new wood produced. The length growth of the autumn planted trees was produced on 9 more branches per tree than in the case of the

trees set in spring. Autumn planting, therefore, resulted in trees with denser heads and a more stocky appearance than when the planting was done in the spring.

The autumn planted trees also seem to be more resistant to attacks by fungous diseases. The Jonathan trees of all three plantings were eliminated from the experiment in 1915 by being cut back severely on account of blight and canker infection. In addition, however, one Winesap and one Early Harvest tree were eliminated from the spring planting for the same reason.

Table XXIII.

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	: Average length : growth : (inches)
Fall	: 1 21/64	: 25.2	: 507.3
Spring	: 1 16/64	: 22.0	: 382.1

Upon comparing the growth during the season of 1915 of all the trees under consideration in this experiment, it is observed that the autumn set trees still maintain considerable advantage over those transplanted in spring. Table XXIII indicates that the average autumn planted tree measured 1 21/64 inches, and the average spring set tree 1 16/64 inches in diameter at the close of the second season. The length growth made by these trees was 507.3 and 382.1 inches, respectively. The greatest difference between these two plantings was in the amount of new wood produced. The autumn set trees exceeded those transplanted in spring by 32 per cent in this respect.

Plate III

Autumn and Spring Planted Apple Trees.
(March 23, 1915)

EARLY VERSUS LATE FALL PLANTING.

If fall planting is practiced, the question may then arise as to how early in autumn the work should be performed. It appeared to be the universal opinion of the writers previously quoted in this paper that fruit trees should be in a dormant condition when planted. It was also the opinion that when fall planting is decided upon the trees should be set as early as they can be taken from the nursery without stripping the leaves, thus affording as much time as possible for the formation of new roots before the ground freezes. It was noted that one objection to fall planting advanced by one of the horticulturists of the northern fruit growing sections is, that matured stock cannot be obtained from the nurseries early enough to admit of planting at this season. This objection seems to have more force in sections where winter comes early and suddenly, than in more southern latitudes where well matured trees are readily obtainable and good conditions for planting extend over a much longer period in autumn. Bailey (1) states, however, that "Trees are mature enough to dig late in September, or early October in northern states, depending upon the season, soil and variety." Clement (15) of Ontario, was able to procure well matured stock from a Canadian nursery sufficiently early for planting in October.

Bedford and Pickering (2-1965) have conducted an experiment comparing early and late fall transplanting

of apple trees. They found that trees planted October 30 had made 46 per cent greater increase in weight at the end of four year's growth than trees which were set December 3. The trees planted on the later date, however, apparently were not affected adversely, since they showed a greater increase in weight than trees planted March 30 or April 16 of the following spring. The authors state that trees planted October 30 formed adventitious roots before the following January.

On November 8, 1913, several Jonathan, Winesap, and Early Harvest apple trees were set on the Horticultural grounds of the Missouri Agricultural Experiment Station. For comparison, an equal number of similar trees were planted December 6. The trees in both sets were the same varieties and were one year old when set. Measurements were taken by the writer of the diameter and length growth of these trees during the summer of 1915, and compared with the record of the previous season's growth. The following table shows a comparison of the average increase in growth of trunk and branches of the trees under consideration.

Table XXIV

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

Trees set Nov.8,1913.			Trees set Dec.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	::

It will be seen from Table XXIV that there is a marked difference in favor of the later planting in the case of each variety of apple trees during each season.

In seeking an explanation of the better development of the later planted trees, the weather conditions at the time of planting should be considered. From the Meteorological Reports of the Columbia Station of the United States Weather Bureau, the writer computed the amount of deviation of temperature and precipitation from the normal for the months of September, October, November and December of 1913. It was found that temperature and precipitation were very nearly normal during September; October was 2.4 degrees below the normal in temperature and 1.7 inches above the

normal in amount of rainfall; the temperature for the month of November was 7.2 degrees above normal, and the precipitation was .4 inches above normal; in December, the temperature was 4.5 degrees and the precipitation .2 inches above normal.

