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

by

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1938

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"Submitted to fulfill partial requirements for a Degree of Master of Forestry"

Ann Arbor, Michigan June 1, 1938

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Introduction

During the Spring of 1937, C. S. Coffman, Jr. started an experiment at the University of Michigan that was devised to determine the effect of root pruning on planted coniferous stock. Although this subject has frequently been a matter of controversy, very little actual data are available. Coffman has outlined the objects of the experiment 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.

Because of the nature of the experiment, it is one which demands several observations over a period of years. This paper will deal primarily with the presentation and interpretation of the data collected during the first observations, made in the Spring of 1938.

Although not clearly stated in the objects of the experiment given above, they were meant to also include a study of subsequent development of the root systems as affected by planting coniferous stock with the roots in one vertical plane, as is done in slit or dibble planting. This subject is one that has attracted considerable attention but has not been adequately covered by experimental research. Although very little can be proven definitely in one year of the experimental observations, it is a necessary link in the problem that must be given adequate consideration in all stages.

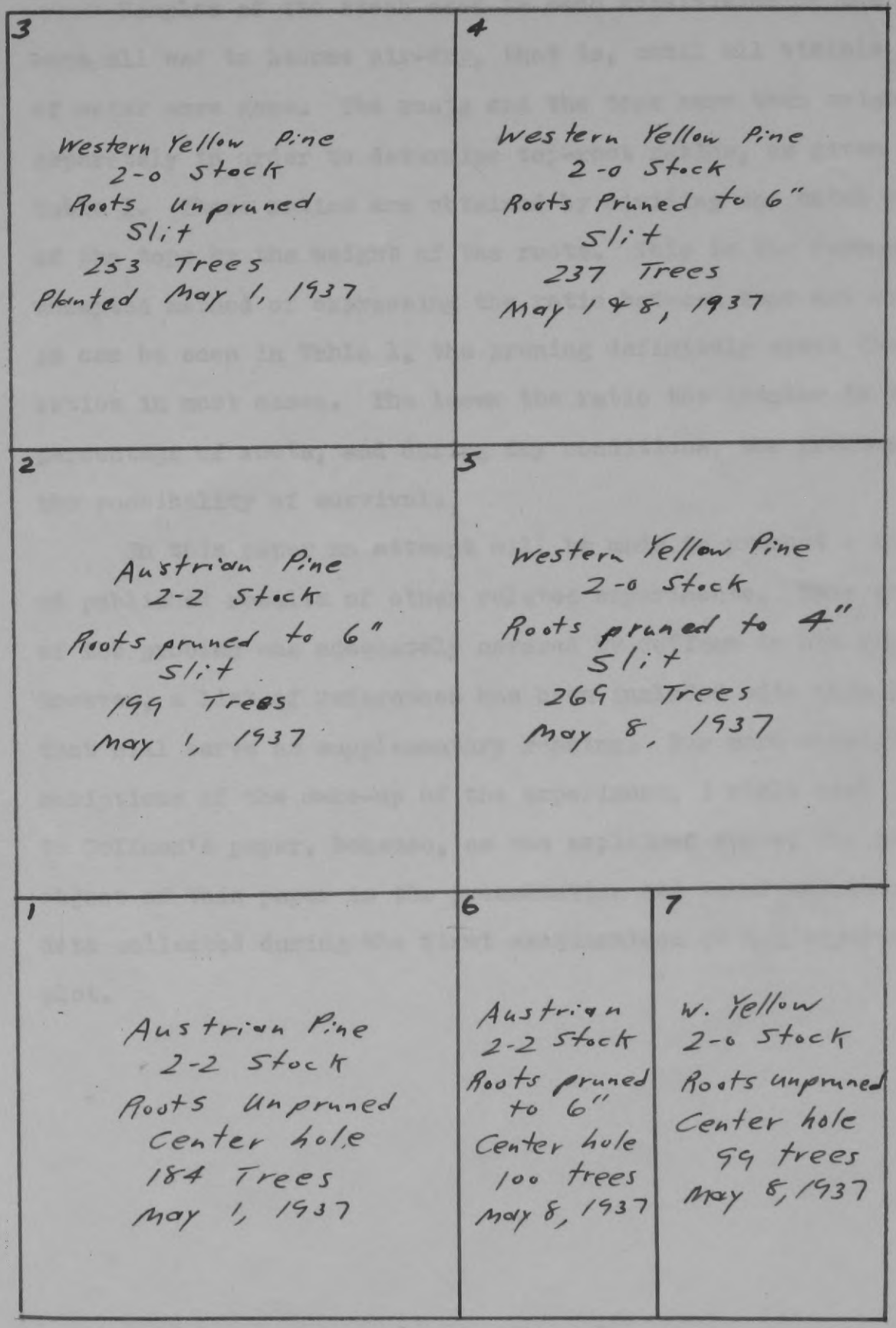
Design of the Experiment

The experimental plot is located in Lot 8 of Stinchfield Woods, which constitutes one of the forest properties of the University of Michigan. It lies approximately 6 miles northwest of Dexter, Michigan in Sections 11, 12, and 14; R. 4 E.; T. 1 S.; M.P.M.. The site for the experimental plot was plowed with a furrow spacing of 2 to 3 feet and was subdivided as shown in Figure 1. In both the location and design of the experiment, Coffman attempted to approach natural forest plantation conditions as nearly as possible. A two by two foot spacing was originally planned, but, because of the interference of stumps with plowing and the individual differences in the planting crew, spacing was quite irregular. Planting was done by three men to equalize differences in planting technique.

