SOME NURSERY INVESTIGATIONS WITH WHITE SPRUCE AND RED PINE

THESIS FOR THE DEGREE OF M. S.

Donald James Weddell

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THESIS

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THESIS

Submitted to the Faculty of the Michigan State College in partial fulfillment of the requirements for the degree of Master of Science in Forestry.

by

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Introduction

More than 100,000 acres are devoted to the production of nursery stock in the United States. Thirty-five of the states operate nurseries, some of the states having two to five separate units. Ten to twelve nurseries are operated by the Federal government and private ones are scattered throughout the country.

Differences in soil, temperature, elevation, and rainfall create distinct problems in nursery management. Nursery problems must be solved for each particular nursery and for this reason the nursery business is fast becoming specialized.

For the purpose of working out some of the problems of nursery practice applicable to the Michigan State College nursery, several experiments were carried out during 1930 and 1931. This included work on thinning seed beds, root pruning seedlings, storage methods, and the control of the strawberry root weevil.

Red pine (Pinus resinosa) and white spruce (Picea glauca) seedlings were used in all the experiments. These species are distinct in habit of root development and of growth. In its initial stage the red pine is a shallow rooted specie and has an open crown. The white spruce, in its initial stage, is a deep rooted specie and has a fairly compact crown.

All the seedlings of each specie were the same age at the beginning of the experiments, all being taken from the same seed bed.

Thinning.

For economic reasons, most nurserymen have a tendency to sow their seed beds too thickly, with a resulting loss in quality of trees. According to Toumey and Korstian (17)[1], "Too dense seeding causes the resulting seedlings to be tall, slender, and weak." Wahlenberg (19) says that it is obvious that seedlings grown in dense stands can not develop as well as those grown without crowding.

In a series of experiments carried on at the Savenac nursery in northern Montana, Wahlenberg (19) has clearly demonstrated the value of growing the seedlings at the proper density. He carried on his experiments using western yellow pine, western white pine and Ingelmann spruce. His conclusions are as follows: "(a) The stem diameter of 1-0[2] seedlings decreased 0.1 mm. for each increase of about 44 trees per square foot. The height growth of 1-2 transplants in the nursery decreased 0.1 inch for each increase of about 24 seedlings per square foot of seed bed. The number of rootlets on 2-0 stock decreased by one for each increase

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1. Numbers in parentheses refer to 'Literature Cited.'
2. The figures 1-0, 2-0, 2-1 refer to the number of years the stock has been in the different beds. The first number refers to the number of years in the seed bed and the second, to the number of years in the transplant bed.

of about 14 seedlings per square foot.

(b) Two-year old western white pine grown in dense stands were much smaller, more slender, and slightly taller than those having more room.

(c) With 3-0 Engelmann spruce, increases in density were accompanied by decreases in characteristics desirable for planting stock."

To determine the value of the proper density of seed beds in the Michigan State College nursery a series of plots, thinned to different densities was laid out during the fall of 1930. These plots were laid out in beds of both the red pine and the white spruce two-year-old seedlings.

One section of each bed was laid out into three plots, each four feet by four feet, separated by a two feet by four feet check plot. The three plots were thinned to 20-40, 60 seedlings per square foot respectively. The intervening check plots remained unthinned. (See Figs. 1,2,3.).

Before thinning, the white spruce beds had a density of 376 trees per square foot and the red pine beds had 130 trees per square foot.

In thinning the plots it was especially desirable that the root systems of the remaining trees be not disturbed. Loosening the soil around the roots might have affected the subsequent development of the trees and pulling the trees to be removed might have broken off some of the roots of he remaining trees and thus acted as a root pruning. To obviate these factors the seedlings to be removed were cut off at the ground line with scissors instead of being pulled, thus leaving the roots of the remaining trees undisturbed.

After growth ceased in the fall, 50 trees from each plot, including the check plot, were dug. No attempt at selection was made; instead, the first 50 trees dug were taken to be representative of the plot. In this way a fairer comparison of the various plots was made.

The tops and the roots were weighed separately, the division being made at the ground line. The tree of average weight was obtained by dividing the total weight by 50. The current height growth of the average tree, in each plot, was also measured. The results for the different plots are given in Table I.

Table I. The effect of thinning on the development of the top and roots of white spruce and red pine seedlings.

Number of seedlings per sq. ft.	White Spruce Top	White Spruce Roots	White Spruce Ratio T/R	Red Pine Top	Red Pine Roots	Red Pine Ratio T/R
	Weight in grams			Weight in grams		
Check*	1.21	.38	3.2	6.33	1.04	6.1
60	1.85	.85	2.2	6.78	1.18	5.7
40	2.38	1.20	2.0	8.59	1.64	5.3
20	4.33	2.00	2.2	8.11	2.12	4.0

Growth, in inches, of average tree

	White Spruce	Red Pine
Check	2.6	4.5
60	1.8	4.7
40	2.0	4.1
20	2.8	3.0

*White spruce - 376 - Red Pine 130

According to Wahlenberg (20) a low top-root ratio indicates a better type of planting stock than a high ratio.

