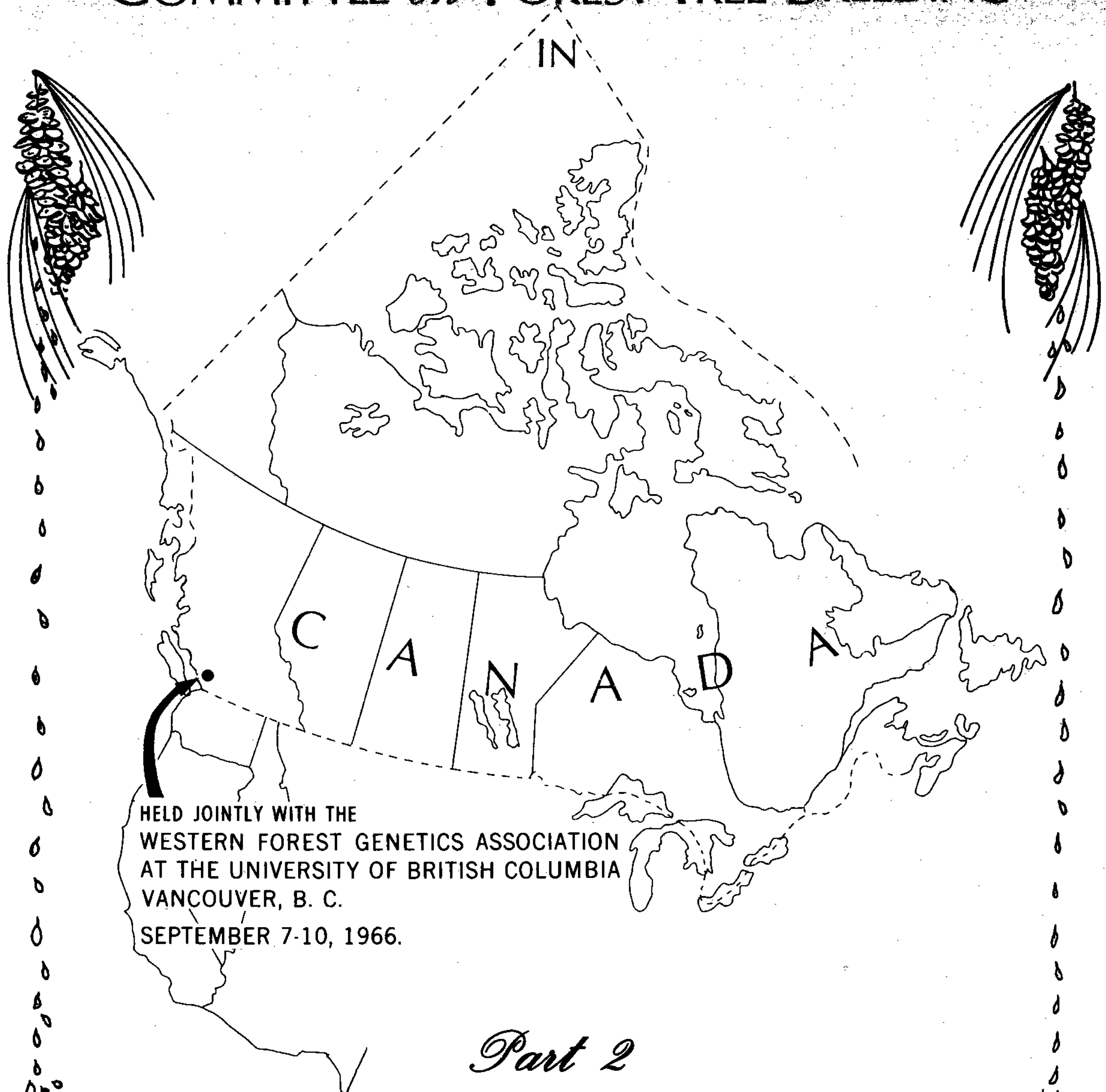
COMMITTEE on FOREST TREE BREEDING IN CANADA



HELD JOINTLY WITH THE
WESTERN FOREST GENETICS ASSOCIATION
AT THE UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, B. C.
SEPTEMBER 7-10, 1966.

Part 2

Reports and Papers

PROCEEDINGS OF THE TENTH MEETING OF

THE COMMITTEE ON FOREST TREE BREEDING

IN CANADA

With the compliments of the Committee.

Please file permanently in your institution library.

Enquiries may be addressed to the authors or to the Executive Secretary, C.F.T.B.C., Petawawa Forest Experiment Station, Chalk River, Ontario, Canada.

The Eleventh Meeting of the Committee will be held in eastern Canada in the summer of 1968. Canadian and foreign visitors will be welcome. Detailed information will be distributed early in 1968 to all members and to others upon request.

If your name, title or address is incorrect or incomplete, please complete and return this correction slip.

TO: Executive Secretary, Committee on Forest Tree Breeding in Canada, Petawawa Forest Experiment Station, Chalk River, Ontario, Canada.

NAME: Prof.
Dr. Mrs.
Mr. Miss. .... Title ....

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....

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Signed ....

PART 2

REPORTS AND PAPERS

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Part 1, Minutes and Discussions, received restricted distribution to Committee members only. Part 2 received wider distribution to persons and organizations actively engaged or interested in forest genetics and tree improvement.

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MEMBERS' PROGRESS REPORTS

EFFECT OF VIGOUR OF WHITE PINE SEEDLINGS ON INFECTION BY CRONARTIUM RIBICOLA FISCHER, THE BLISTER RUST FUNGUS

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In a previous field study (Boyer, 1963) a positive relationship was demonstrated between the apparent vigour of white pine (*Pinus strobus* L.) and the number of cankers induced by the blister rust fungus. In a severely infected plantation in the Dufferin County Forests near Dundalk, Ontario, most white pine exhibiting poor growth characteristics were completely free of disease where adjoining normal trees had from 5 to 29 branch or main stem cankers. No attempt was made at that time to ascertain what factors were involved. Presumably one of four could contribute to disease immunity. Improper planting, poor localized soil conditions, or inferior genotype all might result in poor growth and hence lowered susceptibility to infection. In addition, true genetic resistance cannot be ruled out entirely as a factor in the absence of data to the contrary, although the high incidence of disease-free trees would tend to suggest it was not involved.

Predisposition to resistance through reduced vigour has been known in obligate parasitism for a long time and it would seem to be of nuisance value only in the case of white pine, possibly confounding field selection of resistant material. It would be of some interest to know, however, whether poor soil conditions or other factors which contribute to poor growth, could result in immunity under conditions of higher inoculum potential than is normally observed in the field. Further, it would be of interest to determine to what extent normal genetic variability in growth of the host is associated with susceptibility.

With this in mind a greenhouse study was conducted to determine the effects of four different soils on the growth and susceptibility of white pine seedlings to the blister rust fungus.

Methods

To obtain a marked variation in growth of seedlings, four distinct soil substrates were selected. The soil, designated Dundalk was obtained from samples of the A1 horizon from a 15-year-old mixed red and white pine plantation in the Dufferin County Forests. The control soil consisted of white pine duff from the Midhurst nurseries passed through a Wiley mill and mixed 3 to 1 with washed coarse sand. Soils from Van Dorf and Turkey Point were obtained from exposed and leached sand on the margins of young white pine plantations which had been established to prevent serious soil erosion.

All the soils were sieved and placed in perforated plastic cups. Seeds of white pine (Zone 2), obtained from the Ontario Department of Lands and Forests, were sown and, following germination, cups containing a single seedling were arranged in a randomized block of 40 seedlings; each treatment replicated 10 times. All soils were watered thoroughly twice weekly. At the end of 9 months the seedlings were exposed at random to infected leaves of *Ribes nigrum* L. in a controlled temperature incubator for 48 hours. Counts of infection loci were made 12 months later at the time of harvesting. Seedlings were removed from the soil, washed, cut into three segments: root, hypocotyl and shoot-foliage, dried at

100°C for 48 hours and weighed.

Results

The total dry weight and number of infection loci are given for each seedling (Table 1).

TABLE 1

The effect of soil source on the dry weight of white pine seedlings and the number of infection loci of Cronartium ribicola

	Control		Dundalk		Turkey Point		Van Dorf	
	DW*	IL	DW*	IL	DW*	IL	DW*	IL
	1.04	21	2.48	135	0.67	5	0.31	11
	0.91	56	1.61	50	0.51	13	0.48	13
	1.11	80	1.84	92	0.52	6	0.80	50
	1.07	40	1.01	105	0.60	57	0.50	17
	1.41	65	1.31	185	0.42	13	0.35	8
	1.99	12	1.30	63	0.86	12	0.45	10
	2.42	165	1.03	44	0.79	25	0.69	35
	1.70	112	1.47	227	0.80	11	0.14	16
	1.32	32	1.18	117	0.87	31	0.60	27
	1.64	29	1.20	28	0.77	10	0.60	6
	14.61	612	14.43	1046	6.81	183	4.98	193
mean	1.461	61.2	1.443	104.6	0.681	18.3	0.498	19.3
sd	0.48	49	0.44	76	0.44	16	0.22	18

* DW - oven-dry weight in grams. IL - infection loci.

In using rather extreme examples, the clear difference that exists between the two good and two poor soils with respect to infection by the blister rust fungus is well illustrated. Clearly soil does play some role in susceptibility. By comparing dry weights with the number of infection loci the data suggest that susceptibility was related to vigour, i. e., poor seedlings produced fewer infections. This effect was also evident when the effect of foliage size was reduced by dividing the infection loci by either the total seedling dry weight or the shoot-foliage dry weight.

Even when growth was relatively poor there was no evidence that immunity may be induced by modifying the soil, at least under conditions of high inoculum potential. Although the difference in susceptibility between seedlings grown in the control soil and the Dundalk soil is not significant, it suggests that other factors, not related to dry weight alone, influence infectivity. This aspect deserves further investigation.

An attempt was also made to determine if variation in seedling dry weight within soil treatments had a significant effect on infection (Table 2). Presumably this variation was due to both genetic and environmental factors but the separate components could not be distinguished in this experiment. The effect was tested by determining the levels of infection on either side of the mean and testing their significance at the 0. 1 per cent level by a Chi square test.

TABLE 2

Comparison of the number of blister rust infection loci above the mean dry weight and below the mean dry weight of white pine seedlings.

Soil source	Average number of infection loci on seedlings*		
	Dry wt. above mean	Dry wt. below mean	Chi square
Control	78	112	5.0
Dundalk	154	154	0.0
Turkey Point	101	149	9.2
Van Dorf	143	91	11.5

* The number of infection loci have been divided by the shoot-foliage dry weight in an attempt to remove the effect of the size of the infection court on the incidence of infection. See text.

Significance for 1 degree of freedom at 0. 1% level = 10. 80.

Clearly if any relationship did exist (Table 2) it was partially obscured by the extreme variability in infection loci, as indicated in Table 1. Only in the case of the poorest soil was the level of significance obtained to support the hypothesis that a difference in susceptibility existed between seedlings weighing more than the mean and those weighing less than the mean. Such a result might have been expected in all the samples if any simple relationship exists between a vigour based on growth rate and susceptibility to an obligate parasite such as Cronartium ribicola. A more precise statistical design has been set up to analyse this aspect in more detail.

REFERENCE (Unpublished)

Boyer, M. G. 1963 Studies on factors involved in resistance on white pine to blister rust. Interim Report. Department of Forestry of Canada.

BLACK SPRUCE WOOD QUALITY

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A study conducted over a two-year period - April 1964 to April 1966 - has emphasized the variations in chemical pulping and paper properties, and in wood anatomy and wood density within and between trees in black spruce (Picea mariana (Mill.)BSP.). The Ontario Research Foundation (O. R. F.), retained by the Department of Lands and Forests on an annual grant to conduct research in wood quality, will report directly this year on their chemical and anatomical studies.

DEPARTMENT OF LANDS AND FORESTS

Within the Quality Wood Unit of the Ontario Research Branch the main effort has been the development of a non-destructive sampling method to assess the specific gravity of tree boles for standing black spruce trees. A six-month break in the study occurred between October 1965 and April 1966 during which full time was given to an assessment of the requirements for large-scale production of tubed seedlings. Consequently, final reports have been delayed and a complete assessment of the specific gravity has not been prepared.

Although this report deals with black spruce wood quality, brief reference is made to the tubed seedling method of tree production because it provides a means whereby the tree breeder could readily culture small or large seedlots under greenhouse conditions. The tubed seedling work demonstrated the ease with which black spruce seeds could be germinated with this technique, and the method could be an effective means of introducing improved spruce genotypes through general restocking procedures. Since artificial regeneration of black spruce has been difficult, the new method should provide a consistently high percentage of seedlings from valuable seed in short supply. The most appropriate planting techniques for black spruce tubed seedlings will be developed during 1966. For further information on the Ontario method, reference should be made to publications by McLean (1959) and Williamson (1964), and to the manual prepared by Research and Timber Branches (1966).

A preliminary assessment has been made of the specific gravity variations within black spruce trees from a Site Class I lowland stand (Plonski, 1964). Mean tree specific gravity was determined from destructive sampling in which 26 trees were reduced to 1-inch discs and every fifth disc measured in the bole up to 90% of the total height. Specific gravity was generally highest in the basal 10% and 20% sections of the stem. It approached the tree mean in the 30% section, then decreased gradually to its lowest point around the 70% level after which it again increased but usually did not attain the tree mean value.

The percentage compression wood was assessed on the surface of every fifth disc by means of a random dot field. Those dots lying over identifiable compression wood were expressed as a percentage of the total number in the field. A tree average of 14% compression wood was determined for the 16 trees examined. The greatest amount occurred in the upper 30% and in the basal 10% of the tree stem.

In order to develop a method for the assessment of tree mean specific gravity, sample strips of 20 mm square cross-section were removed from discs along diameters randomly selected by compass direction. (The north side of each disc had been marked when cut.) Correlations have been made between mean specific gravity of trees and the mean specific gravity of single diameter strips. For this purpose, the diameter strip was divided at the pith into two radial strips, each of which was subdivided into four equal segments. The specific gravity of each pair of segments, working from the pith outward, was averaged and weighted by the disc area represented, to provide the weighted mean specific gravity of the diameter strip.

The number of trees used in this first analysis was small, because some material had to be discarded due to the inclusion of branchwood in the sample. The correlation coefficients for groups of 10 to 13 trees ranged from r = 0.98 for strips taken at the 15% height level to r = 0.94 for sample strips taken at the 10% height level. Both coefficients were highly significant.

Further analysis is necessary. However, these data and other considerations suggest if a single core is taken to represent the complete bole, it should be taken around the 15% height level.

Based on 60 diameter strips that were chipped and pulped by the sodium bisulphite method using the O.R.F. small scale digester. (Brajsa and Thomas, 1966), pulp yields were found to be negatively correlated with the diameter strip specific gravities. Since it was unexpected for the denser strips to give the lower yields, and since the strips contained appreciable amounts of compression wood, it appears that per cent compression wood must be assessed to give a meaningful relationship between mean tree specific gravity and chemical pulp yield.

On completion of this first sample, more rapidly-grown trees from slopes and uplands will be destructively sampled in 1966 to determine whether a single curve is adequate for prediction of mean tree specific gravity on different sites.

In order to obtain large core samples from standing trees, a power borer was developed by V. McMullen of the Mechanical Section at Maple. It uses a 3/4 hp Drillgine motor to drive a shaft with a cutting head designed by J. T. Yelf of the Vancouver Forest Products Laboratory, Department of Forestry of Canada. Excellent cores were obtained, but the 15 minutes taken to cut an 8-inch core was excessive. Cutting heads of a new design by Mr. Yelf are now being made commercially and these should improve the rate of cut. Subsequently a more powerful lightweight gas motor of about 3 hp will be expected to provide a 12-inch core in 5 minutes or less.

The O.R.F. chemical group tested the effect of reducing chip size from the normal 3/4 in. x 3/4 in. x 1/8 in. to 10 mm x 10 mm x 1/8 in. (Thomas, 1965) and found no change in pulp yield or paper strength due to the reduced chip size. Consequently the 20 mm core sample would be adequate for pulping trials and will be used to assess plus tree selections.

ONTARIO RESEARCH FOUNDATION

The research program at the Ontario Research Foundation which centres on black spruce, can be discussed under two headings:

(A) The interrelation between growth rate, wood anatomy, and paper properties.

(B) Studies of the internal morphology of one-year shoots, its relation to needle frequency and the frequency of medullary rays.

(A) Two studies are in progress under the first heading. Only one will be commented upon in any detail. This investigation set out to assess and compare the strength of paper made from the corewood of a mature forest-grown tree, from the outerwood of the same tree; and from a 17-year-old tree grown in a plantation at an accelerated rate. The bolt from the latter tree contained an average of 14 rings. The corewood excised from the forest-grown tree contained the same number of rings, so that both this material and that from the fast-grown tree were of comparable age. At the time of writing the analyses are not complete, but they have been taken sufficiently far to show that, with variables such as cooking time and pulp freeness levels taken into account, there was little difference between the strengths of paper made from the fast-grown tree and the corewood of the forest-grown tree, but that the papers from both these sources were markedly weaker than that made from the outerwood.

Very little is known of the anatomical characteristics of black spruce. Of the 833 papers listed in a recent bibliography covering the wood quality field, only a single paper - dealing with specific gravity - gives any information of substance on this species. Recently, two more papers have been written concerning specific gravity. Our knowledge of tracheid length variation in the species appears to be confined to a single diagram made in the early 1920's. In view of this paucity of information the anatomical characteristics of experimental material are being examined in some detail with the dual object of obtaining badly-needed background knowledge and of obtaining data to assist in the interpretation of the results of paper strength tests.

Some of the more important characteristics of the three classes of material mentioned above are given in the following table. Sample weights were considered to be more than adequate.

	Fast-grown tree	Forest-grown tree	
		Corewood	Outerwood
Mean ring width (mm)	4.86	1.24	0.69
Specific gravity	0.376	0.464	0.396
Mean tracheid length (mm)	1.40	1.87	3.40
Mean tracheid diameter (mu)	25.9	24.9	34.9
Over-all mean cell wall thickness (mu) (weighted average of early- and late-wood and radial and tangential walls)	4.8	5.4	5.3

Comments

1. In the forest-grown tree the specific gravity of the corewood was found to be higher than that of the outerwood. This was partly due to the high extractive content of the core (10%) compared with the outerwood (2%). Specific gravity of the core was still higher, however, even when the extractives were taken into account. Recent work in France by POLGE (1964) on a number of species of conifers has shown that, from the pith outwards, there is an initial decline in specific gravity followed by a rise at ages varying from 5 to 25 years. Similar trends were observed in a black spruce by RISI and ZELLER (1960) as well as

in four trees recently examined at the O. R. F. in connection with a study designed to assess the effect of growth rate on paper quality in mature black spruce. In these trees, cell wall percentage estimates (which give results analogous to extractive-free specific gravity) indicated steady declines in wood density from the pith outwards, with upturns not occurring in two of the trees until about the 30th year. Such anomalous trends are of great interest and may have an important bearing upon the quality of the species.

2. The difference in specific gravity between the fast-grown tree and the corewood of the forest-grown tree was probably associated with poorly-developed latewood and with somewhat longer and thinner-walled cells in the former. However, while the specific gravity of the plantation-grown tree was low compared with its forest-grown counterpart, the high growth rate resulted in the production of over four times the weight of oven-dry wood over the same period even when differences in pulp yield were taken into account.

3. There was little change in cell wall thickness from core to outerwood in the forest-grown tree. Latewood percentage was almost identical. Differences in extractive-free gravity were probably due, therefore, to the larger lumen diameters of the outerwood cells and their greater length.

The analysis of the relations between paper strengths and anatomical characters has not yet reached the point where any detailed report can be made, but from preliminary analyses it would appear that of the commonly measured wood characters, only fibre length could account for the differences in paper strength. These differences were clearly not related to specific gravity or to anatomical characters closely linked with the same.

(B) Studies under the second general heading which concern the internal morphology of one-year-old shoots (i. e., leading shoots) centre on the interrelations between the density of the needle array, the size of needles, the amount of leaf trace tissue, and the frequency of medullary rays. Previous studies had shown that:

(a) The number of needles per unit length of internode tends to remain constant on any one tree and this frequency is to some extent independent of elongation.

(b) A tree with inherently closely-spaced needles tends to have a large pith. Thus pith diameter, as well as needle frequency, appears to be an inherent characteristic.

(c) Medullary rays tend to proliferate in the vicinity of leaf traces. It is possible to show a statistical correlation between the relative amount of leaf trace tissue in a shoot and the frequency of rays in the one-year shoot.

Taken together, the results of these studies - which are in abeyance at the time of writing - would appear to suggest that there is an inherent complex in conifers involving the general structure of the one-year shoot, the spacing of the needles, and the amount of ray tissue, i. e., some individual trees tend to have piths of large diameter, closely-spaced needles, a greater amount of leaf trace tissue, and more abundant rays, while others display sparsely-needled shoots, small piths, and fewer rays.

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TREE IMPROVEMENT STUDIES FOR THE PRAIRIE REGIONS

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Tree improvement studies, which have been in progress since 1949, were continued in 1964 and 1965. An increased production program and late spring frosts severely reduced the tree-breeding programs. Severe frosts occurred on June 1 1964, and on May 28 1965, which reduced or destroyed seedcrops of; *Picea pungens*, *Picea glauca*, *Ulmus pumila*, *Ulmus americana*, *Caragana arborescens* and others. The fall of 1964 was extremely dry, while 1965 was favourable to tree growth. The frost-free periods were 103 and 100 days respectively for the two years.

The tree-breeding programs for both years were restricted to late blooming trees which partially escaped frost damage. A shortage of staminate flowers was evident for all selections of *Picea pungens* for both years.

Caragana Improvement

Due to the adverse weather conditions the breeding program consisted mainly of self-compatibility determinations of the late-blooming selections of seven groups of European accessions. A total of 130 selections were self-pollinated. Twenty selections failed to set seed; however, before these can be assumed to be self-incompatible at least one more pollination must be made under more favourable conditions. Greenhouse germination of the inbred seed demonstrated that none of the selections producing seed carried the deleterious albino character.

Cross-compatibility determinations in 1964 were performed for 88 possible combinations involving eleven self-compatible and four self-incompatible selections, as well as four self-compatible and eleven self-incompatible selections. These crossings evaluated the combining potentialities as one-way crosses for those vigorous selections, which were previously found incapable of two-way hybrid combinations. A tester, or carrier, of the deleterious albino and pendulant characters, was utilized in each series of the cross-compatibility determinations to resolve these genotypes for each selection. One of the new self-compatible selections (D10-13) gave 50% set with pollen of one former self-incompatible selection (15-2), but only 12% to 13% set with others. Three other new selections (D180-12, D14-112, D190-1), gave 20% set with the same pollen (15-2). Two of the new self-incompatible selections (D14-112 and D14-12) proved reasonably (21% to 36%) fertile with two previous, vigorous self-compatible selections. Vigour potential of the resulting hybrid seedlings from these eight combinations will be evaluated over a period of eight years.

Cross-compatibility determinations were limited to three self-incompatible seedtrees and eleven vigorous pollen selections in 1965. One seedtree D171-24, which previously appeared self-incompatible in 1964, proved highly (50%) self-fertile in 1965. Another 1964 selection, H-1, of exceptional vigour was compatible with all three seedtrees.

Combining ability for vigour, when expressed as the height of eight-year-old progenies, provides a measure of the potentials for various hybrid combinations. Vigour data for 46 progenies, from 1957 pollinations of five self-incompatible seedtrees with up to thirteen vigorous selections, are listed in Table 1.

Table 1. Vigour[1] of Nine-Year-Old Hybrid Caragana Progenies from 1957 Pollination of Five Self-Incompatible Seedtrees with Thirteen Selections

Pollen Selections	Seedtrees and Vigour of Progenies					Selection Mean
	15-2	13-5	21-16	B1-1	B2-4	
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
B4-5	200.2	216.1	200.4	216.0	236.5	213.8
10-4	-	220.5	-	201.7	223.2	215.1
B3-5	-	218.5	198.0	212.8	232.5	215.4
B3-3	-	217.3	-	226.7	223.6	222.5
7-7	209.3	222.2	232.6	244.6	217.7	225.2
13-1	-	223.4	-	231.4	228.2	227.7
8-4	216.3	238.7	-	229.2	237.5	230.4
B4-2	232.5	210.0	258.0	-	230.0	232.6
A-1	-	234.0	231.3	-	233.2	232.8
B5-1A	-		-	233.4	-	233.4
10-3	-	236.3	239.8	228.0	230.8	233.7
13-8	253.2	-	232.7	235.0	220.8	235.6
7-9	-	253.2	-	245.3	230.6	243.0
Seedtree Means	222.3	226.4	227.5	227.7	228.7	227.8

[1] Vigour expressed as average height of all plants in centimetres (30 cm - 1 foot)

This progeny test consisted of 1958 plantings of five replicated single-plant and 25-plant plots from greenhouse sowings. The results suggest that five-plant samples are inadequate and 25 plants provide a more reliable sample for progeny vigour tests. On the basis of the limited data, high general Combining Ability (C.A.) for vigour was demonstrated by one selection, 7-9; whereas high specific C.A. was manifested by three hybrid combinations of 21-16 with B4-2, 13-5 with 7-9. Vigour data from 48 nine-year-old hybrid progenies, from 1956 combinations of seven seedtrees with thirteen selections, appears in Table 2.

