AN EXPERIMENT ON THE EFFECT OF ROOT PRUNING ON PLANTED CONIFEROUS STOCK

By
C.S. Coffman, Jr.

AN EXPERIMENT ON THE EFFECT OF ROOT PRUNING ON PLANTED CONIFEROUS STOCK

By

C.S. Coffman, Jr.

"Submitted to fulfill partial requirements for a degree of Master of Forestry".

Ann Arbor, Michigan June, 1937

TABLE OF CONTENTS

AN EXPERIMENT ON THE EFFECT OF ROOT PRUNING ON PLANTED CONIFEROUS STOCK

Throughout literature on planting methods and practises may be found statements concerning root and top pruning of stock which is to be planted. Top pruning has as its objective the lessening of the laef surface and, thus, a lowering of the transpiration rate of the plant. This problem, however, is concerned with the effect of root pruning on the growth and survival of the plants.

According to Toumey and Korstian (8) root pruning may be practised when the roots have been severely injured, when the tap root is unusually long, and when there are abnormally developed side roots. Baker (1) states that root pruning is sometimes practised when the root systems of the plants mutilated, scrapped, and barked, thus offering a first class entrance for root rot fungi. No definite extent of root pruning is given in any reference that was consulted. There is a justifiable reason for this in that under varying conditions of site, age of stock, species, and size of roots and tops there would be a corresponding variation in the severity of the pruning that could be used. In other words, local conditions would be the controlling factor and in no case would it be advisable for definite figures to be given. Experiments to determine to what extent pruning might go must be made for each specific case when pruning is to be practised.

Such is the reason for this experiment. In this particular instance the objectives of the experiment are as follows:

(1) To determine the effect on survival and on the growth of both roots and tops of 2-0 western yellow pine stock of various degrees of root pruning.

(2) To determine the same for 2-2 Austrian pine stock. Only one type of pruning was done on this species.

(3) To determine the effect of slit planting as opposed to hole planting on the survival and growth.

The observations will have to be carried on for several years before final conclusions can be drawn. This paper has as its objective merely a description of the set up of the experiment and general comments on the present attitude toward root pruning and slit planting.

Discussion and Review of Literature

Before taking up the effect on the plant of root pruning it might be well to give briefly the general structure and functions of roots. From the base of each root where it is attached to the stem or to another root it tapers gradually towards the free end or root tip. It is at the end of the root that growth in length, water absorption, and most of the primary development of the tissues takes place. The root tip is made up of four regions which perform the above functions. These regions are the root cap which is a protective structure, the growing point which consists of meristem tissue in which actual cell division is going on, the region of elongation immediately behind the growing point where the cells undergo very rapid growth in length, and the region of root hairs where the root is clothed with a dense growth of root hairs which are tubular outgrowths of the epidermal cells. The root hairs are the principal water absorbing agencies of the plant. Some absorption also takes place in the part of the root back of this region.

Back of the root tip in the case of trees growth in thickness of the root occurs, due to the activity of the cambium and cork cambium. Secondary roots arise from the region back of the root tip and are outgrowths of the central cylinder or stele of the root which was formed in the region of the root hairs. (3)

Roots also serve mechanically as supporting organs, but in the problem at hand this function is unimportant.

The foregoing description of a typical root forms the basis of the following discussion on the theoretical effect of pruning on the plant. According to Baker (1) long experience has shown that success in planting depends on the use of stock with a well developed fibrous root system. Such a system gives more absorptive surface for an equal mass of roots, and also gives a distribution of the roots through a much greater volume of soil. During the critical period following planting a much greater absorption of water is possible than would be were the root system small or made up of a single long tap root. Transplanting of stock in the nursery has as one of its chief objectives the development of a fibrous root system and a retarding of the growth of the tops. Apparently the disturbing of the roots in the transplanting process stimulates the growth of many fine lateral roots. This disturbance may be the tearing off of the root tips on the existing roots, thus throwing much of the growing energy to the development of new roots rather than the continued growth of the original roots. Pruning of the roots is also practised at times prior to transplanting. (8)

Root pruning of seedlings in place is done in cases where certain species have to be left in the beds longer than one year. Such pruning has as its objective the slowing down of root growth (downward), the development of a wider spreading fibrous root system, and the slowing down of the top growth. This latter objective is the result of a temporary diminishing of the absorptive surfaces of the roots.

