A STUDY OF NATURAL REGENERATION
and
AN EXPERIMENT ON THE EFFECT OF ROOT PRUNING ON PLANTED CONIFEROUS STOCK

by

Robert L. Metzger

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Forestry

PART I

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

By

Robert L. Metzger

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

Introduction

In the spring of 1937 an experimental plot was established in Lot 8 of Stinchfield Woods. The entire plot is 66 by 108 feet with the four corners marked by 3" by 3" white stakes. The subdivisions of the plot, which are seven, have their corners marked by 2" by 2" unpainted stakes with the exception of the boundary between plot subdivisions six and seven. These are marked by small round limbs driven into the ground and surrounded by large stones.

At the time of establishment Austrian pine 2-2 stock and Western Yellow pine 2-0 stock were planted as follows:

TABLE I

Plot No.	Species	Age	No. Planted	Method of Planting	Condition of Roots
1	Austrian pine	2-2	184	Center hole	Unpruned
2	Austrian pine	2-2	199	Slit	Pruned to 6"
3	W. Yellow pine	2-0	253	Slit	Unpruned
4	W. Yellow pine	2-0	237	Slit	Pruned to 6"
5	W. Yellow pine	2-0	269	Slit	Pruned to 4"
6	Austrian pine	2-2	100	Center hole	Pruned to 6"
7	W. Yellow pine	2-0	99	Center hole	Unpruned
			1341		

Since that time it has been the object of the experiment to obtain data with regard to survival, height growth, root development, and comparison of the slit method to that of the center hole method of planting. Throughout the paper comparisons will be drawn by contrasting data obtained and balancing one against the other.

Discussion and Review of Literature

To understand the question of root-pruning, it is necessary that the subject be analyzed. We prune the roots

(I) Of plants at transplanting time, to remove injured parts and to maintain a balance between root and top;

(II) Of established plants -

(1) To keep the growth within bounds, particularly when it is desired that the plant shall be dwarf;

(2) To concentrate or contract the area of the roots;

(3) To make the plants fruitful.

The first pruning is to be done at the time of planting, when it is necessary to restore the balance between the branch system and the root system, the latter often having been curtailed in the operation of transplanting the tree. First, all injured roots need attention. Broken ones must be cut with a sharp, even draw cut, in such a manner that the face is on the lower side, so that from it new fibrils may form in the natural direction. Bruised roots, if too much lacerated to promise ready healing, are also better removed, since they may otherwise become starting points for rot. If they cannot be dispensed with without too much loss to the tree their treatment may follow the prescription for treatment wounds in general.The wounds heal by the formation of a callus, germs of decay enter exposed wounds, new or adventitious buds or roots start as the result of heavy pruning and a severed leader tends to renew itself. The direction of the roots is important - whether they run horizontally and near the surface, or perpendicularly."The direction, however, is not determined primarily by methods of pruning, but by the nature of the plant, by the soil, and the distribution of moisture and food." (1)

In transplanting a three-year-old tree from a nursery, the necessity will arise for a second root-pruning, the first root-pruning having taken place when the tree was removed from the nursery row. The third, or first root-pruning after the tree is planted in its permanent quarters will probably have to be performed when the tree is between six and eight years old, at which age it will have to become well established with a tendency to produce a large amount of woody growth. Root-pruning is most successfully performed at the fall of the leaf, or sufficiently early in the season to afford severed and damaged roots an opportunity of healing and thereby recovering a healthy condition while the soil is still warm. If the operation is delayed until December, the ground temperature has fallen and so new roots are not so readily formed in the following spring. In treating trees of five or six year's growth, these can be taken bodily out of the ground, and the strongest of their roots shortened by the aid of a strong pruning-knife. Each cut should be made in a slanting direction on the upper surface, so as to induce the fibrous roots formed later to take a more horizontal direction through the soil than would be possible were the cut to be made on the undersurface. Trees from eight to twelve years old and upwards require considerably more care in root-pruning than if the operation were performed in a careless or haphazard fashion, the tree will receive a severe check from which it may never recover. (6)

When the roots are pruned, top growth is checked and, due to the accumulation of organic food, new root growth is probably rather rapid until, by increased root growth and reduced top growth, the normal balance between root and top is reestablished. " Root-pruning is of practical importance only under conditions where it is desired to keep trees small." (3)

The new roots usually arise from firm strong roots the size of a lead-pencil or larger; but they may also arise from the hair-like roots which are on the tree when it is transplanted. The place from which the new roots arise is largely determined by the habit of the individual plant. In some cases, all the roots spring from the main shaft or trunk, and in others they seem to arise almost indiscriminately from the trunk, large roots and very fine roots. Since a large proportion of the rootlets start from along the old roots, it seems possible that, by leaving most of the old root system, more new rootlets might be formed and the tree might thus make better growth at the start. On the other hand, since the roots from the old stem are stronger, the new root system formed might, temporarily at least, be slightly better if a considerable part of the old root system is cut away, thus encouraging rooting from the stem. The extreme application of this possibility is made in the Stringfellow method of pruning, where practically all of the roots except the central one are cut away, the top being cut back proportionally. Card (2), planted 25 trees by the Stringfellow method, with the roots cut back about one-half and the twigs one year old also shortened about one-half, and 25 with the roots unpruned, but with the twigs shortened one-half. These were planted in the semi-arid climate of Nebraska in the spring of 1896. In the spring of 1897 only two trees planted by the Stringfellow method were in good condition, and by June 1898, while half the trees planted by the Stringfellow method were in fair condition, they were far behind those planted by other methods. The trees planted without root-pruning were in decidedly the best condition. The new rootlets had come largely from near the central root of the trees, just as they had where the roots were pruned back about one-half. In fact, with trees whose roots were cut back one-half and with those having no root-pruning, more new roots grew from the central root than grew from the trees pruned by the Stringfellow method.

When a tree has attained to a fruit bearing size and shows no indications of fruiting, but continues to maintain a vigorous growth of branches and is evidently barren as the result of no fruit, a good root-pruning will have the effect of encouraging the formation of fruit buds. Trees in this condition, if root-pruned about the first of August, will receive a check to growth which will cause the formation of fruiting buds during the fall and show good flowering the following spring. (4) " Cutting the roots reduces the water and mineral supply, checks growth, may cause accumulation of carbohydrates in the top and generally causes an increase in fruit-bud formation." (3)

"Heavy pruning of the root tends to lessen the production of wood. The food supply is cut off. Root-pruning is to be compared to reduced feeding. One knows that he prunes the tops of transplanted plants because the roots have been cut, and he must thereby reduce the area to be supported. Root-pruning is practicable chiefly in the growing of specimen plants, or in small amateur plantations, particularly when trees are trained on walls, and the like, that is, when it is desired to dwarf the plants. It has little place in usual American horticultural operations." (1)

Root-pruning should be employed with caution, for while the pruner may improve and still remove a large proportion of the top without causing injury, a relatively small reduction of the root has marked effects and may permanently injure the plant.

Discussion of Experimental Data

It has been the design of the experiment in the last two years to take out 20% of the trees in each plot. The removal of this number from the area acts twofold: first, a thinning is necessary from year to year to keep the beds in a regulated condition, and second, a certain number of trees must be removed for the necessary study purposes. After the seedlings were removed, the most promising criteria were found to be the weight of top and roots (the ground line being taken as the dividing point) and the ratio between the two, or $\frac{\text{weight top}}{\text{weight roots}}$

Only the weight of roots after pruning for field planting was used, and green weight rather than dry weight was determined for each lot of plants.