Table 2. Vigour* of Nine-Year-Old Hybrid Progenies from Combinations of Seven Seedtrees with Thirteen Selections of Caragana

Pollen Selections	Seedtrees and Vigour of Progenies						Selection Mean
	V-17	A-1	V-16	13-5	21-16	B2-4	
B3-3	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
B3-3	188	205	185	177	176	208	190
10-4	191	193	189	196	-	-	193
10-3	197	199	160	-	200	211	194
B3-5	-	189	202	-	201	-	194
13-1	-	194	298	-	-	-	196
D10-1	197	208	175	211	209	-	200
D16-19	-	192	-	-	212	-	202
D16-9	-	195	-	-	210	-	203
8-4	194	202	201	201	217	-	203
B5-1A	-	212	-	-	-	-	212
7-9	206	192	212	224	226	-	215
D26-2	217	202	260	229	221	229	226
13-8	-	-	219	-	-	235	227
Seedtree Means	199	199	200	206	208	221	204

* Vigour expressed as average height of plants in centimetres (30cm - 1 foot)

Adjacent tows or blocks of 100 plants of each progeny at one-foot spacings were planted in 1957 for this vigour test. High general C. A. was evident for one self-incompatible seedtree, B2-4 and for two vigorous pollinators, D26-2 and 13-8. Greatest specific C. A. was manifested by the hybrid progeny of V-16 x D26-2. Growth height for these hybrids was 27% greater than the average height for all hybrids and 10% more than the next most vigorous progeny. These results suggest some new favourable growth factors were introduced by the selection D26-2, from 1952 cuttings of a U. S. D. A. accession (P. I. 107663) from the Mandan Field Station.

Data for the vigour of 18 progenires, resulting from 1959 artificial pollinations of six-self-incompatible seedtrees with three vigorous selections, are listed in Table 3.

Table 3. Comparative Vigour* of Seven-Year-Old Hybrid Progenies from Combinations of Six Seedtrees with three Selections of Caragana

Seedtrees ⊕	Self-compatible selections (♂) D26-2	8-4	B3-3	Mean height
	(cm)	(cm)	(cm)	(cm)
B2-4	192.8	189.3	183.9	188.7
A-1	198.4	178.2	177.6	183.5
V-16	191.8	181.9	169.7	181.1
21-16	187.5	181.3	163.2	177.3
13-5	193.8	173.8	145.8	171.1
V-17	178.9	168.0	159.2	166.6
Means	190.5	178.8	166.6	175.3

* Vigour expressed as average height of 50 plants in centimetres

High general combining ability for vigour was demonstrated by the means for the seedtree B2-4 and the selection D26-2. Greatest specific combining ability was manifested by the hybrid progeny resulting from the seedtree A-1 pollinated by selection D26-2. Two other hybrid progenies from the 1959 breeding program demonstrated high specific combining ability. These were B2-4 x B5-1A and V-16 x 13-8.

Suckering of *Caragana frutex*, a problem of this species, was initiated as a study in 1965. Fourteen plants with few to no suckers were selected from seedlings which resulted from three seed accessions. All plants exhibit foliage and plant characteristics of *C. frutex*, although designated as three species in the original seed accessions. When selfed in 1965, self-compatibility of the 14 selections was found (Table 4) to range from 0% to 38% (pods-per-flower-tripped), with an average set of 2.3 seeds per pod. Four selections manifested self-incompatibility. The resulting inbred seed from ten selections has been sown to investigate the suckering character.

Table 4. Self-Compatibility[1] for Fourteen Selections of Caragana frutex in 1965

Selection No.	Seed Source & Species Designation		Selfed set[1]	
			Seeds/pod	Pods/fl.
D214-4-0	U.S.S.R.[2]	C. fruticosa	0.6	38
-30	"	"	5.3	28
-74	"	"	2.0	24
-81	"	"	2.0	8
-50	"	"	2.0	2
-72	"	"	0	0
-86	"	"	0	0
D153-1	Ottawa[3]	C. f. grandiflora	3.6	36
-8	"	"	2.1	10
D152-4	Ottawa[3]	C. f. frutex	1.7	30
-19	"	"	2.2	16
- 9	"	"	1.8	16
-12	"	"	0	0
-13	"	"	0	0

[1] Self-compatibility in terms of seeds-per-pod and pods-per-flower selfed
[2] Sverdlovsk Botanical Gardens, U.S.S.R.
[3] Dominion Arboretum, Experimental Farm, Ottawa

Propagation of selections, which have demonstrated high C.A. for vigour in hybrid combinations, is conducted annually to provide clonal material for isolated seed production plots. Some 1,200 softwood cuttings of six selections were rooted in misting beds in 1965, and 2,000 rooted cuttings from seven selections in 1964 were lined-out for future plantings of natural crossing blocks. Three pounds of cleaned hybrid seed (A-1 x B5-1A) were harvested in 1965 from plants of the self-incompatible clone in a natural crossing block which was planted with rooted cuttings of the two clones in 1959.

Spruce Improvement

Self- and cross-compatibility determinations were continued in 1964 for 'blue' selections of Colorado spruce. The objective of this program is to identify parental plants for mass-production of 'blue' seedlings by natural cross pollinations. Pollen and cone bloom were again scarce in 1964, probably due to the high precipitation in 1963. Hence, a few self-compatibility pollinations were not possible and of the three cross-compatibility testers used in 1964 only stored 1962 pollen for one (RC-1) was available. All trees in the breeding plots were sprayed with 10% Lindane at 2.5/100 gal. water on May 11 and repeated on June 15 by Mr. H. A. Worden for control of a spruce coneworm. Bloom of 43 'blue' selections were isolated by covering with painted cellulose bags on May 16 to May 19. First male bloom colour was observed on May 14 and first pollen shed on May 28. Regrettably, female or cone flowers on some trees became receptive prior to pollen shed, so that several self-pollinations were delayed or impossible. However, the use of stored pollen of RC1 permitted at least one cross-pollination for all except one of the 43 selections.

All artificial pollinations of Colorado spruce were conducted from May 26 to June 1 1964. Pollen guns were utilized in preference to rubber bulbs with good results.

Isolation bags were removed on June 15 and all cones covered with cotton bags from July 30 to September 3, when they were harvested. Seed was extracted from all cones, cleaned and counted to determine the set of seeds-per-cone for each controlled pollination. Self-compatibility of the 29 selections pollinated ranged from 0 to 105 seeds-per-cone for an average of 26.4, as compared to the respective open-pollination sets of 22 to 217 seeds-per-cone and an average of 95.0. Three of the 'blue' selections (N4-68, N5-24, N5-110) were self-incompatible, but all three set 64 to 119 seeds-per-cone from open- and cross-pollinations. These will be propagated by grafting for future use in natural crossing blocks. Several selections demonstrated a degree of cross-incompatibility with one or more of the three testers, whereas other selections proved as highly self-compatible as cross-compatible. A total of 33,000 hybrid and 2,700 inbred seeds were obtained from the 1964 controlled pollinations for production of progenies to evaluate the genotype of selections and inheritance of the 'blue' characters.

Hybrid 1964 seed, from 71 combinations of three pollen selections with 35 seedtrees, was sown in the seedbeds on May 3 of 1965. Seedling stand in the fall was only 40% of the sowings, due to a combination of seed dormancy and damping-off losses despite fungicidal drenches. Some 500 seedlings from the 1960 hybrid seed, as sown in 1961 and transplanted in 1963, are available for field test plantings in 1966. In view of the fact these 500 plants represent only 11% of the seed sown in 1960, it is apparent that improved cultural practices are required for future production of this hybrid material. Seedbed fumigation offers one method of improving plant stands for future progenies.

Hybrid progenies from two 1959 crosses were planted as permanent shelter-belts on the West and North borders of the nursery in 1965. Some 166 seedlings of P6 x R1 and 268 of P7 x R1 were also planted to investigate the inheritance of 'blue' needle coloration in Colorado spruce. Hybrid progenies from nine 1960 crosses and inbred progenies from 25 'blue' selections, 604 seedlings in all, were also planted for inheritance studies.

Self- and cross-compatibility pollinations were continued in 1965, but were restricted in most cases by spring frosts to selections having female flowers and stored 1964 pollen. Cellulose bags, which were painted with aluminum on one side, were used to isolate the bloom of 28 'blue' selections from May 20 to 24. Artificial pollinations were conducted on June 4 and 5, the cellulose bags removed June 22 and replaced by cotton bags on August 30. Cones were harvested September 8 the seed extracted and compatibilities evaluated on the basis of the average yield of seeds-per-cone as listed in Table 5.

Regrettably, severe infestations of the spruce coneworm, despite two applications of 10% Lindane, reduced seed sets and distorted the results for some trees. Self-compatibility of seventeen selections ranged from 0 to 65 seeds-per-cone, and averaged 18, whereas cross-compatibility of 23 selections ranged from 5 to 125 seeds-per-cone with an average of 30. Four of the six self-incompatible selections proved cross-compatible, and may be promising for natural crossing blocks.

Table 5. Cross- and Self-Compatibility[1] of 28 'blue' Selections of Colorado Spruce

Seedtree Selection	Pollen Selections & Cross-Compatibility R-1	N4-7	N4-119	N4-105	N4-108	Mean	Self-Compatibility
N4-13	--	--	---	-	-	-	65
N2-24	-	-	-	-	-	-	59
N4-113	-	-	-	-	-	-	12
N4-24	-	-	-	-	-	-	0
N4-60	-	-	-	-	-	-	0
N5-27	125	-	-	-	-	125	-
N4-112	79	-	-	-	-	79	0
N5-34	111	72	25	-	-	69	-
N4-119	69	-	-	69	54	64	29
N4-6	40	-	59	68	-	56	8
N4-8	-	56	55	-	-	56	12
N4-115	39	54	31	-	-	41	43
N4-7	0	-	111	9	-	40	31
N5-22	-	40	-	-	-	40	-
N4-4	75	37	13	32	24	37	-
N4-117	49	59	33	-	0	35	-
N4-5	40	49	52	12	20	35	-
N4-61	31	41	45	0	53	34	-
N5-34	27	56	0	-	-	28	-
N4-109	24	-	-	-	-	25	0
N4-22	0	-	-	46	9	18	0
N4-3	42	12	10	0	-	16	-
N4-65	1	23	37	7	2	14	-
N4-36	22	8	18	11	9	14	0
N2-77	4	9	-	14	-	9	17
N4-122	0	11	14	-	-	9	21
N5-21	8	4	9	-	-	7	-
N4-116	3	2	14	-	0	5	14
Mean	38	37	33	25	19	30	18

\- Pollinations not conducted due to scarcity of cone flowers
[1] Compatibility expressed as number of seeds-per-cone harvested

Propagation Studies

Outstanding trees selected for future seed production or tests must of necessity be asexually propagated to retain the original clone. Conifer selections were propagated by grafting on potted plants in the greenhouse during March. Twenty-eight accessions of Ponderosa pine were grafted on Scots pine with 48% success for 56 grafts, but all unions were weak probably due to the small stock. Seventeen selections of Colorado spruce were propagated by 125 grafts with a 58% catch. Sixteen selections of caragana were propagated by 141 grafts with 57% success. Five thousand softwood cuttings of caragana were planted in June under mist and 68% were rooted when harvested in August.

Poplar Improvement

Hybrid selections from crosses made in 1963 between five poplar clones are being evaluated for rooting, vigour and disease reactions. Cuttings were harvested in 1965 from 54 vigorous selections, among the 600 hybrid seedlings from the 1963 pollinations of P. 44-52 with Northwest, Russian, Saskatchewan, Siouxland and Tristis poplars. Average rooting capacity in 1965 was only 51% of 3,000 cuttings from 41 similar selections in 1964. However, rooting capacity ranged from 80% to 93% for the 1964 cuttings from four selections of 44-52 X Saskatchewan hybrids.

Regional poplar and willow tests are being conducted in co-operation with the Saskatchewan Forestry Branch and the Department of Forestry of Canada. Rooted cuttings of 21 poplar and nine willow clones were planted on the nursery as five replicated single-plant plots in May of 1965. Outstanding growth in 1965 was demonstrated by the poplar clone, P. B. L. 3 and the willow *Salix basfordiana*. Excessive branching was recorded for *P. angustifolia* and *S. acutifolia*.

Poplar- and willow-cutting beds of all available clones and species are being established for future testing. Currently these contain 36 clones of poplar and 19 clones of willow. Cuttings for 1966 rooting of 35 willow and 29 poplar clones were received from the Morden Experimental Farm in the fall of 1965 and of 33 poplar clones from Maple, Ontario for propagation and evaluation.

Disease inoculation tests for poplar clones are in progress with the co-operation of Dr. H. Zalasky, Plant Pathologist, Department of Forestry of Canada.

Two provenance tests for Scots pine are in progress. In 1960, eleven Russian sources of 3-0 seedlings were planted for a co-operative study with Mr. M. J. Holst, Geneticist, Department of Forestry of Canada. Height data in 1964 and 1965 would suggest that 9-year-old plants provide reliable measures of the comparative vigour for Scots pine tests. Seedlings from Orel, Kiev and Woronesh demonstrated greater height, longer needles and better survival than those of other provenances; whereas those of the one Finnish (Niska) provenance were the least vigorous with the shortest needles. In the 1962 provenance planting of 31 Russian sources, (a co-operative study with Dr. P. E. Slabaugh of U. S. D. A., Forest Service) the Orel provenance is also outstanding, being surpassed only by the Smolensk provenance for vigour.

A Ponderosa pine provenance study, which consisted of 80 American seed sources, was sown in 1965, in co-operation with Dr. Dawson of the U. S. D. A. Lake States Forest Experiment Station. Average germination for three replications of 50 seed was 77% and seedling stands in October exceeded 7,000.

Seed accessions for new test plantings were continued in 1964. Thirteen lots of pinus ponderosa seed, from 12 superior trees in Denbigh Forest of North Dakota and one seed lot from the Black Hills, were sown on May 1. Average germination ranged from 25% to 75% on June 19. Several types of conifer seed which were purchased from Mr. Moran of Stanford, Montana, were also sown in 1964. Seedbed germination was as follows: three species of Juniper did not germinate, five species of spruce ranged from 15% for *P. sitchensis* to 95% for *Picea g. albertina*, seven species of pine ranged from 40% for *P. flexilis* to 100% for *P. nigra*. All seed was broadcast on the beds and covered with sand. This material will be utilized for test plantings in 1968.

Conifer seedlings are normally transplanted as 2-0 plants and cultured for two or three years prior to planting for performance tests. The 1964 sowings of 18 coniferous species have produced 50,000 seedlings for 1966 transplanting. Twenty-three thousand seedlings from the 1963 sowings of 29 conifer species were transplanted on May 13, with an average fall survival of 67%.

Regional shrub tests being conducted in co-operation with Mr. W. Cumming, Horticulturist, of the Morden Experimental Farm, were examined in 1965 by a new planting of 36 species. Performance data were compiled for the 1960 planting of 60 shrubs, of which 38 were recommended for this area. A complete report on the 60 species is in progress.

The results of the above plantings support the need for additional tests to evaluate fully all available species and races of trees for prairie use.

Three to seven seedlings of 109 species were planted to the field in the spring of 1959 for a five-year performance test which concluded in the fall of 1964. Final performance records indicate 33 species rated as good, 27 medium, 34 poor, and 15 are recommended for retesting. Ratings are based on winter injury, height and spread. All data has been processed, and sent to Mr. Cumming for evaluation. Results of other tests in progress, for 1960, 1961, 1963, 1964 and 1965 plantings including 123 species and 685 seedlings, will be reported as completed.

In 1962, two regional shrub tests were established in Saskatchewan in co-operation with the Plant Industry Branch and the Agricultural Representative Service. These tests were planned to determine the adaptability of several shrub species to soil and climatic factors of these two districts and to evaluate their potential as material for farm shelterbelts and conservation use. The seedlings were planted in a single row with plants two feet apart and shrub species replicated as single plant plots in the row. Planting losses were replaced for the first two years. At Dafoe, where part of the test was planted through a relatively saline area, Siberian elm, Russian olive, Chokecherry, and Buffalo-berry were used, because they are known to have some degree of alkali tolerance. These are long-term projects, and it is much too soon to draw conclusions. Final evaluation cannot be made until the plants reach maturity. In 1960, co-operative tests were planted at three locations by the Department of Agriculture and Conservation of Manitoba. Planting stock was obtained from several sources including the Tree Nurseries of PFRA. The object of the tests was to evaluate species as shelterbelt material and herbicides for weed control in trees. Unfortunately, herbicidal treatments distorted the performance of the plant material and no detailed report is available.

In 1965, two test plantings were established at Davidson and Carrot River, Saskatchewan. Planting survival and top growth for some of the new plant species in these tests approached those of standard shelterbelt species, but further performance data are required over a period of five to ten years to provide reliable information.

The earliest tests by former Superintendents (N.M. Ross, 1904-1941; J. Walker, 1942-1958) was established with 100 plants in 10 x 10 per block at 4 ft. x 4 ft. spacings. These plantings, being cultured under dry land conditions, suffered severely from the 1961 drought, so that removal was necessary in the fall of 1964. Fortunately survival and growth records were compiled for all plantings in 1961 and 1964, and these are summarized in Tables 6 and 7. Unfortunately, the seed sources and correct nomenclature for material in these tests are unknown. Further, it is possible that growth was influenced by differences for survival and density of each planting. The performance data listed in Table 6 clearly demonstrate relative merits of deciduous species currently being recommended for shelterbelt plantings. For example, the survival 53 years after planting was 59% for green ash, 48% for American elm, but only 29% for Manitoba maple and 22% for Siberian elm. Subsequent survival of these species in 1964 following the severe drought of 1961 supports the present use of species for shelterbelts. Most clones of willows showed high survival until 1961, but drought losses to 1964 suggest gold willow may be superior to others followed by white willow. Survival of poplar clones was low under dry land culture and was even lower after the drought. The unusual survival for aspen poplar in 1961 was due entirely to

Table 6. Performance of 1911 to 1947 Plantings* of 20 Deciduous Tree Species

Species Nomenclature	Planted	Survival 1961 (%)	Survival 1964 (%)	D. B. H. range (in.)	D. B. H. mean (in.)	Height range (ft.)	Height mean (ft.)
Acer saccharum	1911	13	4	4.7- 8.4	6.2	42-63	50.5
Acer negundo	1911	29	25	10.5- 3.9	7.3	25-58	43.9
Fraxinus l. pennsylv.	1911	59	41	1.6-10.6	4.6	15-63	33.7
Fraxinus americana	1947	88	44	0.3- 3.3	1.1	9-30	19.0
Populus northwest	**	11	4	8.5-13.0	9.8	58-66	62.5
Populus Woobstii riga	**	4	4	15.3-16.8	15.9	57-68	61.6
Populus "Sask" 2	**	9	6	5.7-13.0	9.8	54-69	59.8
Populus "Sask" 1	**	12	5	6.8-14.7	11.6	39-68	58.5
Populus tremuloides	**	90	8	1.5- 4.8	3.2	16-46	33.7
Populus balsamea	**	4	3	4.9- 7.3	6.2	28-34	30.7
Quercus macrocarpa	1947	6	6	4.7- 7.4	5.8	31-41	34.8
Salix alba	1911	22	17	3.8-10.4	6.4	23-69	40.9
Salix rubra	1911	18	5	4.5- 7.0	5.6	28-36	32.3
Salix aurea	1911	35	34	3.4-13.0	5.8	27-58	29.8
Salix britzensis	1911	5	4	4.7- 6.8	5.5	16-38	27.0
Salix laurifolia	1911	28	0	-	-	-	-
Salix acutifolia	1911	27	0	-	-	-	-
Tilia americana	1913	12	12	4.1-10.1	7.7	43-60	50.4
Ulmus americana	1911	48	45	2.6-13.2	6.4	12-18	34.5
Ulmus pumila	1913	22	13	2.3- 5.9	4.3	27-41	34.4

* Most plantings originally 100 seedlings of unknown origin
** Planting date not recorded; probably some year later than 1911

regeneration by suckers, whereas the 90% loss following drought was repeated throughout the prairie region during 1962-64. On the other hand, Northwest and Saskatchewan poplars were outstanding among the deciduous trees for growth, especially for height. For this reason poplars are still used as "nurse trees" in the farm home shelterbelts. American basswood, although low (12%) for survival demonstrated outstanding height and diameter, as well as the ability to withstand drought when well established. Sugar maple had very low survival, but four trees attained an average height of 50 feet in 56 years. Manitoba maple attained an average height of 43 feet in 53 years in comparison to 34 feet for green ash and American elm.

Performance data as listed in Table 7 for 31 coniferous tree species provides guides for present and future use of conifers for prairie plantings. Colorado spruce proved vastly superior to white, Norway, and black spruce for survival, especially following drought, but was inferior to white and Norway spruce for growth. However, the performance of the Siberian spruce showed promise worthy of further consideration. Siberian fir was superior to balsam fir both in survival and growth. Siberian, American and European larch demonstrated exceptional growth with reasonable (25%) survival. Pines, with few exceptions, were generally higher in survival than most other conifer genera. Scots pine as a group was exceeded only by the Swiss stone pine for survival. The Russian race of Scots pine (as reported in 1953) was superior to all other races for survival, although the Aberdeen and Finnish races performed well. Swiss stone pine with a survival of 37% to 1961 suffered more severely than Scots pine from the drought of 1961, and lacked the growth of Scots pine. Good survival (25%) was demonstrated by lodgepole, limber, and white pine until 1961, but all except lodgepole suffered high drought losses later. Survival of Austrian, red, Jack and Ponderosa pine was generally inferior to the other species. However, Jack and Red pine appeared the most vigorous species approaching 60 feet height in 50 years and Austrian pine the least. Most Scots, white and lodgepole pines made over 50 feet of growth in 50 years, while Ponderosa, Swiss stone and limber pine reached 40 feet height. Douglas-fir and the cedars proved less adapted to the prairies, but demonstrated some ability to survival after being established.

The results of the above plantings support the need for additional tests to fully evaluate all available species and races of trees for prairie use.

Table 7. Performance of 1908-1946 Plantings* of 32 Conifer Tree Species

Species Nomenclature	Year Planted	Survival 1961 (%)	Survival 1964 (%)	D. B. H. range (in.)	D. B. H. mean (in.)	Height range (ft.)	Height mean (ft.)
Abies sibirica	1913	26	19	2.2-11.3	6.3	36-64	51.9
" balsamea	1908	11	5	4.8- 9.0	6.6	38-54	48.4
Larix sibirica	1908	25	25	4.5-12.7	9.1	44-76	65.6
" americana	1908	28	28	4.0-13.0	7.4	46-76	63.8
" europea	1908	26	16	4.3-16.9	10.0	33-72	62.9
" dahurica	1930	60	21	1.5- 7.7	3.7	20-58	40.1
" leptolepsis	1908	7	0	6.2- 9.3	7.9	26-44	39.2
Picea abies (Sept.)	1910	6	0	4.2-14.0	8.8	42-74	61.2
" abies	1910	8	1	2.3-12.9	6.7	27-72	58.1
" glauca	1908	0	0	4.3-11.9	8.6	44-64	56.7
" g. densata	1908	4	1	4.5-12.2	7.9	36.68	53.7
" pungens	1908	37	20	4.4-11.1	7.4	38-64	48.8
" mariana	?	10	26	4.6- 7.6	5.7	32-48	38.8
" obovata fenica	1946	61	46	0.6- 4.0	2.5	9-34	22.7
Pinus banksiana	1908	12	8	3.9- 8.6	5.9	42-75	58.2
" resinosa	1910	7	1	11.2-14.1	12.7	51-63	56.7
" strobus	1913	22	19	3.0-12.5	6.9	30-72	52.9
" syl. (German)	1908	20	20	5.6-11.0	8.2	36-75	52.0
" contorta	1908	26	24	3.5- 8.5	5.9	36-64	51.9
" sylvestris	1913	16	15	6.0-12.8	8.4	37-56	49.2
" syl. (Russian)	1913	34	30	3.7- 9.0	6.6	26-54	42.7
" ponderosa	1913	14	14	4.6- 9.7	7.2	32-52	41.8
" cembra	1908	37	28	1.4- 8.2	5.1	15-54	39.0
" flexilis	1911	26	16	2.4- 9.1	5.8	24-46	36.8
" syl. (Finnish)	1924	44	38	2.5- 6.5	4.6	17-44	34.4
" " (Aberdeen)	1924	32	29	2.2- 8.7	4.9	16-44	32.1
" " (Riga)	1913	20	16	4.2-10.4	6.5	22-44	31.4
" austerica	1911	3	3	2.4- 6.3	4.8	22-27	24.5
" mughus	1908	12	8	not recorded - procumbent			
Pseudotsuga taxifolia	1910	17	16	4.7-11.5	7.4	32-58	43.2
Thuja warreana	1912	12	9	-	not recorded		-
" occidentalis	1908	8	6	2.2- 5.0	3.8	24-38	32.0

* Plantings originally 100 seedlings of unknown origin

NURSERY CULTURAL INVESTIGATIONS

Seed Viability Studies

Dewinging effects on elm seed viability was investigated in 1965. Mature seed of Siberian and American elm was harvested in June of 1964 and stored as winged seed for 260 days at 0°F in sealed polyethylene bags. In April of 1965 large samples of this seed were passed through the dewinging machine from one to three times for partial to complete removal of the wings. Moisture content of the seed was determined before and after dewinging. The seed was then sown at a depth of half an inch in sand in the greenhouse and germination recorded for 25 days with the results listed in Table 8. Germination of winged, partially and completely dewinged seed of Siberian elm was 92, 92, and 95%, respectively, whereas that of American elm was 79, 96, and 49%. These results suggest that 7% of the Siberian elm seed was not viable; whereas 20% of the winged seed of American elm was abortive or empty. Complete dewinging appeared to damage more seed of Siberian elm than of American elm, and all such visually damaged seed was manually removed prior to the germination test. Evidently, much of the damage to completely dewinged seed of American elm was not apparent visually, but was manifested by a 50% reduction in germination as well as by a marked reduction in the moisture content. On the basis of the study it is recommended that elm seed be only partially dewinged for maximum viability.