This pruning in the nursery is followed by a period when the plants are growing under ideal conditions. In the field planting root pruning, if practised, would presumably have the same effect as it does in the nursery. However, it is not done for the same reasons. In most instances pruning before field planting would have two objectives which are closely related to each other. In the first place a large root system requires a larger hole regardless of the method by which it is made. If the hole is not large enough to allow the roots to be fully extended many of them will be doubled back. To prevent this doubling up of the roots pruning may be done to reduce the size of the root system and make it suitable for the size of the hole. In the second place, given two holes of the same size and one plant with a large root system which the holes are big enough to take without any distortion, and another plant with a smaller root system, the latter will be much easier to plant because the roots will not be so apt to catch on the sides of the hole.

In instances where the roots are liable to be distorted by too small planting holes it is questionable as to whether the distortion would be more harmful to the young trees than would be the root pruning. There are so many variable factors involved in such a problem that no general statement can be made. Some of these factors are the site conditions, the weather during the particular season, the degree to which the roots were distorted from their natural position or the severity of the root pruning, and the condition of the planting stock. On favorable sites it is highly probable that neither the distortion nor the pruning would have damaging results.

The following paragraphs contain the comments of various workers on the effect of the distortion of the roots incurred by poor planting precedures and of root pruning.

Toumey and Korstian (8) state that while it is desirable to give the root system its natural position when planted, economic planting does not permit this to be observed too closely. Toumey's investigations with 2-0 white pine on loose, sandy soil in Connecticut showed very little difference in the growth of plants set in holes with their roots spread out normally and those set with the roots crowded together in a vertical plane (i.e. slit planted). This same reference gives Moller's results with Scotch pine on sandy soil in Prussia as indicating the same conclusion. Slit planting which crowds the roots in to a narrow vertical plane has proven successful on loose, sandy soils, but has been time and again a failure on heavy, compact soils. According to these workers the larger the stock, other conditions being equal, the greater the necessity for spreading the roots so that they assume their natural position. Pruning should not be resorted to in forest planting unless it is absolutely necessary. The use of too shallow a hole which causes the roots to be bent to one side is given as one of the frequent defects in planting technique leading to the death of the trees. Although the authors do not say so, it is probable that the bending of the roots has little to do with the death of the trees. The most likely explanation is that the soil dried out to a depth below the root system before the latter had a chance to resume its normal growth downward. This, of course, refers to those species which naturally develop a more or less deep root system rather than a shallow, spreading one.

Toumey (7) has demonstrated the inherent tendency in each species of tree to develop a type of root system peculiar to itself. This type of root system is closely correlated with the particular site conditions under which the species naturally grows. For example, Pinus lambertiana which is native to the mountains of California where dry summers subject the surface soil to drying to a considerable depth has a long tap root which will grow 22 to 30 inches in the first season. When this species was planted in Connecticut where there was plenty of moisture in the surface soil at all times the same type of root developed in the first season. Acer rubrum, on the other hand, which is found naturally both in swamps and on high, dry uplands develops a root system in accordance with the moisture available. In the wet situations a short tap root and wide spreading laterals develop while on the drier sites a deep tap root and short laterals develop. In another experiment by this worker large rocks were placed a few inches below the surface and directly under a red oak seed. The long tap root which this species naturally produces grew downward to this obstruction. Here it curved out along the surface of the rock and continued in this plane to the edge where it again turned downward. This would seem to indicate that although a young plant of a species which had a long tap root was placed in too shallow a hole, the downward growth of the root would not be prevented provided the tip was not injured.

Cheyney (2) made an experiment in Minnesota to determine the effect of the distortion of the roots upon growth. The roots of the plants were rolled into compact balls and the planting done with a spacing of 6 inches in rows 2 feet apart. The control plants were in alternate rows with the test plants and had their roots spread in the most approved fashion. Table I gives the results of this experiment at the end of four years.

TABLE I

Results of Cheyney's planting experiment in Minnesota.

Species	Planting method	No. of trees	Height, ground line to top		
			Max.	Min.	Ave.
W. pine	Roots balled	24	57"	32"	46.8"
	" spread	10	59"	41"	48.5"
Arbor vitae	" balled	48	63"	20"	35.7"
	" spread	24	60"	23"	42.0"
Bl. spruce	" balled	13	58"	22"	34.6"
	" spread	6	38"	24"	28.3"
Total	Roots balled	85			38.7"
	" spread	40			41.5"

At the end of the four years the plants were dug up and the roots inspected. It was found that the balls into which the roots had been rolled at the time of planting were still visible but side roots had grown out so extensively that the root systems varied little in appearance from those of the control plants.