Considerable theoretical justification for such a standard may be adduced. Other things being equal, the greater the surface area (and weight) of the top, the greater the transpiration; and the greater the area (and weight) of the roots, the greater the absorption of moisture from the soil. So, given two plants with tops of the same weight, the one with the heavier root system is able to absorb more moisture and hence under critical field conditions has a higher chance of survival.

Two general statements can be made regarding the comparison of different lots or age classes of a given species:

(1) Of several groups of plants with equal or approximately equal ratios of tops and roots, that with the greatest weight will have the greatest or highest survival in the field, given of course, the same field conditions for all groups;

(2) Of several groups having roots of equal or approximately

equal weight, that with the lowest ratio of weight of tops to roots will have the highest survival.

TABLE II

Plot No.	Species	Age	Method of Planting	Condition of Roots at Planting	Average Top-Root Ratio	Average Height in Inches
1	Austrian pine	4-2	Center hole	Unpruned	1.97	18.84
2	Austrian pine	4-2	Slit	Pruned to 6"	1.20	15.26
3	W. Yellow pine	4-0	Slit	Unpruned	3.78	6.12
4	W. Yellow pine	4-0	Slit	Pruned to 6"	3.38	5.76
5	W. Yellow pine	4-0	Slit	Pruned to 4"	4.18	5.59
6	Austrian pine	4-2	Center hole	Pruned to 6"	2.10	17.16
7	W. Yellow pine	4-0	Center hole	Unpruned	4.49	7.22

Table II indicates the average top-root ratio and average height in inches for each species and condition.

Comparison of Results

A. Austrian pine

It will be noticed that in plot 6 which is pruned to six inches and planted by the center hole method the top-root ratio is largest as compared to the other plots. This means that the root system is small with respect to the top of the tree and this is affirmed by the average height figure in the last column of Table II. So far the Austrian pine planted by the slit method is much more balanced with regard to top-root ratio than that planted by the center hole method. The tops, on the other hand, show greater progress to response when planted by the center hole method.

However, it can be seen definitely that the unpruned stock is well balanced. The root system and top ratio are weighted against each other one to two. The average height of the seedlings is greater than in any of the pruned stock, which proves the theory, so far, that root-pruning retards the growth of the top.

B. Western Yellow pine

Again it is seen in the Western Yellow pine figures that the stock planted by the center hole method shows the largest average height growth in inches. Also, the top-root ratio is the largest when planted by the center hole method, which proves that the root system is small in comparison to the top. It is hard to say, now, whether the trees planted by the center hole method will retain as large a survival count as those planted by the slit method. It may possibly regain its balance within a short time, but will be a good point to note in future work on this experiment.

Again the unpruned stock show greater height growth, but at the same time the top-root ratios are not consistent in any form to draw upon a conclusion. However, those trees which were pruned to six inches show a better developed root system and greater height growth as compared to those pruned to the shortest length of four inches.

Comparison of Figures

A. Austrian pine

Figure I - The seedling on the left of the figure was left unpruned and planted by the center hole method, while the one on the right was pruned to six inches and planted by the same method. The figure affirms the data, in that, the unpruned seedling is greater in average height and looks healthier and stronger than the one which was pruned. The central root is larger and stronger with many tributary rootlets branching off. As expected the roots have attained a greater length as indicated by the blocked-off two inch squares although the ratio of root to top is nearly equalized.

Close observation shows that the stems of the Austrian pine on this figure as well as all succeeding figures are girdled well above the ground line. This is accounted for by the mice in the area and the rather mild snow within the past winter. Why they should prefer the bark of Austrian pine to that of Western Yellow pine is still a question in my mind, however, it may just be a matter of preference. FIGURE I

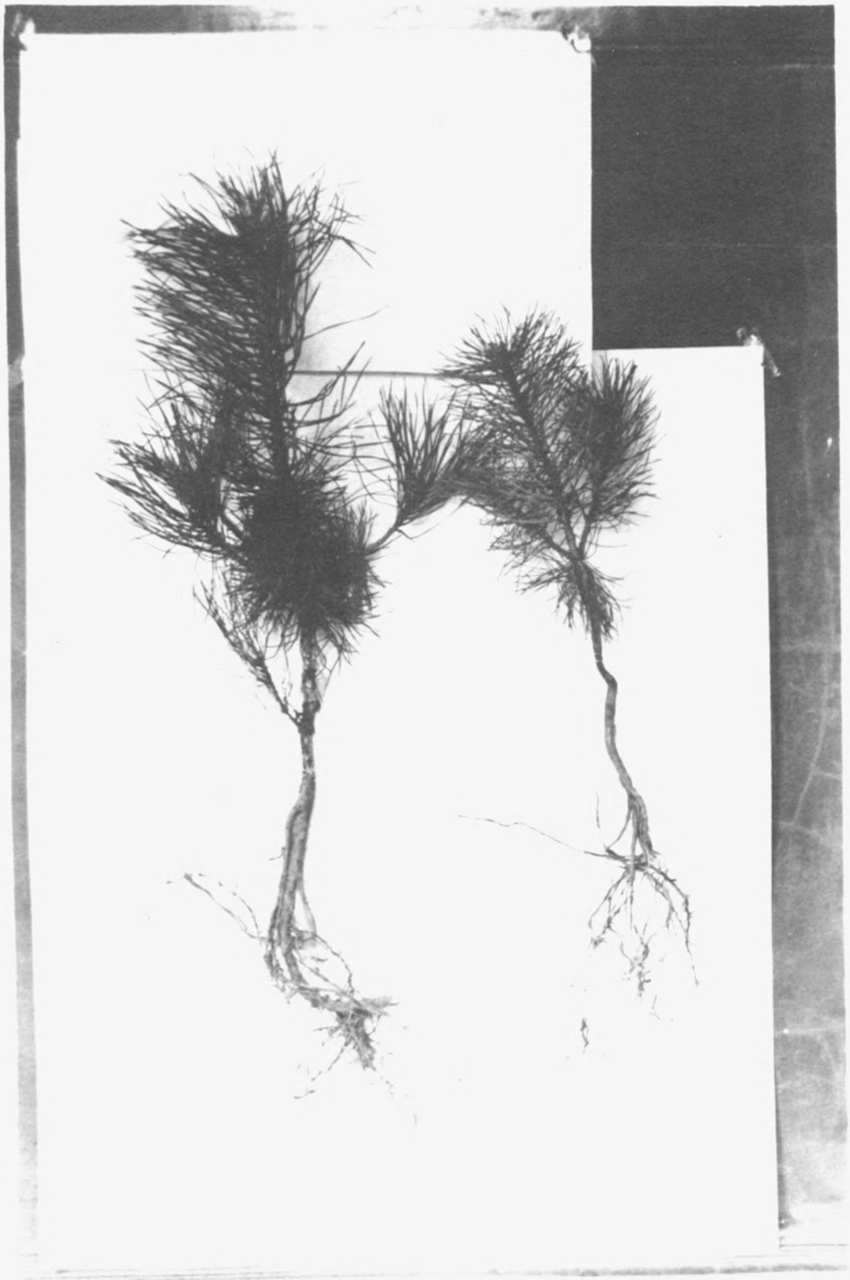


Figure II - The seedling on the left of the figure was left unpruned and planted by the center hole method, while the seedling on the right was pruned to six inches and planted by the slit method. The figure runs in course with the data obtained, in that,

FIGURE II

the average height of the unpruned is very much greater than the pruned (a difference in actual figures of 3.58 inches) - height growth difference like that within only two years is something to note. The root system as seen on the pruned seedling planted by the slit method is developed in equal proportion to the top. It shows indication of healthy stock. Again the unpruned specimen is sturdier looking with a large branching network of roots.