The pruning of the roots was done with a large knife. Many trees were grasped in one hand and all pruned to the desired length by one stroke of the instrument. The seedlings were then planted in the various subdivisions of the plot. Table 1 shows the make-up of each plot.

Table 1. - Make-up of experimental plots.

Plot No.	Species	Age	Condition of Roots	Method of Planting	Top-root Ratio	No. of Plants
1	Austrian pine	2-2	Unpruned	Hole	3.8	184
2	"	2-2	Pruned 6"	Slit	5.1	199
3	W. yellow pine	2-0	Unpruned	Slit	2.9	253
4	"	2-0	Pruned 6"	Slit	2.85	237
5	"	2-0	Pruned 4"	Slit	4.16	269
6	Austrian pine	2-2	Pruned 6"	Hole	5.1	100
7	W. yellow	2-0	Unpruned	Hole	2.9	99



Rough sketch of Fig 1

Experimental Plot

Scale ~ 1" = 13.2'

Fig. I

Samples of the stock used in each subdivision of the plot were allowed to become air-dry, that is, until all visible traces of water were gone. The roots and the tops were then weighed separately in order to determine top-root ratios, as given in Table 1. These ratios are obtained by dividing the total weight of the tops by the weight of the roots. This is the commonly accepted method of expressing the ratio between tops and roots. As can be seen in Table 1, the pruning definitely upset these ratios in most cases. The lower the ratio the greater is the percentage of roots, and during dry conditions, the greater is the possibility of survival.

In this paper no attempt will be made to present a review of published results of other related experiments. This phase of the problem was adequately covered by Coffman in his report. However, a list of references has been included with this report that will serve as supplementary reading. For more complete descriptions of the make-up of the experiment, I shall also refer to Coffman's paper, because, as was explained above, the primary object of this paper is the presentation and interpretation of the data collected during the first examinations of the experimental plot.

Collection of Data

The first examinations of the experimental plots were made during the months of March, April, and May of 1938. The data first collected were those of survival counts and growth measurements. Since the exact numbers of trees planted in each plot were known, it was a relatively easy task to determine survival. However, since the experiment was devised to show the effects of both root pruning and the method of planting on survival, it was necessary to very carefully determine the cause leading to the death of every seedling that had been killed. In order to interpret the results in the light of the experiment, those seedlings that were killed as a result of factors other than the root pruning or the method of planting necessarily had to be eliminated from the survival comparisons.

Each dead seedling was examined carefully above the ground to make certain that mechanical injury, plant competition, careless planting technique, or other related factors were not the cause of the death. After eliminating all possibilities of this nature, the dead seedlings were lifted with the aid of shovels and grub-hoes, care being taken not to cut or break any of the roots. Examination of the root systems, in most cases, showed the probable cause of death. Those seedlings which had been severely attacked by white grubs were easily detected, and, of course, were eliminated in the interpretation of the survival counts. Other trees which showed insufficient or badly distorted root systems were considered in analysing the results of the pruning and the planting methods.

Growth measurements of the surviving trees were the next data collected. At the time the experimental plots were established no height measurements were taken. However, Coffman was of the opinion

that sufficient numbers of seedlings were planted as to make the average heights above ground of the plots containing the same species very nearly equal at the time of planting. Based upon this assumption, all trees were measured to the nearest one-quarter inch in height above the ground, and the differences in average heights were considered as an indication of the differences in height growth between the various plots since the experiment was started.

The next procedure in the examination of the plots was the removal of a part of the seedlings that had received different treatments for the purpose of determining root growth and development. Since the experiment is planned to be continued for a period of 5 years, approximately one-fifth of the trees in each plot could have been removed. However, it is desirable that a few trees be left in the ground for observations after the 5 year period, so more nearly one-sixth of those in each plot were lifted. This difference should easily allow for subsequent mortality and for the few reserve samples. It was at first thought desirable to remove trees of average height, or an equal number above and below the average, so as not to affect next year's growth comparisons. However, this procedure would have involved the element of selection, and it was decided that better average results could be obtained by a definite sample method independent of present heights without affecting future growth data. In plots 1, 2, 3, 4, and 5 every third, eighth, and thirteenth seedlings in each row were selected arbitrarily as the samples to be studied, and in the smaller plots a similar procedure was used. Calculations showed that in every case the average height of the seedlings left was unchanged or was affected but very little.