Korstian and Baker (7) say, "The best criterion of stock suitable for field planting is the balance between the top and the root, which is best expressed by weight. The best class of planting stock is that which has a small top and a large fibrous root system."

Show (15) elaborates on this as follows,".... the most promising criteria were found to be the weight of top and roots and the ratio between the two, or $\frac{\text{weight top}}{\text{weight roots}}$. 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 heaviest root system is able to absorb more moisture and hence under field conditions has a higher chance of survival. Of several groups of equal weight, that with the lowest ratio of weight of tops to weight of roots will have the highest survival."

According to Table I, thinning the seed beds of both species shows a beneficial result. The white spruce, thinned from 376 seedlings per square foot to 60 per square foot, shows a decrease in ratio of 1.0. No appreciable difference in the toproot ratio between the different densities of the white spruce can be noted, but the red pine results show a decrease in ratio for each decrease in number of seedlings per square foot. The irregularities in these data are probably due to the limited sampling.

Table I also shows that the red pine seedlings in the denser plots grew taller than those in the thinned plots. A general trend upward in height growth, from the plots thinned to 20 seedlings per square foot to the unthinned plots, can be noted. The trees in the thinned plots were developing larger root systems while those in the unthinned plots were being crowded by the surrounding trees and having to fight for light and food.

The results from the white spruce plots, with the exception of the plot thinned to 50 seedlings per square foot, show the same general trend in growth as do the red pine plots. The plots thinned to 50 seedlings per square foot seem to be erratic and do not follow the general trend.

Before the seedlings were dug, the plots were studied to see the effect of the thinnings. In the plots of both the red pine and the white spruce that were left unthinned, the plants appeared taller and more spindly, and also appeared in a less thrifty condition than those in the thinned plots. (See Figs. 4,5,6.) The foliage of the plants in the unthinned plots was yellowish green as compared to the dark green color of the plants in the thinned plots. The yellowish color was probably due to a chlorotic condition resulting from a deficiency of certain mineral salts (14). The chlorosis was much more noticeable in the spruce beds than in the red pine beds.

The white spruce plots showed a significant effect of thinning. In the unthinned plots approximately two-thirds of the trees were killed by the strawberry root weevil

(*Brachyrhinus ovatus*), while in the thinned plots none of the trees were attacked. (See Figs. 7 and 8). The weevils seem to prefer the shade of the plants and do the most damage where the seedlings are thickest. A discussion of the control of this insect will be taken up later in this thesis.

To determine the proper density of seed bed, trees from various plots should be planted in the field and yearly measurements made of the growth and survival of the trees from each plot. In this manner the proper density of seed bed for each specie could be determined.

Conclusions

Thinning the seed beds of both species proved beneficial, the top-root ratio of the white spruce being lowered 1/3 from a ratio of 3.2 to 2.2, from the unthinned to the thinned plots, and the ratio of the red pine seedlings being lowered 1/5 from 3.4 to 2.1, from the unthinned to the thinned plots.

Thinning the plots also lessened the damage caused by the strawberry root weevil, no seedlings being injured in the thinned plots while approximately two-thirds of those in the unthinned plots were killed.

Root Pruning

To determine the value of pruning the roots of seedlings before transplanting, three lots of ten trees each, of red pine and white spruce were root pruned to different lengths and then transplanted in regular transplant beds. A fourth lot of each specie, unpruned, was transplanted at the same time, as a check.

The roots of the first lot were left unpruned to act as a check. One-third, one-half and two-thirds, respectively, of the roots of the other lots were cut off. (See Plates I and II). After pruning, the trees were planted in the transplant beds, the trees being spaced four inches apart in the rows. The transplant rows were six inches apart.

The following fall all the trees were dug, the dirt washed off the roots, and the trees weighed. (See Plates III and IV).

The weights were obtained by severing the roots from the tops at the ground line, and weighing each part separately. The weight of the average tree in each lot was obtained by dividing the total weight of all the trees by the number of trees. The ratio between the weight of the top and the weight of the roots was also derived.

The weight of the average tree, and the ratio between the top and the roots, for each lot and for each specie, are shown in Tables II and III.

In the discussion of thinning seed beds, a low top-root ratio was mentioned as indicating a more desirable type of planting stock than a high ratio, and the top-root ratio as the best criterion for the comparison of nursery stock. (See page 4.)

Table II. The effect of root pruning on the development of the top and roots of red pine.

Amount of root cut off	Top Weight in grams	Roots Weight in grams	Ratio T/R
None-check	7.8	5.5	1.4
One-third	8.2	4.7	1.8
One-half	7.2	4.8	1.5
Two-thirds	5.4	2.8	1.9

Table III. The effect of root pruning on the development of the tops and roots of white spruce.