Figure III - The seedling on the left of the figure was pruned to six inches and planted by the center hole method, while

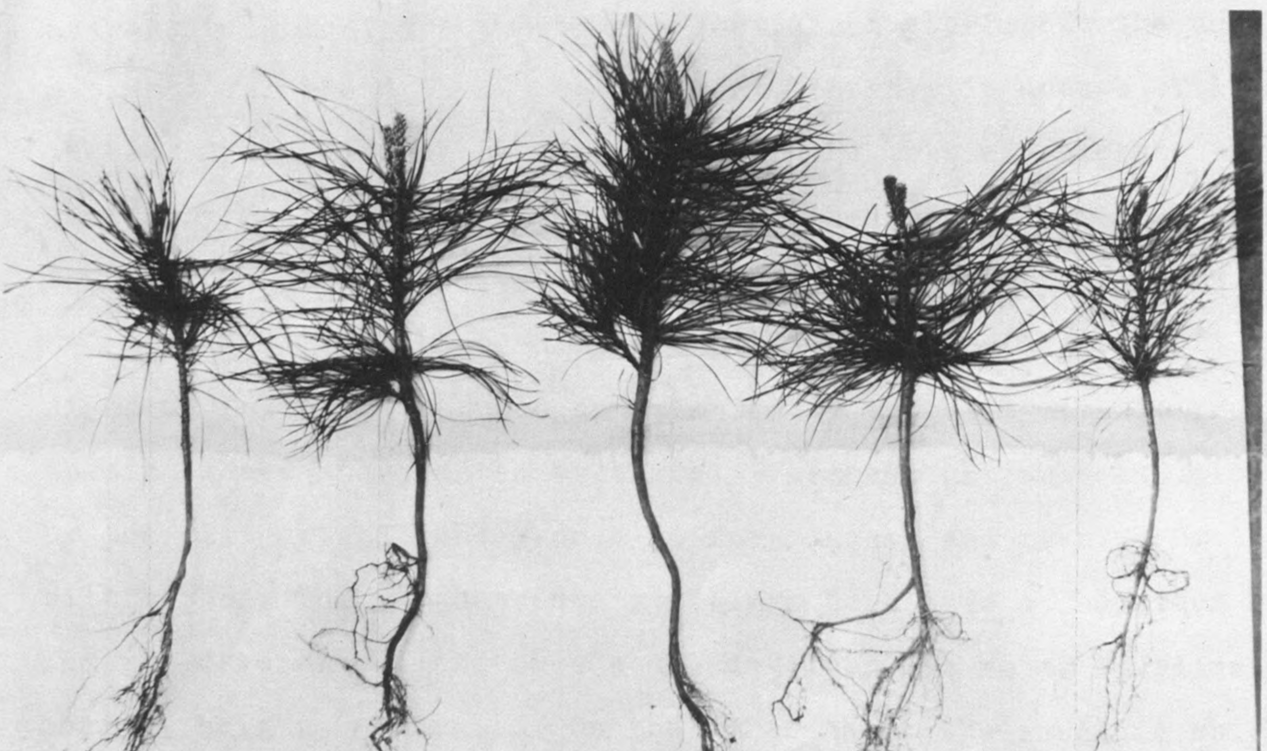
FIGURE III

the seedling on the right was pruned to six inches and planted by the slit method. The slit method of planting shows a greater luxuriance of root system over that of the center hole method of planting and this is substainted by the data. The comparative top-root ratios are 1.2 for the slit as to 2.1 for the center hole or almost twice as much root system in the slit method of planting. The stems are about of equal thickness and both appear equally strong, but it can be rest assured that with such a substaintial root system in the slit planted seedling, the tops cannot help but show a marked progress in the future.

B. Western Yellow pine

Figure IV - The seedlings on the figure read from left to right as follows: unpruned and planted by the slit method; unpruned

FIGURE IV



and planted by the center hole method; unpruned and planted by the center hole method; pruned to six inches and planted by the slit method; and pruned to four inches and planted by the slit method.

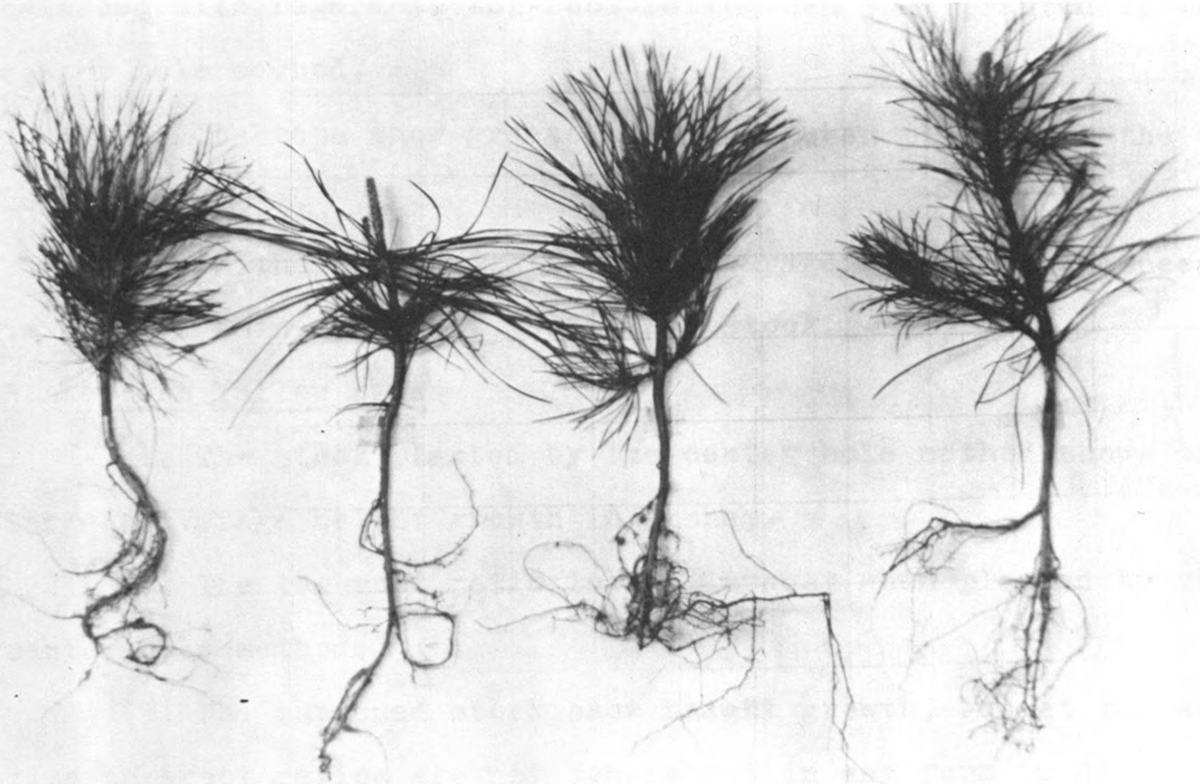
To simplify this discussion let us consider, first, the unpruned slit and unpruned center hole methods. It will immediately be noticed that the top of the seedling planted by the slit method is smaller in proportion to its associate and this is materially upheld by the data, which shows a divergence of 1.1 inches in height growth. The roots, on the other hand, are more tributary and branchingin the slit planted seedling, but the contrast as yet is not too greatly noticed.