Due to the depth of many of the root systems, considerable work was required to remove the trees without injury. Although several methods and combinations of implements were used, a grub-hoe proved to be the most satisfactory. The presence of many rocks and roots prevented the effective use of the shovel. With the grub-hoe a rather deep trench would be dug on one side of the seedling. Then by inserting the implement deeply into the trench with the blade directly under the tree, as is shown in Figure 2, very little damage was done to the root systems. It was also possible by this method to get an accurate picture of the position of the roots in the ground. As each seedling was removed notes were taken as to the distribution and position of the root systems, particularly for those that had been planted in a vertical slit.

The samples to be studied were carefully handled and brought into the laboratory for examination and measurements. For all the stock lifted the total length of the root systems was measured, and, as far as possible, the depth that the roots had penetrated below the ground surface were recorded. It was possible with all the pruned stock to see the point of pruning, so from this point all root growth was measured and averaged for the particular plots. After all root measurements and notes had been taken, most of the seedlings were separated as to tops and roots and allowed to become air-dry. They were then weighed separately for the purpose of obtaining top-root ratios, the air-dry weight being used so as to compare with the ratios determined by Coffman.

After all data had been recorded a few representative seedlings that had not been used for determining top-root ratios were photographed in various combinations to more clearly show some of the present results of the experiment

Sketch of original drawings

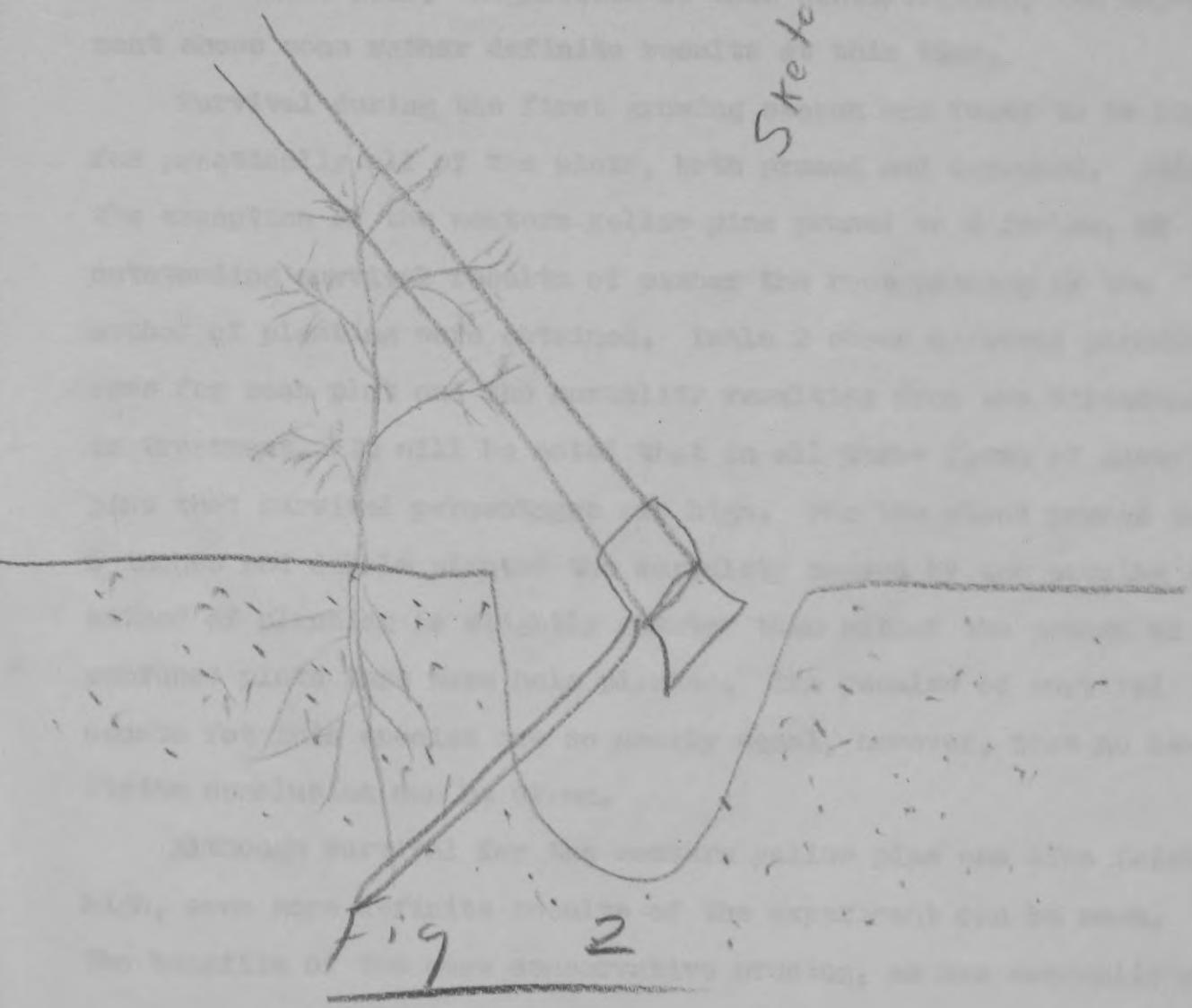


Fig 2

Presentation of Data and Interpretation of Results

There may be some doubt as to the desirability of collecting survival and growth data for an experiment of this nature only one year after planting, and, of course, present conclusions may be entirely disproven after subsequent examinations. Complete records will not only aid in determining results that might be otherwise overlooked, but will also be of importance in contributing to the better analyzation of future developments. Had not survival data, for example, been taken this year, the causes of death to the seedlings would have been much more difficult, if not impossible, to determine next year. Regardless of this justification, the experiment shows some rather definite results at this time.