Amount of root cut off.	Top Weight in grams	Roots Weight in grams	Ratio T/R
None-check	3.1	2.4	1.3
One-third	2.8	2.0	1.4
One-half	3.0	1.9	1.6
Two-thirds	3.0	2.6	1.2

Using the top-root ratio as a basis for comparison, the white spruce seedlings (Table III) with two-thirds of the roots cut off gave the best results. However, the trend in ratio seems to be from the check lot to the lot with the heavier cut roots. The red pine results (Table II) also indicate a trend from the trees with the uncut roots to those with the heavier cut roots. The results from the lot with one-half of the roots cut off seem to be erratic, due probably to an insufficient number of trees.

There seems to be a variance of opinion between different writers in regard to the value of root pruning stock which is to be transplanted. Jan uch (6), working with western yellow pine and Jack pine says, "Root pruning has not shown any advantage to warrant its continuance. Cutting off the prominent tap root of yellow pine causes such a shock to the seedling that its ill effect is continued throughout the year in the transplant bed and the first year in the field." Fox (8), writing of nursery practices in Belgium says, "Interesting tests were made in trimming the roots of two-year-old seedlings before transplanting. The thriftiest plants were obtained from those with uncut roots, a fact which seems to be at variance with the practice in some of the German nurseries." According to Olson (11), "To neglect root pruning when the trees are lifted is to defeat the principal purpose of transplanting. Proper pruning is important and fortunately simple." Tillotson (16) says, "Root pruning facilitates transplanting and to some extend it promotes the formation of a compact, well developed root system."

The average growth during the current year was also measured. The measurements are shown in Table IV.

Table IV. The effect of root pruning on the growth of white spruce and red pine.

Amount of root cut off	White spruce	Red pine
	Growth in inches	
None-check	2.7	2.4
One-third	3.2	2.2
One-half	3.0	1.5
Two-thirds	2.5	1.7

The growth of the red pine shows a tendency to decrease as the amount of roots cut off increases. The exception to this general trend is in the lot with one-half of the roots cut off. The results from this lot seem to be erratic as they were when the top-root ratio was figured.

With the exception of the check plot, the white spruce lots show the same trend as the red pine, a decrease in top growth with an increase in amount of roots cut off.

The question is often raised as to the value of transplanting seedlings. Wahlenberg (19) says, "Results of experiments with western yellow pine and western white pine show that .....transplants are usually prefered to seedlings..." Tillotson (16) says, "Transplanting, like root pruning, has for its object the production of stock which is most likely to succeed in the field planting, particularly on inhospitable sites. Its effect is to check height growth and to stimulate development of the lateral feeding roots." From Table IV it can be seen that the author obtained the same results in the retardation of height growth in the red pine lots. The author of Bulletin 49 of the Pennsylvania Department of Forests and Waters (9) writes, "Trees suitable for reforestation purposes can be grown without transplanting." According to Olson (11), ..."Through timely widening of the growing space it (transplanting) produces not only strong and sturdy, but also uniformly developed roots and crown structure."

By comparing the results of the thinning experiment with that of the root pruning experiment the value of transplanting seedlings is shown. These results show that more than just the widening of the growing space is needed to give the best results.

The comparison of the two experiments is shown in Table V.

Table V. The effect of thinning and transplanting on the top-root ratio of white spruce and red pine.

Treatment of seedlings	White spruce	Red pine
	Top-root ratio	
Unthinned	6.1	3.2
Thinned to 60 per sq. ft.	5.7	2.2
" " 40 " " "	5.3	2.0
" " 20 " " "	4.0	2.2
Transplanted - not pruned	1.4	1.3
" pruned one-third	1.8	1.4
" " one-half	1.5	1.8
" " two-thirds	1.9	1.2

This table shows a considerable lowering of the top-root ratio from the thinned, but not transplanted seedlings, to the transplanted seedlings. Previously, (Page 4) it has been mentioned that the lower the top-root ratio the better the planting stock.

Using the top-root ratio as a basis for comparison, transplanting does improve the stock for planting. In the white spruce plots a decrease in ratio from 4.0, that of the plot thinned to 20 seedlings per square foot, to 1.4, the ratio of the transplanted but not pruned plot, is significant. The improvement in the white spruce is more noticeable than in the red pine. Two factors may be the cause of this difference: the difference in the density of the original seed beds, the difference in the rooting habit of the two species.

Storage

Many times it is necessary to store nursery stock, either over winter or for a short period in the spring.

There are several reasons why it may be necessary to store the stock over winter. The stock may be wanted for spring planting before it can be dug in the nursery, the stock may have been dug for a fall order and the order cancelled, or the planting season may come to an unexpected early end in the fall with some of the stock left unplanted.