Next, let us compare the unpruned center hole to the pruned slit planted seedlings, six and four inches respectively. At present the top-root ratios differ only slightly between the unpruned and pruned, the greatest divergence being in the six inch pruned. The average height of the pruned are just about equal, but the unpruned has shot far ahead in top development, roughly in access of 1.5 inches. Again, it can be stressed that the tops excellerate their growth by remaining in the natural unpruned condition and look as though they could survive unfavorable conditions more readily.

<u>Figure V</u> - The seedlings on this figure read from left to right as follows: unpruned and planted by the slit method; pruned to six inches and planted by the slit method; unpruned and planted by the slit method; and pruned to four inches and planted by the s slit method. The two unpruned seedlings both have a judicious root and top development and show equal developments as to sturdiness, health, height, and ratio. On the other hand, the seedling which was pruned to four inches appears to have a much better developed root system than the one pruned to six inches. The length of the entire

root systems are about the same, but the top of the four inch specmens has reached far out ahead of its associate. This, however, is not the average case, as, the average height figure at the present time to be about equal in development.

FIGURE V



SUMMARY

A. Austrian pine

1. The Austrian pine which was pruned to six inches and planted by the center hole method has at present the largest top-root ratio as compared to the other plots.

2. The Austrian pine planted by the slit method is much more balanced with regard to top-root ratio than that planted by the center hole method.

3. The tops show greater response when planted by the center hole method.

4. In the unpruned stock the average height of the seedlings is greater than in any of the pruned stock.

B. Western Yellow pine

1. The stock planted by the center hole method shows the largest average height growth in inches.

2. The top-root ratio is the largest when planted by the center hole method.

3. The unpruned stock show height growth, but at the same time top-root ratios are not consistent in any form to draw upon a conclusion.

4. The trees which were pruned to six inches show a better development in roots and greater height growth as compared to those which were pruned to four inches.

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PART II

A STUDY OF NATURAL REGENERATION

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A STUDY OF NATURAL REGENERATION

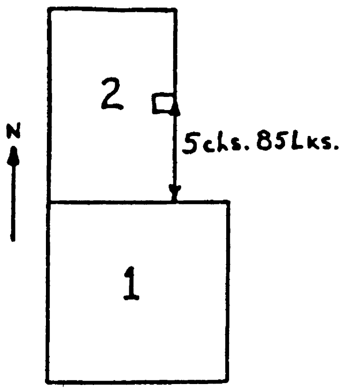
Introduction

The design of this study is being carried out at Stinchfield Woods, a property of the University of Michigan. It is here, that ten Reproduction Plots have been established at various strategic points throughout the property. Each plot is 16.5 by 16.5 feet square and marked at each corner by 2 by 2 inch square stakes.

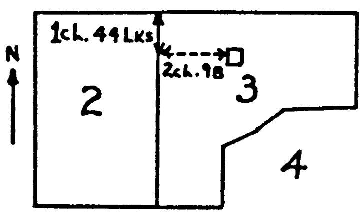
Since the fall of 1937, it has been the purpose of this study to mark each and every individual seedling within these plots with a numbered metal tag. All new seedlings are likewise tagged from year to year and those seedlings which did not survive throughout the year have their tags removed. In all cases, the seedlings are recorded according to species and their total height in inches above the ground line. The newly established seedlings are tagged and recorded in the same manner and note made by number of those which did not survive.

Location of Plots

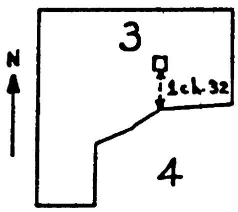
It was found necessary this year to relocate and to reestablish each plot accurately. So, the following diagrams show the location of each plot with respect to their Lot numbers.



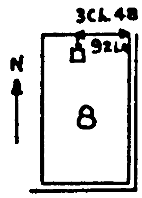
Plot 2A



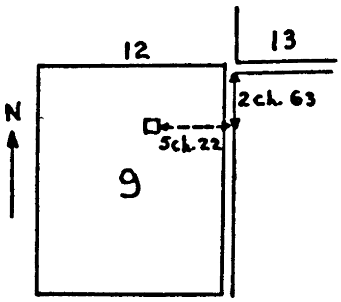
Plot 3A



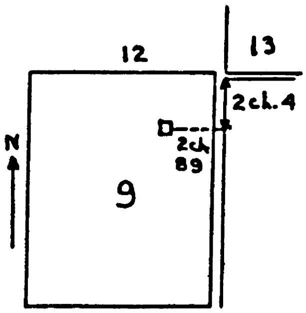
Plot 3B



Plot 8A



Plot 9A



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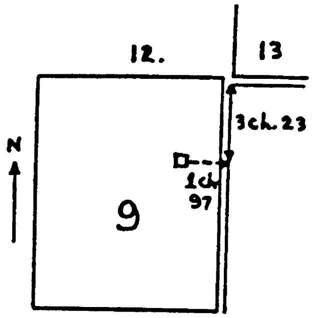
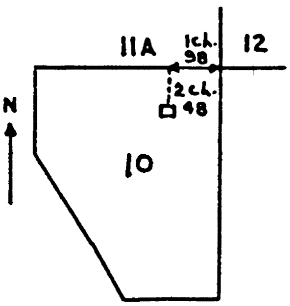
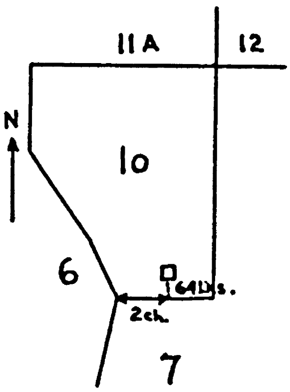


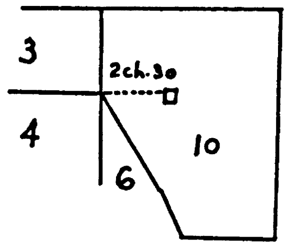
Plot 9C



Plot 10A



Plot 10B



Plot 10E

Discussion of Natural Regeneration

Averell (1) has found that the factors affecting reproduction are:

1. Seed supply - Seed supply depends chiefly on seed production, seed dissemination, insect damage, and rodent activity.

2. Seed germination - Seed that is overlooked by insects and rodents constitutes the small percentage of the original crop which

may germinate. Leaf litter is probably the most important factor influencing germination. It serves as a cover which keeps moisture and temperature conditions favorable.

3. Soil - Soil influences reproduction, in a way, by determining which species can grow on an area and how large and fast they will develop.

4. Climate - The temperature varies from.the normal very little so that it may be disregarded in comparing reproduction resulting from cuttings. However, precipitation varies sufficiently to have a great influence on the survival of young plants. When the precipitation falls below the normal and stays below it during all the growing season the effect on young reproduction is certain to be detrimental.

5. Shrub Competition - Woody shrubs are a cause for the failure of desirable reproduction to survive on certain areas. According to Averell, "Shrub competition lasts for a longer period on the good sites than on poor sites."

6. Rabbit Injury - Rabbit work consists of biting off the most vigorous stems and twigs, usually including the leader, and of eating the buds and tender tips. This seems to be their chief source of food during the winter and early spring.