Survival during the first growing season was found to be high for practically all of the plots, both pruned and unpruned. With the exception of the western yellow pine pruned to 4 inches, no outstanding survival results of either the root pruning or the method of planting were obtained. Table 2 shows survival percentages for each plot and the mortality resulting from the differences in treatment. It will be noted that in all three plots of Austrian pine that survival percentages are high. For the stock pruned to 6 inches and dibble planted the mortality caused by the pruning and method of planting is slightly greater than either the pruned or unpruned plots that were hole planted. The results of survival counts fot this species are so nearly equal, however, that no definite conclusion can be drawn.

Although survival for the western yellow pine was also fairly high, some more definite results of the experiment can be seen. The benefits of the more conservative pruning, as was accomplished

Table 2. - Survival percentages and causes of mortality for various plots

Plot No.	Species	Metohd of Planting	Condition of Roots	No. Trees Planted	No. Trees Dead	Mortality due to Pruning	Mortality due to Planting	Mortality from other causess	Survival
7	W. yellow	Hole	Unpruned	99	6	0.0%	2.0%	4.0%	94.0%
3	"	Slit	Unpruned	257	18	0.0%	2.3%	4.7%	93.0%
4	"	Slit	Pruned 6"	237	3	0.0%	0.4%	0.8%	98.8%
5	"	Slit	Pruned 4"	269	22	5.2%	1.5%	1.4%	91.9%
1	Austrian	Hole	Unpruned	184	6	0.0%	1.1%	2.1%	96.8%
6	"	Hole	Pruned 6"	100	1	0.0%	0.0%	1.0%	99.0%
2	"	Slit	Pruned 6"	199	5	1.0%	1.5%	0.0%	97.5%

Table 2

by the 6 inch pruning can be seen by reference to the mortality percentages for plot 4. This result, however, is more indirect in that it shows the effect that the pruning of the roots had upon the planting. For both of the unpruned plots the root systems of most of the dead seedlings were bent upwards so that the fine, fibrous roots were very close to the surface of the ground; while for the pruned plots practically all seedlings showed normal positions of the roots. In no instances for the plot pruned to 6 inches could be found any evidences of death due to the pruning alone.

The most striking result of the pruning of the western yellow pine became evident in plot 5, which was pruned to 4 inches. There are all indications that four inch pruning with this species was too severe. A mortality of 5.2% was obtained as a result of the pruning so severe to the root systems that the seedlings were unable to commence growth and develop adequate roots. Most of the dead seedlings lifted from this plot showed only a dead stub for their root systems with no indication of lateral root development. Some of the green, but not growing, trees removed later confirmed this observation (Plate I), and, unless moisture conditions during the next growing season are very favorable, additional mortality will result from this cause.

Mortality from causes other than those inflicted by the experiment will only be briefly discussed here, but for future reference this data has been included in the Appendix. Only in plots 3, 5, and 7 was white grub damage severe enough to be detected. Very little damage was done, however, except in plot 3. This plot showed a mortality of approximately 4% as a result of white grubs, which in some instances consisted of the eating of the

complete root systems by the grubs. It was also of interest to note that most of the damage occurred in a centralized area at one corner of the plot. Another cause that was eliminated in the analysis of the mortality data was that of competition from surrounding vegetation. The area in which the experimental plot is located was rather heavily covered with grass-sod and weeds. Plowing of furrows left narrow rows for planting and in some cases the sod and weeds have almost completely overgrown the furrow. This condition in some instances was too severe for the seedlings and will probably account for the future death of some of the smaller and slower growing seedlings.

Height growth during the first growing season has shown some rather definite results of the root pruning for both Austrian and western yellow pine. Reference to Table 3, which shows average heights for the various plots, confirms the conclusion that 4 inch pruning of the western yellow pine was too severe, even under the most favorable growing conditions.

Table 3. - Average heights above ground for various plots.