Table 8. Dewinging Effects on Viability of Siberian and American Elm Seed

Degree of Dewinging[1]		Moisture content[2]		Germination	
		Siberian	American	Siberian	American
		(%)	(%)	(%)	(%)
None	(0)	10.2	-	92.5	79.0
Partial	(1)	10.0	10.4	92.5	96.0
Most	(2)	10.0	-	83.8	-
Complete	(3)	10.6	7.8	95.0	49.0

1 Dewinged by one to three passes through clipper EP26B dewinger

2 Moisture content of seed as % fresh weight

3 Average germination capacity in 25 days for 8 samples of 25 seed

Sowing depths for elm seed was investigated in the greenhouse. Winged seed of Siberian elm was sown at four depths in 2:1 and 1:2 mixtures of soil to sand, and the termination recorded for 25 days. Soil texture appeared to have little effect on germination speed or capacity of elm seed under greenhouse conditions. Germination at the 0.12 inch depth was 92% and 94% at the 0.5 inch depth. Most seedlings from the shallow 0.12 inch sowings were lost after germination due to exposure. It is recommended that winged seed of elm be sown as near as possible at a depth of half an inch.

Stratification of old elm seed increased both germination speed and capacity. Winged seed of American elm was harvested in 1962 and stored at room temperatures in polyethylene bags until the fall of 1965. Samples were stratified in moist sand for 20 days at 40°F, then sown in the greenhouse with non-stratified checks. Within 15 days germination capacity of the stratified seed was 55% as compared to 29% for the check, and the corresponding indices (Bartlett's) of germination speed were 0.99 and 0.75, respectively.

Viability of stored conifer seed is determined annually in the greenhouse during the winter for the production program. Samples for these tests are taken from all seedlots in storage following inventory of same in December. These are divided into four lots of 25, surface sterilized, by dipping in a 0.5% solution of HgCl, and stratified for 0, 15, or 30 days in moist sand at 40°F, then sown in the greenhouse. Germination data is recorded twice weekly for 20 days with the results listed in Table 9 for the 1965 study. The results suggest that seed of Colorado spruce and Scots pine from nursery collections is equal or superior to commercial and other sources, whereas local seed of white spruce is inferior in viability. It is evident that the 1962 and 1964 seed of Colorado spruce must be stratified for 15 days prior to spring sowing, and that the commercial seed should be sown at twice to three times the normal rate. The 1964 seed of Scots pine requires no stratification, but that of 1962 should be stratified for 15 days and that of 1955 should be sown at double the rate or discarded. Fall sowing of the Alberta 1958 and the nursery 1964 seed of white spruce is necessary, but the 1962 and commercial 1964 seed could be spring sown after 15 days of stratification.

Table 9. Viability of Stored Conifer Seed Following Stratification[1]

Conifer Species	Origin	Year	Germ. rate[2] 0	15	30	Germ. cap.[3] 0	15	30
			(index)	(index)	(index)	(%)	(%)	(%)
Colorado spruce	Nursery	1962	.33	.67	.72	25	87	78
	Commercial	1962	.34	.68	.81	9	25	29
	Nursery	1964	.47	.76	.78	22	90	89
	Commercial	1964	.51	.68	.83	28	48	57
White spruce	Alberta	1958	.44	.70	.95	10	46	68
	Nursery	1962	.22	.85	.57	3	73	26
	Commercial	1964	.64	.95	.88	22	79	80
	Nursery	1964	.27	.61	.70	3	44	68
Scots pine	Nursery	1955	.53	.60	-	32	35	-
	Manitoba	1962	.60	.85	-	47	86	-
	Nursery	1964	.80	.94	-	77	75	-

1 Seed stratified for 0, 15, and 30 days in moist sand at 40°F
2 Rate of germination index, the larger the ratio the earlier emergence
3 Germination capacity as % of seed sown 20 days earlier

Maturity of Scots pine cones and seed were investigated for the 1962 and 1964 seedcrops. Cones were harvested from three trees on three consecutive dates in October of 1962 and on four consecutive dates in September and October of 1964. Specific gravity and moisture content of five cones were determined for each date of harvest. Seeds per cone and weight of 1,000 seeds were recorded, then germination tests conducted for stratified and non-stratified seed. Data for the above cone harvests and seed characteristics are summarized in Table 10. Both specific gravity and moisture content of the cones gradually decreased with each subsequent harvest in 1962 and 1964. However, agreement of the moisture content for cones from all three seedtrees on each date of harvest would suggest this is the more reliable index of cone maturity. Variability for the number of seeds per cone extracted was apparently a seedtree characteristic, which in 1962 was exceptionally high for two of the three trees on the first two dates of harvest. Possibly, the more mature cones of Scots pine require special moisture treatments to facilitate the release and extraction of all seed.

Table 10. Cone and Seed Characteristics for 1962 and 1964 Harvests of Scots Pine (Means for three trees)

Date of Harvest	Cone[1]		Seed[2]		Germination[3]	
	S. G.	Moist.	per cone	wt/1000	strat.	non
		(%)	(No.)	(gm.)	(%)	(%)
Oct. 12/62	1.002	44	24	6.7	97	97
" 18	0.995	43	23	6.7	98	97
" 31	0.893	31	6	7.6	97	97
Sep. 14/64	1.081	47	10	7.5	95	89
" 28	1.028	45	19	7.3	91	72
Oct. 13	1.019	43	11	6.2	87	42
" 27	0.954	36	6	5.8	92	94

1 Average specific gravity and moisture content of 5 cones
2 Seeds extracted per cone and average weight of 1,000 seeds
3 Germination capacity of stratified (15 days) and non-stratified seed

Maturity of the cone appeared to have little influence on germination capacity of the resulting seed, although stratification slightly increased germination of the less mature seed. However, germination tests of the 1962 seed in 1964 demonstrated that seed from the two earlier harvests decreased 20% in viability after storage for two years. The above results suggest cones of Scots pine may be harvested from mid-September to the end of October, but that harvesting in late October is recommended if the seed must be stored for several years.

Dormancy of maple and ash seed has handicapped greenhouse investigations for herbicides and fertilizers. In preliminary tests the germination of Manitoba maple seed was increased from 4% to 39% by stratification for 15 days in moist sand at 40°F, but no improvement followed longer stratification nor acid treatments. Germination of green ash increased from 5% to 85% following 60 days of stratification, and increased to 20% after soaking in concentrated sulphuric acid for five minutes.

A caragana nodulation study was conducted in 1964 and 1965 with the co-operation of Dr. M. Timonin, Pathologist of the Department of Forestry of Canada. Three preparates of Rhizobia inocula were applied to caragana prior to sowing in June of 1964. Stand, growth, and nodulation data were recorded for the resulting seedlings in the fall of 1964 and 1965. No significant differences for these characteristics were apparent or attributable to the inocula treatments under the existing nursery conditions.

Four sowing depths for caragana seed of two diameter sizes were investigated in the greenhouse. The seed was sown in two types of germination media in the greenhouse to evaluate the effects on seedling emergence. Seed was sown at increasing depths of half an inch from 0.5 inch to 2.0 inches in a heavy (1 sand: 2 loam) and lighter (2 sand: 1 loam) soil media with the results listed in Table 11. Germination capacity of the seed of both sizes was markedly reduced by each increase in sowing depth in each type of soil media, but to a lesser degree in the lighter soil. No significant differences for germination were apparent for these two sizes of seed, which normally constitute approximately 80% of all caragana seed harvested. Average germination was 82% at the 0.5-inch sowing depth in both soil media, only 50% and 60%, respectively, for the heavier and light soil at the 1-inch sowing depth, 32% and 45% at the 1.5-inch depth, and 0.5% and 9.0%, respectively, at the 2-inch sowing depth. Rate of germination manifested a similar decrease with each increase in sowing depth. Thus it is evident that under optimum moisture conditions caragana seed should be sown at a depth of one-half inch, but under adverse moisture and soil conditions should not be sown deeper than 1.5 inches even in light soil.

Table 11. Germination Capacity and Rate for Two Diameter Sizes of Caragana Seed when Sown at Four Depths in Light and Moderate Textured Soils

Germination Media	Depth Sown	Germination capacity[1]		Germination rate[2]	
		3.0 mm	3.5 mm	3.0 mm	3.5 mm
(Sand: loam)	(inches)	(%)	(%)	(index)	(index)
1:2- - - -	0.5	83.0	85.0	0.50	0.49
	1.0	44.0	57.8	0.35	0.38
	1.5	29.0	36.0	0.21	0.22
	2.0	1.0	0.0	0.02	0.00
2:1 - - - -	0.5	81.0	79.0	0.61	0.64
	1.0	67.0	54.0	0.47	0.49
	1.5	45.0	46.0	0.35	0.33
	2.0	0.0	18.0	0.00	0.15

1 Germination capacity as % of seed emerged in 50 days
2 Germination rate as index from total emergence divided by dates x emergence

Chilling requirements of tree seedlings for greenhouse studies were investigated in 1964. Seedlings of five deciduous tree species were potted and stored at three temperatures for 7 to 90 days to determine chilling requirements for promotion of new growth. One-year-old seedlings of Siberian elm, American elm, caragana, green ash, and Manitoba maple were harvested on October 14 1964, and stored in moist sand at 50°F until potted on November 26. These potted seedlings were then stored at 28°, 35°, and 41°F and the effects evaluated as days to bud-break when placed in the greenhouse after 7, 14, 48, 62, 76, and 90 days of storage. None of the above supplementary chilling treatments appeared to shorten the period of bud-break for any of the tree species beyond that of the checks. Bud-break of the check seedlings required 6, 18, 19, 27, and 28 days, respectively, for the above five species. It would appear that the temporary post-harvest storage treatment of 40 days at 50°F conditioned the seedlings beyond the influence of subsequent chilling treatments.

Investigations at the Tree Nursery also involve: Tree Nutrition, Herbicides, Entomology, Seedling Storage, Conifer Transplanting, and Irrigation. Results of the studies are reported annually in the Summary Reports, which are available at the Nursery.

AMINO ACID AND PROTEIN CONTENT OF THE EMBRYO AND FEMALE GAMETOPHYTE OF JACK PINE AS RELATED TO CLIMATE AT THE SEED SOURCE

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Non-stratified seed from collections taken across the natural range of jack pine (cf. Holst 1963) were studied for free amino acids and soluble proteins (pH 8.3, 0.1 M Tris-glycine) by methods of Benson and Patterson (1965) and Durzan (1966).

More than 20 free amino acids and 18 proteins were found in the female gametophyte (Haploid) and embryo (diploid). Their concentrations reflected not only genetics of the tissue but also climate at the seed source. All protein amino acids were detectable free together with γ-aminobutyric acid, ornithine, citrulline, β-alanine, and the amides. Almost twice as much soluble protein occurred in the gametophyte.

Major climatic factors together with dry weight, years from seed collection, % germination, etc., totalling 17 variables and their combinations were selected for regression analyses too detailed to be described here. Preliminary examination of the results show that smaller seed high in protein come from northern sources with a shorter growing season, lower annual temperature but greater rate of change in photoperiod.

In haploid nutritive tissue, highly significant relations exist between content of both protein and amino acids to the interaction of the length of growing season x dry weight. The main nitrogenous storage compound, arginine, was affected by temperature x precipitation. Main forms of translocated nitrogen, i.e., amides, glutamine and asparagine, were influenced by precipitation. A key amino acid, alanine, related to protein synthesis and by transamination to the tricarboxylic acid cycle was affected by dry weight rather than climatic factors.

In the embryo, a different pattern emerged. High protein content was dependent on dry weight and temperature x precipitation. Total amino acids reflected mostly the interaction of precipitation to dry weight. Arginine content was affected by temperature x precipitation. Amides reflected temperature x dry weight and, alanine, temperature x precipitation.

These and many other factors are not described here, e.g., sugar content will be published in detail elsewhere and will cover the relationships of between composition, climate and facets of metabolism uncovered from this study.

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SEED ORCHARDS AND SEED PRODUCTION AREAS IN ONTARIO

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PROVENANCE TESTS

Jack Pine

In spring 1966, in co-operation with Forest Research Branch, Department of Forestry of Canada, five sections of an all-range jack pine prevenance experiment, 255-E, were set out in Cochrane, Port Arthur, Sioux Lookout, Sudbury and Swastika Districts in northern and northwestern Ontario. Each section consists of 5-tree plots with ten replications of from 57 to 85 provenances.

In addition, two sections of an experiment, 268-E, containing jack pine provenance hybrids were set out in Sudbury and Swastika Districts. Each section consists of 5-tree plots with three replications of 25 provenance hybrids and 50 control provenances.

White Spruce

In December 1964, a measurement was made of a white spruce provenance test, 93-C, planted in 1958 in Artemesia Township, Lake Huron District. The information was forwarded to M. Holst, Petawawa Forest Experiment Station, for comparison with other sections of the test.

SEED ORCHARDS

Four seed orchard sites were selected and established in the past two-year period, as shown in Table I. Seed orchards previously established are also listed to show the number of clones and acreage planted in 1965 and 1966.

TABLE I

		Planted			
		1965		1966	
Species	Location	No. of Clones	Acres	No. of Clones	Acres
White Pine*	Lindsay District Orono Nursery	x	3.8	x	5.5
White Pine*	Parry Sound District Gurd Twp.	12	0.5	NIL	

TABLE I (continued)

Species	Location	Planted 1965 No. of Clones	1965 Acres	1966 No. of Clones	1966 Acres
Red Pine *	Parry Sound District Gurd Twp.	21	2.0	8	2.0
Red Pine *	Swastika District Grenfell Twp.	22	3.0	36	5.5
White Spruce	Lake Simcoe District Midhurst Nursery	N I L		18	2.0
Black Spruce	Lake Simcoe District Midhurst Nursery	N I L		18	2.0
White Spruce	Port Arthur District Camp 503	N I L		15	2.0
Black Spruce	Port Arthur District Camp 503	N I L		16	2.0

* Previously established.

Red Pine

Seed orchard development in red pine has been given reduced emphasis in the past two years. Acknowledging that red pine is fully self-fertile and does not suffer inbreeding depression the program of grafting red pine for clonal seed orchards is to be maintained only to fill fail spots in present seed orchards.

Some mortality has been noticed in the oldest (1959) planting of red pine in the Grenfell Township seed orchard. There is the possibility of incompatibility with Scotch pine under-stock, although it is now difficult to identify the root-stock species from bark characteristics. However, mugho pine root-stock is obvious and it was noted on a recent inspection that one of the tallest and best-formed red pine was grafted on mugho pine root-stock.

White Pine

The white pine seed orchard at Orono Nursery is derived from scions supplied by the Tree Breeding Unit of our Research Branch and obtained from trees selected for indicated resistance to blister rust. In the past four years sufficient grafts have been set out at an 18-foot x 18-foot spacing to fill the 9-acre open field available for the seed orchard. The area is isolated from mature white pine but there is an extensive white pine plantation immediately to the north. Rather than destroy the plantation, field-grafting each year in early spring has been carried out in conjunction with greenhouse grafting. Scions were collected during the winter and kept frozen until field-grafting time in March or early April. Grafting success has been very satisfactory using winter-collected scions and stored frozen. However, in 1964, scions were collected in early April, just prior to field-grafting time. Survival dropped to 18% (after six months) from 63% (1963 grafting after 18 months) for freezer-stored scions.

Other factors, such as weather conditions at the time of field-grafting, would no doubt contribute to differences in survival, but there appears to be a distinct advantage in spring field-grafting of white pine using winter-collected scions stored frozen until required.

White and Black Spruce

When selecting spruce seed orchard sites in northern and northwestern Ontario some difficulty is experienced in finding areas with necessary isolation from natural spruce. The best opportunities occur in a young extensive stand of jack pine or poplar. Black spruce occurs, usually as an understory, in many jack pine stands. White spruce and/or black spruce occur in poplar stands as an understory, or more commonly as a mixedwood type, with a much higher number of stems per acre than in jack pine stands.

In the case of the Camp 503 orchard, Port Arthur District, a 45-year-old stand of jack pine was selected. It is roughly a mile square and with the orchard site centred in the stand, provides a satisfactory surround of about one quarter mile in each direction. Scattered black spruce occur as saplings and in a few cases as larger trees which have reached flowering age. A program to remove all spruce from the surrounding area is being carried out. Costs of clear cutting the jack pine for the seed orchard are partially offset by stumpage revenue.

SEED PRODUCTION AREAS

Four seed production areas have been established in the past two-year period, as follows:

Species	Location	Site Region	Acres	Development
Red Pine	Kenora (Willingdon Twp.)	5S	5.2	Releasing and crop tree marking 1966.
Jack Pine	Cochrane (Sheraton Twp.)	3E	20.0	None.
White Spruce	Cochrane (Clute Twp.)	3E	2.0	Poplar overstory removed and area brushed, 1964. Thinned 1965.
Black Spruce	Cochrane (Ottaway Twp.)	3E	16.0	Poplar overstory removed 1965.

Red Pine - Lynn Tract - Oro Township

In 1963, an experiment was carried out to determine the effect that various combinations of nitrogen and potassium might have on seed production during the second year of cone maturation. From the data obtained and analyses made, the levels and combination of nitrogen and potassium did not significantly influence total seed production, average number of seeds per cone, total weight of seed or the average weight of the seed. Losses through damage by insects and squirrels were such that approximately 56% of the cones counted in June were lost by September, indicating the necessity of control measures in stands managed for seed production. The development of a medium crop for 1966 resulted in the decision to apply DDT 25% emulsion concentrate; one gallon of concentrate in 25 gallons of water to obtain a drenching application. Two applications were made, 3 weeks apart.

White Spruce - Aurora Township

In fall 1960, a special collection of seed was made from twenty white spruce in Aurora Township, Cochrane District. The 20 seedlots were sown separately at Swastika nursery and lifted as 2-2 transplants in the spring of 1966. One hundred trees from each seedlot were selected and planted 6-foot x 6-foot on a prepared site in Clute Township, Cochrane District. The trees were selected on the basis of best height growth and form, single-stemmed with a dominant leader. The plantation will be thinned as required to retain the best trees of each progeny as seed crop trees.

White Spruce - Pagwa - Geraldton District

Windthrow of scattered large seed trees was occurring in this area. The trees have large boles and large, deep crowns. Assessment work, future thinning and release would be hempered and considerable damage caused to seedlings, some now in their sixth growing season. It was therefore decided to remove all the white spruce seed trees in a controlled cut. This was done in the winter of 1965-66 when there was more than 3 feet of snow on the ground. Residual poplars are to be girdled and poisoned.

SEED COLLECTION

The tree improvement program carried out by the Timber Branch is geared to requirements of seed for the total artificial regeneration effort, including nursery stock production for Crown and private land planting, production of tubed seedlings, and the direct seeding program. Seed requirements for fall 1966, to maintain the necessary reserved, are for the equivalent of 20,850 busheld of cones and rough seed. Nearly half a billion viable seeds were distributed from the Ontario Tree Seed Plant at Angus, Ontario, in 1965. The seed inventory as of June 1, 1966, shows that we have in storage nearly 1-$\frac{3}{4}$ billion viable seeds, of 46 species, weighing over 10-$\frac{1}{2}$ tons. Poor seed crops in the past few years, have caused serious shortages, particularly in red pine. Over 8,000 bushels of this species are required this fall.

Predicted requirements for seed for 1975 are the equivalent of over 21,000 bushels of cones. Development of seed production areas and seed orchards must keep pace with the expanding artificial regeneration program so that an increasing amount of seed of improved quality may be obtained from stands selected or established, and treated for early and abundant seed production.

PHYSIOLOGY OF FLOWERING AND CONE PRODUCTION IN DOUGLAS-FIR, 1965-66

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Recent fertilizer experiments, established co-operatively with the reforestation division of the British Columbia Forest Service, to test the effect of treatment rate, retreatment schedule, formulation and timing, have confirmed and extended information on nitrogen induced cone production of Douglas-fir. Control trees in a 20-year-old stand bore no cones in the poor crop year of 1965. Under these conditions only negligible response resulted on 4-inch diameter trees from fertilizer treatments applied at vegetative bud break the previous year. A mean of 50 cones per 5- and 6-inch trees resulted from an optimum rate of 200 lb N/acre as ammonium nitrate. Double or quadruple this rate was optimum for 7-inch trees with a mean of 200 cones produced per tree. Under the excellent cone crop conditions of 1966, mean cone production in the second year after treatment ranged from 60 to 100 cones per tree over the 50 to 400 lb N/acre initial treatments. The initial heavy rates of 800 and 1,600 lb N/acre reduced female cone production to the control level of 20 cones per tree. Retreatment at 400 lb N/acre as ammonium nitrate in 1965 increased the number of bearing trees and doubled cone production in 1966 over that of non-retreated plots. The experimental design provides for continued comparison between non-retreated and annual and biennial retreatment to determine the optimal fertilization schedule for seed orchard management.

Mean cone counts in 1966 of 25, 67, 114, 176, and 180 were obtained on 3-inch diameter class trees on a medium site, 11-year-old plantation, from applications of 0, 200, 400, 800, and 1,600 lb/acre, respectively, of nitrate nitrogen applied just prior to vegetative bud break during a prolonged dry period in 1965. The high optimum rate required in this instance on these small trees is probably attributable to decreased availability of applied fertilizer under the dry conditions of 1965, compared to the wet conditions which accompanied initial treatment of the 20-year-old stand in 1964. A weaker response was obtained where the experiment was repeated on a poor site in the same plantation. No worthwhile response was obtained on either site from ammonia nitrogen applied at the same rates.

No response was obtained from nitrate nitrogen applied at 200, 400, and 800 lb/acre to two-year-old grafts on five-year-old rootstocks at the Quinsam seed orchard.

A further experiment in the 20-year-old stand compared the effect of fertilizing with nitrate versus ammonia nitrogen at 400 lb/acre, applied at the time of flowering in mid-April, just prior to vegetative bud break in late May, and after advanced new growth in mid-June. April and June nitrate treatments and May ammonia treatment increased cone production to a mean of approximately 150 cones per tree compared to a mean of 100 cones per control tree. However, a mean of 527 cones per May-nitrate-treated tree emphasized the importance of formulation and correct timing. Urea nitrogen, applied at same rate in May was deleterious to growth and cone production.

An intensive observation and sampling program has accompanied these experiments to determine the physiological basis for the differential cone crop responses to formulations and timing. No differences due to formulation is apparent in rate of nitrogen uptake, concentration of total nitrogen in buds or twigs, or twig dry weight and length increase. The total number of buds per twig was similar for all treatments and the control, and the percentage of aborted buds on twigs from non-inductive treatments was similar to that of the control. However, April and May nitrate treatment strikingly reduced the proportion of aborted buds. This suggests that a qualitative difference in nitrogenous assimilates at the locus of cone bud production may result from the two different ionic forms of nitrogen. Undefined metabolic patterns accompanying nitrate nitrogen treatment may favour bud development and, when correctly timed, the floral initiation process. Laboratory investigations on collected samples will pursue these possibilities in detail.

A 60-day drought treatment in 1964 on potted 1959 grafts, bracketing the time of vegetative bud break, resulted in female cone production on 25% and male cone production on 40% of the treated ramets. Male and femaly cone production has also been obtained by drought treatment on 2+2 seedlings following lifting and potting just prior to bud break. New experiments are proceeding to determine the optimum period and minimum duration of drought treatment for floral initiation on grafts and seedlings. Conditions of the original experiment suggest that moisture stress, not temperature, is the primary factor responsible for floral initiation in hot dry seasons. The moisture stress concept provides a unifying theory for floral initiation due to such varied causes as root pruning, spring flooding, distress crops accompanying root rot disease, and to some degree the responses from girdling and heavy fertilizer treatments.

TREE BREEDING WORK AT THE FACULTY OF FORESTRY, UNIVERSITY OF TORONTO

J. L. Farrar,
Abitibi Prof. of Forest Biology

J. J. Nicholson
Graduate Student

Two experiments are in progress. One is aimed at determining whether white spruce, found growing in regions with limestone soils, has become specially adapted to such sites. Five provenances from granitic and limestone sites were grown from seed in a growth chamber for three and a half months with nutrient solutions containing 1, 8, 64, and 512 ppm of Ca^{++}. Root and top weights of individual provenances showed considerable fluctuation in the four treatments, so the five provenances from each of the two site types were pooled together. It was found that with both root and top weights, there was little difference between site types in the calcium treatments with the weights from the granitic sites being slightly higher. However, with the highest level of calcium, root and top weights of the limestone site group were greater than for the granitic group. The ratio of top weight to root weight increased with increasing calcium concentration in the lowest three treatments with a negligible difference between site groups; but in the highest level of calcium the ratio increased sharply for the granitic sites.

The second study is concerned with the analysis of different sources of variation in wood properties of seedlings from controlled crosses of Douglas-fir grown under long and short photoperiods. Seedlings were supplied by the University of British Columbia. Variation between crosses was not significant but variation between seedlings within crosses was highly significant for most properties indicating a small effect due to inheritance. Repeatabilities have been calculated and causes for difference in the magnitude of between-seedling and within-seedling variance components in the two photoperiods are being analysed.