December, 1913 may have been slightly more favorable than the normal for that month for transplanting trees, as severe freezing was slightly delayed. It is doubtful, however, if the cause of the better growth of the trees planted in December was due to this slight deviation of weather conditions. It seems far more probable that early fall planted trees dry out somewhat in October and November from warm, dry autumn weather and bright sunlight in this interior region. On the other hand, trees planted in early December are exposed to cool weather, the twigs do not dry out and yet the soil still holds sufficient heat for roots to form before severe winter weather sets in.

These statements appear to be confirmed by the results of moisture determinations which appear in Table XXVI. The writer found that the average water content on January 16 of trees transplanted December 7, 1915 was 51.13 per cent as compared with 48.67 per cent for those set over a month earlier or November 1, 1915. It would seem, therefore, that the

greater drying of the earlier planted tree must have taken place during the month of November.

It is also interesting to note that roots were formed at approximately the same time after planting upon the early and late planted trees. This may indicate that roots are slow in starting while excessive evaporation is taking place from trees planted in early autumn.

The condition of the tree, also, is no doubt more favorable for transplanting at the later date than it is earlier in autumn. When young trees first lose their leaves in October or early November they are not well matured. They do not reach their complete rest period before December. Up to this time they draw more heavily upon their root system to supply water evaporated from their twigs than they do after their activity has been reduced to that of winter rest.

Plate IV

Autumn and Spring Planted Apple Trees
(March 23, 1915)

Planted Dec. 6, 1913.

Planted Apr. 18, 1914

Specimens of Apple trees shown in Plate IV (May 11, 1914)

ROOT FORMATION OF EARLY AND LATE FALL
PLANTED APPLE TREES.

The chief advantages ascribed to fall transplanting of deciduous trees are; that the roots become thoroughly established during the winter, the ends of the wounded roots become calloused over, and new roots are pushed out in fall or very early spring. It seems to be an unsettled question, however, as to what extent the success of fall planting depends upon the callousing of the wounded roots and the formation of new roots before winter sets in. In view of the fact that planting late in the fall of 1913, at this station, gave better results than planting a month earlier, it would be interesting to compare the root development of trees set in early autumn with that of trees transplanted later.

Reference to the available literature upon the subject of root growth of trees reveals the following statement by Jost(31); "Owing to the obvious difficulties of research, the problems connected with root growth have been as yet little elucidated." Physiologists agree, however, that the roots of trees differ greatly in respect to periodicity of development from the stem. 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 atmos-

phere, 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."

In regard to the effect of wounding roots in autumn, as occurs when trees are transplanted, Lindley (36) writes as follows: "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) warns against exposure of the roots for, "once dried out, the cut surfaces do not heal themselves again." Other writers, however, appear to regard the callousing of the wounds as less important than the formation of lateral or adventitious roots on the larger roots, and even the stem itself. Bedford and Pickering (1-1908; p. 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 encumbrances to the tree". These authors state further, that if the tree is lifted a few weeks after transplanting and the roots examined, 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, though not actually from the cut end itself."

Card (10-1898) found that apple trees planted at the Nebraska Station October 22, 1897, formed a few root tips 1/8 to 1/4 inch in length before November 16, (1897). Peach trees planted at the same time showed no root growth. Root growth was still active on a peach tree which had not been disturbed. An examination of these trees April 8, 1898, showed that root growth was progressing nicely." The cut surfaces were beginning to callous, none having apparently taken place during the fall or winter." It was found at the Missouri Botanical Garden that apple trees transplanted November 3 had formed roots one to two inches in length by December 14, but no callouses had formed. Peaches had made no roots, but all had commenced to callous.

It is evident from the above statements, that there is a lack of definite knowledge concerning the root development of fall transplanted trees. For the purpose of throwing further light upon this question, the writer conducted the following investigation during the winter of 1915-16.

On October 30, 1915, or as soon as 90 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, over a month later, when it was apparent that the ground would soon be frozen, an additional planting was made, comprising 5 Jonathans, 5 Ganos, and 5 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 listed 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 callousing 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 shrivelled in appearance. These trees were replanted for further observation. Examination of a tree in the nursery which had not been disturbed showed that 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 13 new root tips on the Gano, 6 on the Jonathan and 5 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 four 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 (Dec. 2), was taken up January 29. It was seen that there were two large root tips, $1/4$ to $1/2$ inches 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 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 callousing 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 callousing of the cut surfaces of the roots.