Plot No.	Species	Method of Planting	Condition of Roots	No. Trees Basis	Average Height above ground inches
7	W. yellow pine	Hole	Unpruned	93	2.36
3	"	Slit	Unpruned	239	3.39
4	"	Slit	Pruned 6"	234	3.17
5	"	Slit	Pruned 4"	247	2.60
1	Austrian	Hole	Unpruned	178	9.31
6	"	Hole	Pruned 6"	99	8.44
2	"	Slit	Pruned 6"	194	8.40

The average height growth for the western yellow pine pruned to 4 inches was approximately 3/4 of an inch less than height growth for the unpruned and the pruned to 6 inch plots, all planted with the dibble. Not only was height growth less but the trees as a whole were less vigorous in appearance than those of plots 3 and 4. By merely looking at the growth figures in Table 3 one would be inclined to interpret the smaller average height figure of plot 7, unpruned and hole planted, as a direct result of the experiment, and contrary to the observation made above regarding the growth of the trees in the plot pruned to 4 inches. It is my belief, however, that this is not the case. Only 93 trees were available for growth data in plot 7; while well over 200 trees were used in determining the average heights for the other three plots. This smaller sample of trees might easily be responsible for this result. Then, too, plot 7 was the last part of the experiment to be established. It is quite possible that the planting crew unintentionally used smaller stock for this plot. Future growth data, however, will be necessary before this can be definitely decided. Future growth data will also be more reliable now that average heights for the various plots are available.

For the Austrian pine average heights in Table 3 distinctly show growth for the unpruned plot to be greater than for either of the pruned plots. This tends to confirm my opinion that, although root pruning may be desirable as it makes for easier planting, unpruned seedlings can start top growth more quickly and are not faced with the necessity of the development of an adequate root system. While top growth for the first growing season was greater for the unpruned trees, it will be shown later that the pruned succeeded in replacing its reduced root length to a great

extent during one season. At the present time no significant differences in height were obtained that show definitely any direct results upon growth of the different methods of planting. Whether the distortion of the root systems by planting with the dibble will affect the rate of growth, remains yet to be seen.

Before proceeding further with data on root growth and root developemnt, it is advisable to analyze growing conditions since the time the experiment was begun in order to determine how they might have affected the results of the experiment. From all indications the first growing season was confronted with abnormal conditions. In an experiment on root pruning and planting technique the soil moisture condition is undoubtedly the most important outside influencing factor upon growth and survival. Since soil moisture does have a direct bearing upon growing conditions, precipitation data were obtained to serve as an indicator of soil moisture. Figure 3 shows graphically total precipitation by months during the Spring and Summer of 1937 and averages over a 29 year period for the same months. These data were collected at the University of Michigan Observatory in Ann Arbor, Michigan, and, although approximately 16 miles from the experimental plots, are quite satisfactory for this comparison. It is very evident that precipitation for the growing season of 1937 was very much greater than normal. For the Months of April, May, June, July, and August the average precipitation is 15.20 inches; while the total of the same months in 1937 amounted to 23.85 inches. This total is one of the highest ever recorded in this vicinity and must have contributed greatly to the high percentages of survival that were obtained in this experiment during the first year. It also probably affected growth to a considerable extent.