PINE AND SPRUCE BREEDING AT THE SOUTHERN RESEARCH STATION, MAPLE, ONTARIO

1964 and 1965

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In January 1964, C. C. Heimburger officially retired as head of the Tree Breeding Unit. This position was filled by D. P. Fowler. Dr. Heimburger continues to play an active role (officially a consultant) in the program - see report on Populus by C. Heimburger.

In September 1965, Miss R. M. Rauter (U. of T. Forestry, 1965) was hired to work in the Tree Breeding Unit.

Work with white pines, hard pines, and poplars continued on an active basis, while work with cedar continued on a maintenance basis. A spruce breeding project was initiated in 1964.

HARD PINE

The production of a red pine or red pine-like hybrid, resistant to the European pine shoot moth, Rhyacionia bouliana (Schiff.) and of satisfactory growth rate and growth form continued to be the objective of this program. Studies of natural genetic variation in red pine have largely been completed, with the conclusion that red pine is genetically a very uniform species. No new large scale studies with red pine are anticipated. The present experimental planting will be maintained. Three small studies to examine what appears to be a strong maternal effect in red pine were initiated.

In 1963, an effort was made to produce inter-specific hybrids between red pine and other species of the Lariciones group. Emphasis was placed on the use of species hybrids in these crosses, because of the more variable gametes produced by such hybrids. A small proportion (5%) of known crossable pollen was used in many of the attempted crosses to stimulate conelet and cone development. To date, a detailed evaluation of the resulting progenies has not been carried out.

Efforts to produce a rapid-growing southern pine hybrid that can be grown in southern Ontario were continued. Northern sources of pitch pine, Pinus rigida Mill, were crossed with southern pines. Progenies produced, using pollen of P. taeda from North Carolina on Canadian P. rigida, were found to be damaged by frost at Maple. It is hoped that progenies, in which northern P. taeda (New Jersey) was used as a male parent, will be hardier.

Acquisitions

The following new clones and populations were acquired in 1964 and 1965:

Species	Origin	No. Clones	No. Populations
P. nigra var. Koelelaer	Belgium	1	6
P. (densiflora x silvestris) x open	Pennsylvania		1
P. (thunbergii x densiflora) x open	Pennsylvania		1
P. leucodermis	Bulgaria		1
P. silvestris	Finland	2	
P. nigra (poiretiana)	Midhurst, Ont.	1	
P. resinosa	Angus, Ont.	26	
P. virginiana	Henry County, Va.		16
P. rigida	Thousand Islands, Ont.	5	
P. banksiana	Origin unknown (S.R.S.)	5	

Hybridization

The following populations resulted from the hard pine pollinations made in 1963 and harvested in 1964:

Cross	No. Crosses Made	No. Seeds	No. Full Seeds	No. Seedlings
P. (densiflora x austriaca) x resinosa + 5% nigra	1	540	32	25
P. (densiflora x austriaca) x res. + 5% dens.	1	177	4	4
P. (austriaca x densiflora) x res. + 5% nigra	1	519	348	314
P. (austriaca x densiflora) x res. + 5% dens.	1	132	82	82
P. (densiflora x silvestris) x res. + 5% silv.	1	211	22	18
P. hwangshanensis x res. + 5% hwangshanensis	1	2278	26	25
P. tabulaeformis x res. + 5% dens.	2	129	8	8
P. densiflora x res. + 5% hwangshanensis	1	16	3	2
P. resinosa x (dens. x austriaca) + 5% res.	3	532	99	96
P. resinosa x thunbergii + 5% resinosa	3	1372	302	291
P. resinosa x leucodermis + 5% res.	3	143	93	77
P. resinosa x (silvestris x montana) + 5% res.	4	445	153	124
P. resinosa x (densiflora x silvestris) + 5% res.	4	653	241	216
P. resinosa x (austriaca x densiflora) + 5% res.	3	556	279	250
P. nigra x resinosa + 5% nigra	2	1078	530	462
P. nigra x thunbergii	1	964	363	360
P. silvestris x resinosa + 5% thunbergii	5	216	180	96
P. (silvestris x montana) x res. + 5% silvestris	14	428	246	166
P. silv. x silv. (same population, early flowering)	16	810	651	198*
P. silv. x silv. (early x late flowering)	18	910	678	115*
P. silv. x silv. (different pop. early flowering)	23	840	618	191*
P. montana uncinata x montana uncinata	14	99	38	38
P. montana uncinata x mugho	14	36	33	30
P. rigida x pinaster	2	73	1	1

* 200 seeds only to germinate

The following pollinations, crossed in 1964, yielded seeds and seedlings * in 1965:

Cross	No. Crosses Made	No. Seeds	No. Full Seeds	No. Seedlings
P. (densiflora x austriaca) x silvestris	4	464	233	232
P. (densiflora x austriaca) x taeda	1	48	12	12
P. (silvestris x silvestris) x taeda	1	18	15	15
P. (densiflora x taeda) x silvestris	1	357	96	96
P. rigida x serotina	4	52	12	11
P. rigida x taeda	4	2117	263	263
P. rigida x open	1	78	3	3
P. pungens x rigida serotina	1	129	11	11

The following hard pine pollinations were made in 1965:

Cross	No. Trees	No. Strobili Pollinated
P. (densiflora x silvestris) x silvestris	41	775
P. tabulaeformis x silvestris	5	98
P. silvestris x densiflora	2	44
P. (densiflora x austriaca) x silvestris	10	190
P. (austriaca x densiflora) x silvestris	5	157
P. pungens x attenu-radiata	1	54
P. densiflora x silvestris	1	32
P. hwangshanensis x silvestris	7	127
P. (hwangshanensis x nigra) x silvestris	1	31
P. rigida x attenu-radiata	15	190

* Authenticity of Hybrids not verified

WHITE PINE

Resistance to blister rust and weevil, and satisfactory growth form and growth rate are the main objectives of this project.

BLISTER RUST

Two approaches have been used in attempting to develop rust-resistant trees. They are: (1) selection and breeding of Pinus strobus L., and (2) interspecific hybridization using rust-resistant species as a source of disease resistance. To date, both approaches appear promising.

(1) Selection and breeding of Pinus strobus has progressed to the point where the Timber Branch of the Department of Lands and Forests is using scions from tested rust-resistant trees for the establishment of clonal seed orchards. A large number of trees have been tested and selected in respect to rust resistance. Many of these are presently being used in combining ability tests to determine their ability to transmit resistance to their progenies. Mass selection (for rust resistance) was started in 1964 in an effort to increase the quantity and quality of rust-resistant materials. In 1964 and 1965, 22,600 and 13,300 white pine seedlings respectively were artificially infected with blister rust.

(2) Very few of the first generation interspecific hybrids appear to be of direct value for reforestation purposes because of their generally low resistance to blister rust. The most promising first generation hybrids are those between P. griffithii and P. strobus, one progeny of which shows considerable promise. Many interspecific white pine hybrids are beginning to produce male and female flowers in quantity. The production of F_2 populations and back crosses was intensified in 1964 and 1965.

WEEVIL

Final evaluation of the white pine weevil resistance test, established in 1957 at Thessalon, Ont., was made in 1964. A report of this work is being prepared by Dr. C. Heimburger and Dr. C.R. Sullivan.

It was found that phenotypic selection of Pinus peuce for weevil resistance was successful. Apparently the greater resistance of P. peuce, in comparison with P. strobus, is based mainly on heavy resin flow after weeviling and not on a differential in weevil attack (P. peuce was actually more heavily attacked by weevil than P. strobus).

NATURAL VARIATION

In 1965, two white pine provenance tests, established in 1955, as part of a co-operative U.S. Forest Service experiment, were measured. There appears to be a fairly strong correlation between latitude of origin and height growth. Some evidence of climatic damage was apparent in the data from the more northern of the two test areas. The results of this study are being prepared for publication. The summarized height data is as follows:

Population No.	Origin and Latitude °N		7-Year Seedling Height, metres Turkey Point	Ganaraska
272	Ga.	34.8	1.66	1.34
273	Tenn.	36.0	1.42	1.19
277	Ohio	40.8	1.46	0.99
274	Pa.	41.1	1.43	1.37
278	Iowa	43.3	1.01	1.02
275	N.Y.	44.4	1.32	1.22
281	N.S.	44.4	1.39	1.33
276	Me.	44.9	1.19	1.12
280	Wisc.	45.8	1.20	1.08
283	Ont.	46.4	1.23	1.03
279	Minn.	47.4	1.15	1.03
282	P.Q.	47.5	1.00	1.08

ACQUISITIONS

The following materials were acquired in the form of scions:

Species and origin	Clones	Successful Grafts
P. monticola, Larch Hills, B.C.	75	1432
P. monticola, N.Y.	2	27
P. peuce, Bulgaria	13	295
P. strobus, Finland	3	88
P. strobus, Midhurst, Ont.	28	691
P. strobus, Shelburne, Ont.	4	98
P. griffithii x *strobus*, Holland	1	23
P. parviflora glauca x *strobus*, Holland	1	13

The following populations were obtained in the form of seeds:

Species and Origin	No. Populations
P. strobus, Midhurst	18
P. strobus, Warrenburg, N.Y.	1
P. peuce, Bulgaria	2
P. strobus x *excelsa*, Italy	3

HYBRIDIZATION

The following crosses, made in 1963, were harvested in 1964:

Parentage	No. of Crosses	No. of Seeds	No. of Full Seeds
P. strobus x strobus	28	5732	4776
P. strobus x (monticola x strobus)	4	1282	1066
P. (strobus x griffithii) x (griffithii x strobus)	1	1425	580
P. (peuce x strobus) x (peuce x strobus)	4	1385	516
P. (griffithii x strobus) x strobus	3	248	98
P. griffithii x strobus	2	507	123
P. strobus x (peuce x strobus)	5	907	459
P. (strobus x parviflora) x strobus	1	116	2
P. (griffithii x strobus) x (griffithii x strobus)	9	600	265

The following crosses, made in 1964, were harvested in 1965:

P. strobus x strobus	21	3444	2172
P. griffithii x strobus	19	6369	1191
P. monticola x strobus	13	1972	647
P. (griffithii x strobus) x (griff. x strobus)	2	788	280
P. cembra x albicaulis	4	553	59
P. armandi x lambertiana	1	4326	26
P. koraiensis x lambertiana	3	238	144
P. (peuce x strobus) x (peuce x strobus)	8	2288	812

The following crosses were made in 1965:

Parentage	No. of Crosses	No. of Cone Set
P. strobus x strobus	28	414
P. (griffithii x strobus) x (griff. x strobus)	17	58
P. (strobus x griffithii) x (griffithii x strobus)	1	12
P. (griffithii x strobus) x (griffithii x strobus)	2	162
P. monticola x (griffithii x strobus)	1	46
P. griffithii x (griffithii x strobus)	7	538
P. pumila x (strobus x parviflora)	1	0

SPRUCE

Early in 1964 a project in spruce breeding was approved by the Chief of the Research Branch. The purpose of this work is to locate or develop spruces of superior quality for planting in northern Ontario. Advantage was taken of the very heavy flowering of spruce in the spring of 1964 to study genetic variation in black and white spruce, as well as to examine interspecific crossability patterns of black spruce and *P. schrenkiana*. In 1964 and 1965 the following crosses were made:

Cross	No. Trees	No. Successful Crosses	No. full seed/cone
1964			
P. schrenkiana x self	5	5	29-89
" x *glauca*	5	5	0.1-28
" x *mariana*	5	0	--
" x *omorika*	5	0	--
" x *glehnii*	4	1 *	0-0.3
" x *jezoensis*	3	0	--
" x *koyamai*	4	1 *	0-0.1
P. mariana x self	12	12	0.1-17
" x cross	12	12	1-23
" x *omorika*	5	3	0-3
" x *glehnii*	13	4 *	0-2
" x *jezoensis*	5	1 *	0-0.1
P. glauca x self	5	5	0.2-15
" x cross	5	5	5-43
1965			
P. schrenkiana x *pungens*	2	1 *	0-4
P. glauca x *schrenkiana*	1	0	--
P. omorika x self	2	2	31-49
P. omorika x cross	2	2	31-94
P. omorika x *mariana*	2	2	24-42

* Authenticity of hybrid not verified

ACQUISITIONS

The following materials were acquired in the form of scions:

Species and Origin	No. Clones	No. Grafts
Picea abies (origin unknown)	1	40
Picea glehnii, Finland	10	150
P. glehnii, Rochester, N.Y.	3	64
P. jezoensis, Rochester, N.Y.	1	30
P. mariana, Fredericton, N.B.	1	18
P. omorika, Midhurst, Ont.	3	55
P. omorika, Rochester, N.Y.	1	27
P. schrenkiana, Rochester, N.Y.	1	24

The following populations were obtained in the form of seeds:

Species and Origin	No. of Populations
P. glehnii, Japan	2
P. koyamai, Tigerstedt (from Angus, Ont.)	1
P. mariana, Chalk River, Ont. (open pollinated)	1
P. mariana, Fredericton, N.B. " "	2
P. omorica, Sandwich, Mass.	1

UPLAND AND LOWLAND ECOTYPES OF BLACK SPRUCE

In 1960, black spruce seeds were collected from five upland and five lowland stands in each of the Cochrane, Geraldton, and Port Arthur districts. These seeds were sown in two nursery and one greenhouse experiment. Results from the greenhouse experiment indicate that there apparently is no ecotype development in uplands and lowlands in northern Ontario. There are significant differences between the progenies from the three main collection areas.

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RECENT ADVANCES IN TREE PHYSIOLOGY AT THE PETAWAWA FOREST EXPERIMENT STATION, CHALK RIVER, ONTARIO

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Since the last report, the studies into the developmental anatomy of the reproductive and vegetative shoot tip of black spruce were completed; the water cycle on several sites was analysed for the 1949-64 period; flower induction, as affected by root pruning, was further explored in spruce saplings grown under natural and extended photoperiod; growth substances were evaluated by the straight *Avena* coleoptile test, and investigations with the application of gas chromatographic methods were started.

The author was seconded to the Joint Division of Atomic Energy in Agriculture of the Food and Agriculture Organization of the United Nations and the International Atomic Energy Agency, to serve as Associate Director of an International Training Course in the Use of Radioisotopes and Radiation in Forestry Research. Preliminary experiments in radiation tolerance of spruce and birch seeds and other radioisotope experiments were conducted in the winter and early spring of 1964-65. This work was done in co-operation with the Biology Division, Atomic Energy of Canada, using both a two million-volt X-ray machine and a Gamma Beam 1500 (Co^{60}). This exploratory work was done first in Canada and then in Germany in conjunction with the development of the syllabus for the course, which was held at the Institute of Radiobiology, Technical University, in Hanover. While in Germany, an early-flowering strain (two years from seed to seed) of *Betula verrucosa* was observed at the Forest Research Institute, near Hamburg. Some of this material was later procured and the plants are now part of the experimental material for physiological studies of flower induction at Petawawa.

The initiation of the National Research Council Post-doctorate Fellowships within the Department of Forestry of Canada has benefited the program; the first incumbent, Dr. V. Chalupa from Prague, Czechoslovakia, arriving in February, 1965. While his main interest concentrated on the carbohydrate content in the different parts of white spruce seedlings grown under various thermo- and photo-periods, he also co-operated with M. Holst and D. J. Durzan by analysing seed from various jack pine provenances.

Uniform stock is needed for proper evaluation of individual treatments. Thus, when investigations into the flowering process of white and black spruce and its artificial induction were initiated, seedlings were planted in the Corry Lake Tree Physiology Area during four seasons, 1956, 1958, 1961, and 1964, to provide sapling material for treatment. While a portion of each age class was grown under natural photo-period, part was grown under continuous light during the summer months. An artificial shading method in 1964 and 1965 was also introduced for the proper evaluation of the effect of light on vegetative and reproductive growth. Of the 1956 planting, 200 saplings were root pruned in the spring of 1961 and then again in 1962. Some saplings of the 1958 planting were similarly treated in 1964. Although a detailed report will be available later, some advanced observations should be in order for this meeting.

(1) Long photo-periods stimulated leader growth.

(2) Long photo-period saplings produced reproductive buds two years earlier than those grown under natural photoperiod.

(3) Root pruning accelerated flower primordia initiation in long photo-period saplings.

(4) Root pruning reduced respiration rate and moisture content of shoot tips and modified growth hormone patterns.

(5) High auxin activity persisted longer in the long photo-period seedlings.

(6) A reduced photo-period was associated with a reduction of apical extension, needle length and growth period.

(7) Female primordia usually formed a year or two before male ones.

(8) White spruce formed reproductive buds sporadically while black spruce formed reproductive buds at a younger age and more consistently.

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SELECTION, PROPAGATION AND SEED ORCHARD ESTABLISHMENT PHASES OF THE DOUGLAS-FIR BREEDING PROGRAM OF THE B.C. FOREST SERVICE

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Selection of Plus Trees for Use in the Douglas-fir Breeding Program

The objective of this project is the selection of superior phenotypes from throughout the coastal range of Douglas-fir in British Columbia and their propagation in the B. C. Forest Service clone banks at Cowichan Lake. These trees will serve as a population on which intensive breeding studies may be conveniently carried out and as a source of material for the initial seed orchards.

Since this project was last reported, cruising has been continued both by the B. C. Forest Service and by members of the Tree Improvement Sub-committee; this is the co-operative body in the field of tree improvement and it is comprised of foresters from major logging companies on the coast, the University of British Columbia, the Provincial Forest Service, and the Department of Forestry of Canada.

During the summer of 1964, two B. C. Forest Service crews carried out selection, concentrating their efforts in stands on the lower mainland. Thirty-six trees were registered. The co-operative cruise, Plus Tree Week, was held at Mission in the Fraser Valley, and sixteen trees were retained. In 1965 it was felt that an effort should be made to expand the geographic limits of the trees included in the register and work was concentrated in the northern coastal portions of the species range. Five member companies of the Tree Improvement Sub-committee combined to finance a three-man selection party which was supervised and directed by the Research Division and worked with the Division's own crew. Stands were visited between Dean River (Lat. 52°50') and Sechelt (Lat. 49°40') and, in all, 67 trees were registered. Plus Tree Week was again held and nine trees were accepted. The accompanying map shows the areas from which selections have been made since the last report to the Committee.

The plus tree register now contains 442 selected trees in addition to those 161 which have been included for special purposes; these include veterans, sample trees and specimens from outside the B. C. coastal range. All but 79 of this total number of 603 have been propagated by grafting in the B. C. Forest Service clone banks at Cowichan Lake.

Scion collections from these trees by Research Division crews continues and scions are made available to co-operating companies on request; for example, 139 scion lots were provided in the spring of 1966 from collections made by Research Division staff.

Members of the Tree Improvement Sub-committee are still active in this field and in addition to the cruising, clone banks and seed orchards are being established and progeny testing initiated. In August 1964 a Tree Improvement Conference was held at Cowichan Lake to evaluate the first five years' activities of the Sub-committee and to consider future plans. In August 1965, a field trip was arranged for members to visit tree breeding establishments and Douglas-fir seed orchards in Washington and Oregon. In the spring of 1966, a one-day course in pollination techniques was arranged by the Sub-committee.

The stage has now been reached where the primary objectives of the project have largely been attained. Enough untested selections are available for the first clonal seed orchards and at least some attempt has been made to obtain trees over the species range in coastal British Columbia. Four hundred and forty-two represents a very small number of individuals upon which to base a comprehensive program but it is now felt that before greater investment is made in the selection phase, some consolidation is necessary. Breeding studies are needed to evaluate the present selections and to endorse or disprove the criteria in current use. The trees at present have been selected as desirable phenotypes which should have superiority of height, volume, and form characteristics when compared with three neighbouring dominant trees. It will be seen that no consideration of internal characteristics, which could be extremely important, is undertaken but it is hoped that this will soon be remedied. Selecting trees by the present method, especially in inaccessible areas, is costly and, with limited funds available, the emphasis must shift from this phase to the maintenance of the clone banks and to the more intensive breeding work. In the future therefore, it is planned to reduce the emphasis which has been placed on selection by the Research Division since the program was started in 1957.

Although considerable interest is being shown by the forest industry for improvement work in other coastal species, it is impracticable for the B. C. Forest Service to consider diluting its resources by attempting such work. The companies concerned are therefore proceeding independently under the guidance of Dr. Sziklai, technical adviser to the Tree Improvement Sub-committee.

B.C. Forest Service Seed Orchards

The establishment of the first B. C. Forest Service seed orchard at Campbell River is continuing. Two years of severe snow breakage have caused considerable delay. The decision was also made to restrict the forty-two clones used in the orchard design, to trees of Vancouver Island origin. However, a ten-acre portion of the twenty-six acre cleared area is now almost completely grafted and drainage has been completed for the whole area. A cover crop is being established. Experiments concerned with increasing cone and pollen production through fertilizer treatments have been initiated in the orchard by Dr. Ebell of the Department of Forestry of Canada.

Plans for the second seed orchard are being made. It is to be located at Duncan and will be aimed at producing seed for the higher elevation areas on the lower mainland. In the light of current experience, graft incompatibility in various forms can be expected to limit the productive life of grafted clonal orchards and as such their establishment becomes an expensive investment. The possibility of using a seedling orchard, based on wind-pollinated progeny from the plus trees is being considered. 1966 shows promise of being a good crop year and it is felt that much will be gained by collecting seed from the trees and selecting in the seedbeds for vigour. Accordingly plans are being made to collect cones from the selected trees at higher elevations on the coastal mainland.

Grafting in Douglas-Fir

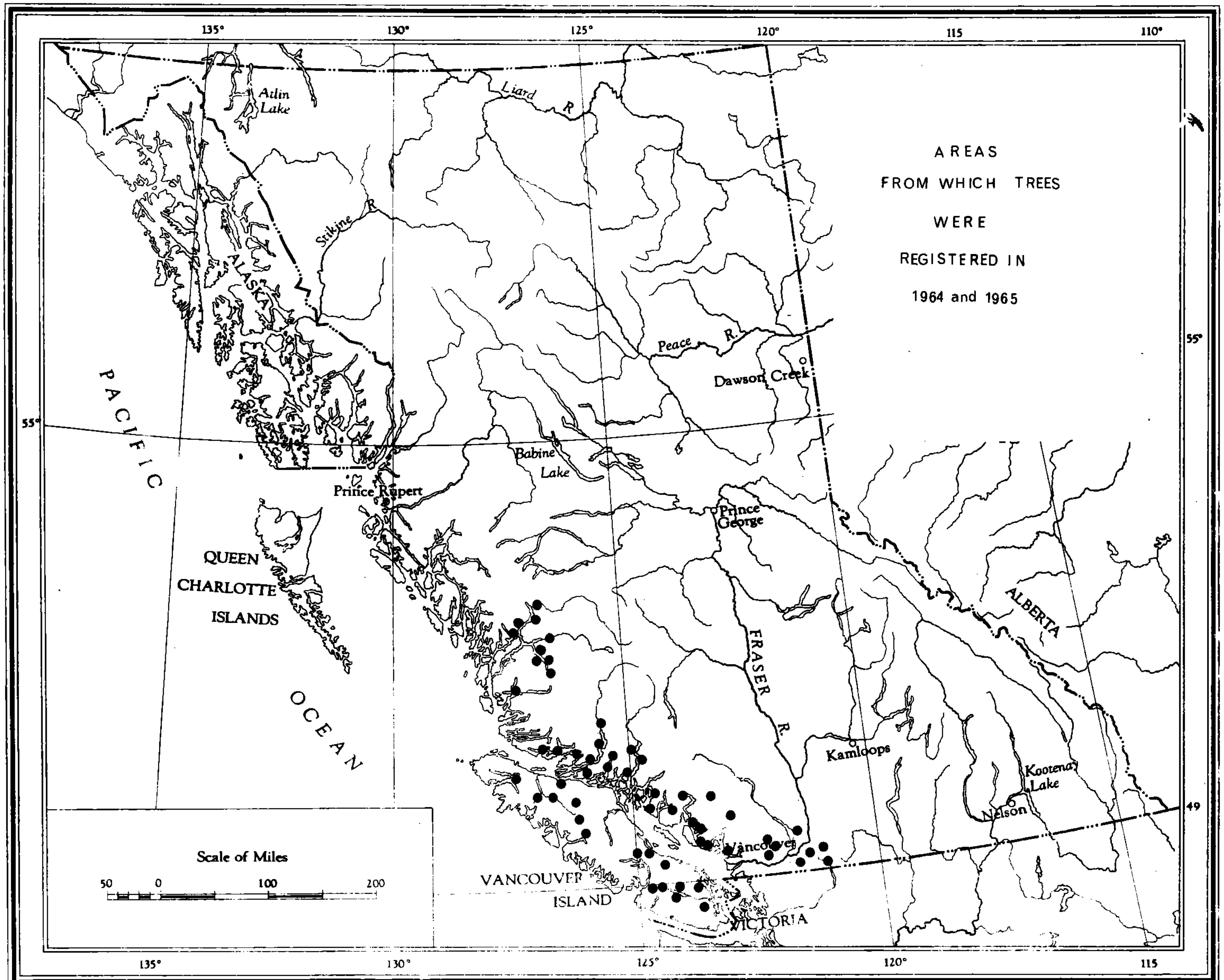
Since the last report to this Committee, the failure of established graft unions has increased and continues to be a major problem in the B. C. Forest Service clone banks at Cowichan Lake. Improved grafting techniques are expected to bring some reduction of the trouble but it is likely that the most lasting solution will be from developing compatible rootstocks. It appears that such rootstocks will only be found by experiment. Clonal rootstocks are not yet available in Douglas-fir and progeny of controlled crosses therefore represent the most uniform and most repeatable material on which to work.