The effect of wedge or slit planting on the subsequent development of the root system is a problem which is unsettled and which seems to depend on the soil type more than on any other factor. In this type of planting the sides of the hole are made compact by the action of the planting bar. With a heavy soil this makes it very difficult for the roots to make normal growth. Turner (6) cites as an example of the effect of compact layers of soil in shaping root systems the known fact that in the nursery where western yellow pine are transpalnted by the trencher method, the root systems invariably develop only in the plane corresponding to the longitudinal axis of the trench. In an experimental planting by the same author this species was planted by the "mound" or "cone" and the "side-hole" methods. An examination of the root systems after four years showed that in the latter method the growth of the roots had been away from the side of the hole toward the looser soil.

Whether or not this effect on the growth and shaping of the roots is permanent is unknown. Turner is of the opinion that any distortion imparted to the roots at the time of planting is retained for an indefinite period, possibly for the life of the tree. He is also of the opinion that the extension of the roots is probably controlled as much by the initial direction as by differences in soil texture. There are some facts which tend to disprove this latter idea, however. One of these is the inherent tendencies of the roots of the different species to develop in a specific way. Another is illustrated by Cheyney's experiment which has been given. A third is the result of extensive observations by Münch in Germany on the effect of oblique planting. In this method of planting a slit is made in the ground with a mattock at an angle sloping away from the worker. The plant is inserted in the opening and the slit closed by tramping on the clod of earth raised by the mattaock. The roots are thus given a start in a direction other than they would have were the plant placed vertically in the soil. Munch dug up some of these trees

18 years after they were planted. In cases where the oblique planting was done in soil which had the same amount of cultivation as that in which the control plants wre set, there were no apparent differences in the root systems. There was no difference in the height growth of the stems either. These plants were pines,1 and 2 years old when set out. (4)

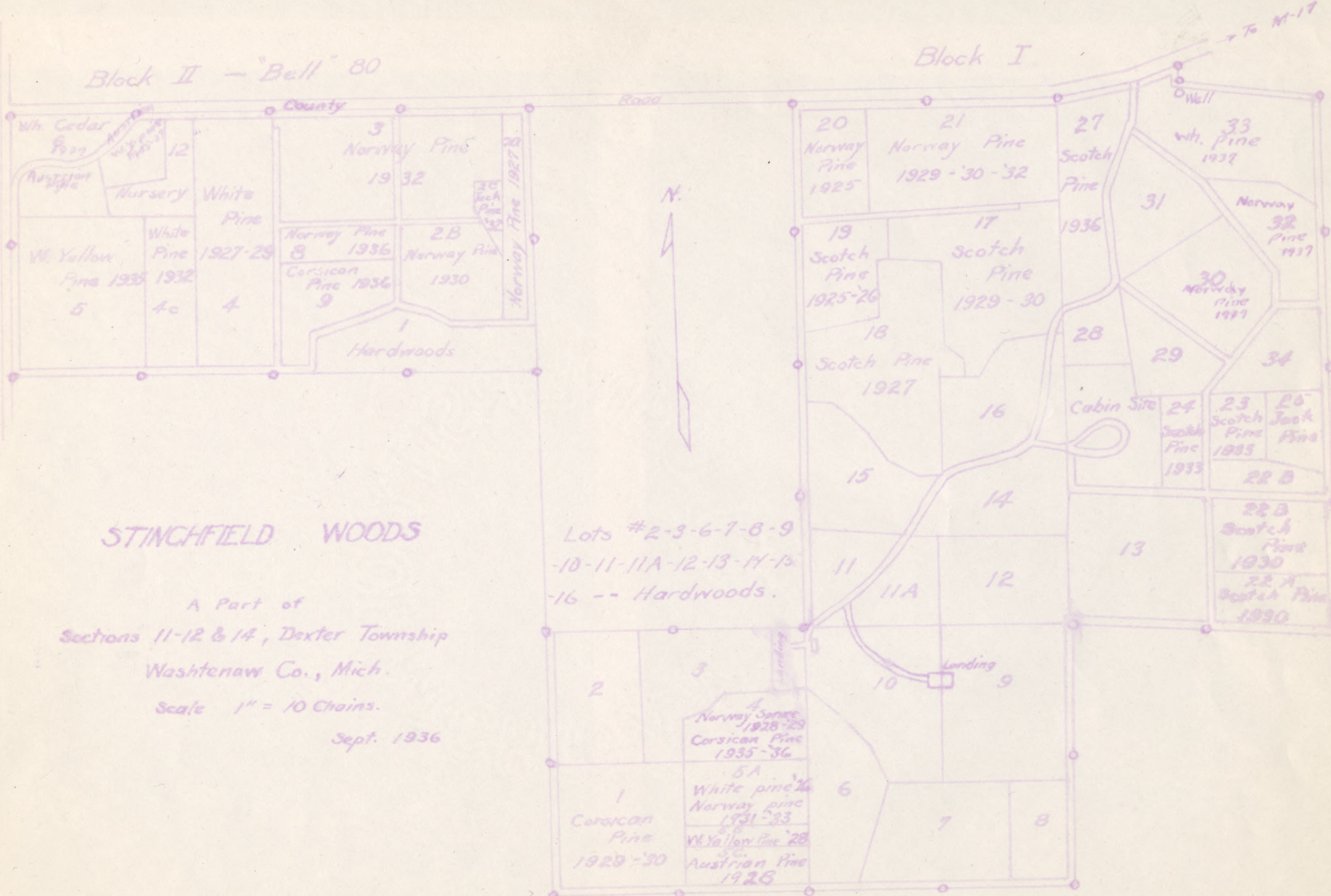
References will be made to other literature when the design of the experiment is discussed.