7. Slash

The practial value of stored seed in the forest floor for restocking areas depends on the condition in which the forest floor is left after a cutting. The duff should not be burned or mostly all of the seed is destroyed. In order to avoid the destruction of the duff, one should pile the slash and burn the slash, so that, the fire will not spread over the entire surface of the ground. "This method has proved satisfactory in the White pine region of Idaho, where piling of slash is feasible. In the Douglas Fir region of the coast the piling of slash would not be practicable because of the large amount of debris and the consequent cost. The large percentage of the surface which would necessarily be burned over even by pile burning would reduce the value of the operation for conserving seed stored in the duff, which is usually all destroyed by broadcast burning of slash." (3)

The accumulation of seed in the forest floor is no longer a theory, but has found to be an actual condition by an analysis of the duff. Of course, the age of these seeds can not be determined, and the depth to which they are buried should not be taken as an index as to how long they have been there. Very probably the greatest factor in storing seed is rodent activity, by which seeds are buried at various depths and forgotten.

The accumulation of seed over a period of years can prove advantageous only if the stored retains its viability. With regard to this, each species possesses a dormancy habit of its own, and these habits have been growing more familiar to the forester through nursery observation and experiment. " In the Wind River Nursery seed bed, germination of Douglas Fir has been continued through three seasons. Western White pine has often produced better germination during the second season after sowing, even under the best germination conditions." (3) With conditions such as these obtained in regular nursery practice, it is not at all surprising that germination could be delayed under the forest cover. The cool layers of leaf mold and duff of the forest floor constitute an ideal natural storage medium.

The establishment of a forest by means of wind disseminated seed is a slow process. With only this means of regeneration practically all large areas would be denuded areas or would have but a few scattered trees. This would inevitably produce an uneven-aged and irregular forest; although the stands which follow most burns are even-aged. " When a forest is destroyed by fire or a cutting and is replaced over large areas, the succession depends upon the seed produced at the time of or before the destruction of the forest and the ability of the seed to retain its viability through the period of destruction, whether by fire or cutting. This type of reproduction replaces a forest almost immediately by the same species which comprised the original stand and usually in the same proportions." (3)

Since the seed must be produced by the stand before it is destroyed, the age at which different species begin to produce seed is very important. It varies greatly and this variation alone is often the controlling factor in determining the composition of the second growth stands.

TABULATION OF DATA

Reproduction Plot 2A

Seedling Number	Cherry	Hickory	Sassafras	Ash	Oak
1			38.7		
2			37.6		
3			7.6		
4			16.8		
5	24.4				
2832					5.1
2834	10.1				
2835	8.4				
2836	3.6				
2833	9.6				
(1)2837					
2838					8.3
2839	7.5				
2840					4.4
(1)2841					
2842			4.4		
2843					4.6
(2)2779		5.8			
(2)2780					4.5
(2)2784				5.3	
(2)2785		5.1			
(2)2786					4.6
(2)2787			4.7		
(2)2788	4.3				
(2)2789		4.0			
(2)2790					5.8
(2)2796		6.0			
(2)2798	5.1				
(2)2799					4.5
(2)2803		4.8			
(2)2804					5.5
(2)2805			5.6		

(1) Seedlings found dead - Nov. 4, 1938

(2) New seedlings tagged - Nov. 4, 1938

Reproduction Plot 3A

Seedling Number	Ash	Sassafras	Cherry	Hickory
6			41.6	
7	23.3			
8	21.5			
9	27.5			
10	18.8			
11	27.7			
12		9.3		
13	14.0			
15	20.1			
16	41.4			
17			20.8	
18	60.4			
19	48.4			
20	26.5			
21	13.6			
22			16.5	
23			35.8	
24	35.5			
26	40.6			
27	46.3			
28	24.5			
(1) 29				
30	57.5			
31	67.8			
32	59.4			
33	30.9			
34	38.2			
35	23.5			
36	19.6			
37	30.0			
38	48.4			
39	33.6			
40	73.6			
41	33.9			
42	11.9			
43	15.0			
44	41.5			
45	98.7			
46	15.4			
47	24.6			
48	21.3			
49	21.3			
51	47.5			
52	15.6			
53	66.4			
54	28.2			
55	22.6			
56	13.3			
57	17.7			
58	12.9			
59	73.1			
60	68.6			
61	34.1			
62	35.3			

Seedling Number	Ash	Sassafras	Cherry	Hickory
63	71.0			
64	36.3			
65	39.4			
66	11.9			
67	33.5			
68	78.6			
69	41.3			
70	59.6			
71	72.7			
72	55.1			
73	31.0			
74	18.8			
75	48.1			
77			75.5	
78	86.4			
79	63.4			
80	42.4			
81	26.7			
82	21.9			
83	20.1			
84	21.4			
85	26.4			
87	29.0			
88		64.0		
90	40.9			
91	36.4			
92	26.3			
93	80.4			
94	36.9			
95	32.0			
96	45.1			
97	66.5			
98	21.4			
99	19.0			
100	21.4			
101	38.6			
102	37.6			
103		45.8		
104	50.1			
105	36.5			
106	18.6			
107	89.2			
109	23.1			
110	26.6			
111	61.3			
112	33.6			
113	30.0			
114	61.4			
115	24.1			
116	50.0			
117	38.4			
118	20.8			
119	11.1			
120	18.2			
121	49.3			
122	23.5			
123	21.6			

Seedling Number	Ash	Sassafras	Cherry	Hickory
124	34.9			
125	49.9			
126	24.0			
127	23.0			
128	13.8			
14	41.0			
25	32.5			
2844	10.3			
2845	8.1			
2847	7.4			
2849	16.5			
2850	16.0			
2851	10.3			
2852	15.5			
2854	9.4			
2856	22.4			
2858	21.7			
2859	9.3			
2860	11.1			
2861	9.5			
2863	11.6			
2864	8.6			
2865	10.9			
2866	7.6			
2867	26.4			
2868	8.2			
2869	18.7			
2870	10.8			
2871	10.3			
2874	17.6			
(1)2875				
2876	18.1			
2878	12.5			
2879	35.4			
2880	14.9			
2881	14.3			
2883	12.2			
2884	13.6			
2885	11.8			
2886	13.7			
2890	11.5			
2891	17.1			
2892	19.0			
2893	3716			
2894		44.8		
2895	14.9			
2896	42,8			
2897	8.6			
2898	17.3			
2899	16.7			
2900	15.0			
2901	9.8			
2902	19.1			
2903	9.5			
2904	9.9			
2905	13.6			
2906				7.4

Seedling Number	Ash	Sassafras	Cherry	Hickory
2907	7.0			
2908		35.0		
2909	11.7			
2872	16.3			
2887				6.4
(2)2806	5.4			
(2)2807	7.2			
(2)2808	7.8			
(2)2812	7.9			
(2)2813		11.5		
(2)2814	6.8			
(2)2815	6.3			
(2)2816	12.0			
(2)2817				7.1
(2)2820	9.0			
(2)2821	8.3			
(2)2825	6.2			
(2)2826			7.5	
(2)2827	14.3			
(2)2828	7.1			
(2)2829	9.8			
(2)2830	7.5			
(2)2831	7.0			
(2)2832	6.8			
(2)2833		6.4		
(2)2834	7.3			
	20	3	1	

(1) Seedlings found dead - Nov. 5, 1938

(2) New seedlings tagged - Nov. 5, 1938

Reproduction Plot 3B

Seedling Number	Cherry	Ash	Sassafras	Oak
3108			58.1	
3109			45.0	
3111		8.8		
3112		30.6		
3113	18.5			
3114		10.5		
3115		16.1		
3116	16.3			
3117		11.7		
(1)3118				
3119		28.0		
3120		26.0		
3122		22.7		
3123		23.5		
3124		14.1		
3125		8.9		
3126		11.1		
3127		17.8		
3128		23.5		
3129			74.5	
3130		17.7		
3131		26.1		
3134			10.3	
(1)3135				
3136		7.6		
3138		11.7		
3139		9.9		
3140		27.3		
3141		18.6		
3143		10.0		
3144		25.3		
3145		14.4		
3146		10.4		
3149		11.2		
3150	24.9			
3152		10.0		
3153		22.3		
3154		16.1		
3155		24.5		
3156		42.6		
3157		8.6		
3159		17.5		
3160		9.8		
3161		11.5		
3162		18.5		
3163		12.0		
3164		13.4		
3165		9.5		
3166		13.0		
3167		14.2		
3168			46.5	
3169		17.3		
(1)3170				
3171		11.1		
3172		25.1		