Spring storage may be necessary to utilize some of the area in trees for new seed beds, or the stock may be wanted for late spring planting, after the growth has started in the nursery.

There are several methods in common use for the storage of nursery stock: heeling-in in the open, heeling-in under cover, in ice or snow pits, in cold storage.

To determine the best method of storing trees in cold storage, and also the best material to use for packing, an experiment was started during the fall of 1950, using two-year old white spruce and red pine planting stock.

The procedure, which was the same for both species, was as follows: On November 11, 1950, 310 two-year-old seedlings were dug. These were separated into five lots of 62 trees each. Lot A was planted at the Kellogg Farm near Augusta, Michigan. The following day Lots B and C were stored in the college root cellar, Lot B being packed in moss and Lot C packed in sand. Lots D and E were stored in the cold storage room of the horticultural building, Lot D in moss and Lot E in sand.

The temperature of the cold storage room is automatically controlled and ranges between 32°F and 40°F. During the winter the packing material in both storage places was kept moist, water being added at irregular intervals. In storing trees in any material constant watch must be kept to see that the packing material does not dry out, for if it once becomes dry, the roots of the trees will also become dry, and dry roots mean dead trees.

A record was kept of the temperature and relative humidity of the root cellar during the time the trees were stored there. The temperature ranged from 61°F to 71°F. The relative humidity varied from 68.3 percent to 84 percent. At no time did the relative humidity become low enough to cause excessive transpiration.

On April 2, 1951, 124 more seedlings were dug and separated into two lots of 62 trees each. Lot F was packed in moss and stored in the root cellar, and Lot G was packed in moss and stored in the cold cellar.

Sixty two trees (Lot H) were dug April 15, 1951. These, with all the other lots, were planted the following day at the Kellogg Farm.

The only manner in which the storage methods and packing materials could be compared was to plant the trees, let them grow for at least one growing season, and then compare the rate of growth, as well as the survival per cent of the various lots.

All the trees were planted in the same field, under the same conditions with regard to soil, moisture, slope, aspect, method of planting and spacing. In other words the only variable was the time of digging and the method of storage.

The soil in which the trees were planted is classified as the Bellefontaine sandy loam (12). This soil tends to be rather gravelly, mixed with clay on the surface, and is underlaid by a horizon of sand, gravel, and clay. It is possible that the "A" horizon[3] on this area has been completely eroded, leaving only the "B" and "C" horizons.

The soil plays a very important part in planting operations and in many cases it determines the success or failure of the operation.

At the time of the spring planting a check of the planting done the previous fall was made. At this time approximately 15 per cent of the trees had been heaved out of the ground and were lying on the surface.

Heaving is due to the alternate freezing and thawing of the soil moisture. Haasis (5) says, "In general, the soils having the greatest moisture content are those which show the greatest amount of heave." Haasis also says that the greatest damage to seedlings, due to heaving, is on a soil classified as 'stony-clayey'. By classifying the soil of the experimental area on the same basis that Haasis used,

3. This is according to the Glinka classification in "The Great Soil Groups of the World", translated from the German by Marbut. Edward Bros. Ann Arbor, Mich. 19[illegible]4

the Bellefontaine sandy loam would also be classified as a 'stoney-clayey' soil.

The excessive amount of heaving on the experimental area is probably due to the large water-holding capacity of the soil. In most cases, fall planting should not be attempted on soils which contain much clay.

The two years that the seedlings were in the seed beds, as well as the year they were growing in the field were exceedingly dry. The United States Weather Bureau maintains a co-operative observing station at the Kellogg Farm and at this station a monthly record of the precipitation is kept. The record for 1929, 1930, and 1931 is charted on page 20. From this chart it is seen that 1929 was 9.5 inches below normal in rainfall, 1930 was 13.71 inches below normal, 1931, up to the time of planting, was 2.1 inches below normal, and up to the time growth ceased in the fall was 9.6 inches below normal.

After growth ceased the following fall, a count was made to determine the survival of the various lots. This count showed the loss in the white spruce lots to be so great that they were not considered further. The survival percentages of the red pine are shown in tabular form in Table VI and in graphical form in Fig.9.

The growth of each surviving tree, for the current year, was measured, but due to the low survival of each lot, no conclusions based on growth can be made.

The poor survival in all the lots may be due to the deficiency of rainfall, the experimental area being so dry preceding and following planting that only the most vigorous trees could survive.

Table VI. The effect of different storage methods on the survival, in the field, of red pine seedlings.