Description of the Experimental Plot

Location: The plot for this experiment is located in Stinchfield Woods, a property of the University of Michigan which is located in Sections 11, 12, and 14 of R.4 E., T.1 S., M.P.M. This tract is in Dexter Township of Washtemaw County, Michigan. The plot on which the plantings were made is in Lot 8 of the Woods (see map, page 12). It is 66 by 108 feet with the four corners marked by 3" by 3" black and white stakes which project about one foot out of the ground. The subdivisions of the plot have their corners marked by 2" by 2" unpainted stakes with the exception of the boundary between divisions 6 and 7. Here the markings are small, round limbs driven into the ground and surrounded by several large stones. (See map, page).

Soil: The soil which is Bellefontaine sandy loam is described in the "Soil Survey of Washtenaw County" (9) as follows: "The plow soil, to a depth of 6 or 7 inches, is grayish-brown friable, or loosely coherent, sandy loam or fine sandy loam. This is underlain, to a depth ranging from 15 to 30 inches by pale yellow sandy loam. Beneath and extending to a depth ranging from 3 to 4 feet, the soil material is somewhat red, is sandy, and in places is coarse gravelly, or cobbly, but contains sufficient clay to render the mass coherent and compact. The substratum, or parent drift material is a confused mass of sand, sandy clay, gravel, and boulders.

"The virgin soil contains only a small quantity of organic matter but sufficient to impart a light brown timt to the cultivated soil. The organic matter,or humus, is not so durable


STINCHFIELD WOODS
A Part of
Sections 11-12 & 14, Dexter Township
Washtenaw Co., Mich.
Scale 1" = 10 Chains.
Sept. 1936
Block II — "Bell" 80
Block I
County Road
To M-17
N.
Lots #2-3-6-7-8-9
-10-11-11A-12-13-14-15
-16 -- Hardwoods.
Wh. Cedar & Pop
Austrian Pine
Nursery
12
White Pine
W. Yellow Pine 1935
5
White Pine 1932
4c
White Pine 1927-29
4
3 Norway Pine 1932
Norway Pine 8 1936
Corsican Pine 1936 9
2B Norway Pine 1930
Norway Pine 1927
1 Hardwoods
20 Norway Pine 1925
21 Norway Pine 1929-'30-'32
27 Scotch Pine 1936
33 Wh. Pine 1937
Well
19 Scotch Pine 1925-26
17 Scotch Pine 1929-30
18 Scotch Pine 1927
31
Norway 32 Pine 1937
30 Norway Pine 1937
28
29
34
16
Cabin Site
24 Scotch Pine 1933
23 Scotch Pine 1933
26 Jack Pine
22 B
15
14
13
22 B Scotch Pine 1930
22 A Scotch Pine 1930
11
11A
12
Landing
10
9
2
3
4 Norway Spruce 1928-29 Corsican Pine 1935-'36
5A White pine '26 Norway pine 1931-'33
W. Yellow Pine '28
Austrian Pine 1928
1 Corsican Pine 1929-'30
6
7
8

as in the heavier soils. The surface soil is loose and pervious, but the subsurface soil contains sufficient clay and the structure is sufficiently tight to check the free downward movement of water. The soil is only moderately retentive, but holds sufficient moisture to carry crops through ordinary periods of dry weather. The surface soil generally exhibits medium acidity, but below a depth of 2 or 3 feet the reaction is less acid, and the substratum commonly contains sufficient calcium carbonate to effervesce with acid or to give an alkaline reaction."