RELATIVE TRANSPIRATION FROM DORMANT BRANCHES OF
NORMAL AND OF AUTUMN TRANSPLANTED APPLE
TREES.

Transpiration takes place from dormant twigs even on the cold days in winter. This loss of water, even though 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 reestablished 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 XXV
MOISTURE CONTENT OF DORMANT BRANCHES FROM UNDISTURBED
TREES AND FROM TREES TRANSPLANTED IN AUTUMN

Trees	Percent 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 above 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 trees except for the disturbance due to transplanting two of them. The soil is a heavy clay loam. Twigs in a healthy conditions and from the corresponding portions of the different trees were removed for analysis on the dated indicated in the above table. 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 XXVII, the average per cent of moisture in the twigs of trees under normal conditions on January 16 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 .52 per cent 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, 14 respectively. January 19, after three days of continued cold,

when the minimum temperature was 0 and the maximum 32 degrees F., another analysis was made. The undisturbed trees showed a slight loss of moisture. The transplanted trees, however, indicated a slight gain. It is probable that the undisturbed trees showed 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 percent and the latter, .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 above 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 percent 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 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 which were 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, would interrupt the absorption of water, and consequently stop the growth of the branches, and accelerate the ripening of their wood. Chandler (13) concluded also that greater concentration of sap - which would result 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 .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 (Dec. 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 tree 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.

EFFECT OF MULCHING APPLE TREES AT THE TIME OF
TRANSPLANTING IN AUTUMN

It is a general opinion among horticulturists that trees should be mulched when transplanted in autumn. Clement (15) advised banking up fall planted trees 8 inches with soil and a mulch of manure. It is also believed that the injury to fall planted trees from heaving of the soil from the action of frost during winter may be avoided or lessened by the presence about the trees of a mulch of some light material. Wickson (52), speaking for 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 tree."

In addition to conserving moisture, a mulch of straw of similar material has an equalizing effect upon the temperature of the soil. 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 maintained the higher minimum temperature until spring. In spring, the soil warmed up much less rapidly where the mulch was maintained than was the case on cultivated or grass plots. It has been observed at this Station that the soil beneath a good mulch remains free from frost for a considerable period after the surrounding ground has begun to freeze. This means

a longer period for the formation of roots on the fall planted tree.

The data accompanying this discussion were obtained in 1914 in connection with the experiment upon fall and spring transplanting. Immediately after planting, the alternate trees in each row were mulched with cornstalks and straw. The mulch extended for a distance of approximately two feet from each tree and averaged 2 inches in thickness. It was allowed to remain about the trees until the time of beginning cultivation in the following spring, which was in April. As is indicated in the following tables, the varieties used were Transparent, Grimes, Jonathan, Winesap and Early Harvest. The first two varieties named were two years old at the time of planting, and the latter three varieties were one year old transplants.

Table XXVI

SHOWING GROWTH DURING THE SUMMER OF 1914 OF APPLE
TREES MULCHED AT THE TIME OF TRANSPLANTING IN AUTUMN.

Variety and date of planting.	Diam. when set. (inches)	Diam. Aug. 14, 1914, (inches)	Diam. Nov. 20, 1914, (inches)	Amount of length growth (inches)
Transparent :	:	:	:	:
Nov. 8, 1913 :	32/64	42/64	52/64	237
:	20/64	46/49	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
Grimes :	:	:	:	:
Dec. 6, 1913 :	20/64	29/64	29/64	52
:	28/64	38/64	44/64	90
:	20/64	28/64	48/64	333
:	24/64	30/64	34/64	187
:	20/64	37/64	48/64	161
:	32/64	37/64	42/64	119
Jonathan :	:	:	:	:
Nov. 8, 1913 :	18/64	27/64	35/64	171
:	8/64	28/64	36/64	339.5

Table XXVI (continued)