Lot	Date lifted	Place stored	Packing material	Date planted	Survival: Number of trees	Survival: % of total planted
A	Nov. 11			Nov. 12	15	12.09
B	"	R.C.	Moss	Apr. 16	29	23.38
C	"	"	Sand	"	27	21.72
D	"	C.C.	Moss	"	21	16.93
E	"	"	Sand	"	6	4.83
F	Apr. 2	R.C.	Moss	"	43	34.67
G	"	C.C.	"	"	30	24.19
H	Apr. 15			"	10	8.06

R.C. - Root Cellar C.C.- Cold Cellar

The trees that were dug in the spring and stored in moss for two weeks previous to planting show the best survival. These trees were able to absorb considerable moisture from the moss and in this way improve their physical condition. With the improved physical condition the trees were better able to withstand the hardships of the dry planting site.

The trees that were dug in the spring and planted at once were very dry when planted, having been growing during two years of drought. Planted, as they were, on an exceedingly dry site and growing during a third dry year, their chance for surviving was very small.

The trees that were dug in the fall and planted at once were also very dry when planted. Furthermore they also were planted on a very dry site. The survival percentage of this lot was also lowered by the loss due to frost heaving.

The trees that were stored all winter show almost as good survival as the trees stored for two weeks in the spring. The former trees also had a chance to absorb considerable moisture from the packing material and thus were better able to withstand the dry conditions after planting than those trees that were planted as soon as dug.

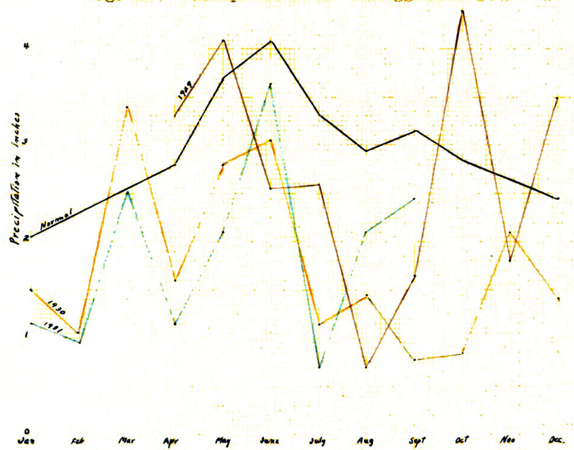
The trees packed in moss show a slightly higher survival percentage than those packed in sand. The moss was able to absorb and hold more of the water than was the sand. The sand has a tendency to cake and thus cause the water to run off instead of percolating through to the roots of the trees.

Fig. 9 The Results of Different Storage Methods on the Survival of Red Pine Seedlings

LEGEND

Lot	Dug	Stored	Material	Planted
F	Apr. 2	Root Cellar	Moss	Spring
G	Apr. 2	Cold Storage	Moss	Spring
B	Nov. 12	Root Cellar	Moss	Spring
C	Nov. 12	Root Cellar	Sand	Spring
D	Nov. 12	Cold Storage	Moss	Spring
A	Nov. 12			Fall
H	Apr. 15			Spring
E	Nov. 12	Cold Storage	Sand	Spring

Fig. 10 Precipitation at Kellogg Farm



A New Control for the Strawberry Root Weevil[4]

The strawberry root weevil (*Brachyrhincus* [*Otiorhynchus*] *ovatus*), long a serious pest in the strawberry industry, is attacking in great numbers, the coniferous nursery stock of the Michigan State College nursery. The root weevil, also known as the crown girdler, first appeared in epidemic form in the nursery during the spring of 1929. Since that time it has increased in numbers and in extent of damage.

The strawberry root weevil, an introduced specie, probably first came from Europe, though it has been reported in both Europe and northern Asia (1).

One of the first outbreaks in this country occured in Massachusetts in 185[illegible]. Since that time it has been reported from Pennsylvania (1874), Michigan (Detroit 1875), New Hampshire (1878), southern Michigan (188[illegible]), Illinois (1883), Ohio (189[illegible]), Indiana (189[illegible]), Wyoming (1893), New Mexico (1894), Minnesota (1895), Montana (1897), and Washington (1904). Nova Scotia (1889), Quebec (1892), and British Columbia in the Dominion of Canada also have reported outbreaks of the pest ([illegible]).

The adult weevil is dark brown to black in color and varies in length from three-sixteenths to five-eights of an inch. When the weevil first emerges from the pupal stage it is nearly white, soon becomes light brown, changes to

4. Permission was granted by letter of Dec. 8, 1931, from the Graduate Council, to use this portion of the thesis for publication in the Journal of Forestry.

darker brown and finally becomes very dark brown. The shell is very hard. Because the elytra, or wing covers, are fused together, the weevil is unable to fly.

The eggs are very minute, measuring about .25 mm. long. When first laid they are milky white but soon change to a pale brown color.

The larvae are white in color, with a brownish colored head. When first hatched they are about .5 mm. long. The full grown larvae are about three-eights of an inch long.

The larvae change to pupae in small, burrow-like cells in the ground. The pupae are white in color and have the various appendages and body parts of the adult weevil.