Topography: The elevation of the plot is about 1000 feet. The aspect is to the southeast, with the northwestern corner sloping steeply and the remainder of the plot being of a gentle slope.

Cover: The cover on the area was originally an oak-hickory forest. At present the land immediately surrounding the experimental plot has an open stand of second-growth oak and hickory. The plot itself is on land which was clear cut in the winter of 1936-37. A fairly heavy cover of grass had developed on the area due to the open nature of the stand.

Weather: The weather of the past is of little value to this problem, so nothing will be given on it. Later, in the interpreting of the data collected from the plot the weather from th e time of planting to that date will have to be taken into account.

Design of the Experiment

The plbt was divided into the subdivisions shown by the map on page 15. The entire plot was furrowed in preparation for the planting, the furrows being spaced between 2 and 3 feet apart as near as was possible using a tractor and plow. Several stumps interfered with an exact, regular spacing.

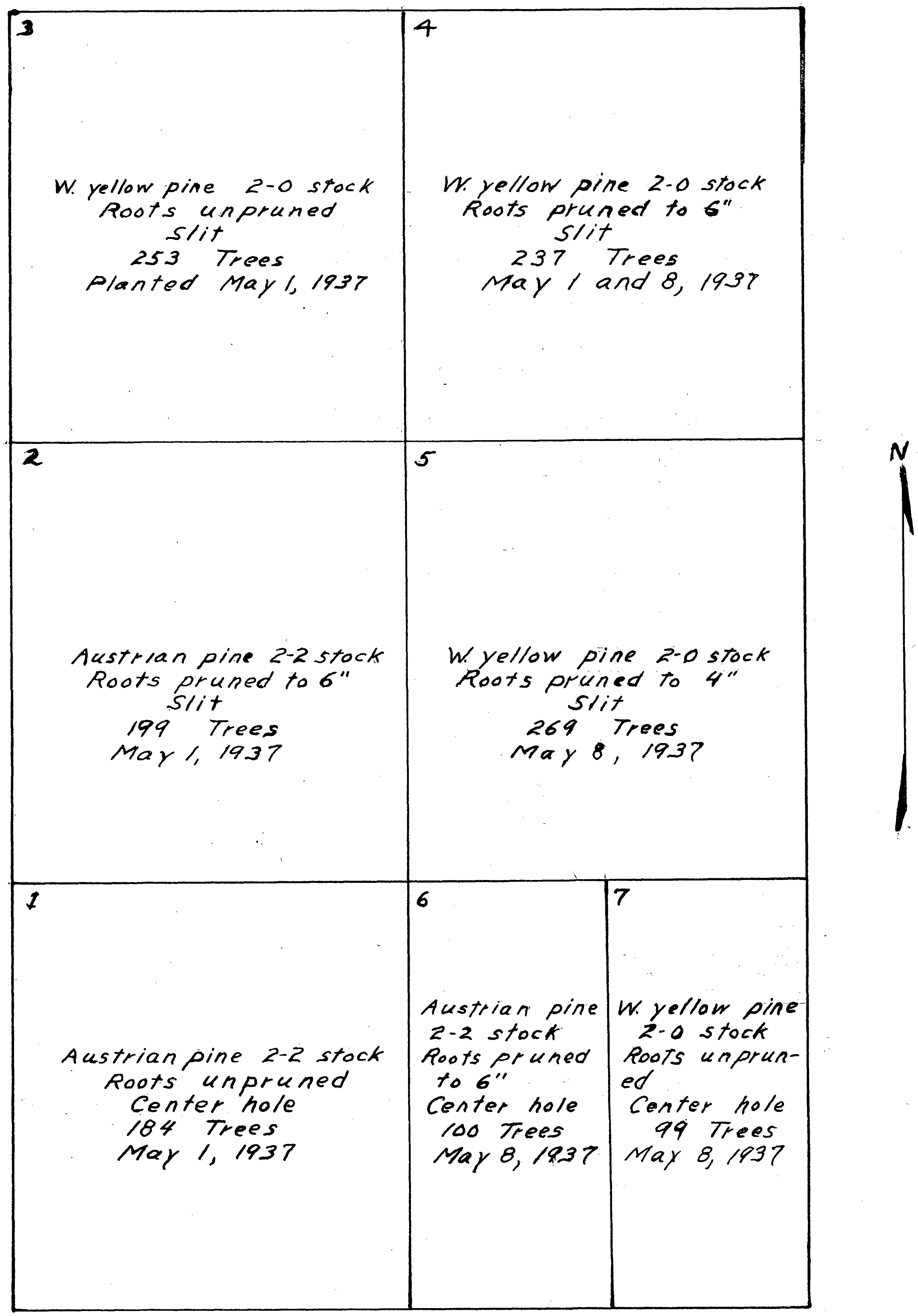
Table II gives in condensed form the make-up of each subdivision of the plot.