In the spring of 1966, seedling material from seven controlled crosses was available and an experiment has been established with the primary objective of determining which of these seven crosses provides rootstock showing least incompatibility when grafted with scions from a variety of ortets. Scions will be taken from clones which have already shown good and bad grafting qualities in the established clone banks. A secondary objective will be to test whether improved graft unions result when scions from a tree are grafted on to its own progeny.

The rootstocks of seven origins were planted out as 1 + 1 stock in a replicated block design on the Forest Experiment Station in the spring of 1966 and it is planned to graft them in the spring of 1967.

In the past seedlings originating from bulked seed lots have been used for rootstocks, but only those from single tree collections will now be planted in the clone banks. Whenever possible, progeny from controlled crosses will be used. In this way through the maintenance of records, origins showing good general compatibility may be identified and repeated. In 1966, all the 3, 154 rootstocks planted on the Forest Experiment Station were from controlled crosses.

Approximately 2, 000 grafts have been made annually and although initial survival has been excellent, heavy losses have been sustained from snow damage. Losses of ramets grafted the previous spring were severe in the winter 1964-65 when approximately 70% were damaged or lost at Cowichan Lake. Losses in the winter 1965-66 were appreciably reduced by some staking and by removal of the snow before it became compacted. Improved staking will be carried out in future and it is hoped that this will prove effective.



Base map compiled by Geographic Division, Surveys and Mapping Branch, Dept. of Lands & Forests, Victoria, B.C.

SUMMARY REPORT ON FOREST TREE BREEDING

1964 and 1965

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POPLAR

The production of aspen-like hybrids suitable for growing in southern Ontario, having good growth rate and growth form, good wood and ease of vegetative propagation, are the aims of this project. At present the main objective is the production of new hybrids with good rooting ability from stem cuttings.

Acquisitions

The new acquisitions were as follows:

Species	Origin	Clones
P. alba	Germany	1
P. alba	Hungary	2
P. alba	U. S. S. R.	9
P. alba x davidiana	Korea	1
P. alba x grandidentata	Iowa	2
P. canescens	Czechoslovakia	7
P. canescens	Germany	13
P. canescens	Yugoslavia	3
P. tremula	Holland	2
P. tremula x alba	Germany	9
P. tremula x alba	Spain	1
P. tremula x deltoides	Spain	1
P. ciliata	Holland	1
P. przewalskii	Bulgaria	1
P. songarica	Kew Gardens	1
		54

Hybridization

The following successful crosses were made:

Parentage	Number of Crosses
P. alba x alba	1
P. alba x tremula	1
P. canescens x (alba x tremuloides)	1
P. grandidentata x alba	1
P. grandidentata x sieboldii	1
P. (alba x grandidentata) x canescens	7
P. (grandidentata x alba) x canescens	8
	20

Selection

The following numbers of clones were selected from populations under test:

Species	Number of Clones
P. alba x glandulosa	13
P. alba x sieboldii	26
P. canescens	7
P. canescens x (alba x grandidentata)	172
P. davidiana	2
P. tremula	6
P. tremula x tremuloides	3
P. tremuloides	4
	233

Rooting Ability Tests

The production of poplar hybrids with good rooting ability from stem cuttings is based on an efficient method of testing numerous seedlings in respect to this character under reasonably uniform conditions. Such a method has been described in the progress report for 1962-63 and has since then given quite satisfactory results. The results still vary considerably from year to year, but good average values for rooting ability are gradually being obtained from an increasing number of clones. These data are then used in their evaluation.

In 1963, the first breakthrough was obtained in a population of P. canescens x (alba x grandidentata) which, after three years of mass selection, gave an average rooting ability of over 90%. This was utilized in making numerous clonal selections from this population and in making similar double crosses involving P. alba as the common parent species. It has also been found that the rooting ability of P. alba can be enhanced in crosses between western origins (England, France, Spain, North Africa) and eastern origins (Poland, Czechoslovakia, Hungary, Yugoslavia) which, in all likelihood, is based on some kind of complementary genes for rooting ability in these two regional groups. The western group of P. alba usually has rather poor growth form, while the eastern group contains several excellent growth form types. Unfortunately, the latter usually have very poor rooting ability from stem cuttings. Thus western P. alba can be characterized as having poor growth form but good rooting ability from stem cuttings, while the eastern materials have good growth form but root very poorly from stem cuttings. It can be assumed that the various P. canescens found in Europe have originated by means of natural hybridization of the local P. alba materials with P. tremula and have, in part, inherited some of the rooting ability of their putative P. alba parents. If this is the case, then crosses between eastern and western P. canescens types should yield at least some hybrids with increased rooting ability. So far, most of the planted P. alba materials in Canada and northern U. S. have been found to be of western European origin, based on their taxonomic characters. Consequently, their hybrids with the native P. grandidentata and P. tremuloides can be assumed to correspond to western P. canescens types in respect to the genetic basis of their rooting ability and crosses of such hybrids with eastern P. canescens materials should yield hybrids with improved rooting ability. This may explain the breakthrough in respect to rooting ability obtained in 1963. Since then, the main efforts have been directed towards making further crosses of a similar kind, to obtain additional aspen-like types with good rooting ability from stem cuttings. Mass selection within this kind of hybrid material is at present in progress.

Raising Seedlings

The favourable results from early sowing obtained in 1963 have been confirmed in later years and this has been incorporated as standard practice. The distribution of seedlings in the seedbeds still leaves much to be desired and various methods of strip and drill sowing of aspen seeds mixed with sifted peat and muck are being tried. As already found in Hungary, seedlings of P. alba have, generally, a much stronger expression of dominance than aspen seedlings and can stand crowding better. The various hybrid types show an intermediate response to crowding, being more similar to aspens in this respect. Several methods to alleviate or avoid crowding are under test.

Dieback

Dieback is still a serious factor in the breeding of aspen hybrids. Hybrid materials are being evaluated in respect to dieback and only clones showing weak or moderate attack are being used for further breeding work. No information is yet available on the reaction of the recently obtained seedlings with good rooting ability, to dieback. This will probably be a factor of importance in test plantations.

FOREST TREE BREEDING AND GENETICS AT THE PETAWAWA FOREST EXPERIMENT STATION

M. J. Holst
Department of Forestry

INTRODUCTION

This report is an outline of the work done by the Forest Tree Breeding and Genetics Section at the Petawawa Forest Experiment Station, Chalk River, Ontario.

The 1962-64 biennial report dealt in detail with the objectives of the work of this section. The present report is concerned primarily with work done in the last 2 years and highlights those areas where most progress has been made.

The emphasis in our tree breeding effort continues to be placed on provenance research and population genetics.

PERSONNEL

Mr. C. W. Yeatman returned from Yale University in June 1964, to continue his research on the jack pine provenance problems. This work resulted in a Ph.D. thesis which was successfully defended in May 1966. The degree will be awarded in January 1967.

Mr. E. K. Morgenstern returned from Hamburg University on March 16, 1966, having completed his doctor's dissertation on the population structure in black spruce. The degree will be awarded in July 1966.

Dr. A. H. Teich, a crop breeder from Iowa State University of Science and Technology, Ames, Iowa, joined the Forest Tree Breeding and Genetics Section on August 9, 1965.

On April 15, 1966, Mr. B. S. P. Wang transferred from the Ontario Region to manage our local seed laboratory and the Departmental seed bank at the Petawawa Forest Experiment Station.

SPRUCE

During the period 1950-63 the Tree Breeding and Genetics Section, in co-operation with provincial authorities, industry, and universities, established a total of 180 experiments on 386 acres. During the last 2 years an additional 31 experiments have been planted on 90 acres. Of the 211 experiments distributed, some 30 have been planted in the United States. The 30 experiments with Canadian spruces sent to overseas countries are not included in this summary.

White Spruce

In co-operation with member companies of the Canadian Pulp and Paper Association, the Ontario Department of Lands and Forests, universities, and various American research organizations, a number of white spruce (Picea glauca) provenance experiments were planted in the field (Exp. No. 194). The material consisted of provenances from the Great Lakes-St. Lawrence Forest Region. The seed was sown in 1959, 1960 and

1961. Of the 29 experiments established in North America, two are located in Newfoundland, two in New Brunswick, eleven in Quebec, eight in Ontario and six in the United States. In addition to these, seven experiments were established with seed shipped overseas. Thus the establishment phase for this large co-operative project is nearly complete. Details regarding location of planting sites, design, and co-operators are given in Table 1.

An older series of experiments (Exp. No. 93) with white spruce provenances from the middle part of the Great Lakes-St. Lawrence Forest Region was measured. The Ontario Department of Lands and Forests provided data from the experiment located in Artemesia Township in southern Ontario, the Canadian International Paper Company rated the experiment located on the Harrington Forest Farm, Quebec, and the Quebec Region of the Department of Forestry provided data for the experiment established by the Southern Canada Power Company near Drummondville, Quebec. These data are now being analysed.

Needle samples were collected from three limestone ecotypes and three acid-site ecotypes grown on a limestone site (Artemesia Township) and on an acid site (Petawawa F. E. S.) (Exp. No. 290). Data from these samples will be analysed by Dr. P. J. Rennie, Soils Section, Petawawa F. E. S.

Five limestone ecotypes and five acid soil ecotypes were grown in nutrient solutions of varying calcium content by Professor J. L. Farrar and Mr. J. E. Nicholson at the University of Toronto (Exp. No. 293-B), as reported elsewhere in these Proceedings.

Four single-tree progeny tests were measured in their ninth and eleventh year from seed. Heritabilities were calculated, and will be reported in a paper being prepared for publication. It is concluded that selection followed by progeny testing is an effective method of improvement in white spruce.

The lower Ottawa Valley white spruce may be one of the fastest growing provenances of the species. To study genetic variation within this area, seed was collected from 80 trees in 14 stands. Detailed records were made of the parent trees, including the assessment of wood properties. The seed was sown in the fall of 1964. This experiment should provide material for a study of the population structure and heritability of local white spruce.

The wood of several 27-year-old local single-tree progenies was sampled by double borings to search for trees with high and low wood density. In another 30-year-old plantation of local white spruce, 4000 trees were sampled with an increment hammer and visually classified as having high, medium, or low wood density. The 170 trees of good growth and those in the extreme high or low classes were checked by taking double increment cores from each tree. The selected trees will be used for a study of heritability of wood density.

Twenty-four white spruce provenances from Ontario and Quebec were crossed with Petawawa white spruce. This gave 178 single-tree progenies for a preliminary evaluation of gain to be expected by provenance hybridization in white spruce.

A number of species hybrids were attempted. While P. glauca x abies and P. (glauca x sitchensis) x abies and P. (abies x koyamai) x glauca failed to yield viable seed, P. glauca x koyamai, P. glauca x schrenkiana, P. (glauca x sitchensis) x schrenkiana and P. (glauca x sitchensis) x koyamai were successful.

Red and Black Spruce and their Hybrid Swarms

Seed beds for an early red spruce (Picea rubens) provenance experiment with 22 provenances were sown in 1954 and 1955. Twenty-seven field plantings were eventually established in Canada and the United States. Two of these plantations were established at the Petawawa Forest Experiment Station, one in a frost pocket and one on an upland site. On the upland site growth has been surprisingly good and slight frost damage to the needles has been confined to the southernmost provenances. In the frost pocket all the pure red spruce provenances were severely frozen back. Only those provenances showing introgression with black spruce have grown well and the more black spruce characteristics they contained, the hardier they were.

Mr. E. K. Morgenstern studied population structure in black spruce (Picea mariana) along a latitudinal transect from Lake Erie to the Northwest Territories (Exp. No. 289. See separate report). Seedlings raised by him at the Institut für Forstgenetik and Forstpflanzenzüchtung, Schmalenbeck, Germany, were transferred to Norway for further study. Comparable material raised at the Petawawa Forest Experiment Station was established in a nursery test on dry, fresh, moist, and wet sites.

Earlier reports have discussed the possibilities for producing heterotic species and provenance hybrids by crossing selected provenances of black spruce with selected provenances of red spruce and then testing the hybrids in an intermediate habitat. To test this assumption, hybrids between black spruce from Petawawa, Cochrane, Kapuskasing in Ontario, and from Sandilands and Riding Mountain National Park in Manitoba, and red spruce from Clingman's Dome, Waterrock Knob and Wolf Laurel Gap in North Carolina as well as from Bear Heaven, Droop Mountain and Gaudineer Fire Tower in West Virginia were produced. In addition, Canadian red spruce from St. Jovite, Quebec, were crossed with the red spruce from North Carolina and West Virginia. The resulting seedlings were field planted in our Spruce Hybrid Area.

Dr. D. J. Durzan and Mr. M. J. Holst used the embryo and female gametophyte of seed from red, black and red x black spruce to study variation of the nitrogen compounds in relation to taxonomy (Exp. No. 287).

A collection of Appalachian red spruce flowered for the first time and trees from the Great Smokey Mountains in North Carolina were crossed with black spruce from Kapuskasing in Northern Ontario.

Black spruce, red spruce and red x black spruce were successfully crossed with Picea glehnii, P. koyamai, and P. omorica.

Norway Spruce

The production of hardy, fast growing and weevil resistant types continue to be the main objectives of the breeding work with Norway spruce (Picea abies).

As the provenance material established in Canada is still rather limited, we have started two new tests, both sown in 1965. One includes 25 of the fast growing but perhaps somewhat frost-tender provenances from the eastern and southeastern extension of the range, i. e., mainly the Carpathian Mountains (Exp. No. 277). The other is a test of the somewhat hardier types from both sides of the spruce-free corridor in Poland (Exp. No. 310-A) and consists of 24 well documented provenances provided by Dr. M. Giertych of the Kornik Arboretum.

Weevil-free trees have been selected and propagated. Several new families have been produced by controlled pollination of weevil-free trees. The parents of two of these families were second generation Norway spruce in Canada, following an initial selection by Dr. C. C. Heimburger for hardiness in one case and growth and form in the other. In addition, weevil-free trees were marked in the IUFRO provenance experiment and within-provenance crosses were made in the following provenances: Tarcau-Fata Strajei, Valen-Bistrei, and Valea Mare in Roumania; Ivanovsk in Russia; and Latvia.

Other weevil-free selections were obtained from Dr. Hans Nienstaedt, Northern Institute of Forest Genetics, Rhinelander, Wisconsin, who provided two provenances not available in Canada: Dolina, Ukrainian S. S. R. ; and Svinosice, Czechoslovakia.

A number of progenies of slender plus trees, and other promising progenies of selected stands in northern Europe, were transplanted (Exp. No. 265).

Professor R. W. Kennedy's study of four Norway spruce originating from the Hudson's Place population was published (Kennedy 1966). Broad sense heritabilities in excess of . 8 were found for whole-ring specific gravity and percentage of late wood. It was particularly interesting that the quality of the early wood varied between clones and showed higher broad sense heritability than latewood (respectively . 86 and . 56).

Norway spruce was crossed with *Picea schrenkiana*, *P. koyamai*, and *P. jezoensis*.

Other Species

A number of exotic species have been sown or grafted during the period under review. The species are: *Picea pungens*, *P. jezoensis*, *P. omorica*, *P. orientalis*, and *P. glehnii*.

Other Work with Spruces

Needle samples of white spruce provenances, of red, black and red x black spruce, and the Rosendahl spruce and the control, and from several exotic spruces were sent to Dr. Ernest von Rudloff, National Research Council, Saskatoon, Saskatchewan, for a chemotaxonomical study of the volatile oils (Exp. No. 288).

PINE

During the period 1950-63 the Tree Breeding and Genetics Section at the Petawawa Forest Experiment Station in co-operation with the Ontario Department of Lands and Forests established 125 experiments with pine on the latter's land, 27 experiments on land belonging to the various Canadian co-operators, and 20 experiments in the United States - a total of 172 experiments on 429 acres. During the last 2 years an additional 27 experiments were established on 43 acres by the Tree Breeding and Genetics Section.

Tests of provenance material, single-tree progenies, and provenance and species hybrids are carried out in nursery, field and controlled environments. To estimate genotype x environment interaction, tests are scattered across Canada and the United States, and also to a limited extent overseas. Plantation experiments are established by co-operators including industrial companies, universities, and federal, provincial and state forestry organizations.

Jack Pine

Most work has been done in the all-range jack pine (Pinus banksiana) provenance experiment (Exp. No. 255). In the two nursery provenance experiments located at Petawawa Forest Experiment Station and at Longlac in northern Ontario, the following characteristics have been recorded for 99 provenances: survival and frost damage; height; lammas and prolepsis growth; double leaders; branch length; branch angle; number of branches in the 1965 whorl; needle fresh-weight and dry-weight; and needle serration. Wood samples for a preliminary analysis of cambial activity and lignification were collected. These data are now being compiled and evaluated.

Seed for 12 field plantings to be established in Ontario, Quebec and the Maritimes in the spring of 1966 was sown at the Petawawa nursery. Planting plans were made for these field plantings which include from 99 to 49 jack pine provenances.

Other seed beds and nursery provenance experiments were established with the same jack pine provenances in Manitoba, Saskatchewan, Alberta, and Northwest Territories in Canada; in the Lake States and the New England States of the United States; in Czechoslovakia; Denmark; Finland; Holland; Scotland; and in New Zealand.

Mr. C. W. Yeatman also worked with this material and has analysed seedling data obtained from 87 provenances in controlled environments, a greenhouse and the three nursery experiments at Petawawa Forest Experiment Station, Acadia Forest Experiment Station and at Longlac. (See separate report).

In a co-operative study, Dr. V. Chalupa and Dr. D. J. Durzan studied free sugars, amino acids, and soluble protein in the embryo and female gametophyte of seed obtained from 14 widely scattered sources across the natural range of jack pine (Exp. No. 318).

A breeding arboretum intended for provenance hybridization was established with 93 of the all-range jack pine provenances (Exp. No. 255-B). Furthermore, the first plantation experiment of this series containing 88 provenances was established near Quebec City (Exp. No. 255-A-5-1).

Twelve jack pine provenance hybrids with their control provenances were field planted at the Petawawa Forest Experiment Station (Exp. No. 268-D-1). Ten of these were planted as demonstration plots in the Pine Graft Arboretum (Exp. No. 268-D-2). Five of the jack pine provenance hybrids were tested together with various lodgepole x jack pine hybrids on dry and wet soils at the Petawawa Forest Experiment Station (Exp. No. 300-A) and by the Marathon Corporation of Canada in the Central Plateau Section of the Boreal Forest Region in Ontario (Exp. No. 300-B). This is to investigate whether the jack pine provenance hybrids have a wider ecological amplitude than the parent provenances, and also to find out whether lodgepole pine, the various lodgepole x jack pine hybrids, or jack pine are the better choice for planting on heavy soils in northern Ontario.

Plans have been made for planting a new set of 50 jack pine provenance hybrids and their control provenances in five test areas from southern Ontario to northern Quebec (Exp. No. 268-E).

To study population structure and inheritance of cone characteristics, stem form and branch angle in several populations of jack pine, open pollinated cones were collected from 300 single trees. The surviving 255 progenies were field planted in 1964 (Exp. No. 273).

Crosses between 75 single trees of jack pine representing five types of stem form and some extreme types of branch form were made. These crosses will be compared with open pollinated controls collected from the upper and the lower part of the crown.

Data from some of our earlier provenance experiments have been analysed.

Red Pine

A stand test of Petawawa red pine (Pinus resinosa) containing 80 single-tree progenies testing five local stands were field planted in 1965 (Exp. No. 238-D).

Scions were collected from plus and minus trees selected in an original stand of red pine at Angus, Ontario. This population has proven to be fast growing. It must be preserved in a breeding arboretum because seed collected from the original stand is liable to be the result of contamination by pollen from surrounding plantations of unknown origin.

Thirty-five crosses were made in a co-operative study to produce provenance hybrids between red pines from Trout Lake, Wis., and Angus and Petawawa, Ontario. The cones for these crosses had to be protected from the red pine cone beetle, which in some years damage more than 90 per cent of the cones in this area. Pipes ending in a sprinkler head were rigged in the trees and the trees were sprayed with insecticide several times through the growing season.

A number of grafted selections and provenance material were field planted.

Germination tests were made in soil samples taken from some of our local red pine provenance experiments that exhibit extreme site variation. Delayed and low germination were associated with poor stunted growth of the plantation trees, but the tests were not conclusive and must be repeated.

Data from a number of older provenance experiments were analysed.

Scots Pine

The breeding work in Scots pine (Pinus silvestris) continues to have the following objectives: 1) testing of stands and provenances in terms of timber production; 2) selection and breeding of Christmas trees; 3) heritability studies of quality traits and weevil resistance; 4) production of a precocious dwarf rootstock.

A study of heritability of hardiness, weevil resistance, and Christmas tree quality traits is under way. Controlled crosses and grafts have been made (Exp. No. 280).

Ten new Christmas tree selections were propagated for further evaluation.

Other Pines

In co-operation with the Forest Pathology Laboratory at Maple, Ontario, we have established a progeny test of four needle-blighted and four healthy white pine (Pinus strobus) trees from the Petawawa Forest Experiment Station (Exp. No. 290). Grafts of three white pines, one heavily blighted, one moderately affected, and one free of the disease, were made for a small observation plot.

Seed of lodgepole pine (Pinus contorta var. latifolia) provenances to be selected for Cronartium resistance, good growth rate, and form have been assembled (Exp. No. 240).

Selected trees within and among these populations will be used for producing hybrids with jack pine. The same provenance material was distributed to Czechoslovakia, East Germany, Norway, Sweden, and Yugoslavia.

OTHER CONIFERS

A number of exotic fir (Abies) species and hybrids were propagated to test their hardiness at Petawawa Forest Experiment Station (Exp. No. 328). In Douglas-fir (Pseudotsuga menziesii) seed was assembled to test the hardiness of the fast growing high elevation types from Arizona and New Mexico (Exp. No. 278-C).

In co-operation with Mr. Bent Soegaard, Arboretum, Hørsholm, Denmark, the hybrid between western red cedar and eastern white cedar (Thuja plicata x occidentalis) was made, to produce a fast growing hardy cedar for eastern Canada (Exp. No. 303). Other provenances from interior British Columbia are also being tested.

Provenance material of central European larch (Exp. No. 252-A) and botanical collections of Russian and Asian larch (Larix spp.) (Exp. No. 252-B) were maintained in the nursery. One older European larch provenance experiment (Exp. No. 35-A) was measured and thinned.

HARDWOODS

A Canada-wide birch (Betula spp.) collection obtained from Dr. W. H. Brittain will be maintained as a demonstration plot at the Petawawa Forest Experiment Station (Exp. No. 285).

The Canadian yellow birch (Betula lutea), went on trial in the Lake States where Dr. Knud E. Clausen, of the Northern Institute of Forest Genetics, Rhinelander, Wisconsin, is conducting a range-wide yellow birch seed source study (Exp. No. 294). The seedlings will be raised at Rhinelander and several tests will be established in Canada with this material. Provenances from the northern part of the range in Canada went on trial in Finland.

Sapsucker damage has been extensive in older plantings of European birches (Betula verrucosa and B. pubescens). The sapsucker prefers the European birches to paper birch (Betula papyrifera).

TECHNIQUES IN TREE BREEDING AND FOREST GENETICS

Work in flower induction, breeding techniques, and growth control has the following objectives: to find methods that will induce early and abundant male and female flowering in spruce and pine; to find the best techniques for vegetative propagation and pollination; to make genotypic evaluations of populations, progenies and individual seedlings at an early stage of development, and to relate these patterns of variation to the results gained from long-term and less intensive field studies; to study seedling growth in relation to environmental factors, individually and in combinations and to determine the optimal levels and sequences of environmental factors necessary to promote more rapid growth than is possible under normal nursery or field conditions.

Since 1951, studies have been made of effects of fertilizers, sprays, root and branch pruning, and girdling on flowering in spruce and pine. Root pruning promotes flowering in spruce but has a negative effect in pine. In pine, ammonium nitrate promotes female flowering but reduces male flowering. Spraying with anti-auxins promotes male flowering in pine. All treatments must be timed carefully.

During the period under review, 25-year-old red pines in Drury Forest in southern Ontario were given ammonium nitrate, ammonium sulfate and potassium nitrate for studies of the flower inducing effect of the ammonia and nitrate ions. The fertilizer applications were adjusted to equivalent rates of ammonia and nitrate on the basis of molecular weight (Exp. No. 315).

A somewhat similar experiment was started in the Pine Graft Arboretum on the Petawawa Forest Experiment Station where grafts of red pine, jack pine, Scots pine, and Mugho pine were given ammonium nitrate, ammonium sulfate and potassium nitrate. Here the fertilizer applications were adjusted to equal amounts of nitrogen (Exp. No. 316). In an older experimental series in red pine, it was found that the flower inducing effect (on female flowers) of ammonium nitrate lasts only 1 year and is followed by several years of very low flowering. Parts of the two experiments described above will be treated annually to investigate this effect further.

Flowering of the red pines in Drury Forest has been recorded annually since 1953. Various treatments were given, including different fertilizers and different times of application. Untreated controls have been maintained which are suitable for a study of the effect of climate on flowering.

The flower-inducing treatments applied in spruce have not been effective and the more severe treatments have resulted in extensive injury to the trees. A new series of spruce experiments was initiated with container-grown plants. Norway spruce clones (in large clay pots) were given five different fertilizer treatments, three different drought periods at four different dates to determine if a combination of early drought and fertilizer would induce flowering (Exp. No. 313).