The weevil is known to feed on many of the cultivated plants as well as on the grasses and on various species of trees. Downes (3) mentions the weevil feeding on strawberries, loganberries, sorrel, timothy, white clover, snowberry, oak, hemlock, and balsam. Mote and Wilcox (10) add to this list June grass and quack grass.

In the nursery at Michigan State College the weevil has been found working in beds of Norway spruce, white spruce, western white pine, red pine, northern white pine, Jack pine, Japanese larch, American Larch, and arbor vitae.

The damage to nursery stock results from the feeding of the larvae on the bark of the roots. In many cases the roots are completely girdled.

In 1931 from 50 percent to 75 percent of the 2-0 and 3-0 white spruce, 40 percent to 50 percent of the Norway spruce and lesser percentages of the various pines and larches in the Michigan State College nursery were destroyed by the weevil. In a nursery growing 3,000,000 trees a year this loss of growing stock becomes important.

The larvae seem to prefer the denser beds and do the most damage in the center of the beds. This was more clearly shown in a series of experiments carried on by the author during 1930 and 1931.

In these experiments a bed of 2-0 white spruce was thinned to different densities per square foot. One plot was left unthinned to act as a check, the next was thinned to 60 seedlings per square foot, the next to 40 seedlings and the last to 20 seedlings. In the unthinned plot, having 278 seedlings per square foot, approximately two-thirds of the seedlings were killed by the root weevil, while in the thinned plots none of the seedlings were injured. In the plot that was attacked, only those threes in the center of the plot were killed, leaving a border of live trees around the outer edge.

Transplant rows seemed to be immune from attack, probably because the plants are so far apart.

Various methods of control have been tried in order to determine the best way of combating this pest.

In the strawberry producing region of British Columbia, the growers resorted to the use of trap-boards, tanglefoot, road oil, insecticides, and soil fumigants with varied results. Treherne (11), writing about the pest in British Columbia, says, "At the outset it may be said that no satisfactory method of artificial control has yet been devised in the control of this weevil."

In Oregon a home-made bait consisting of ground apple waste mixed with calcium arsenate was used with good results in the strawberry patches. A commercial product called "Go-Bait" also gave reasonably good results. These baits were used to kill the adult beetle.

In Pennsylvania, Perry, Senior Research Forester (18), applied a pint of commercial grade CS_2 to four square feet of seed bed after it was prepared for planting, then covered the bed with two or three thicknesses of damp burlap. This protected the beds from weevil damage for a year or two. These beds were laid out in an area from which seedlings had just been removed and which was very thickly infested with the weevils.

At the suggestion of Miss Eugenia McDaniel of the Michigan State College Entomology Department, a new control method was tried out in the late spring of 1931. This experiment, which was started on June 16, seems to show some measure of success.

In an area where the weevil was known to be present, a bed eight feet by four feet was laid out. This bed was enclosed by a board frame set four inches in the ground and extending six inches above the ground.

The top of the ground was loosened up slightly in order that the solution to be applied might penetrate more easily. A solution of eighty gallons of water, containing 860cc. of miscible carbon disulphide was applied to the plot. The amount of carbon disulphide to be applied varies with the soil temperature as follows:

40° - 50°F	68 cc. to 10 gallons of water
50° - 60°F	57 cc. " " " " "
60° - 70°F	45 cc. " " " " "

As the temperature of the soil the day the experiment was started was 68 F., 45cc. of the carbon disulphide was mixed with each ten gallons of water. The solution was mixed in a ten gallon milk can, the water being added to the carbon disulphide, and poured on the bed at once.

Forty-eight hours later a count was made to determine the results of the experiment. Eight square foot of soil was dug up and very carefully examined. All stages of the weevil from the larvae to the adult beetle were found in the soil.

A total of 67 dead and four live weevils was found in the small plot. All the larvae were dead, as well as all the adults excepting those that had reached the hard-shelled stage. The solution did not affect the white grubs of the June beetle (Phyllophaga spp.) which also were present in the ground.

In order to determine the effect of the solution on growing trees, a second bed, two feet by four feet was laid out in a bed of 2-0 white spruce. Twenty gallons of water with 90 cc. of the miscible carbon disulphide was added to this bed.

The trees were inspected the following fall and no injurious effects could be found. However, this does not prove that the solution can be used on all species while growing, without injurious effects. According to the manufactures of the miscible carbon disulphide, it has been found that the ground should be treated when the trees are dormant, just before the beds are planted or just after the trees are dug.

During the fall of 1941, control measures on a large scale were carried on. A carbon disulphide emulsion was used. This emulsion, which corresponds to the miscible carbon disulphide in its action, is made from the following ingredients:

1 pt. of Bentonite
2 " " CPO soap
3 " " CS_2
2 " " water

On an area of [illegible],[illegible]40 square feet from which 3-0 white spruce had just been removed and which was heavily infested with the weevil, carbon disulphide emulsion in water was added. The emulsion was applied at the following rate, according to the soil temperature:

40° - 50°F.	13.6 cc. per gallon of water
50° - 60°F.	11.4 cc. " " " "
60° - 70°F.	9.0 cc. " " " "

The solution was mixed in a 150 gallon "Bean" sprayer. One filling of the sprayer covered 60 square feet of area, the material being applied at the rate of two and a half gallons to one square foot.