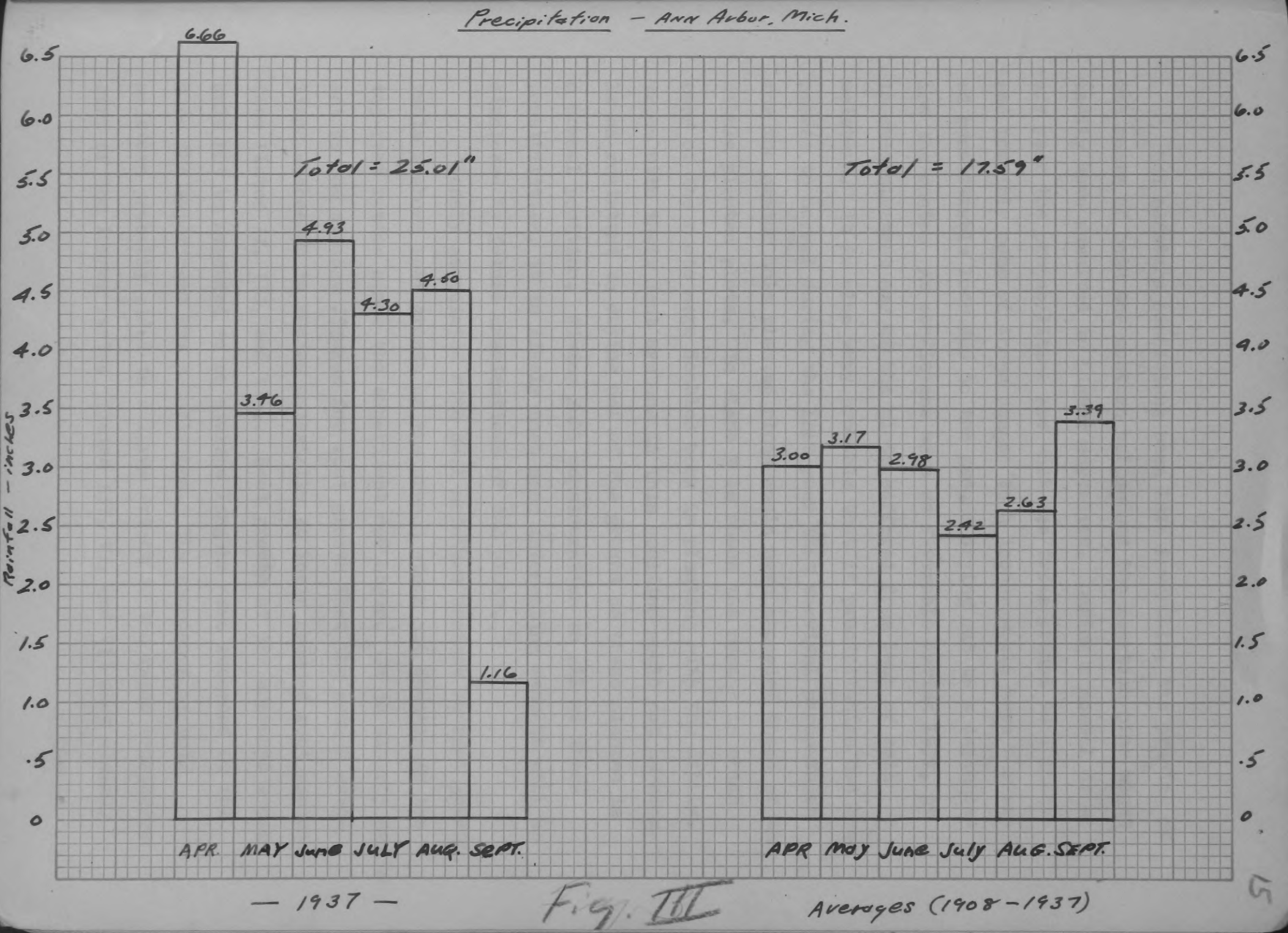

Precipitation – Ann Arbor, Mich.
Rainfall – inches
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
6.66
3.46
4.93
4.30
4.60
1.16
Total = 25.01"
APR. MAY June JULY AUG. SEPT.
— 1937 —
3.00
3.17
2.98
2.42
2.63
3.39
Total = 17.59"
APR May June July AUG. SEPT.
Averages (1908 – 1937)

Fig. III

Had moisture conditions been less favorable, the pruning of the roots of both the western yellow and the Austrian pine might easily have resulted in higher mortality. During a normal or a dry year the probabilities are that the trees pruned to 4 inches and possibly some of those pruned to 6 inches would have suffered considerable loss due to the ground drying out to a depth below the roots. As conditions were so favorable during 1937, it is unlikely that any of the plots suffered from lack of soil moisture. It is also very probable that if precipitation had been nearer to normal during the last year that survival percentages for the center hole planted plots would have exceeded those of the dibble planted plots. In Plate V is shown the manner in which many of the roots were doubled back in planting with the dibble. Trees with their root systems in this position would not be nearly as resistant to drying out of the ground as those planted in a normal position. Giving full consideration to all of these possibilities, it is likely that many interesting results will be disclosed by future examinations of the plots.

Closely associated with soil moisture content is root growth. Table 4 shows root growth of the pruned stock and changes in the top-root ratios since the experiment was begun. It is clearly evident by the average figures for root growth that the pruned seedlings succeeded in adding materially to their reduced root systems (See Plates II, III, and VI).. Root growth of the unpruned stock could not be measured as no average lengths were recorded at the time the experiment was established. The abundance of soil moisture probably aided to a large extent in the rapid establishment of the longer roots. Plates III, VI, and VII show clearly

Table 4. - Root growth and top-root ratios for various plots.

Plot No.	Species	Method of Planting	Condition of Roots	Ave. Root Growth	Top-root Ratio 1937	Top-root Ratio 1938
7	W. yellow pine	Hole	Unpruned	----	2.9	3.38
3	"	Slit	Unpruned	----	2.9	3.58
4	"	Slit	Pruned 6"	3.14"	2.85	3.64
5	"	Slit	Pruned 4"	3.35"	4.16	3.76
1	Austrian	Hole	Unpruned	----	3.8	3.65
6	"	Hole	Pruned 6"	4.85"	5.1	3.80
2	"	Slit	Pruned 6"	4.70"	5.1	3.68

the points at which pruning of the roots was done and the subsequent growth that has taken place. In many cases it was evident that the pruning had stimulated the development of many, fine, lateral roots. Had not moisture conditions of the soil been extremely favorable, it is quite probable that many trees would have died before they had provided themselves with adequate root systems. However, until more data, covering a wider range of conditions, are available, it would be difficult to say definitely that it was the pruning alone that stimulated the root growth. As can be seen by reference to Table 4, average growth for the two pruned plots of western yellow pine was slightly over 3 inches; while almost 5 inches was the average for the pruned Austrian pine. This difference is no doubt due only to the relative size of the two species as it effects their required root capicity. At any rate, one can conclude that, under favorable conditions, planted coniferous stock that has been root pruned will during the first growing season replace to a large extent its decreased root system. No significant difference of root growth was evident between the

pruned Austrian pine dibble planted and the pruned Austrian pine hole planted. The western yellow pine pruned to 4 inches showed a slightly larger average root growth than that pruned to 6 inches. This difference is so slight, however, that no definite conclusions were drawn.