TABLE II

Make-up of an experimental plot planted at Stinchfield Woods on May 1st and 8th, 1937.

Subdivision No.	Species	Age	Condition of roots	Method of planting	Top-root ratio	No. of plants
1	Austrian pine	2-2	Unpruned	Center hole	3.8	184
2	"	2-2	Pruned to 6"	Slit	5.1	199
3	W. yellow pine	2-0	Unpruned	Slit	2.9	253
4	"	2-0	Pruned to 6"	Slit	2.85	237
5	"	2-0	Pruned to 4"	Slit	4.16	269
6	Austrian pine	2-2	Pruned to 6"	Center hole	5.1	100
7	W. yellow pine	2-0	Unpruned	"	2.9	99
		Total number of plants				1341

If a 2 by 2 foot spacing as originally planned for had been carried out, the number of plants in subdivisions 1, 2, 3, 4, and 5 would have been approximately equal. The discrepancies which occurred were probably due to psychological reasons. The larger plants of the Austrian pine caused the planting crew to



Experimental Planting Plot
Stinchfield Woods
Scale: 1 inch = 13.2 feet

place the trees a little farther apart than the proposed 2 feet. There were three men doing the work and each one did about an equal amount of planting so as to equalize any differences in the final conclusions which might result from the personal factor.

The pruning was done with a large knife or cleaver. As many trees as could be grasped in one hand were pruned with a single stroke of the instrument.

A commonly used expression for the relation of the roots to the top is the top-root ratio. This ratio is obtained by dividing the weight of the top by the weight of the roots. The green weight may be used (5). In this instance the roots were allowed to dry, after being taken from the water in which the plants were brought from the field, only until all visible traces of water were gone before weighing. Generally speaking, the lower the ratio the greater will be the absorptive surface of the root system in relation to the transpiring surface of the top. According to Baker (1) this ratio is not so important, but under severe climatic conditions the trend is for an increasing survival percentage with a decreasing ratio. Show (5) says that in California among plants with root systems of the same weight the highest survival is found with those which have the lowest ratios.

In this experiment no effort was made to secure an average top-root ratio which would stand up as accurate when put to a statistical analysis. All that was sought was an indication of the change in the ratio which root pruning caused. An inspection of the values in column 6 of Table II will show that pruning the Austrian pine transplant roots to a length of 6 inches definitely increases the ratio. In the case of western yellow pine seedlings pruned to a 4 inch length there is also a definite increase in the ratio over that of the unpruned plants. However, pruning the roots of the western yellow pine to 6 inches does not show an increased ratio. Undoubtedly, had more plants been weighed the ratio would have been increased rather than decreased. Nevertheless, the result obtained indicates that pruning to 6 inches did not materially affect the relation between the tops and roots as regards weight. The absorptive capacity of these pruned roots would be decreased to considerable extent in all probability. In the event that a drought occurred soon after planting, the pruned roots would be left in the dried out top soil sooner than the unpruned ones, and, as a result, the plants would be less likely to survive. Figures I and II show the typical differences between the root systems of the pruned and unpruned plants. Regarding the western yellow pine, one can readily see that the pruning to 6 inches would not cause much difference in the weight of the roots. However, the depth to which the roots reach into the ground is reduced by about 4 inches above the depth to which the roots of the unpruned roots will reach.