A rectangular board frame, seven feet wide by eight feet, seven inches long and eight inches deep, was used to hold the solution until it could soak into the ground. The frame was built to these dimensions so that it would enclose just 60 square feet of area and hold one tank of material. The outside of the frame was banked with soil to prevent leakage. By the time the tank was filled with water, the solution was lowered in the frame enough to permit the removal of the frame to the next location.

It required 18 gallons of emulsion and 44 hours (22 hours for two men) to cover the whole area with the solution.

The cost of the operation was as follows:

44 hours at 50¢	$22.00
18 gallons of emulsion at 65¢	11.70
	$33.70 for 2,340 square feet or .0143 per square foot.

The largest item of expense is the labor. This item can be considerably lowered either by using two or more tanks or by using some method of filling the tanks more quickly.

No live larvae were found in the area treated, checks being made every few feet.

Conclusions

Though no definite conclusions can be drawn from one seasons work the following recommendations seem warranted.

In order to combat the weevil successfully it will probably be necessary to use a combination of two or more control measures.

By applying the carbon disulphide to those parts of the nursery that are worked, at the time that most of the weevils are in the larvae stage, the majority of the larvae will be destroyed.

The next step should be to surround that part of the nursery on which the emulsion was applied, with poison baits, in order to keep out the adult weevils. By making the bait attractive to the weevils they will feed on it as they crawl over it.

Control measures must be carried on for several years in order to reduce the number of weevils to a point where the damage they do will be negligible.

Views of White Spruce Seed Beds After Thinning

Fig. 1
20 per square foot

Fig. 2
40 per square foot

Fig. 3
60 per square foot

Views of White Spruce Seed Beds After One Seasons Growth

Fig. 4
20 per square foot

Fig. 5
40 per square foot
Note the work of the strawberry root weevil
in the unthinned plots.

Fig. 6
60 per square foot

View of White Spruce Beds Showing Effect of Strawberry Root Weevil on Unthinned Plots

(Brachyrincus [Otiorhyncus] ovatus)

Fig. 7
Unthinned plot - much of bed destroyed

Fig. 8
Thinned plot - no damage done

Plate I

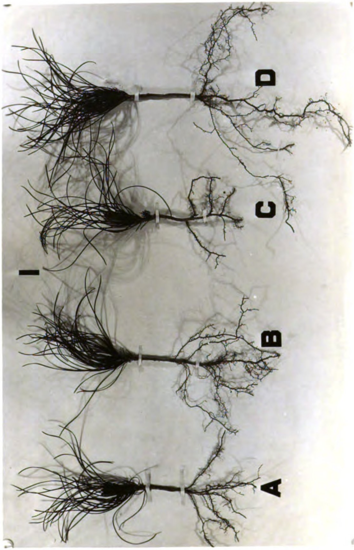


PLATE I

Red pine seedlings ready for transplanting

A. One-half of roots cut off

B. One-third of roots cut off

C. Two-thirds of roots cut off

D. Check-none of roots cut.

PLATE II

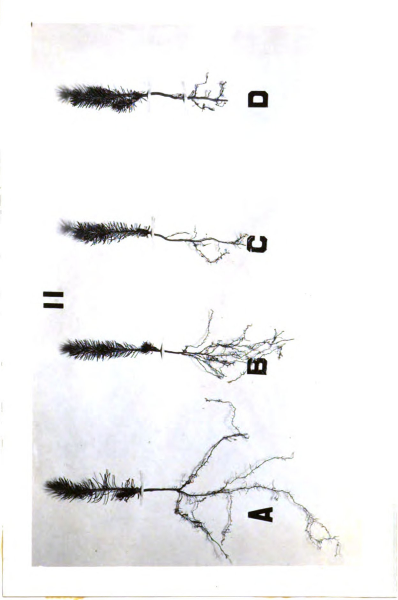


PLATE II

White spruce seedlings ready for transplanting.