Reciprocal grafts of red, jack, and Scots pine demonstrated that red and jack pine are incompatible, and that promising combinations of red and Scots pine failed after some years of satisfactory growth. Reciprocal grafts of red, black, white, and Norway spruce indicated that these species are completely compatible.

Interspecific grafts in spruce and pines have been maintained and measured. Vigorous and straight-stemmed grafts of spruce scions from mature to over-mature trees have resulted from a study of grafting position in relation to scion quality.

Growth cabinets have been used effectively to demonstrate genotype x environment interactions in young jack pine seedlings. Seedling growth has been controlled and accelerated by using controlled temperatures and extended photoperiods during the growth and maturation stages of seedling development, and artificial chilling during the dormant stage. These latter techniques are potentially valuable for the promotion of rapid development in select and hybrid seedlings, reducing the time period between seed germination and sexual maturity.

Work buildings and technical installations were constructed at the Thomas Lake nursery. A new wing was added to the greenhouse buildings, which will include facilities for growth cabinets in the basement.

NURSERY

Seedlings were raised without transplanting for a number of pine experiments. Jack pine, in particular, can be field planted as 2-0 stock.

About 118,000 seedlings were transplanted for various experiments and 2,677 grafts were produced in spruce, pine, and fir (Tables 2, 3, 4).

PLANTATIONS

Twenty-seven experiments including 61,000 seedlings covering 39 acres were field planted at the Petawawa Forest Experiment Station. An additional 2,016 grafts were planted on 6 acres (Table 5).

Another 22 experiments were planted by co-operators in Canada and the United States. These include 118,000 seedlings which were planted on 96 acres (Table 6).

Seed of white spruce provenances (Exp. No. 194) were sent to Denmark, France, Germany, Japan, Norway, and Sweden. Seed of the all-range jack pine provenance experiment was sown in several locations in Canada and was also sent to Holland and New Zealand (Table 7).

Table 1. Experiment No. 194. Co-operative experiments with white spruce provenances from the Great Lakes-St. Lawrence Forest Region.

Part & year planted	Agent	Exp. Design	No. of Seedlots	No. of Plants	Area Acres	Location
A 1963	Ontario-Minnesota Pulp & Paper Co. Ltd., Fort Frances, Ont.	Latt. Sq. 3 (5 x 5)	25	6,982	6.48	Rainy River Dist., Buriss Twp., Ont.
B 1963	Spruce Falls Power and Paper Company, Kapuskasing, Ont.	Latt. Sq. 3 (5 x 5)	25	9,480	7.50	Stringer Twp., Ont.
C 1963	Ontario Dept. of Lands and Forests, Swastika Dist.	Latt. Sq. 3 (5 x 5)	25	13,464	11.40	Truax Twp., Ont.
D-1 1963	Dept. of Forestry, Petawawa Forest Exp. Sta.	Latt. Sq. 3 (5 x 5)	25	13,464	11.14	P.A. 125, P.F.E.S., Chalk River, Ont.
D-2 1963	Mr. J.B. Santon	Rand. Bl. 10 reps.	12	6,048	2.77	Wilberforce Twp., Renfrew Co., Ont.
E 1964	Ontario Dept. of Lands and Forests, Lake Huron Dist.	Latt. Sq. 6 (5 x 5)	25	5,859	4.80	Euphrasia Twp., Grey Co., Ont.
F 1964	University of Toronto, Dorset, Ont.	Latt. Sq. 6 (5 x 5)	25	7,965	6.50	Univ. Forest, Ridout Twp., Ont.
G 1964	Canadian International Paper Co., Grenville Div.	Latt. Sq. 6 (5 x 5)	25	7,884	6.50	Harrington Forest Farm, Calumet, Que.
H	Canadian International Paper Co., Maniwaki Div.	Latt. Sq. 6 (5 x 5)	25	7,884	6.50	West of Baskatong Lake, Gatineau Co., Que.
I-1	Consolidated Paper Co., Grand'Mere	Latt. Sq. 6 (5 x 5)	25	6,280	4.50	Grand'Mere, Que.
I-2 1965	Ditto	Rand. Bl. 9 reps.	28	3,292	2.50	Jacques des Piles, Que.

Table 1 - Experiment No. 194 - cont'd.

Part & year planted	Agent	Exp. Design	No. of Seedlots	No. of Plants	Area Acres	Location
I-3 1965	Consolidated Paper Co., Grand'Mere	Rand. Bl. 6 reps.	28	2,192	2.00	Casey, Que.
I-5 1965	New York Conserv. Dept., Forest Research Unit	Rand. Bl. 10 reps.	28	3,360 +surr.	3.00	Ref. Area 1, Washington Co., N. Y., U. S. A.
I-6 1965	Maine Forest Service, Passadumkeag Nursery	Rand. Bl. 10 reps.	28	2,800	2.50	Passadeumkeag, Me., U. S. A.
I-7 1965	Newfoundland Forest Service, Corner Brook	Rand. Bl. 2 reps.	28	3,256	2.40	Southwest of Corner Brook, Nfld.
J 1964	Fraser Companies Ltd., Edmundston, N. B.	Latt. Sq. 6 (5 x 5)	25	13,236	10.90	Plaster Rock, Victoria Co., N. B.
K-1 1965	Dept. of Forestry, Fredericton, N. B.	Rand. Bl. 10 reps.	50	6,360 +surr.	6.00	Acadia F. E. S., Fredericton, N. B.
K-2 1965	New York Conserv. Dept., Forest Research Unit	Rand. Bl. 12 reps.	20	2,400 +surr.	2.00	Ref. Area 1, Schenectady, N. Y., U. S. A.
L-1 1965	Université Laval	Latt. Sq. 8 (7 x 7)	49	10,652	8.8	North of Lac Septiles, Que.
N-1 1965	Ontario Dept. of Lands and Forests, Port Arthur Dist.	Latt. Sq. 8 (7 x 7)	49	16,621	14.0	Pearson Twp., Port Arthur, Ont.
N-2	New York Conserv. Dept., Forest Research Unit	To be planted 1967	25	ca. 3,000	ca. 3.0	-

Table 2. Summary of grafting during the spring in the years 1964 and 1965.

Project or Exp. No.	Material	Number of Grafts
	1. Spring 1964	
328	4 clones of Abies koreana and A.	149
	nephrolepis from Siberia via Finland	149
	5 clones of A. sibirica x balsamea	25
	2 clones of A. lasiocarpa arizonica	20
244	1 population of Picea jezoensis	216
	2 populations of Picea glehnii	280
	10 clones of Picea glehnii	99
280-B	Weeviled and non-weeviled Scots pine clones	1,005
	Scots pine Christmas tree selections	211
P-144	1 population of Pinus taeda x densiflora fram Japan	22
	the parent clones of above cross	41
	Total number of grafts 1964	2,068
	2. Spring 1965	
244	3 clones of Picea orientalis via Rochester, N. Y.	60
	7 clones of Picea glehnii via Rochester, N. Y.	140
	2 clones of Picea omorika x sitchensis from Perthshire, Scotland	60
	1 clone of Picea omorika x glehnii from Perthshire, Scotland	30
155	20 white spruce clones	249
	Scots pine Christmas tree selections	60
128	11 clones of Pinus resinosa from Angus, Ontario	110
	Total number of grafts 1965	709

Table 3. Sowings of tree breeding material 1964 and 1965.

Project or Exp. No.	Material	Number of Seed lots
	1. Spring 1964	
255-E	*Pinus banksiana* provenance experiment	98
85 and 272	*Pinus silvestris*, controlled pollination	63
324	*Pinus banksiana* x *virginiana*	9
	Odd lots of conifers	8
	Odd lots of hardwoods	5
	Total number of seed lots 1964	183
	2. Fall 1964 and Spring 1965	
292	Investigation of population structure of 14 local white spruce populations	80
277	Norway spruce provenances from eastern and southeastern Europe	25
310-A	Norway spruce provenances from Poland	24
	Odd lots of conifers	9
	Odd lots of hardwoods	19
	Total number of seed lots 1965	157

Table 4. Transplanting of tree breeding material 1964 and 1965.

Project or Exp. No.	Material	Number of Plants
	1. Spring 1964	
267	Dr. Brittain's birch collection	4,254
217-D	Japanese birch species	1,612
285-A	Hybridization between European birch and Petawawa paper birch	1,106
252-A	Provenance experiment with central European larch	6,270
	Botanical collections of Russian and Asiatic larch	769
266	European Scots pine provenances	6,062
86	Scots pine single-tree progenies from controlled and open pollination	3,150
268 and 300	*P. banksiana* provenances of various origins crossed with Petawawa provenance plus control lots	3,551
87 and 300	*P. contorta* var. *latifolia* and introgressed types crossed with Petawawa jack pine	7,663
255-B	*P. banksiana* provenances	4,190
	Odd pine lots	3,477
222 and 223	Provenances of Engelmann and western white spruce and some introgressed populations	6,328
265	*Picea abies* provenances from Europe and two single-tree progenies from Petawawa	15,981
	Odd spruce lots	1,813
	Total transplanting 1964	66,226

Table 4 - Cont'd.

Project or Exp. No.	Material	Number of Plants
	2. Spring 1965	
285-B	Hybridization between European birches and Petawawa paper birch	2, 523
268-E	Provenance hybridization in jack pine	9, 109
	Controls for Exp. No. 268-E	12, 440
87 and 268	Testing lodgepole pine x jack pine hybrids on dry and wet sites	4, 360
207	Provenance hybridization in red pine	1,685
	Controls for Exp. No. 207	1, 800
6	Intraspecific hybridization of Norway spruce (Breeding for weevil resistance)	3, 960
72	Testing red spruce, red x black spruce, and black x red spruce hybrids	5, 217
284	Testing single-tree progenies of *Abies fraseri* for winter hardiness	763
	Rootstocks and odd lots	9, 500
	Total transplanting 1965	51, 357

Table 5. Field planting in 1964 and 1965 at Petawawa Forest Experiment Station.

Exp. No.	Description	Number of Plants	Area Acres	Plantation Area
	Seed Plants 1964			
98-open	Interspecific hybridization of Petawawa red pine with *P. densiflora* and *P. thunbergii* from Maple, Ont.	35	0.12	P.A. 115
176-B	Provenance experiment with balsam fir from the Maritimes	259	0.43	P.A. 132
208-open	Comparison of good and poor genotypes in white spruce	384	0.56	P.A. 114
208-open	Ditto	263	0.43	P.A. 116
211-B	Comparison of 'tassel' pine hybrids with red pine from P.F.E.S.	350	0.29	P.A. 111-D
211-C	Ditto	83	0.07	P.A. 120
211-D	Ditto	70	0.23	P.A. 115
273	Single-tree progeny test in jack pine	19,043	10.90	P.A. 129
290-A	Progeny testing of needle-blighted and healthy white pine trees from P.F.E.S.	2,716	2.24	P.A. 124
291	Single-tree progeny test in red pine, including tests of stored pollen and effect of crown position	1,098	0.91	P.A. 111-D
	Total 1964	24,301	16.18	
	Seed Plants 1965			
72-B-1	Comparison of red and black spruce and their hybrids (St. Jovite x P.F.E.S.)	738	0.61	P.A. 125
72-B-2	Ditto	360	0.30	P.A. 125
72-B-3	Ditto	210	0.31	P.A. 133

Table 5 - Cont'd.

Exp. No.	Description	Number of Plants	Area Acres	Plantation Area
86-open	Selection of the perfect Scots pine Christmas tree	84	0.07	P.A. 121
87-open	Investigation of the jack pine, lodgepole pine and their hybrids for resistance to sweet fern blister rust	80	0.26	P.A. 115
194-M	Provenance experiment of white spruce from the Great Lakes-St. Lawrence Forest Region	7,468	6.17	P.A. 125
238-D	Single-tree progeny and population test in red pine	9,420	3.46	P.A. 111-D
243-open	Interspecific hybridization in *Picea*	229	0.76	P.A. 116
243-open	Ditto	309	0.26	P.A. 125
243-open	Ditto	310	1.02	P.A. 133
255-B	Arboretum lots of the all-range jack pine experiment	1,787	2.97	P.A. 115
268-D-1	Provenance hybridization in jack pine	2,876	2.37	P.A. 131
268-D-2	Ditto	300	1.00	P.A. 115
289	Investigation of population structure in black spruce along a transect from Lake Erie to the Northwest Territories	9,920	0.25	P.F.E.S. Nursery
300-A-1 (Wet)	Testing of jack pine and lodgepole pine hybrids on a wet site	953	0.79	P.A. 124
300-A-2 (Dry)	Testing of jack pine and lodgepole pine hybrids on a dry site	1,368	1.13	P.A. 131
307-A	Provenance hybridization with Appalachian red spruce	350	0.80	P.A. 133
	Total 1965	36,762	22.53	
	Total 1964	24,301	16.18	
	Seed Plants, Grand Total 1964-65	61,063	38.71	

Table 5 - Cont'd.

Exp. No.	Description	Number of Plants	Area Acres	Plantation Area
	Grafts 1964			
85-open	Selection of early flowering Scots pine for rootstock purposes	59	0.20	P.A. 115
128-open	Grafted red pine population samples intended for provenance hybridization	70	0.23	P.A. 115
128-open	Ditto	128	0.21	P.A. 104
238-C	Clone test of red pine populations	329	1.09	P.A. 115
242-open	Selection of white spruce plus trees	300	1.00	P.A. 116
244-open	Selection and testing of exotic spruces	393	0.65	P.A. 132
257-B	Testing of red pine stands by means of single-tree sampling	100	0.33	P.A. 115
	Total 1964	1,379	3.71	
	Grafts 1965			
86-open	Selection of the perfect Scots pine Christmas tree	540	1.78	P.A. 115
86-open	Ditto	60	0.60	P.A. 114
211-E	Selection of fastigiate pine from the Lake States	37	0.12	P.A. 115
	Total 1965	637	2.50	
	Total 1964	1,379	3.71	
	Grafts, Grand Total 1964-1965	2,016	6.21	

Table 6. Plantations established in 1964 and 1965 by co-operating agencies.

Exp. No.	Description	Number of Plants	Area Acres	Agency and Location
	Seed Plants 1964			
194-E	Provenance experiment with 25 races of white spruce from the Great Lakes-St. Lawrence Forest Region (Re-establishment)	5, 859	4. 8	Ont. Dept. of Lands Lake Huron District
194-F	Ditto	7,965	6. 5	University of Toronto, Dorset, Ont.
194-G	Ditto	7, 884	6. 5	Canadian Int. Paper Co., Grenville Div., Calumet, Que.
194-H	Ditto	7, 884	6. 5	Canadian Int. Paper Co., Maniwaki, Que.
194-I-1	Ditto	6, 280	4. 5	Consolidated Paper Co., Grand'Mere, Que.
194-J	Ditto	13, 236	10. 9	Fraser Companies Ltd., Edmundston, N. B.
194-U-2	Ditto	1, 500	1. 2	Université Laval, Quebec, Que.
216-H	Red pine provenance experiment including Lake States and Canadian provenances	270	0. 2	Université Laval, Quebec, Que.
	Total 1964	50, 870	41. 1	
	Seed Plants 1965			
194-I-2	Provenance experiment with 28 races of white spruce from the Great Lakes-St. Lawrence Forest Region	3, 292	2. 5	Consolidated Paper Co., Grand'Mere, Que.
194-I-3	Ditto	2, 192	2. 0	Consolidated Paper Co., Grand'Mere, Que.

Table 6 - Cont'd.

Exp. No.	Description	Number of Plants	Area Acres	Agency and Location
194-I-5	Ditto	3,360 + surr.	3.0	Forest Research Unit, New York Conserv. Dept., Washington Co., N. Y., U. S. A.
194-I-6	Ditto	2,800 + surr.	2.5	Maine Forest Service, Passadumkeag, Me., U. S. A.
194-I-7	Ditto	3,256	2.4	Newfoundland Forest Service, Corner Brook, Nfld.
194-K-1	Provenance experiment with 50 races of white spruce from the Great Lakes-St. Lawrence Forest Region	6,360 + surr.	6.0	Dept. of Forestry, Acadia F. E. S., Fredericton, N. B.
194-K-2	Provenance experiment with 20 races of white spruce from the Great Lakes-St. Lawrence Forest Region	2,400 + surr.	2.0	Forest Research Unit, New York Conserv. Dept., Schenectady, N. Y., U. S. A.
194-N-1	Ditto	16,621	14.0	Ontario Dept. of Lands and Forests, Port Arthur Distr.
194-U-3	Provenance experiment with 25 races of white spruce from the Great Lakes-St. Lawrence Forest Region	1,500	1.2	Université Laval, Quebec, Que.
255-A-5-1	All-range jack pine experiment	4,400	4.0	Université Laval, Quebec, Que.
300-B-1	Testing of jack pine and lodgepole pine hybrids on sandy soil	2,231	1.5	Marathon Corp. of Canada Ltd., Marathon, Ont.
300-B-2	Testing of jack pine and lodgepole pine hybrids on loamy soil	2,100	1.4	Marathon Corp. of Canada Ltd., Marathon, Ont.

Table 6 - Cont'd.

Exp. No.	Description	Number of Plants	Area Acres	Agency and Location
300-B-3	Testing of jack pine and lodgepole pine hybrids on wet soil	2, 196	1. 5	Marathon Corp. of Canada Ltd., Marathon, Ont.
300-B-4	Observation plots of jack pine and lodgepole pine hybrids	4, 200	3. 0	Marathon Corp. of Canada Ltd., Marathon, Ont.
	Total 1965	67, 560	55. 8	
	Total 1964	50, 870	41. 1	
	Grand total 1964 and 1965	118, 430	96. 9	

Table 7. Distribution of plants and seeds to outside agencies in 1964 and 1965.

Exp. No.	Agent	Location
194-N-2	Forest Research Unit, New York Conserv. Dept.	Albany, N. Y.
194-O	Statskovenes Planteavlstation	Humlebaek, Denmark
194-P	Arboretum Hørsholm	Hørsholm, Denmark
194-Q	Gullviks Fabriken	Malmö, Sweden
194-R	Tokyo University	Yamabe, Sorachi, Japan
194-S	Ecole Nationale des Eaux et Forêts	Nancy, France
194-W	Norwegian Forest Research Institute	Vollebekk, Norway
194-X	Institut für Forstpflanzenzüchtung	Graupa, Germany
255-C-5	Stichting Bosbouwproefstation "De Dorschkamp"	Wageningen, Holland
255-C-6	Forest Research Institute, New Zealand Forest Service	Rotorua, New Zealand
255-D-1) 255-D-2) 255-D-3) 255-D-4) 255-D-5)	District Office, Forest Research Branch, Dept. of Forestry	Winnipeg, Man.
255-D- 6) 255-D- 7) 255-D- 8) 255-D- 9) 255-D-10)	Forestry Branch, Saskatchewan Department of Natural Resources	Prince Albert, Sask.
255-D-11) 255-D-12) 255-D-13)	District Office, Forest Research Branch, Dept. of Forestry	Calgary, Alta.
255-D-14	Superintendent of Forestry, Northern Administration Branch, Dept. of Northern Affairs and National Resources	Fort Smith, N. W. T.

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AN INDUSTRIAL TREE-IMPROVEMENT PROGRAM IN NORTHERN ONTARIO

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Kimberly-Clark Pulp and Paper Co. has been a member of the Committee on Forest Tree Breeding in Canada only since 1962 but has been engaged in tree improvement work since 1958. Only now, is the work advanced to the stage where progress can be reported. As this is the initial report to this committee, a brief account of the background story is in order.

Beginning in 1949, Kimberly-Clark Pulp and Paper Co. became actively engaged in planting cut-over forest land. Within 5 years, a tree nursery had been established and was producing 1 million spruce transplant stock annually. By 1965, planting reached 1-$\frac{1}{2}$ million trees per year, of which 1 million were black and white spruce transplants and $\frac{1}{2}$ million were jackpine seedlings. This stock was planted on approximately 2800 acres in 1965. The seed for this stock is of local provenance; cone collection was made or controlled by company foresters. The seed origin was stands selected in the current cut areas; it is entirely a wild seed, unimproved in any way beyond the fact that collection was controlled and confined to the specific stands.

In 1958, positive steps were taken to improve the quality of future seed supplies. A program of tree selection, scion collection, grafting and clone orchard was drawn up. Mr. J. T. Dorland became an active member of this committee and initiated the parent tree selection and resulting clone orchard. The staff learned as they worked, turning to this committee, scientific and trade journals, and consultation with Government agencies for information and techniques. They have remained firstly foresters and secondly tree breeders; the scope and depth of the work is limited accordingly. In 1963 the tree improvement work was assigned to Mr. E. R. Humphreys, the present member of this committee.

The objective of the Kimberly-Clark program is:

(1) to establish a readily accessible supply of spruce and jackpine seed; and

(2) to provide, through selection and controlled pollination, seed with improved quality, for pulpwood or fibre use.

The objective is being pursued from three directions simultaneously:

(1) the clonal orchard;

(2) the seedling orchard, using nursery planting stock; and

(3) the natural seed forest.

Clonal Orchard:

At present, it is 7 acres in extent and contains 552 spruce clones representing 76 parent trees. Spacing is 12 feet. Black and white spruce range to 5 feet in height and are producing a few cones now. Progeny testing has not started. Selection ratings for the earlier selected parents are being continually reviewed and up-graded. Roguing is anticipated within a few years. Selection criteria for parent trees are height, age, form, crown, and diameter.

Seedling Orchard:

This potential seed source contains black and white spruce from a nearby nursery. Trees are added to the orchard as they occur in the nursery on a year by year basis, generally about 100 trees annually. Selection criteria are superior height growth, form, stem diameter, and colour. Spacing is 6 feet by 12 feet.

Seed Forest:

This program got under way in 1964. Two natural forest stands have been reserved for the production of seed during the interim time of clone orchard establishment and seed production:

(a) Lydia Lake Seed Forest - 17 acres of 50-years-old black spruce, potentially 3000 trees.

(b) Raynar Lake Seed Forest - about 5 acres of advance growth white spruce, ranging to 30 feet in height and of uneven aged.

No silvicultural treatments or improvements have been applied to either of these two forests. The search for and selection of additional natural seed stands is continuing, as security against disaster striking the Lydia and Raynar Lake forests.

There are at present, four areas in which Kimberly-Clark Pulp and Paper Co. need information and the assistance of this committee:

(1) Criteria and method for non-destructive measuring and rating parent tree quality for chemical pulping. The Ontario Research Foundation, the Pulp and Paper Research Institute Report 381, and other agencies are researching this field; the information can be used now.

(2) Base from which improvement should be measures. We need to establish a base or standard from which the amount, degree or type of improvement can be ascertained. Should the base be natural or created forest?

(3) Field Tools: Accessibility to the fruiting crowns of natural seed trees is required. At present, there is no known machine that will provide accessibility, at reasonable cost, to the slender crowns of black and white spruce.

(4) Progeny Testing: Is there a means or technique to reduce the time element associated with the traditional progeny testing process? Can a growth chamber, for example, be employed to obtain at least an early assessment to support the morphological and anatomical assessment of the parent?

TECHNIQUES FOR REPRODUCING HIGH QUALITY SILVER MAPLE PHENOTYPES

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There is a great need in southern Ontario to re-stock many of the swamps with high quality trees of desirable species to replace the elm which are being devastated by the Dutch elm disease. Silver maple appears to be the most suitable species for general planting in such swamps.

Unfortunately, many silver maple tend to be heavily forked which greatly reduces their value for veneer and lumber. Nevertheless, trees of exceptionally high quality have been encountered in the bush which would indicate that there are individual trees and groups of trees within this species which could serve as a potential source for the production of high-quality nursery stock. These observations led to the initiation in 1958, of a program for locating, selecting, evaluating, and reproducing high quality silver maple phenotypes in southern Ontario for reforestation purposes.

LOCATING SUPERIOR TREES

A large number of high-quality silver maple stands have been located on county maps in southwestern Ontario and numbered for future reference. Many of these have been methodically inspected by one to four men traversing it at 100 foot intervals and examining carefully any high quality trees which were encountered along and between the lines. The quality of these superior-looking trees was assessed by using quality standard tables (Table 1) which had been developed earlier for evaluating tree quality of silver maple. If any high-quality trees were encountered the stand number and the tree number was printed on their trunk for future reference.

Locating work was started in March 1959 in the Stratford Zone of the Lake Huron District by inspecting the silver maple in a number of swamps. This survey has been continued to the present time. The first high-quality phenotypes for lumber and veneer production were not located until the fall of 1961. These were found near the Otter Creek Tract, on Conc. XII, Lots 16, 17 and 18, Burford Township, Brant County. The superior trees occurred in two different locations in the same swamp. One area contained 10 trees and the second area had 6 trees. In the same year, four more superior trees were located in the Beverly Swamp, Conc. IX, Lot 21, Beverly Township, Wentworth County. All trees were growing on private land and permission had to be obtained before the scions were removed from the selected trees.

SELECTING SUPERIOR TREES

Considerable variation in growth habits occurs in silver maple. Some trees are tall, straight, and lightly branched while other trees within the same stands are forked, crooked, and heavily branched. It is generally agreed that differences in the form and growth habits of a tree may be attributed to environment or heredity or a combination of these two factors.