Where drought conditions are common the planting of trees with roots so short that they will not reach below the dried out layers of soil is impossible. In southern California it is believed impossible to plant successfully with ordinary stock with absorbing rootlets no deeper than 5 to 8 inches (5).

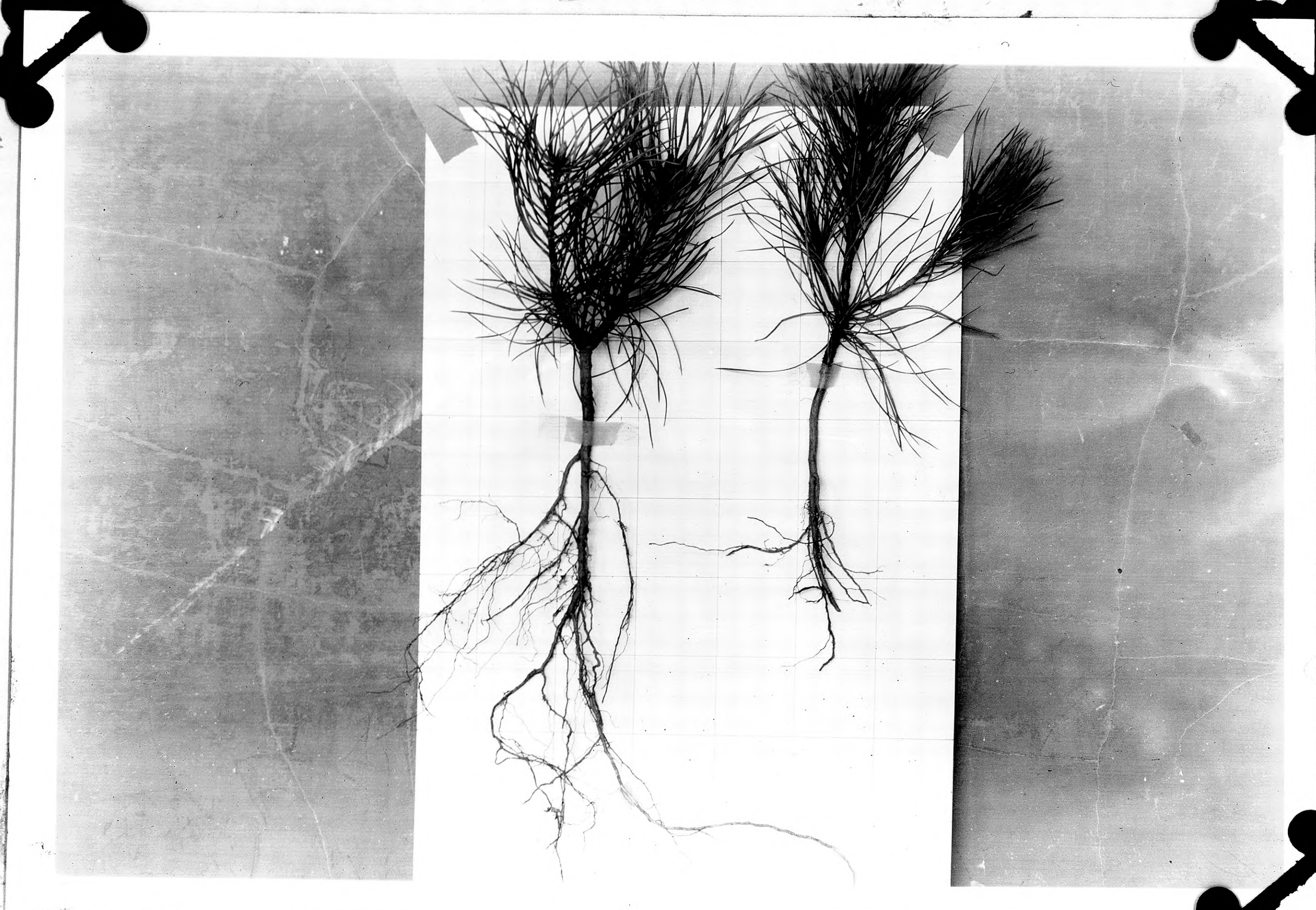
FIGURE I

Western yellow pine 2-0 stock with the roots unpruned, pruned to 6 inches, and pruned to 4 inches. The squares are 2 inches on a side.