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
Early Harvest	:	:	:	:				
Nov. 8, 1913	:	8/64	:	26/64	:	34/64	:	117
	:	12/64	:	26/64	:	30/64	:	55
Jonathan	:	:	:	:				
Dec. 6, 1913	:	8/64	:	26/64	:	34/64	:	135
	:	8/64	:	27/64	:	34/64	:	183
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
Early Harvest	:	8/64	:	34/64	:	39/64	:	132
Dec. 6, 1913	:	12/64	:	34/64	:	40/64	:	163
<hr/>								
Total	:	572/64	:	1058/64	:	1296/64	:	5570.5
Average	:	17/64	:	33/64	:	40/64	:	174.0

Table XXVII

SHOWING THE GROWTH DURING THE SUMMER OF 1914 OF
APPLE TREES NOT MULCHED AT THE TIME OF TRANSPLANTING
IN AUTUMN

Variety and date of planting	Diam. when set. (inches)	Diam. Aug. 14, 1914, (inches)	Diam. 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	353.5
:	32/64	57/64	57/64	166
:	28/64	33/64	42/64	120
:	24/64	56/64	55/64	136
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
Jonathan :	:	:	:	:
Nov. 8, 1913 :	12/64	16/64	44/64	258
:	16/64	36/64	45/64	255
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

Table XXVII (continued)

Early Harvest:	:	:	:	:
Nov. 8, 1913	: 12/64	: 30/64	: 38/64	: 173
	: 20/64	: 33/64	: 44/64	: 162
Jonathan	:	:	:	:
Dec. 6, 1913	: 12/64	: 33/64	: 43/64	: 277
	: 12/64	: 31/64	: 45/64	: 262
Winesap	:	:	:	:
Dec. 6, 1913	: 12/64	: 34/64	: 44/64	: 352
	: 12/64	: 31/64	: 45/64	: 218
	: 12/64	: 34/64	: 43/64	: 390
Early Harvest:	:	:	:	:
Dec. 6, 1913	: 12/64	: 30/64	: 42/64	: 92
	: 20/64	: 36/64	: 43/64	: 193
<hr/>				
Total	: 540/64	: 901/64	: 1150/64	: 5738.7
Average	: 20/64	: 33/64	: 42/64	: 212.5

Tables XXVI and XXVII indicate that during the season of 1914 the mulched trees made an increase in diameter of trunk nearly identical with that of the trees which were not mulched. In length of new wood produced, the trees which were not mulched at the time of transplanting excelled the others by the small margin of 38.5 inches. These results apparently indicate that there is little if any advantage in maintaining a mulch about fall planted trees during the winter months. This is contrary to the general recommendations of horticulturists. It should be noted, however, that the trees in this experiment are not growing in a typical fruit soil, it being a heavy clay loam and rather poorly drained. Under these conditions it is probably true that mulching fall planted trees is not beneficial and may even be detrimental.

EARLY VERSUS LATE SPRING PLANTING

It is a general opinion that spring planting should be done as early in the season as possible. This may be true for species like cherries which start slowly. With other species of deciduous trees, however, there is probably little advantage in planting before conditions are such that root growth as well as top growth can start immediately.

While the conditions in early spring may be favorable for good top growth, the condition of the soil is likely to be quite unfavorable for an early start of new roots. The atmospheric temperature rises early and rapidly in spring. On the other hand, the soil at this season of the year contains its minimum store of heat. Its temperature rises slowly, especially if the soil is wet. Observations made by Whitten (51) of the Missouri Experiment Station, illustrate what may be expected as the result of planting under such conditions. He has observed that spring set trees, after coming out into full leaf have made no further development for several weeks. Inspection of the roots of early spring planted trees also showed that they were in full leaf fully four weeks before evidence of new root growth could be detected. It can be readily seen that such trees would be affected disastrously by their top growth starting so much in advance of their roots.

Observations made by the Horticultural Department on early and late spring planted trees indicate that late plant-

ing has given uniformly better results under average conditions. Hence, the later planting may be preferable, provided the trees are dormant when planted.

A Method of Holding Trees for Late Spring Planting.

If late spring planting is to be practiced, it becomes necessary to hold the trees dormant until the time of planting. This may be accomplished by "heeling-in" the trees in dry, well drained soil in autumn or early spring, and lifting and re-heeling them as often as evidences of growth appear. The writer was able by this means to prevent appreciable expansion of the leaves before May 10, which was forty days after the date of the first spring planting.