Some very interesting results of the experiment can be seen in the figures shown in Table 4 for top-root ratios. Although pruning of the roots definitely upset these ratios at the time of planting, after only one growing season they have in all cases become nearly equal. This can be interpreted in several ways. First, it shows that growth of the unpruned stock for both species was about equally divided between top and roots. Secondly, it shows that more growth took place on the roots of the pruned stock than on the tops. These two conclusions more definitely confirm the observation that the growth in height of the pruned stock was less than that of the unpruned stock. The effect that growing conditions had upon the change of these ratios would be difficult to determine, but it is possible that during a drier season results might be entirely different.

The study of the effects of planting methods on growth, survival, and root development is one that has received considerable plubicity and is extremely interesting. As was explained above, very little in the way of definite results were obtained during this first examination as to the effect of planting methods upon growth and survival. Future examinations, however, might show more along this line.

The position and development of the roots as affected by the method of planting show some interesting results at this time. One observation of interest was the average depth of the roots in

the ground for the various plots, which is shown in Table 5.

Table 5. - Average root lengths and depths of the roots in the ground for the various plots.

Plot No.	Species	Method of Planting	Condition of Roots	Average Root Lengths	Average Depths of Roots in Ground
7	W. yellow pine	Hole	Unpruned	10.1"	8.3"
3	"	Slit	Unpruned	11.5"	7.9"
4	"	Slit	Pruned 6"	9.4"	7.3"
5	"	Slit	Pruned 4"	7.4"	7.0"
1	Austrian	Hole	Unpruned	12.2"	9.1"
6	"	Hole	Pruned 6"	10.8"	8.6"
2	"	Slit	Pruned 6"	10.7"	7.2"

This shows definitely that the use of the dibble in planting does not succeed in getting the root systems extended to their fullest extent in many cases. Where the dibble was used in planting unpruned stock and much of the stock pruned to 6 inches, a great percentage of the samples lifted showed that the main roots had been bent upwards in planting. This is shown quite distinctly in Plates IV and V. In most instances when the roots were turned upward in planting, the new growth of roots started rapid growth downward to replace them (Plate V); but in some cases (Plate III, Center) new growth of roots continued the upward direction. Mortality from this type of planting would undoubtedly be greatest during the first year. However, trees that did have their main roots bent upward had a year of very favorable conditions during which to extend them deeper into the soil.

The effect of the dibble or the vertical slit method of planting on the position of the roots is one of the most conclusive parts of the experiment. The roots of practically all slit-planted stock lifted showed distinctly that the old roots and most of the new roots were in a vertical plane (Plate VIII). In many instances while digging up the trees a large clod of dirt containing the roots would cleave open along a plane that was made by the planting bar, exposing nearly all of the roots. A few of the roots that had penetrated deeper into the soil by subsequent growth, however, showed a tendency to spread out away from the plane to a certain extent. Whether or not the root systems will in time assume normal positions cannot be predicted at this time. Many differences in opinion have been brought forth on this subject but little has been done in the way of experiment. It seems quite probable that the position of the roots will show the effect of the planting for a good many years, but it is doubtful that all subsequent growth will be affected. The type of the soil is supposedly responsible for the way in which roots develop from the slit in which planted. A heavy clay that packs tightly would be more impenetrable for the roots than a loose, sandy soil. The soil in this experimental plot is of about medium density and is a sandy to a gravelly-clay. If future observations disclose very conclusive results, soil texture will have to be more carefully analysed.

Summary

Based only upon the first of a series of observations of an experiment to determine the effect of root pruning on planted coniferous stock, the following conclusions can be offered in the way of a summary:

1. Survival counts made after the first growing season were high for both Austrian and Western yellow pine, both pruned and unpruned stock, and for both methods of planting (i.e. slit and center hole).

2. Root pruning of 2-0 western yellow pine to 4 inches was, according to amny indications, too severe. For the plot pruned in this manner and dibble planted, mortality was higher than in any of the other plots; height growth was noticeably less; and from general appearances and study of the root systems, it seems likely that many of the trees in this plot will die during the next season unless moisture conditions remain very favorable.

3. Several causes of mortality not related to the experiment, particularily white grub damage and competition of vegetation, were found and had to be disregarded in the interpretation of the survival results.

4. Height growth for the first season was greater with the unpruned stock of both species.

5. Six-inch root pruning of western yellow pine did not cause any mortality, and growth for this plot was only slightly lower than that for the unpruned plots.

6. Pruning of the Austrian pine to 6 inches did not cause much increase in mortality, and, although height growth was less than the unpruned stock, the ease of planting was greatly increased.

7. No appreciable differences upon survival and top growth were produced by the two methods of planting. In a drier season, however, it is probable that survival for the unpruned stock would exceed that of the pruned stock.

8. The first growing season of the experiment was greatly complicated by very heavy precipitation. During the Months of April, May, June, July, and August of 1937 total precipitation was over 1½ times the normal for these months.

9. This large amount of rainfall undoubtedly contributed greatly to the survival and growth of the trees, and future observations made during normal years may show entirely different results.