Seedling Number	Cherry	Ash	Sassafras	Oak
3173		39.5		
(1)3175				
3176		40.4		
3177		30.8		
3178		14.0		
3179		33.4		
3180		20.4		
(1)3181				
3182		15.2		
3183		28.3		
3184		22.5		
3185		35.5		
3186		41.2		
(1)3187				
3188		21.0		
3189		21.5		
3190		25.4		
3191		39.9		
3192		31.4		
3193		25.4		
3194	31.1			
3195		30.1		
3196		22.9		
3197		34.8		
3198		18.3		
3199		10.5		
3200		19.1		
3201		59.8		
3202		50.2		
3204		32.7		
3205		24.0		
3208	36.4			
3209		32.6		
3210		28.3		
3211		45.0		
3212		15.1		
3214		27.8		
3215		32.3		
3216		13.8		
3217		19.2		
3218		17.3		
3219		12.9		
3220		17.8		
3221		60.3		
(1)3222				
3223		57.9		
3224		32.1		
3225		25.5		
3226		26.0		
3227		32.0		
3228		29.5		
3229			56.0	
3230		29.2		
3231			35.5	
3232		32.4		
3233		27.9		
3234		43.0		

Seedling Number	Cherry	Ash	Sassafras	Oak
3235		54.8		
(1)3236				
3237		26.4		
3238			58.4	
3239		58.1		
3240		20.0		
3242		39.2		
3243		57.8		
3244			14.0	
3245			8.0	
3246		52.0		
3247		62.1		
3248			46.0	
3249		29.7		
3250		60.5		
3251		46.4		
3252		20.8		
3253		16.3		
3254		13.0		
3255		15.9		
3257		13.5		
3258		10.0		
3259		19.9		
3260		19.3		
3261		37.0		
3262		16.1		
3263		31.9		
3264		15.2		
3265		19.3		
3266		51.1		
3267		41.5		
3268		22.0		
3269		38.0		
3270		15.0		
3271		13.6		
(1)3272				
(1)3273				
3274		12.7		
3275		17.5		
3276		33.0		
3277		16.9		
3278		14.6		
3279		10.8		
3280		36.6		
3281		14.9		
3282		45.2		
3283		40.0		
3284		24.1		
3285		15.7		
3286		20.0		
3287		36.6		
3288		24.5		
3289		17.4		
3290		13.6		
3291		13.6		
3292		23.0		
3294		37.9		
3295		50.0		

Seedling Number	Cherry	Ash	Sassafras	Oak
3296		49.5		
3297		42.2		
3298	41.8			
3299		48.2		
3300		15.5		
3301		10.2		
(1)3302				
3303			16.5	
3304			41.5	
3305		10.6		
3306		13.1		
3307		37.2		
3308			57.8	
3309		13.5		
3310		12.1		
(2)2754			6.4	
(2)2755		5.1		
(2)2756		7.3		
(2)2757		10.2		
(2)2758		8.3		
(2)2760		13.2		
(2)2762		9.5		
(2)2763		7.2		
(2)2764				5.7
(2)2766		10.0		
(2)2768		7.9		
(2)2769	11.5			
(2)2770		6.8		
(2)2771		7.7		
(2)2772		8.7		
(2)2773		7.1		
(2)2774		7.9		
(2)2775		7.4		
(2)2776		10.5		
(2)2777		10.2		
2778		9.0		

(1) Seedlings found dead - Oct. 29, 1938

(2) New seedlings tagged - Oct. 29, 1938

Reproduction Plot 8A

Seedling Number	Sassafras	Oak	Hickory
411		9.9	
412			8.8
413			9.0
415		7.2	
417			5.0
418			4.5
419			5.5
420		7.0	
421		7.3	
422			18.6
423			6.4
424			11.6
3048	25.7		
3049	35.6		
3050	30.2		
3051	29.5		
3053	27.9		
3054			9.3
3056	60.5		
3057	55.4		
3058	53.6		
(1) 3060			
3061	18.4		
3062	10.8		
3063	17.9		
(1) 3064			
3067	24.4		
3069	13.7		
3070	21.6		
3071			4.5
3072		39.1	
3073	19.3		
(2) 2672	18.3		
(2) 2673	5.1		
(2) 2674	6.4		
(2) 2675		8.1	
(2) 2676	10.7		
(2) 2678		6.7	

(1) Seedlings found dead - Oct, 15, 1938

(2) New seedlings tagged - Oct. 15, 1938

Reproduction Plot 9a

Seedling Number	Cherry	Hickory	Maple	Elm	Oak
167					49.9
168	24.7				
169	14.4				
172	11.0				
173		18.3			
175			8.4		
176			39.0		
177				18.5	
178	21.3				
179					14.1
180			20.0		
181	24.8				
182				37.6	
183	7.0				
184				77.3	
(1) 185					
186		10.2			
187	19.8				
(1) 188					
190		7.8			
(1) 191					
192			21.0		
193			29.5		
195			50.6		
196					7.6
197					23.8
198					35.0
199			71.5		
200				70.7	
201		22.3			
202					16.8
203					22.8
204			73.7		
205		29.2			
206	27.8				
207				60.2	
208			43.0		
209					24.3
212					8.5
213				59.4	
214					26.0
215	21.2				
216	25.3				
217		8.9			
218					10.4
219					25.3
2932				13.0	
2933					10.6
2935					5.4
(2) 2601		11.7			
(2) 2602	5.4				
(2) 2603				28.8	
(2) 2605		3.1			
(2) 2606				16.0	
(2) 2607		5.7			

Seedling Number	Cherry	Hickory	Maple	Elm	Oak
(2)2608				7.3	
(2)2611	5.5				
(2)2612		4.3			
(2)2613	7.8				
2931			9.5		

(1) Seedlings found dead - Oct. 7, 1938

(2) New seedlings tagged - Oct. 7, 1938

Reproduction Plot 9B

Seedling Number	Cherry	Sassafras	Maple	Oak	Hickory	Elm
221				18.3		
222	27.4					
223	15.3					
224	79.3					
225	13.7					
226	17.2					
227	14.8					
228	17.5					
229	21.0					
230	41.0					
231	20.5					
232	30.7					
233	28.5					
234	20.5					
236	20.5					
237	27.7					
238	29.0					
239	37.0					
240	38.5					
241	31.3					
242	19.7					
243	17.3					
244	40.2					
246	33.2					
247	16.7					
248	24.2					
249	25.5					
250	20.8					
251	13.7					
254	36.8					
255	12.7					
257	36.0					
258	39.8					
259	26.3					
260	32.7					
261	36.5					
(1) 262						
263	43.0					
264	35.7					
265	35.5					
266	24.2					
267	29.3					
268	31.0					
269	26.3					
270	15.0					
271	30.0					
272	27.0					
273	16.5					
275	19.5					
277	48.3					
279	9.3					
280	22.5					
281	15.5					
282	23.7					
283	43.3					
284	41.8					