A. Check - none of roots cut.

B. One-third of roots cut off.

C. One-half of roots cut off.

D. Two-thirds of roots cut off.

PLATE III

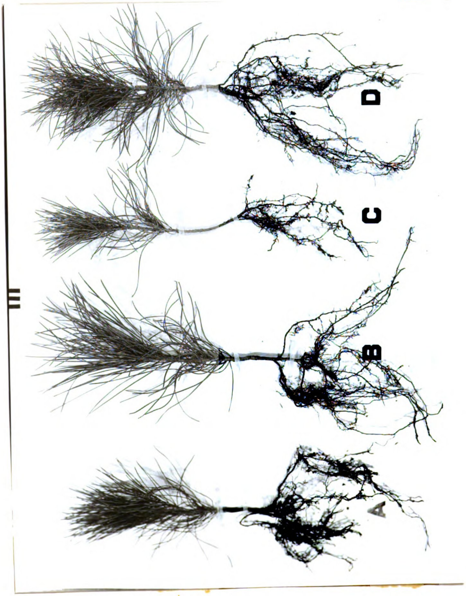


PLATE III

Red pine transplants after
one seasons growth

A. One-third of roots cut off.

B. One-half of roots cut off.

C. Two-thirds of roots cut off.

D. None of roots cut - check.

PLATE IV

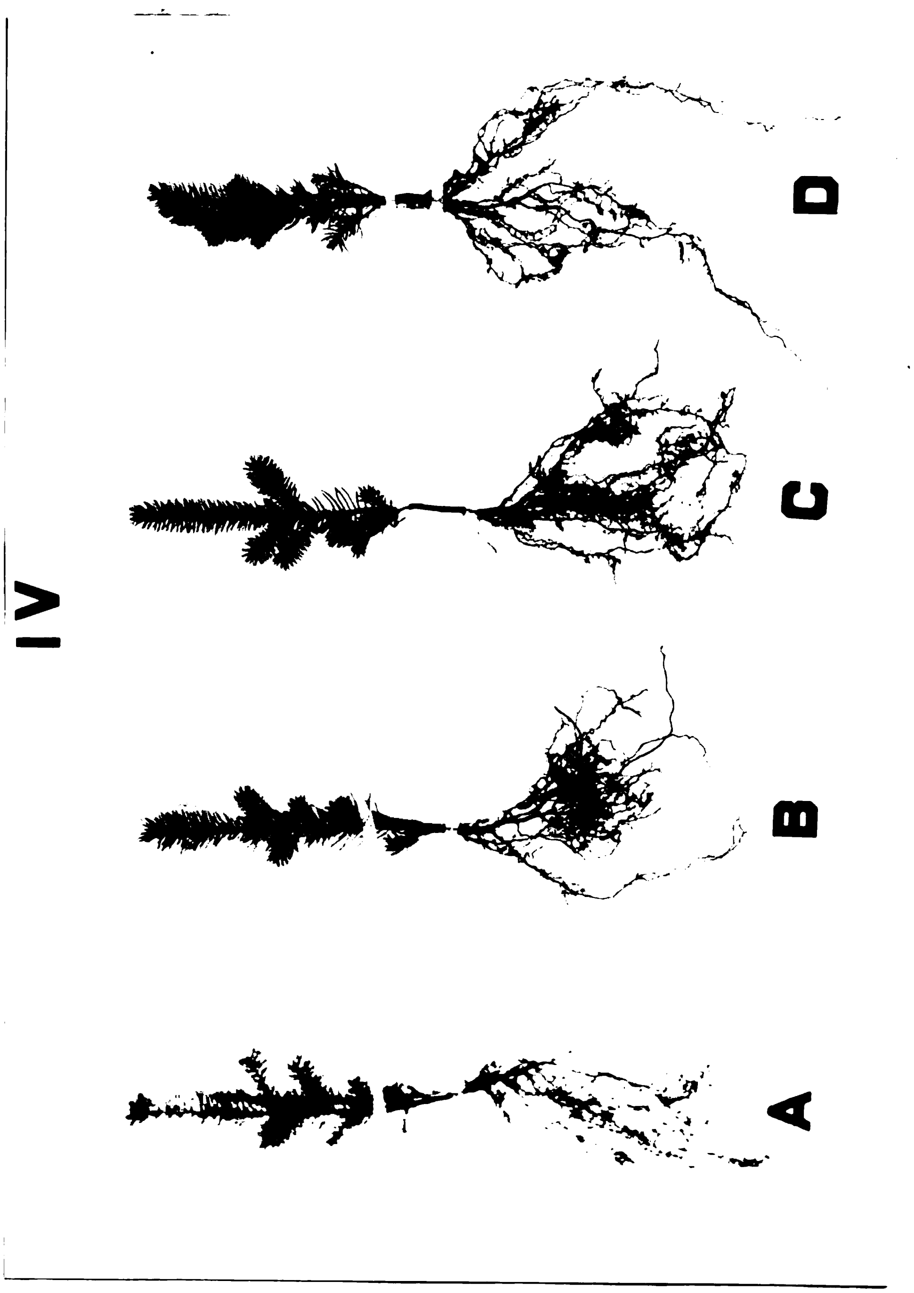


PLATE IV

White spruce transplants
after one seasons growth

A. Check - none of roots cut.

B. One-third of roots cut off.

C. One-half of roots cut off.

D. Two-thirds of roots cut off.

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