At present, it is most difficult to determine whether the comparative effects of environment and heredity, the two factors responsible for the exceptional qualities of some silver maple phenotypes which are occasionally encountered in the bush. In some instances, after a very careful analysis of the site and the stand history, it is possible to segregate some of the important effects of the environment. For instance, it is not unusual to find a high-quality tree and a low-quality tree originating as coppice from the same stump or from the same root collar. In this example, one may assume that environmental conditions rather than genes determined the ultimate quality of the two trees. However, if two or more high-quality stems occur from the same stump we may assume that genes might be responsible, but generally one cannot be certain and all one is able to do at present is to reproduce such trees asexually and determine at a later date if the ramets exhibit the same features of quality as the parent tree.

EVALUATING SUPERIOR TREES

Quality standard tables were initially prepared for numerically assessing the lumber producing qualities of silver maple within stands. Provisions were made in this table to include a list of qualities to distinguish superior trees within the species. Each main feature of a tree was given a numerical score and when all the scores were added together they had to give, for a superior tree, a total of 91 to 100 points. The following table served as a guide in selecting the elite silver maple clones for asexual propogation by budding and layering.

TABLE 1

Quality features of superior silver maple phenotypes for lumber production.

	Quality Features	Score
1.	Must have three potential 16 foot logs.	30
2.	Bole of the first two 16 foot logs should be free of branches and those which might be present on the third potential log should not be greater than 2 inches in diameter at point of attachment to the bole (loss of 5 points if there is some branching.)	20
3.	Bole must be straight, single stemmed and uniformly rounded in cross section (Tree is put in lower quality class if any of the above qualities are missing.)	20
4.	Bole must be straight grained (Spiral grain will cull tree).	10
5.	Must have a well balanced crown in relation to competition. (Deduct up to five points if crown unbalanced).	5
6.	Must be dominant or codominant.	5
7.	Must be healthy (If unhealthy, tree is culled).	10

PROPAGATING SUPERIOR TREES

Propogation of the 20 high-quality silver maple phenotypes located in 1961, 1962, and 1963 in the South Western Region was started in early August of 1962 by budding eight of these selected trees and one inferior tree. Since then, approximately 20 superior trees have been budded each year. This work consists of three main steps, namely: collecting the bud sticks, budding, and layering.

Collecting the bud sticks

A crew of three men were used to collect the bud sticks. Two of the men used bicycle climbers to climb the trees and the third man collected the severed branches and prepared scions from the fresh terminal shoots of that year. Each shoot was cut into six inch bud sticks bearing from two to six buds. The leaves were severed to leave a half-inch of the petiole to serve as a handle when budding. The bud sticks were placed in bundles of from 10 to 50 sticks and were labelled with the phenotype number and the origin of the branch, that is whether it was a lateral, epicormic, or coppice branch. The scion bundles were wrapped in wet cloth and covered with ice in a cooler where they remained from 1 to 3 days until required for budding.

Budding

The high-quality silver maple phenotypes which had been located in 1961, 1962, and 1963 were budded in August of 1962, 1963, 1964, and 1965 on 2 and 3-year-old silver maple nursery stock at the Orono Forest Tree Nursery of the Ontario Department of Lands and Forests.

The technique consisted of T-budding at 2 to 6 inches from the ground. The bud section was a shield-type which was held firmly in the incision by a special $\frac{1}{2}$-inch wide plastic band wrapped around the stem. The budding bands remained in place until the following spring when they were removed by cutting. Buds from each of the selected phenotypes were budded on to 50 silver maple seedlings. A record was kept of the time of budding, phenotype number, and whether the bud was a terminal or lateral bud from a coppice, epicormic, or main branch.

Each spring, the budded trees were tallied as to success or failure. All successfully budded trees were marked with yellow paint below the bud and the nursery seedling was then cut off at from 1 to 2 inches above the growing bud. In August, the successfully budded trees were root pruned. In early September, the total heights of the ramets of each clone were measured and the presence or absence of forks and branches as well as any other pertinent information on growth was recorded.

Layering

A pilot layering-bed was established beside the budding-bed in the spring of 1964. The successfully budded phenotypes of 1962 were layered by planting half of the trees vertically and the remaining half horizontally in the layering bed.

The severed stems of the grafting stock of the vertically planted ramets were placed to a depth of approximately 6 inches below the soil surface to insure that they would not send up coppice. The stem of the budded tree was then cut off at about 6 inches above the surface to induce coppicing. The horizontally planted ramets were laid in a trench at about 30 degrees to the horizontal, and both the roots and the severed stem of the grafting stock was covered with more than 6 inches of soil to prevent it from coppicing. The stem of the budded phenotype was held in the trench in this almost horizontal position with bent wire pins.

The basal sections of the vertically planted ramets and the elongated stems of the horizontally planted ramets were nicked with a knife, the injured portions were treated with a commercial rooting hormone called Stim Root and were then covered with soil to induce rooting. The soil was kept moist during the rest of the growing season.

The treated stems were examined as to success or failure of the treatment in the spring of 1965. All successfully rooted layers were then taken to a production layering-bed and were planted in trenches for further mass layering.

RESULTS

Budding Success

Eight high-quality trees and one inferior tree were budded in early August of 1962. Table II indicates that of the nine trees budded at that time only five of the trees were successfully propogated.

TABLE II

Number and size of 1-year-old silver maple ramets in August of 1963 which had been budded in August 1962

Phenotype number	Bud origin	Success %	Range in height (inches)	Average height (inches)
B-3-1	Coppice - side	6	54-66	60
B-3-2	Branch - side	12	34-54	42
B-3-4	Epic.* - side	0		
B-3-5	Branch - side	0		
B-3-6	Epic.* - top	16	8-32	22
B-3-7	Branch-top & side	0		
B-3-8	Epic.* - side	0		
B-3-9	Branch-epic. - side	6	33-52	43
Cull - 639	Branch - side	2	69	69

* Epic. - Epicormic

Nineteen trees and one inferior tree were budded in early August of 1963. Table III indicates that of the 20 trees budded in 1963 only 13 of the trees were successfully propogated.

TABLE III

Number and size of 1-year-old silver maple ramets in August 1964 which had been budded in August 1963

Phenotype number	Bud origin	Success no.	Success %	Range in height (inches)	Average height (inches)
B-3-0	Branch - side Epic.*- side	6	12	29 - 60	44
B-3-1	Branch - side	7	14	36 - 82	62
B-3-2	Branch - side	10	22	37 - 62	52
B-3-3	Branch - side	5	10	24 - 48	40
B-3-4	Epic. * - side	16	31	36 - 73	61
B-3-5	Branch - side	5	9	48 - 79	68
B-3-6	Branch - top	9	21	21 - 77	49
B-3-7	Branch top-side	0	0		
B-3-8	Epic. * - side	0	0		
B-3-9	Epic. * - side	3	6	23 - 68	43
B-3-10	Epic. * - side	0	0		
B-3-11	Epic. * - side	1	2	81	81
B-3-12	Branch-top	0	0		
B-3-13	Epic. * - side	0	0		
B-3-14	Branch-top	11	22	26 - 76	52
V-1-1	Branch top-side	5	11	1 - 67	52
V-1-2	Branch-side	4	8	68 - 90	83
V-1-3	Branch top-side	0	0		
V-1-4	Branch top-side	0	0		
Cull V-5	Branch -top	1	2	69	69

* Epic. - Epicormic

Nineteen silver maple plus phenotypes and two inferior trees were budded in August of 1964. Table IV indicates that nine of the phenotypes were successfully propogated in 1964.

TABLE IV

Number and size of 1-year-old silver maple ramets in August 1965 which had been budded in August 1964.

Phenotype number	Bud origin	Success no.	Success %	Range in height (inches)	Average height (inches)
B-3-0	Branch top-side	0	0		
B-3-1	Coppice-side	17	40	10 - 39	24
B-3-2	Branch-side	9	24	5 - 26	18
B-3-3	Epic. - side	4	8	23 - 37	29
B-3-4	Branch-side	1	3	3 - 3	3
B-3-5	Branch-side	0	0		
B-3-6	Not budded in 1964				
B-3-7	Branch-side	0	0		
B-3-8	Coppice-side	0	0		
B-3-9	Branch-side	4	8	1 - 39	29
B-3-10	Epic. -side	6	12	34 - 78	55
B-3-11	Epic. -side	0	0		
B-3-12	Branch-side	0	0		
B-3-13	Epic. -side	0	0		
B-3-14	Branch-side	12	24	4 - 55	40
B-3-15	Branch-side	0	0		
V-1-1	Branch - side	5	10	32 - 59	42
V-1-2	Branch-side	5	10	47 - 68	61
V-1-3	Branch-side	0	0		
V-1-4	Branch-side	0	0		
Cull M-13-689	Branch-side	0	0		
Cull V-1-5	Branch-side	0	0		

Layering success

Measurements were taken of the coppice from the mound layered and of the shoots from the horizontally layered ramets on 16 June 1964, and again on 25 September 1964. Observations indicated that the shoots from the mound layered ramets grew more rapidly than did those of the horizontally layered trees (Table V).

TABLE V

The number and the heights of shoots which developed in the 1964 growing season from mound- and horizontally-layered ramets of four high-quality and one low-quality silver maple phenotypes.

			Shoots		Shoot height	
Phenotype number	Ramet no.	Type of layering	Total no.	Average no.	minimum (inches)	maximum (inches
B-3-1	1	Mound	7		9	41
	2	"	5	6	15	38
	3	Horizontal	9		4	15
	4	"	7	8	4	28
B-3-2	1	Mound	6		14	39
	2	"	6		11	25
	3	"	3	5	8	33
	4	Horizontal	7		3	18
	5	"	9		5	36
	6	"	7		5	24
	7	"	6	7	4	52
B-3-6	1	Mound	4		3	42
	2	"	2		23	50
	3	"	6	4	4	41
	4	Horizontal	4		13	30
	5	"	7		4	22
	6	"	11	7	2	29
B-3-9	1	Mound	5		6	42
	2	"	5	5	9	34
	3	Horizontal	8	8	3	15
M-13-639	1	Mound	4	4	57	62

The success of the treated and the untreated stems was evaluated in the spring of 1965 by digging them up and examining each one for the presence or absence of roots.

TABLE VI

Presence or absence of roots on mound- and horizontal-layered shoots one year after half of them were treated with a rooting hormone (Stim Root)

Phenotype no.	Ramet no.	Type of layering	Treatment	Success	Total rooted
B-3-1	1	Mound	R. H. *		
	2	"	N. R. H. **		
	3	Horizontal	R. H.	Roots	
	4	"	N. R. H.		
Total					7
B-3-2	1	Mound	R. H.	Roots	
	2	"	N. R. H.		
	3	"	R. H.	Roots	
	4	Horizontal	N. R. H.	Roots	
	5	"	R. H.	Roots	
	6	"	N. R. H.	Roots	
Total					13
B-3-6	1	Mound	R. H.		
	2	"	N. R. H.		
	3	"	R. H.		
	4	Horizontal	N. R. H.		
	5	"	R. H.		
	6	"	N. R. H.		
Total					0
B-3-9	1	Mound	R. H.	Roots	
	2	Horizontal	N. R. H.	Roots	
	3	"	R. H.	Roots	
Total					9

* R. H. - Rooting Hormone ** N. R. H. - No Rooting Hormone

Table VI indicates that a rooting hormone is not absolutely essential for inducing rooting but it is recommended for optimum results. In one phenotype, B-3-6, no roots occurred after treatment with Stim Root. Although Table VI does not show the fine differences in rooting between the mound-and horizontally-layered trees, nevertheless, it was quite evident that the best rooting occurred in the horizontally-layered trees.

PROGRESS IN TREE IMPROVEMENT IN THE MARITIMES REGION

by

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Tree-improvement work for the Maritimes Region, Department of Forestry of Canada, during the past two years was mostly concerned with the establishment and maintenance of provenance tests; two of red spruce (Picea rubens Sarg.), two of white spruce (P. glauca (Moench) Voss), two of red pine (Pinus resinosa Ait.), one of jack pine (P. banksiana Lamb.), and one involving provenances of Japanese larch (Larix leptolepis (Zieb. and Zucc.) Gord.), European larch (L. decidua Mill.), and tamarack (L. laricina (Du Roi) K. Koch). In addition, one progeny test in red spruce was established and a small amount of tree breeding was done. Some early results from provenance tests and tree breeding were studied.

Picea

Two provenance plantations were established in the spring of 1964 as part of a project to study the variation of red spruce in the Maritime Provinces; one at Fundy National Park, and the other on Cape Breton Island. In this test there are now six plantations in the Maritime Provinces plus one in Maine (Fig. 1), and three in Newfoundland. Each plantation contains trees from 30 provenances (28 from the Maritime Provinces and Maine, and two from West Virginia), established in 10 or 20 randomized blocks, using 4-tree plots, 6-foot spacing, and in most cases, four rows of surround trees.

A progeny test, to study the breeding value of 30 superior and 15 inferior red spruce mother trees, was established in the spring of 1964, adjacent to Plantation F in the red spruce provenance test at East Kemptown, Nova Scotia (Fig. 1). The mother trees had been selected in 15 of the best stands in Nova Scotia and southern New Brunswick. Cones from some of the mother trees were collected during both good and poor seed years. The test consisted of 52 progenies, planted in 20 randomized blocks using 4-tree plots, 6-foot x 6-foot spacing, and four rows of surround trees. Dead and missing trees were replaced during the following autumn. One peculiarity of some of the grafted scions from the mother trees is that the buds failed to produce shoots. The scions, while retaining their needles and looking healthy, have not increased in length. In such cases feeder branches were left on the rootstocks. Two years ago these scions were sprayed at monthly intervals with a gibberellic acid solution, about 0.5 fluid ounces of Gibrel* in 25 fluid ounces of water, in an attempt to stimulate bud elongation or bud production. To date this has had no effect.

A white spruce provenance test was established at Acadia in the spring of 1965 in cooperation with M. J. Holst, Petawawa Forest Experiment Station. The trees were from seed collected mostly in the Great Lakes-St. Lawrence Forest Region and those areas of the Boreal Forest Region to the north of it. Some New Brunswick white spruce was included for a control.

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* Trade Name, Merck & Co.

The test consisted of 54 provenances, established in 9 randomized blocks and one demonstration block. Twelve-tree plots, 6-foot x 6-foot spacing, and two rows of surround trees were used. The demonstration block was laid out mainly to show the relationship of latitude of seed source to the way in which the trees will grow.

The tree heights attained in 10 growing seasons from germination of seed were measured on three red spruce plantations that form part of a study of the variation through out most of the range of this species. Each plantation consists of trees from 16 seed sources. One plantation is located in northwest New Brunswick, a second at Acadia in south-central New Brunswick, and the third in the Fundy Fog Belt. Mortality was low. Significant differences occurred among the average heights for the various provenances within each plantation. The influence of hybridization of red and black spruce is evident in some provenances and this must be studied further before final conclusions are drawn.

A number of relationships were found for red and black spruce between the latitude of seed source (the independent variable) and the dependent variables: (1) average weight of full seed, (2) average number of cotyledons, and (3) length of the "growing period" (the number of days between the completion of 10% and 90% of the season's growth) of the leaders. Damage caused by winter drying was found to be related directly to the average tree height rather than to seed source of various lots of 2 + 2 red spruce growing at Acadia. The greater susceptibility of the taller lots to winter drying may have been caused by their greater exposure to the sun and wind, or to the failure of the more vigorous lots to harden properly in the autumn, or to a combination of both. Black spruce, from the same general seed-source area as red spruce, was much more resistant to winter drying even though the average height of black spruce was greater than that of red spruce. Juvenile growth of red spruce from northern seed sources of low elevation was more vigorous than that of red spruce from southern seed sources of high elevation.

Small observation plots of several exotic spruces were planted at Acadia in 1965.

Larix

Average heights for several small lots of 7-year-old larch showed tamarack x Japanese larch to be the most vigorous (average height was 180% of the average height of local tamarack) followed by Polish larch (L. decidua var polonica (Racib.) Ostenf. and Syrach). The smallest and weakest trees were those resulting from the self-pollinations of tamarack and of Japanese larch. No definite conclusions can be drawn at this time as some of the lots consist of only a few trees, but the prospect for increasing yield through the hybridization of tamarack and Japanese larch and the use of non-native species and provenances appears promising. Significant differences occurred among the average heights for twenty 7-year-old provenance lots of Japanese larch, three of European larch, and two of tamarack. Compilation of data is incomplete. One lot of tamarack from a seed source in the Adirondack Mountains was the most vigorous. In the spring of 1965, controlled pollinations were attempted on tamarack using pollen from locally-grown European and Japanese larches.

Pinus

Inspections of red pine provenance plantations at Iris, Prince Edward Island, and at the Garden of Eden, Nova Scotia, indicate that the European pine shoot moth (Rhyacionia buoliana (Schiff.) will no doubt be a destructive pest in both areas.

Relationships were demonstrated for jack pine from 96 provenances growing in a nursery plantation between the dependent variable, average height of 3-year-old jack pine, and the independent seed-source variables, (1) latitude, (2) longitude, (3) length of growing

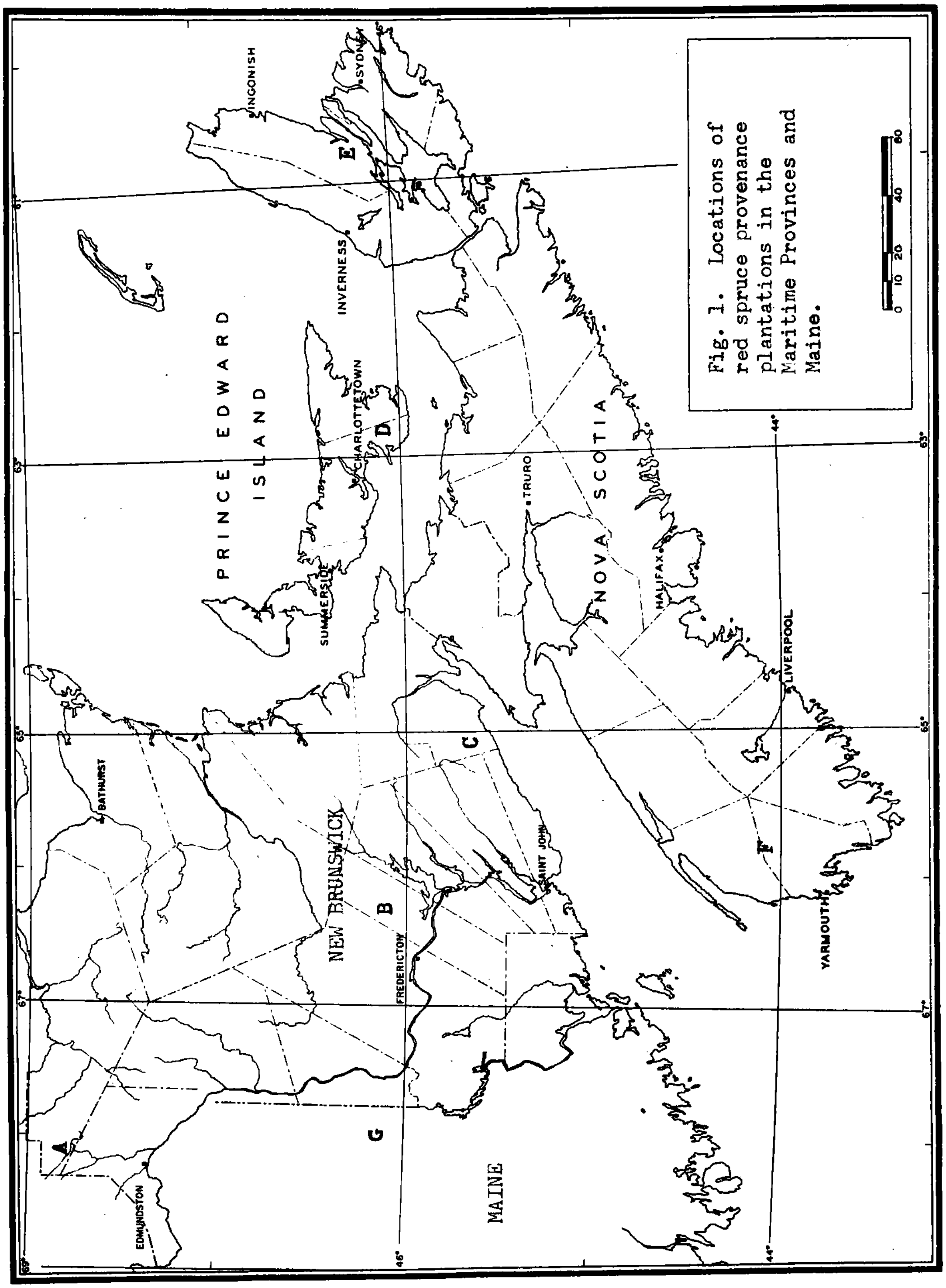

Fig. 1. Locations of red spruce provenance plantations in the Maritime Provinces and Maine.

season, (4) length of frost-free period, (5) daily mean temperature for June, July, and August, and (6) daily mean temperature for July. Relationships were shown between the dependent variable, the number of trees with late-season growth (lammas growth, prolepsis growth, and elongated buds), and the independent variables, (1) average height of 3-year-old trees and (2) the latitude of the seed source. There also appear to be relationships between the "growing period", days between the completion of 10% and 90% of seasonal growth of jack pine leaders, and the independent seed-source variables, (1) latitude, (2) longitude, (3) length of frost-free period, (4) daily mean temperature for May and June, and (5) daily mean temperature for May, June, July and August.

Two pine plantations were established in co-operation with the Nova Scotia Department of Lands and Forests in the spring of 1964. One consists of about 400 pitch pine (P. rigida Mill.) and about the same number of Austrian pine (P. nigra var. austriaca (Hoess) Aschers and Graebner) to be tested as windbreak species on the Guysborough Barrens. The second was a trial of red pine from two seed sources, pitch pine, and lodgepole pine (P. contorta var. latifolia Engelm.) on the Shelburne Barrens. These were planted in four randomized blocks, 324-tree plots, and 6-foot x 6-foot spacing.

Abies

No significant differences were found among the average heights of eight lots of balsam fir (Abies balsames (L.) Mill.) from seed sources in the Maritime Provinces growing in a replicated experiment at Acadia.

Four species of fir from Western North America (A. amabilis, (Dougl.) Forbes, A. concolor (Gord. and Glend.) Lindl., A. lasiocarpa (Hook.) Nutt., and A. nobilis Lindl.) and six from Eastern Asia (A. homolepis Sieb. and Zucc., A. holophylla Maxim., A. mariesii Mast., A. mayriana Miyade and Kudo, A. sachalinensis Mast., and A. veitchii Lindl.), together with local balsam fir, were planted in the autumn of 1964. Some species are represented by trees from more than one seed source. This 7-acre plantation is located under a low-grade hardwood overstory that was killed in the spring of 1963 using 30 pounds of Dybar to the acre. In the spring of 1965 plots A. grandis Lindl., and A. lasiocarpa (Hook.) Nutt., with a few A. firma Sieb. and Zucc. were added to the collection of firs planted at Acadia.

GENETIC VARIATION PATTERNS IN BLACK SPRUCE, *PICEA MARIANA* (MILL.) BSP.

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The objectives of this study were (1) to identify the important ecological factors influencing black spruce variation; and (2) to determine whether the resulting variation pattern is clinal in response to its wide geographic distribution, or clinal and ecotypic in consequence of its geographic distribution and occurrence on upland and bog sites in boreal regions. A hierarchical sampling scheme was adopted whereby seed was collected from 148 single trees in 24 stands and 9 regions (Rowe, 1959) between 42 and 60 degrees of latitude in a southeast-northwest transect. Twenty-one of these stands were located on a series of five moisture regimes (Hills, 1955) ranging from "moderately wet" to "moderately dry" in six regions between Lake Erie and James Bay in Ontario. Of the remaining three stands, one each was located in Wisconsin, Manitoba, and the Northwest Territories. An attempt was made to limit collection to the 1963 crop, and to collect seed in a south-to-north sequence in conformity with the process of seed maturation. In this way it was hoped to get more uniform seed that would provide reliable results in physiological experiments.

Experiments were begun in 1963 in a greenhouse at Petawawa Forest Experiment Station to study germination, and in 1964 in greenhouses and the nursery at Institut für Forstgenetik, Schmalenbeck, Germany, to study drought resistance, growth, and phenology. Results were subjected to correlation, multiple regression, and principal component analyses (Seal, 1964) to identify the main factors influencing the observed physiological responses. Variance components, derived from the hierarchical analyses of variance, provided estimates of variation at the level of populations (among regions), subpopulations (among stands within regions), and half-sib families (among single-tree progenies in stands).

The following ecological factors were identified. In the germination experiment, regression analysis showed that rate of germination and survival of germinant seedlings 31 days after sowing were related to soil moisture (P=0.01), with higher values recorded in the progenies from dry sites. But the coefficient of determination, r^2, indicated that only 7% of the total variation in both characters was explained by soil moisture. In the same experiment, the following factors were extracted by principal component analysis given in decreasing order of importance; "seed weight", "vigour", "variation in experimental conditions", "longitude and latitude", and "soil moisture".

In the greenhouse experiments on drought resistance, survival, and growth of first-year seedlings were correlated (P=0.001) with seed weight but not with soil moisture. However, soil moisture still played a role as was demonstrated by principal component analysis.

The nursery experiment on growth and phenology of second-year seedlings showed high correlations of prolepsis, initiation and cessation of growth, and height growth with latitude, longitude, day length, and seasonal temperatures. Correlations with soil moisture were generally lower than in the germination experiment and not significant in most cases. The factors extracted by principal component analysis were "latitude", "spring temperature", "seed weight", and "soil moisture".