10. Root growth of the pruned stock of both species was large during the first year of the experiment, about 3 inches average increase in length for the western yellow pine and nearly 5 inches average for the Austrian pine. This increase of root systems will make the trees better able to withstand drought conditions that might occur.

11. Although top-root ratios were changed considerably by root pruning at the time of planting, after one year all plots for both species have about the same ratios. This shows a tendency for seedlings to maintain a balance of roots and tops.

12. The average depth of the roots below the ground surface was greater for the seedlings planted by the center hole method than those planted with the dibble.

13. Dibble planted stock that was unpruned showed in practically all cases that the main roots had been bent upward in the slit in which they were planted. Pruning of the roots eliminated much of this distortion of the root systems.

14. The 2-2 Austrian pine was so large that in some instances even planting by the center hole method did not succeed in establishing the roots in their normal positions.

15. After one season those seedlings planted in a vertical slit showed practically all of their roots still in the one vertical plane, with little tendency for lateral expansion past the sides of the slit.

Western Yellow Pine

Plate I

All Roots Pruned to 4"

Dibble Planted

(Squares on background 2")

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Western Yellow Pine

Plate II

Left; Unpruned, Dibble Planted

Center; Pruned to 6", Dibble

Right; Pruned to 4", Dibble

(Squares on background 2")

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Western Yellow Pine

Plate III

Left; Unpruned, Dibble Planted

Center; Pruned to 6", Dibble,
(Note upgrowing roots & stub)

Right; Pruned to 4", Dibble,
(Note point at which pruned)

(Squares on background 2")

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Western Yellow Pine

Plate IV

Left (2); Unpruned, Dibble

Right (2); Unpruned, Center Hole

(Squares on background 2")

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Austrian Pine

Plate V

Left; Pruned to 6", Center Hole

Right; Pruned to 6", Dibble

(Squares on background 2")

Austrian Pine

Plate VI

Left; Unpruned, Center Hole

Right; Pruned to 6", Dibble

(Squares on background 2")

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Austrian Pine

Plate VII

Left; Unpruned, Center Hole

Center; Pruned to 6", Center Hole

Right; Pruned to 6", Dibble, (Note dead stub of pruned root)

(Squares on background 2")

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Austrian Pine

Plate VIII

Both Pruned to 6", Dibble

Left: Shows compression of roots into plane

Right: Broadside view

(Squares on background 2")

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* First 9 references from Coffman's Report of 1937

Appendix

Plot 1. Austrian pine (2-2); Unpruned; Center hole

Original number of seedlings planted		184
Total number dead (1938)	6	
Number removed for data	31	37
* Present total		147

Causes of death of seedlings:

a. Competitionof grass or weeds	2
b. Mechanical injury, broken off	1
c. Planted too deeply in furrow	1
d. Unknown (no apparent cause)	2

Plot 2. Austrian pine (2-2); Pruned to 6"; Slit

Original number of seedlings planted		199
Total number dead (1938)	5	
Number removed for data	31	46
* Present total		163

Causes of death of seedlings:

a. Roots doubled back in planting	3
b. Too severe pruning (no laterals)	1
c. Unknown (no apparent cause)	1

Plot 3. Western yellow pine (2-0); Unpruned; Slit

Original number of seedlings (recorded as 253, with 4 seedlings just outside north end of plot that may not have been counted)		257
Total number dead (1938)	18	
Number removed for data	42	60
* Present total		197

Causes of death of seedlings:

a. White grub damage ---------- 10

b. Competition of grass or weeds --- 2

c. Planting (roots doubled back) --- 5

d. Unknown (no apparent cause) ----- 1

Plot 4. Western yellow pine (2-0); Pruned to 6"; Slit

Original number of seedlings ---------- 237

Total number dead (1938) ---------- 3

Number removed for data ---------- 42 45

* Present total ---------- 192

Causes of death of seedlings:

a. Mechanical injury (broken off) -- 2

b. Planted too shallow ---------- 1

Plot 5. Western yellow pine (2-0); Pruned to 4"; Slit

Original number of seed lings ---------- 269

Total number dead (1938) ---------- 22

Number removed for data ---------- 42 64

* Present total ---------- 205

Causes of death of seelings:

a. Too much pruning (no laterals) -- 10

b. Combination (no laterals and planted too shallow) ---------- 4

c. White grubs ---------- 2

d. Competition of grass or weeds --- 2

e. Unknown (no apparent cause) ----- 4

Plot 6. Austrian pine (2-2); Pruned to 6"; Center hole

Original number of seedlings planted ---------- 100

Total number dead ---------- 1

number removed for data ---------- 15 16

* Present total ---------- 84

Causes of death of seedlings:

a. Mechanical injury ---------- 1

Plot 7. Western yellow pine (2-0); Unpruned; Center hole

Original number of seedlings planted ---------- 99

Total number dead (1938) ---------- 6

Number removed for data ---------- 15 21

* Present total ---------- 78

Causes of death of seedlings:

a. White grubs ---------- 1

b. Competition of grass or weeds - 3

c. Unknown (no apparent cause) --- 2