The speed with which planting can be done with the planting bar has been the reason for the adoption of this method of planting. As previously stated one of the objectives of this experiment is to determine the survival and growth of trees planted in this way as opposed to the same for trees planted in a hole large enough to let the roots assume their natural position (i.e. the so called center hole method). It must be remembered that the cost of planting by the various methods must be calculated on the basis of cost per surviving tree, and not on the basis of which method gives the highest survival percentage. Of course, the number of surviving trees must be large enough to give a satisfactory stocking of the area. The greater speed of the slit method has given the lowest cost per surviving tree and as the method has given satisfactory stocking on light soils it is generally used on such soils. The results of this experiment may be used to check on the above statements.

In another part of this paper the easier planting of

FIGURE II



Austrian pine 2-2 stock with the roots unpruned and pruned to 6 inches. The squares are 2 inches on a side.

small rooted stock by the slit method was explained. This fact was illustrated in the planting of this experimental plot as the subdivisions which were planted with pruned stock were done much faster than the others.

The use of the slit method to plant the 2-2 Austrian pine stock is rather unusual, as it is generally considered inadvisable to use this method with such large stock (8). It was done to see if such a practise would be successful under the existing conditions. As dibbles with 10 inch blades were used it would have been very difficult to plant unpruned stock of this type as the roots would have been far too large for the hole made by the bar. Figure II shows the roots before pruning to be well over 12 inches long. The lateral roots would have also caused trouble in getting the plant into the hole. After pruning it was rather easy to use the slit method with this stock.

The set-up of the different subdivisions may be given in another way than that given in Table II. Table III gives the conditions on the subdivisions and suggests a way in which the results may be compared.

TABLE III

Austrian Pine

Control, subdiv. 1 Hole planted Roots unpruned	----------------------	Pruned roots Slit planted Subdiv. 2
	----------------------	Pruned roots Hole planted Subdiv. 6

TABLE III (continued)

Western Yellow Pine

Control, subdiv. 7 Hole planted Roots unpruned	Control, subdiv. 3 Slit planted Roots unpruned	Roots pruned to 6" Slit planted Subdiv. 4
		Roots pruned to 4" Slit planted Subdiv. 5

The dates of planting given on the map on page 15 are there for future reference. The stock used on May 8th had been heeled in during the week elapsing from May 1st to the 8th. This might be of interest in the interpretation of data.

Although the future compilation of data from the plot will not be dictated in this paper, some suggestions will be made along this line. Survival counts will be the first data that can be collected. Later growth data may be gathered. This will have to be measured from the ground line as no top measurements were taken at the time of planting. By averaging individual measurements differences due to the variations in size and condition of the stock at the time of planting can be reduced to minor importance. Examinations of the development of the root systems as a result of the varying conditions under which the stock was planted will be made from time to time.

Summary

1. This experiment to determine the effect of root pruning and slit planting on growth and survival of 2-2 Austrian pine and 2-0 western yellow pine was started May 1, 1937 at Stinchfield Woods.

2. Austrian pine was planted by the center hole method with normal roots and with roots pruned to 6 inches, and by the slit method with pruned roots.

3. Western yellow pine was planted with unpruned roots by the slit and by the center hole methods, with roots pruned to 6 inches by the slit metnhod, and with roots pruned to 4 inches by the same method.

4. Observations on the plot will be carried on for several years to collect data on survival, height growth, and root development.

Literature Cited

1. Baker, F.S. - 1934 - Theory and Practise of Silvisulture.

2. Cheyney, E.G. - 1927 - The Effect of the Position of Roots upon the Growth of Planted Trees. Jour. of For. 25: 1013

3. Holman, R.M. & Robbins, W.W. - 1928 - A Textbook of General Botany.

4. Münch, E. - 1932 - Schrapflanzung. Tharandter Forst. Jahrb. 83: 1-62. (Trans.)

5. Show, S.B. - 1930 - Forest Nursery and Planting Practise in the California Pine Region. U.S.D.A. Circ. 92.

6. Turner, H.C. - 1918 - The Effect of Planting Method upon Growth of Western Yellow Pine. Jour. of For. 16: 399.

7. Toumey, J.W. - 1926 - Initial Root Habit in American Trees and Its Bearing on Regeneration. Proc. of the Int. Cong. of Plant Sciences 1: 713-728.

8. -----------, & Korstian, C.F. - 1931 - Seeding and Planting in the Practise of Forestry.

9. Veatch, J.O., Wheeting, L.C., & Bauer, A. - 1930 - Soil Survey of Washtemaw County, Michigan. U.S.D.A. Series 1930, Number 21.