Seedling Number	Cherry	Sassafras	Maple	Oak	Hickory	Elm
285	37.0					
286	20.5					
287	33.5					
288	28.7					
289	37.6					
290	21.1					
291	39.0					
292	24.7					
293	10.7					
294	10.5					
295	24.3					
299			15.0			
300	29.4					
301	10.8					
302	25.3					
303	11.2					
(1) 304						
(1) 305						
306	25.2					
307	12.3					
(1) 308						
309	35.0					
312	25.0					
314	38.4					
315	19.0					
316	7.6					
317	11.0					
319	13.7					
320	7.8					
321	15.3					
322					7.9	
326	25.3					
327	23.8					
328	17.5					
329	37.0					
330	20.0					
331	17.8					
332	25.6					
333	52.533					
334	38.0					
335	24.5					
336	18.2					
337	20.5					
338	34.3					
339	47.2					
3401	17.3					
341	20.2					
342	22.0					
343	16.9					
344	22.0					
345	29.5					
346	25.5					
347	29.6					
348	28.7					
349	21.8					
350	27.5					

Seedling Number	Cherry	Sassafras	Maple	Oak	Hickory	Elm
351	29.3					
352	24.5					
353	29.2					
354	25.7					
355	15.3					
356	38.8					
357	29.7					
358	37.5					
360	16.2					
362	13.3					
363	13.0					
364	35.0					
365						54.7
366	23.7					
367	25.3					
368	24.5					
370	16.5					
372	13.6					
373	17.5					
374	17.7					
375	15.3					
376	19.0					
377	18.7					
378	18.2					
379	19.2					
380	11.5					
2937	18.1					
2938	20.9					
2939	8.7					
2940	8.0					
2941	11.5					
2942	7.4					
2943	11.3					
2945	18.9					
2946	9.4					
2947	10.5					
2949	18.0					
2950	17.5					
2951	13.7					
2952	12.0					
2953				8.3		
2954	9.5					
2955	9.0					
2956	10.1					
2957	11.7					
2958				~~7.0~~		
2960	9.5					
2961	17.0					
2964	21.8					
2965	14.7					
2966	17.7					
2967	17.0					
2968	10.6					
2969	10.6					
2971	15.0					
2972	11.5					
2973	11.0					

Seedling Number	Cherry	Sassafras	Maple	Oak	Hickory	Elm
2974	22.5					
(1) 2976						
2977	14.2					
2978	8.5					
2979				8.8		
2980	14.0					
2981	15.6					
2982		28.5				
(1) 2984						
2986	19.0					
2987	8.7					
2988	10.1					
2989	15.0					
2990	21.8					
2991	15.5					
2993	19.0					
2994	9.0					
2995	18.7					
2996	39.5					
2997				12.0		
2998	28.3					
(1)2999						
3000				6.3		
3002	17.5					
3003	27.2					
3004	23.5					
3005	13.5					
3006	22.4					
3007	20.2					
3011	24.5					
3012	21.2					
3013	19.0					
301417.0	17.0					
3015	22.0					
3016	20.3					
3017		46.3				
3018		47.5				
(2)2614		5.3				
(2)2615	3.2					
(2)2616	3,1					
(2)2617	5.0					
(2)2618	4.6					
(2)2619	5.5					
(2)2620		5.5				
(2)2621	7.9					
(2)2622	7.7					
(2)2623	7.0					
(2)2624	17.2					
(2)2625	9.8					
(2)2626		4.8				
(2)2627	6.5					
(2)2630		4.7				
(2)2631	7.5					
(2)2632						7.5
(2)2633	4.7					
(2)2640	5.5					
(2)2639		6.3				

Seedling Number	Cherry	Sassafras	Maple	Oak	Hickory	Elm
(2)2641	12.7					
(2)2642	6.8					
(2)2643	8.3					
(2)2644		6.0				
(2)2645		7.7				
(2)2646	8.3					
(2)2647	6.8					
(2)2648	9.7					
(2)2649	27.5					
(2)2656	13.5					
(2)2659	26.3					
(2)2628		6.0				
(2)2636	4.1					
(2)2637	8.6					
(2)2638		4.3				

(1) Seedlings found dead - Oct. 7, 1938

(2) New seedlings tagged - Oct. 7, 1938

Reproduction Plot 9C

Seedling Number	Maple	Oak	Cherry	Hickory
381	5.0			
382			7.6	
383		4.5		
384			14.4	
385		7.5		
388	19.5			
389	5.1			
390			9.4	
392			5.3	
(1) 393				
394	17.4			
(1) 396				
397	20.4			
399			8.1	
401		9.5		
402			12.7	
403	11.8			
404			18.3	
405			23.2	
406	14.6			
(1) 407				
409			8.3	
410		4.9		
408				4.0
3022		5.3		
3023		7.0		
3024		4.6		
3027			4.0	
3028		5.0		
3029			6.4	
3030		7.8		
3032				5.6
3034			13.5	
(1)3035				
3036			12.4	
3037	32.6			
3038		5.9		
3039			7.6	
3040			8.1	
3041			7.3	
3042	5.2			
3043			31.9	
3044		9.7		
3045			18.3	
(2)2650	3.1			
(2)2652		3.7		
(2)2655		6.3		
(2)2657	3.6			
(2)2658		5.4		
(2)2659	7.6			
(2)2660		6.2		
(2)2663		2.8		
(2)2664				3.9
(2)2667		5.5		
(2)2666			6.7	
(2)2668		3.7		

Seedling Number	Maple	Oak	Cherry	Hickory
(2)2669		5.6		
(2)2670			5.7	
(2)2671		3.9		
(2)2677		9.1		

(1) Seedlings found dead - Oct. 15, 1938

(2) New seedlings tagged - Oct. 15, 1938

Reproduction Plot 10A

Seedling Number	Cherry	Sassafras	Ash	Oak
129	10.8			
131	10.0			
132	10.1			
133	12.5			
134	23.4			
135			14.6	
136	21.5			
137	12.1			
138	9.1			
139	27.0			
140		24.7		
141	19.7			
(1) 143				
144	35.4			
145	29.8			
147	33.2			
148	18.6			
150	26.3			
151	16.2			
152	18.6			
153	7.8			
154	12.6			
155	14.8			
156	10.7			
157			11.5	
158	13.5			
159	20.4			
160	15.4			
162	19.3			
163	12.5			
164	24.3			
165	17.1			
166	39.6			
191	16.5			
2910		21.0		
2912	8.3			
2913	4.2			
2914		21.0		
2915		11.0		
2916		17.5		
2917		4.6		
2918		7.0		
(1)2919				
2921		8.5		
(1)2922				
2923			4.6	
2925			5.3	
2926		5.0		
2927		5.2		
2928		5.4		
2930	6.8			
(2)2714		7.0		
(2)2715				3.3
(2)2716		7.8		

Seedling Number	Cherry	Sassafras	Ash	Oak
(2)2717		5.7		
(2)2718				7.3
(2)2719		10.2		
(2)2721				3.5
(2)2722				4.0
(2)2725				2.7
(2)2727	4.4			
(2)2728		9.3		