Since the trees must be cut back at the time of planting, they may be still further checked by cutting away the growing tips of the branches, thus reducing the drain upon the stored food of the trees.

A STUDY OF THE ROOT DEVELOPMENT OF SPRING TRANSPLANTED
APPLE TREES.

A study of the subsequent root development of trees transplanted in spring, necessitates a preliminary study of normal root growth upon trees which remain undisturbed. With reference to the resumption of root growth in spring, Engler (20) writes as follows: "It is found that various species begin root activity before bud development; namely, at Zurich in March and April, a few days to four weeks before buds open. In high altitudes (severe climate) the time difference becomes smaller and in some cases vanishes entirely." Goff (26) observed root growth starting on apple and other trees about March 31, before the buds had perceptibly swollen. He also found that growth in spring is most active near the surface of the soil, and that it starts where it left off in autumn; there being no general death of the finer roots as is often supposed to occur. Observations made by the writer indicate that root growth, on undisturbed trees continues throughout the winter, below the frost line. . Observations made March 17 on a Jonathan apple tree showed that root growth was progressing rapidly at that time.

It is evident, therefore, that when the time arrives for transplanting fruit trees in spring, more or less root growth has already taken place on trees under natural conditions. If the trees for the spring planting are lifted directly from

the nursery, it is clear that many, if not all of these new root parts will be destroyed in the process of replanting. Since the development of roots during the dormant season is at the expense of reserve food material, their destruction represents a direct loss to the transplanted tree. The loss of root hairs also disturbs the pressure of sap within the roots and stem of the tree, which Goff(25) has shown to be one of the causes of the expansion of leaves in spring. He found that when artificial root pressure was applied to transplanted trees, that nearly every tree promptly opened its buds. It may be noted in this connection that Goff's experiment well illustrates one of the advantages which fall transplanted trees possess over those set in the spring, since it was shown in the previous discussion that a new root system may become partially established on the former trees before the time of spring planting.

The observations which the writer has made for the purpose of determining the period of renewal of root activity on spring transplanted trees, will now be considered.

On March 25th, 1916, five trees each of the Jonathan, Winesap and Gano varieties were transplanted. These trees had been selected in the fall to duplicate the autumn set trees and were allowed to remain in the nursery during the winter. Four days later, an equal number of trees of the same vari-

eties 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 and 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 25 days after planting, another tree was lifted. A new root 1 inch long was observed, as well as several other root tips which were from 1/8 to 1/2 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 1/2 to 4 inches in length and proceeded from the shorter main roots. Eight roots 3/4 to 1 1/2 inches long were growing from the end of a root 1/8 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 $3/4$ inches in width. The leaves on the spring set tree were not quite so far advanced, as on those planted in autumn.

Examination on April 22 of a Winesap tree which was transplanted March 29, showed that three new root tips, $1/8$ 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 2 inches in length and were few in number. Since this was nearly 40 days after planting, it would appear that root growth was progressing rather slowly as compared with that of autumn set trees. It will be remembered in this connection that, earlier in this paper, the writer called attention to the fact that autumn planted trees made a much larger proportion of their entire season's growth in diameter prior to August 14, than did spring planted trees. This may be a result of the earli-

er formation of a new root system upon fall transplanted trees.

These observations confirm the statements made by other writers that resumption of root growth in spring upon fruit trees precedes the unfolding of the buds. Under Missouri conditions, root activity may continue throughout the winter in those roots which are below the line of frost. If trees are allowed to remain in the nursery until the time of planting in the spring, much new root growth may be sacrificed in the operation of transplanting. Root development was retarded for a period of at least three weeks upon early spring transplanted apple trees.

THE SOIL TEMPERATURE IN RELATION TO AUTUMN
AND SPRING TRANSPLANTING.

A comparison of the root systems established by autumn and spring planted trees indicates that the temperature of the soil is one of the determining factors of root growth. Hence, a comparison of results of autumn and spring planting should include observations upon the soil temperature during these two seasons.