(1) Seedlings found dead - Oct. 22, 1938

(2) New seedlings tagged - Oct. 22, 1938

Reproduction Plot 10B

Seedling Number	Cherry	Oak	Sassafras	Hickory
425	5.5			
428	8.2			
431	5.0			
432	14.3			
433	6.5			
434	6.9			
435	6.0			
436		3.9		
437	6.4			
439	6.1			
440	8.6			
441	7.0			
442	5.7			
443	6.2			
444	7.8			
445	10.4			
446	10.1			
447	9.8			
448	8.9			
450	9.6			
451	8.1			
452	13.4			
453	18.9			
454	9.5			
455	6.3			
456	8.0			
457	8.1			
458	4.3			
459	12.9			
460	7.2			
461	7.5			
462	10.4			
463	12.1			
464	11.3			
465	11.5			
466	12.6			
467	13.5			
468	9.5			
471	135			
472	12.1			
473	6.1			
474	15.4			
475	20.5			
476	8.1			
(1) 477				
478	11.8			
479	8.5			
(1) 480				
482	11.4			
483	8.7			
484	10.9			
485	11.2			
487	11.0			
488	14.1			
489	15.4			

Seedling Number	Cherry	Oak	Sassafras	Hickory
494	11.3			
495	13.0			
496	14.4			
449	9.0			
501	10.9			
509	16.1			
510	10.4			
511	12.5			
515	10.7			
517	9.8			
518	10.1			
519	12.3			
521	13.2			
522	12.6			
525	17.7			
529	9.6			
530	10.0			
532	8.6			
533	12.0			
534	6.1			
536	11.5			
537	16.9			
538	7.8			
539	11.9			
540	13.5			
542	15.6			
544	19.3			
545	7.6			
546	13.7			
547	8.9			
548	15.2			
549	15.5			
552	12.0			
553	12.7			
555	10.3			
557	10.3			
558	14.1			
559	13.6			
560	14.5			
561	11.4			
562	9.4			
563	13.3			
564	11.7			
565	11.6			
566	6.0			
567	8.0			
568	6.3			
569	10.6			
570	13.9			
572	12.2			
573	10.4			
574	12.9			
575	11.8			
576	21.1			
577	9.3			
578	14.1			
579	11.4			

Seedling Number	Cherry	Oak	Sassafras	Hickory
580	12.1			
581	11.3			
582	10.8			
583	13.0			
584	7.6			
585	5.1			
586	22.4			
587	19.4			
588	9.8			
589	14.3			
590	9.9			
591	12.4			
592	26.5			
593	20.5			
594	50.1			
595			47.3	
597			57.8	
596	14.0			
600			59.1	
601	15.8			
602	10.0			
604	8.0			
605	8.1			
606	8.6			
607	0.8			
608	8.4			
609	13.3			
610	12.0			
611	14.6			
612	7.1			
613	9.9			
614	12.1			
615	13.5			
616	10.5			
617	0.8			
618	4.9			
619			27.8	
6201	10.6			
621	10.3			
622	16.0			
623	11.8			
624	12.3			
625	7.8			
626	11.7			
628	8.6			
629	10.4			
630	14.0			
631	9.3			
632	22.0			
633	13.6			
634	10.5			
635	11.9			
636				6.0
637			27.9	
(2)2079	5.9			
(2)2080		5.8		
(2)2081	7.9			

Seedling Number	Cherry	Oak	Sassafras	Hickory
(2)2683	6.1			
(2)2684		4.3		
(2)2685	6.3			
(2)2686	2.9			
(2)2687	11.1			
(2)2688	3.6			
(2)2692	5.9			
(2)2693	5.0			
(2)2694	3.4			
(2)2695	4.9			
(2)2696		3.6		
(2)2697	2.9			
(2)2698	6.1			
(2)2699	14.1			
(2)2700			4.5	
(2)2701	3.4			
(2)2702	4.8			
(2)2703	7.3			
(2)2704	7.8			
(2)2705	6.2			
(2)2706	5.0			
(2)2707			9.0	
(2)2708	5.6			
(2)2709			9.4	
(2)2710	5.4			
(2)2711	5.9			
(2)2712			6.5	
(2)2713			7.6	
3074		3.9		
3075	14.6			
3077	11.8			
3078			18.9	
3079		3.5		
3082	7.6			
(1)3083				
3084	6.0			
3086	6.3			
3087			29.3	
3088			40.0	
3090	6.8			
3091			27.9	
3092			40.5	
3094	18.6			
3095	10.6			
3096			60.8	
3097			38.2	
3098			27.5	
3100			57.5	
3101			67.3	
3102			49.0	
3103			48.3	
3104	7.1			
3105	13.0			
3106			28.4	
3107			21.8	

(1) Seedlings found dead - Oct. 22, 1938

(2) New seedlings tagged - Oct.22, 1938

Reproduction Plot 10C

Seedling Number	Cherry	Ash	Hickory	Beech	Sassafras
3311	17.7				
3312		23.3			
3313		24.0			
3314	12.0				
3315		58.0			
3316		24.5			
3317		17.8			
3318		22.5			
3319	8.4				
3320		12.5			
3321		19.8			
3322		48.3			
3323	7.1				
3324		17.1			
3325		41.6			
3326		45.0			
3327		35.4			
3328		10.5			
3329		41.4			
3330		13.0			
3331		55.1			
3332		11.6			
3333				23.7	
3334	10.9				
3335	14.1				
3336	11.1				
3337	11.1				
3338		59.0			
3339		41.5			
3340		13.6			
3341		38.0			
3342		28.9			
3343		52.8			
3344		27.3			
3345		20.9			
3346		20.1			
3347		21.4			
3348		58.1			
3349		44.0			
3350		68.8			
3351		54.7			
3352		70.1			
3353		43.6			
3354		15.5			
3355		104.5			
3356		71.5			
3357		35.7			
3358		112.4			
3359		14.0			
3360		43.8			
3361		89.0			
3362		41.8			
3363		38.6			
3364		21.2			
3365		75.5			
	8	(31) 46		1	

Seedling Number	Cherry	Ash	Hickory	Beech	Sassafras
3366	26.6				
3367		22.3			
3368		81.7			
3369		36.1			
3370		34.4			
3371		102.2			
3372		44.6			
3373		34.2			
3374		41.4			
3375		90.9			
3377		71.4			
3378		75.2			
3379		42.5			
3380		102.3			
3381		49.2			
3382		83.4			
3383		76.5			
3384		51.1			
3385		32.4			
3386		52.7			
3387		43.6			
3388		85.5			
3389	22.6				
3390		55.6			
3391		43.3			
3392		22.2			
3393		49.8			
3394	10.4				
3395	18.9				
3396	85.4				
3397	17.6				
3398		58.0			
3399					26.1
3400		60.9			
3401		81.3			
3402	22.7				
3403		70.8			
3404		24.1			
3405		93.5			
3406		19.9			
3407		78.4			
3408		75.1			
3409				21.4	
3410		53.8			
3411		83.5			
3412		99.4			
3413					82.9
3414		64.8			
3415		75.9			
3417		69.6			
3418		41.9			
3419		16.0			
3420		101.6			
3421		25.3			
3422		28.6			
3423		26.8			

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Seedling Number	Cherry	Ash	Hickory	Beech	Sassafras
(2)2726	5.2				
(2)2729	6.8				
(2)2730	5.4				
(2)2732	3.6				
(2)2733	11.8				
(2)2734	10.1				
(2)2735	6.6				
(2)2736	5.4				
(2)2737	5.9				
(2)2738		7.3			
(2)2739	7.9				
(2)2742		62.4			
(2)2743		7.8			
(2)2744	3.3				
(2)2745			6.8		
(2)2746		9.9			
(2)2747			7.4		
(2)2749	6.1				
(2)2751	7.4				
(2)2752	5.0				

(1) Seedlings found dead - Oct. 28, 1938

(2) New seedlings tagged - Oct. 28, 1938

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3. Hoffmann, J.V. - 1917 - " Natural Reproduction from Seed Stored in the Forest Floor ", Jour. of Agri. Research, Oct.1 , p. 19