For the purpose of making such observations in connection with the plantings of apple trees made in the autumn of 1915 and spring of 1916, the writer secured a continuous record of the temperature of the soil from November 8, 1915 to May 1, 1916. The instrument used was a Julien P. Freiz and Sons thermograph. The bulb was placed at a depth of 15 inches, or at the average depth of the root system of a transplanted tree. The remainder of the instrument was suitably housed in order to protect it from possible influence by the sun's rays. The weekly maximum and minimum temperatures from the week ending November 15 to the week ending May 1, are shown on the chart following page 85. The atmospheric temperature for the same period is shown in a similar manner. The temperature record was obtained from the Columbia, Missouri Office of the United States Weather Bureau. The reading of the thermograph was checked by comparison with standard thermometers.

Possibly the most noticeable fact illustrated by the ac-

companying chart is the comparative uniformity of the soil temperature as compared with the extreme fluctuations of the atmospheric temperature. A sudden extreme in the temperature of the air has only a slight effect upon the temperature of the soil at the depth of 15 inches. It is of interest to note that on one occasion the minimum temperature of the air was 47 degrees below that of the soil for the same week.

Further examination of the chart will show that there is a gradual depression of the curves representing the maximum and minimum soil temperature until the week ending January 24, when a gradual rise begins. It will also be noted that the soil temperature during the week ending November 15 was practically identical with the temperature May 1st. The mean of the atmospheric temperature dropped below that of the soil during the last week of November, and began to fluctuate by the normal soil temperature in the last week of January. In other words, the mean temperature of the air became lower than the mean temperature of the soil by the first of December and continued so, with one minor exception, until toward the last of February, when a rapid rise in temperature of the air began.

The above observations have a direct bearing upon the problem of autumn and spring planting. Shoot growth of deciduous trees ceases with the shedding of the leaves in autumn, which is completed in this sect on about October 30. Young

trees in the nursery may retain their leaves much longer. It will be seen, however, that conditions remain favorable for root growth long after top growth has ceased. The soil in the latitude represented by Missouri contains its maximum amount of heat in October. The emergence of this heat from the soil during the winter months stimulates root growth in much the same manner as a gentle hot bed might do. A concrete illustration of this "bottom-heat" in the soil in winter is afforded by the following observation. It may be seen in more northern latitudes where a more permanent snow cover is present during the winter months, that soil which was frozen previous to the snow-fall becomes thawed beneath the snow.

The conditions confronting the spring transplanted tree are quite different from those met by the tree set in autumn. The aerial portions of the tree have emerged from their resting period and are readily stimulated into growth by the rapidly rising atmospheric temperature. While the soil may be nearly as warm as in late fall, the formation of a new root system is impeded by the demands made upon the stored food materials by the expanding buds, and the consequent increase in transpiration of the upper portions of the tree.

Records of soil temperature obtained by MacDougal (38) indicate that in more northern latitudes the decline of temperature in autumn and the rise in late winter is more rapid than in

this section. The temperature curve also goes lower. The rise in the temperature curve began earlier than in Missouri. It is possible that this was due to the influence of snow cover, although MacDougal makes no definite statement to that effect.

See additional file for unfolded version.

WOUNDING STIMULATES ACTIVITY OF ADJACENT
BUDS.

It is a matter of common observation that the terminal bud upon a branch is the first to start in spring, the lateral buds expanding several days later; also, that when the terminal bud is removed, as occurs when a tree is cut back at the time of transplanting, the lateral buds which remain at the end of the pruned branch expand earlier than those lower down on the twig. Furthermore, Howard (29) determined that autumn planted trees made a much more vigorous growth the following spring if cut back at the time of planting rather than in the spring. The same is true of trees which are not transplanted. It may not be clearly understood, however, why removing a portion of a branch in autumn after the leaves are shed causes the lateral buds at the apex of the pruned stub to develop into more vigorous shoots than when the pruning is done in spring. The following statement by MacDougal (39) may shed some light upon this problem. "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." It is clear that a certain amount of evaporation would take place from the pruning wound. According to Howard (29) desiccation acts as a stimulus to the enzymic activity of a plant. Hence, wounding trees after they

have entered their rest period may serve to hasten the awakening of their buds in spring.

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 through 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 7 groups of 6 twigs each. The character of the wound made on half of the twigs in each group was an incision with a knife through the cortex across the axis of the twig. On the other half a small notch about $1/6$ 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 in No. 7 were checks.

The accompanying photograph 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 maturity of 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. 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 through 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 to the bud. The greatest stimulus

is afforded by an incision through the cortex immediately above a 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.

PLATE VI.

Illustrating the effect of wounding upon the activity of dormant buds. Twigs from Delicious apple treated on February 22, 1916 in the following manner:

- Group I - Wounded below alternate buds.
- " II - Wounded above alternate buds.
- " III - Wounded above and below alternate buds.
- " IV - Wounded on one side of alternate buds.
- " V - Wounded on both sides of alternate buds.
- " VI - Pruned to different lengths.
- " VII - Checks.

Arrows indicate some of the wounded buds.

"a" indicates wounding by incision through the cortex.

"b" indicates wounding by notching, a small portion of the cortex being removed.

Plate VI.

CONCLUSIONS.

1. It is apparent that the season of transplanting of fruit trees should be governed by climatic conditions. Autumn planting is evidently better than spring planting toward the south, and is less favorable toward the north. Autumn planting is especially unfavorable in arid sections. For Missouri conditions, the following conclusions may be drawn.

1. Autumn planting of hardy fruit trees gives better results than spring planting. This is particularly true of young cherries.

2. Late autumn planting favors better growth than early fall planting.

3. Late spring planting apparently gives better results than very early spring planting, provided the trees can be held dormant until planted.

4. Autumn planting of apple trees enables them to come into bearing earlier.

5. Formation of new roots begins at approximately the same time upon early and late autumn planted apple trees, which was found to be in the early part of January under Missouri conditions.

6. Root formation upon autumn planted trees is not necessarily preceded by callousing of the cut surfaces of the roots.

7. Roots below the frost line on undisturbed trees continue to grow throughout the winter under Missouri conditions.

8. Active root growth in spring precedes the opening of the buds of autumn planted trees.

9. Root growth of early spring planted trees may not become active until several weeks after planting.

10. A relatively small amount of moisture is lost during the winter by autumn planted trees. This desiccation, provided it is not too severe, may render trees less susceptible to injury from low temperature.

11. Trees whose root systems have been disturbed by transplanting in autumn may not lose water as rapidly during periods of severe cold in winter as trees which have remained on their entire root system and hence are more turgid at the beginning of the cold periods.

12. Both transplanted and undisturbed trees tend to become more turgid during warm periods in winter, but this is more marked in the case of the latter than in the former.

13. Trees transplanted in early autumn may suffer somewhat from desiccation for the first few weeks following transplanting. Trees transplanted in late autumn are not subject to injury from desiccation.

14. The temperature of the soil at a depth of 15 inches on the Horticultural grounds November 15 was similar to the soil temperature at the beginning of the following May. Thus it will be apparent that soil temperature is as favorable for transplanting fruit trees in late autumn as it is in late spring.

15. There seems to be no advantage, on the heavier soils of Missouri, in mulching apple trees at the time of planting in autumn.

16. The effect of the wound made in pruning back a transplanted tree is to stimulate earlier activity of the adjacent bud.

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Dean Walter Miller,
Graduate School,
Columbia, Mo.

My dear Dean Miller:

I am handing you herewith copy
of the thesis by Mr. Leroy Dexter Jesseman
in partial fulfilment of the requirement for
the degree of Master of Arts. I have approved
the thesis which in my judgment fully meets our
requirements for a master's thesis.

Very truly yours,

J. C. Whitten

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DEPARTMENT OF BOTANY

May 23, 1916

Dean Walter Miller,
Columbia, Mo.

My Dear Dr. Miller;-

In accordance with your request I have gone over very carefully the dissertation of Mr. L. D. Jesseman presented for the degree of Master of Arts. I find that Mr. Jesseman has accumulated an unusually large amount of experimental data bearing on the relation of the time of transplanting of certain fruit trees, especially apples and cherries, to their subsequent vigor and development; that the results presented show a power of initiative, of carrying experiments through to conclusion, and of drawing conclusions from the results obtained; and that the dissertation meets fully the standard which has been established in this University for the Master's dissertation.

Yours very sincerely,

E. J. Durand

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