The variation pattern, indicated by variance components, differed in the two stages tested. At the stage of germinant and first-year seedlings, differences were greatest among half-sib families. Moderate differences among subpopulations of the same population were also observed. At the stage of second-year seedlings, the greatest differences were those among populations. Differences among subpopulations and half-sib families were comparatively small. Since in the first year the results are influenced to a certain extent by mother effects, e.g., seed nourishment, second-year results are probably more reliable. This leads to the interpretation that the variation pattern is predominantly clinal (Morgenstern, 1966).

It is realized that this finding is relative to the sampling procedure adopted. It depends, for example, on the number of regions sampled and the distribution of stands within each region. It does not allow us to conclude that artificial selection within each region would be completely ineffective. This question will be discussed in subsequent papers.

One reason why subpopulations on various soil moisture regimes are not greatly different from each other is probably lack of isolation. In most of the regions sampled black spruce was found in pure stands or mixtures with other species in a continuous series from wet to dry sites. Thus there is little opportunity for selection to accumulate character differences (Ford, 1964). The broad tolerance range of this species, evident in its pioneer characteristics and its persistence on various sites with different associates, suggests that evolutionary mechanisms have been at work which favoured broad adaptibility instead of narrow specialization. This point of view (Bradshaw, 1964) seems best to explain the situation encountered in this study.

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BREEDING *PSEUDOTSUGA* IN COASTAL BRITISH COLUMBIA

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Inbreeding experiments with Douglas-fir

Every effort is being made both to self-pollinate a few selected plus trees each year in order to increase the number of S_1 inbred lines and to make further self-pollinations on some of the inbreds to produce the S_2 generation. At the present time, sixteen S_1 lines are already established at Lake Cowichan and another six trees were self-pollinated this spring. The more vigorous inbreds in the S_1 lines are being self-pollinated whenever possible and five trees have produced S_2 progeny. Another 10 S_1 inbreds were self-pollinated in 1966. Such pollinations have to be made with great care in order to avoid any pollen contamination. Whenever possible both the male and female strobili are enclosed in the same bag to rely entirely on natural rather than on artificial self-pollination.

This work at present is mainly concentrated on 11-year-old inbreds in five of the S_1 lines. To induce early flowering these trees were first fertilised in 1961. The results were quite variable but sufficient strobili were produced for pollinations to be made (Orr-Ewing, 1965). In 1965, selected trees from three of these same lines were fertilised again on May 7th with a lighter application of ammonium nitrate. The results again demonstrated how little is actually known about flower induction in young Douglas-fir. In one inbred line, for example, 42 trees were fertilised but only four of these produced a few strobili. No strobili were produced on the 53 unfertilised trees. This same line, however, had produced numerous strobili in 1962. In two other lines growing in the same replicated block, the results were completely different. In one, 28 trees were fertilised and 13 of these produced highly variable numbers of male and female strobili. Thirty-four of the 68 unfertilised trees, however, produced male and female strobili, moreover these were produced in such numbers that self-pollinations were possible in some cases. This line again had produced strobili in 1962. One can only conclude that certain trees will flower at an early age and that this is not primarily determined by fertilisers.

Inter- and intraspecific crosses within the genus Pseudotsuga

The prospects of interspecific crossing with the Douglas-fir do not appear too promising at the present time. Pollinations made in 1962 and 1964 with pollen from *P. macrocarpa* (Vasey) Mayr., the bigcone Douglas-fir from California, resulted in very small amounts of viable seed being produced. In 1963, another interspecific cross was attempted with pollen from *P. wilsoniana* Hayata, from Formosa. No viable seed was produced at all. There has therefore been more emphasis on intraspecific crossing where the results have been much more promising.

The intraspecific crossing program has expanded considerably since its inception in 1963. In March and April 1966, 3,595 1 + 1 seedlings from the first intraspecific crosses made in 1963 were planted on four areas in southern Vancouver Island. These areas had been selected the previous autumn with the co-operation of the Greater Victoria Water District, B. C. Forest Products Limited, and MacMillan, Bloedel & Powell River Limited. Another 18,607 1 + 0 seedlings from the 1964 intraspecific crosses were transplanted at the Lake

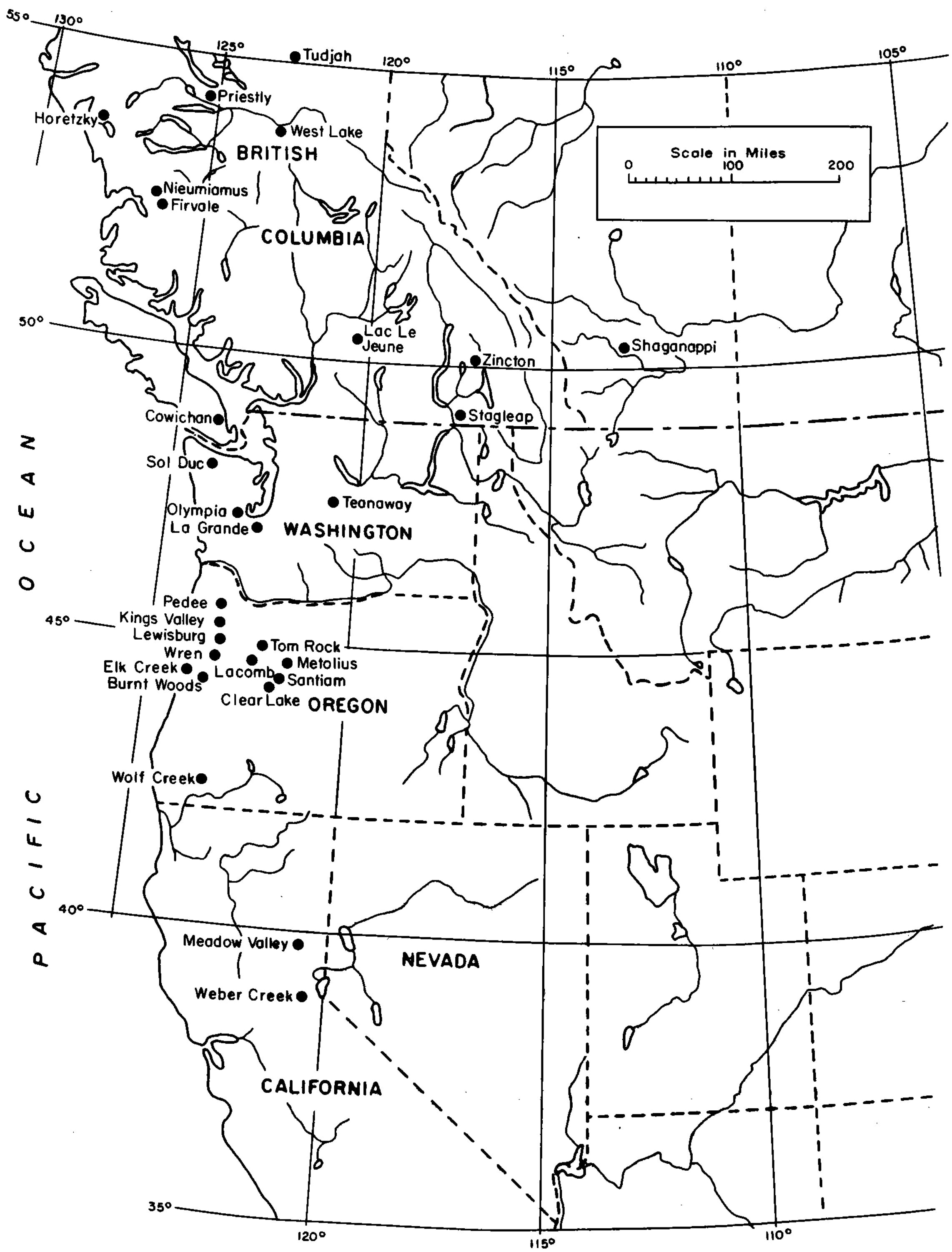

Figure 1. Location of the pollen parents used for the intraspecific crosses made with Douglas fir 1963-1966.

Cowichan nursery. A brief summary of the development of the 1963 and 1964 crosses at Lake Cowichan has recently been published (Orr-Ewing, 1966). Four more permanent seed beds were built and these, together with the other eight beds, were spot seeded in early May with 29,895 seeds from the 1965 crosses together with the remainder of the seed from the 1964 crosses. The remaining space in the beds was used for seed from small provenance collections and for rootstock.

The first pollinations possible on clonal material from selected plus treed were made in 1966, the Forest Service clone banks at Cowichan lake and Gordon River being used for this purpose. In addition, Mr. J. Leesing, Divisional Forester for Rayonier kindly make his company's clone bank at Gordon River available for further pollinations. Six hundred and fifty intraspecific pollinations were made on 14 clones representing selections in Vancouver Island and the Lower Mainland. Two local pollen parents were used as controls to the other crosses made with pollen from Prince George, B.C., Washington, Oregon, and California. The dry pollination technique was used exclusively for these crosses. Unfortunately severe damage was caused to the developing cones in the Gordon River clone banks by unusually severe frosts in late May.

Figure 1 shows the location of the pollen used in the intraspecific crosses from 1963 to 1966. These intraspecific crosses have only been made possible through willing co-operators in the U.S.A. and Canada. However, the problem of obtaining pollen in sufficient quantity at the right time and from selected areas, remains and makes a balanced crossing program very difficult. Efforts are now being made, therefore, to increase the breeding potential at Lake Cowichan so that most of the pollen required can be produced locally. In addition to clonal material from the 403 trees selected from coastal British Columbia, 37 clones from the interior of the province and from Alberta have been established at Lake Cowichan. A further 77 clones from Washington, Oregon, and California have also been established. Small seed plantations throughout the range of Douglas-fir are also being planted and, at present, these represent 31 locations in Arizona, California, Colorado, Mexico, Montana, and New Mexico. This approach has already proved its value as pollinations were made this year on three trees of an Arizona provenance which were only planted in 1960. Other pollinations were also made on two clones from Washington and Oregon which were grafted in 1963. This approach also permits reciprocal crossing which is seldom possible at the present time.

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SPRUCE PROVENANCE RESEARCH IN BRITISH COLUMBIA

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GEOGRAPHIC VARIATION IN SPRUCE CONE SCALE MORPHOLOGY

There are four species of spruce in British Columbia: Sitka spruce (Picea sitchensis (Bong.) Carr.), black spruce (P. mariana (Mill.) BSP), white spruce (P. glauca (Moench) Voss subsp. Engelmannii). The nomenclature follows that proposed by Taylor (1959). In certain areas of the Province these species overlap and introgressive hybridization occurs between white and Engelmann, and possibly between white and Sitka, and white and black.

The general distribution of the components of this great spruce complex over broad geographic regions has been established (Garman, 1957). However, a much more detailed knowledge of the distribution of the species and its hybrid components is necessary to provide criteria for the initiation of a program of selection and breeding, and for the establishment of seed transfer rules.

The objective of this study, which is being conducted concurrently with the provenance research reported below, is to provide genecologic data which will characterize, as objectively and precisely as possible, the species and hybrid components of the spruce complex of the interior of British Columbia. It is expected the results of both these studies will be mutually corroborative with regard to this objective.

The spruces referred to above exhibit characteristic differences in cone and needle morphology. However, in areas where they overlap, particularly with regard to extensive hybrid areas of white and Engelmann spruce, these differences are not sufficiently striking to be assessed by casual observation, and are determined only when detailed measurements are made on a mass collection of cones and foliage.

During the summers of 1963 and 1964 a collection of spruce cones was made in 157 areas throughout the interior of the Province from latitude 49°00' to the Yukon Border. Five trees, all of which were at least 100 feet apart, were sampled in each area. Twenty cones were taken at the base of each tree, totalling 100 cones per sampled area. Foliage was sampled only in those areas where the species overlapped.

A single scale was taken from the mid-point of each cone and measured. Five measurements were made, and five further measurements were then derived from these basic measurements (Fig. 1). Measurement was facilitated by photographing the cone scales and taking all measurements from 7- by 5-inch enlargements.

A detailed assessment of all field data pertaining to this study is currently underway. Comprehensive results are not yet available. Therefore the following conclusions, which are based on a preliminary examination of a portion of the data, are tentative.

(1) A sympatric zone of white and Sitka spruce occurs in the Skeena River valley between latitudes 54 30' and 55 30' and longitudes 127 30' and 128 40' (Fig. 2).

(2) Spruce populations exhibiting cone scale morphological characteristics of both white and Sitka spruce have been found in the sympatric zone indicated in (1). This sympatric zone is ecologically transitional between the coastal and interior forest regions. It is possible, therefore, that introgressive hybridization is occurring between the species in this region.

(3) White and Engelmann spruce are sumpatric in many regions throughout the interior of British Columbia south of latitude 55°00'.

(4) The sympatric zone commonly lies between 2,000 and 3,000 feet and is ecologically transitional between montane and sub-alpine forest regions.

(5) Variation in cone scale morphology is strongly clinal in white and Engelmann spruce populations which are continuous in their distribution from montane to sub-alpine forest regions (Fig. 3).

(6) Hybrid populations between both these species exist and have been recognized and delimited on the basis of cone scale morphology.

(7) Black spruce is a major component of the black and white spruce complex along the Alaska Highway in Northern B. C. north of latitude 55°00'. No evidence has been found to support the view (Raup, 1948) that *Picea glauca* var. *porsildii* occurs in this area.

(8) Numerous individual trees exhibiting characteristics of both black and white spruce have been found along the Alaska Highway. Therefore the possibility of introgressive hybridization between these species should not be discounted until further evidence has been produced.

(9) A spruce population exhibiting a bark type identical with that which characterizes var. *porsildii* has been found at Telegraph Creek, latitude 57°52', longitude 131°12', elevation 1,325 feet.

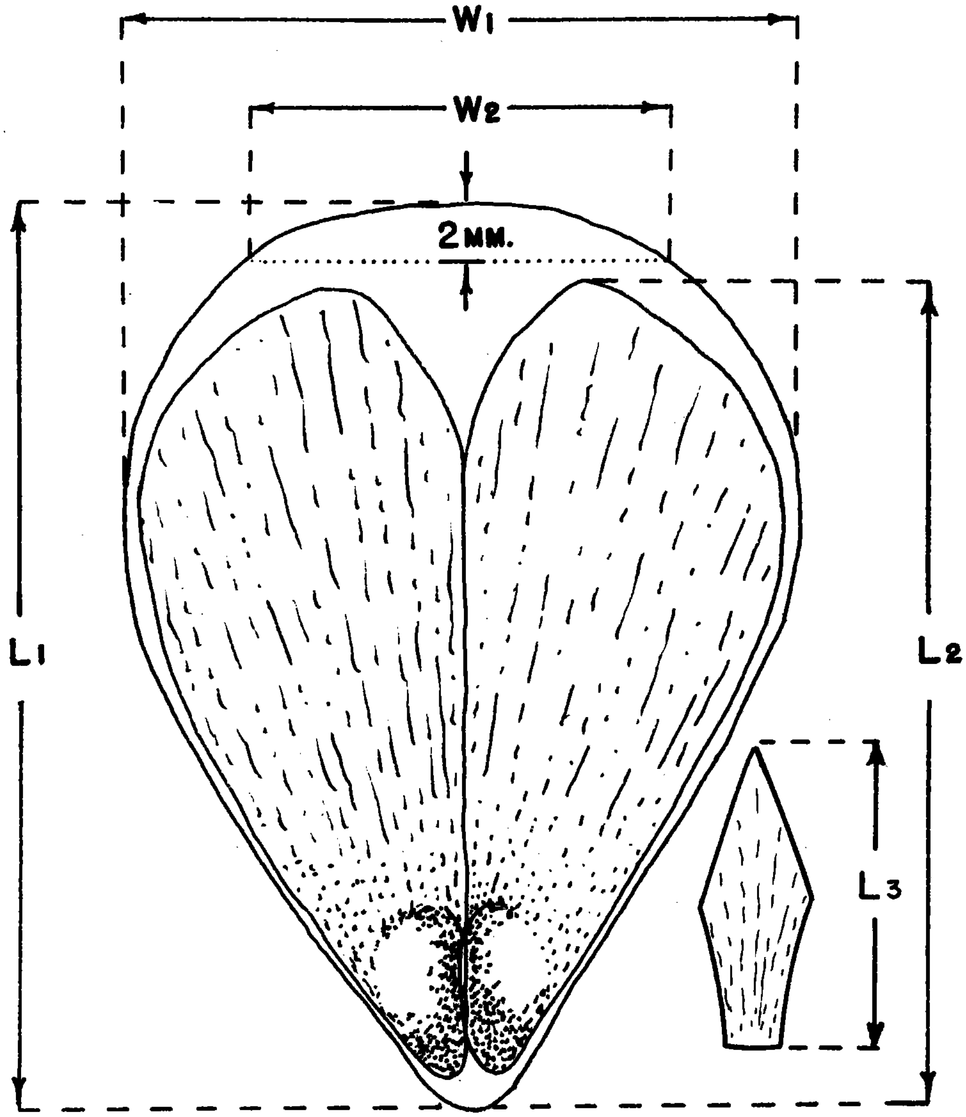

Fig. 1. Diagrammatic representation of spruce scale and bract showing five basic measurements. The five derived measurements are

$\frac{L1}{L2}$, $\frac{L1}{L3}$, $\frac{L1}{W1}$, $\frac{L1}{W2}$ and $\frac{L1}{L2} \times L3$

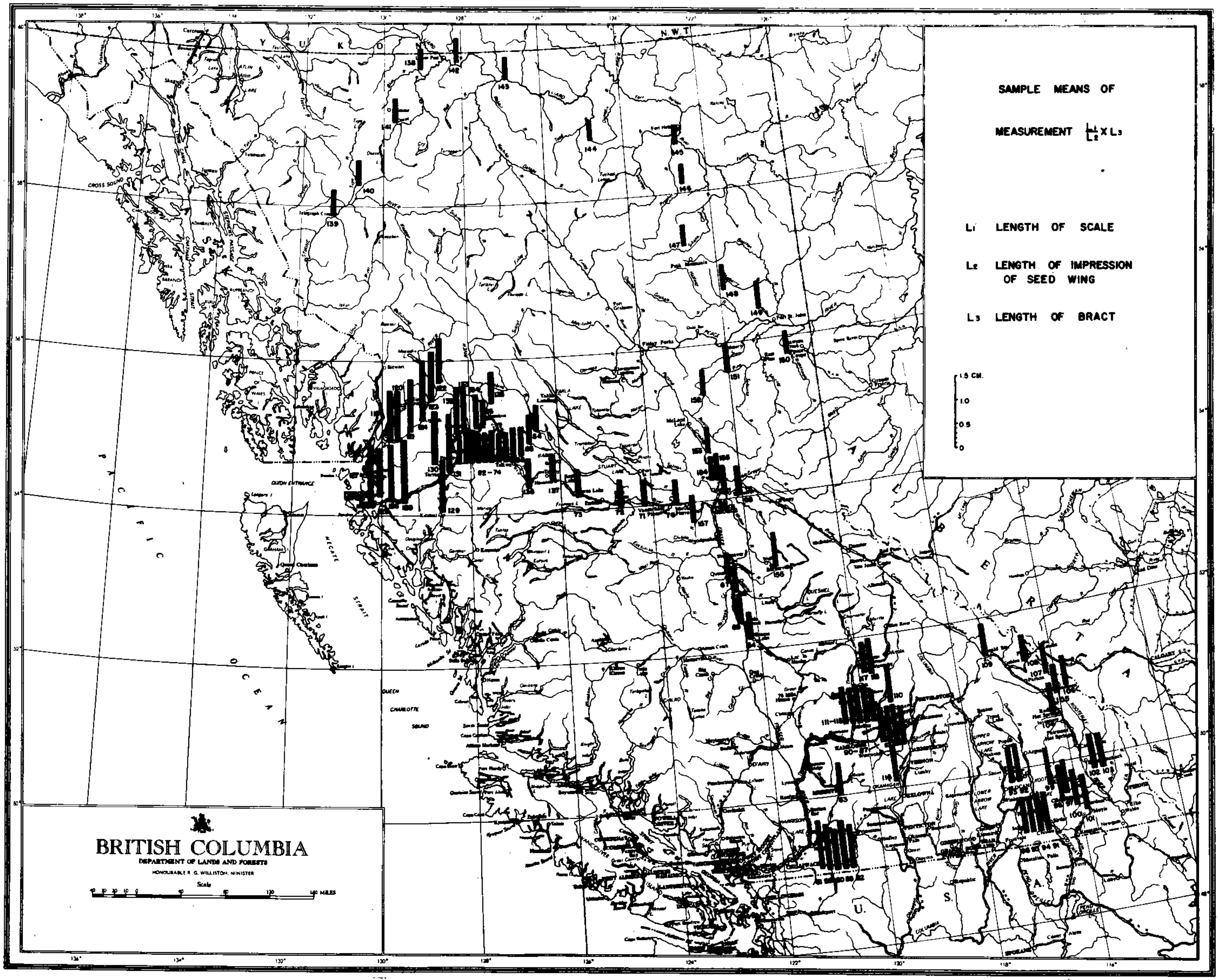

Fig. 2. Variation in cone scale morphology throughout the spruce complex in British Columbia. Note the sympatric zone of white and Sitka spruce.

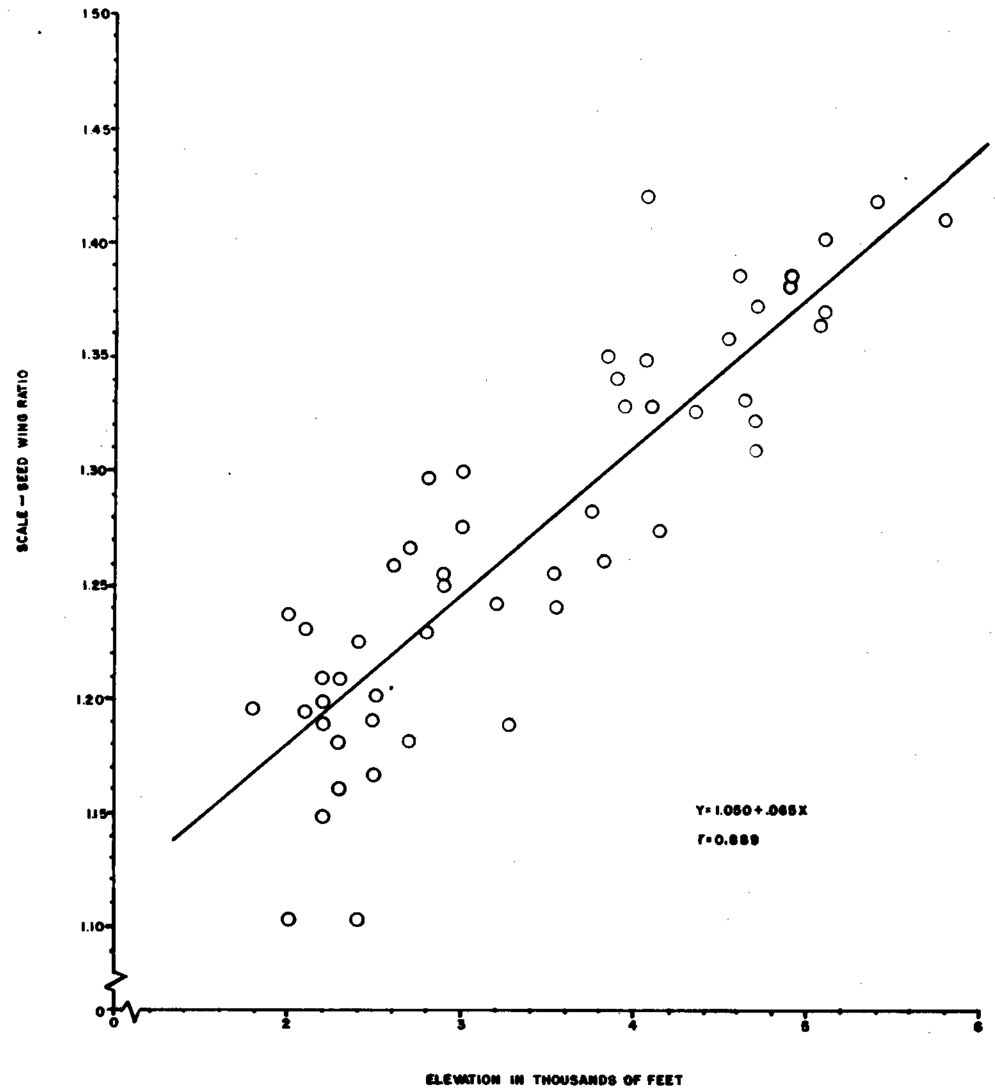

Fig. 3. Relationship between elevation and spruce cone scale-seed wing ratio in the white-Engelmann spruce complex in British Columbia.

GEOGRAPHIC VARIATION IN WHITE AND ENGELMANN SPRUCE SEEDLINGS IN A COASTAL NURSERY

Twelve white and Engelmann spruce provenances were sown in the spring of 1964, and 150 Engelmann and Sitka spruce provenances were sown in the spring of 1965 in the B. C. Forest Service research nursery at Cowichan Lake, Vancouver Island. The geographic location of all these provenances and the Cowichan Nursery is shown in Fig. 4. The 12 provenances sown in 1964 were randomized in each of four blocks and sown 6 inches apart at right angles to the long axis of the bed. Two of the blockswere of California B11 soil mix (University of California 1957) and two of a local soil. The 150 provenances sown in the spring of 1965 were randomized in each of six blocks and sown 6 inches apart at right angles to the long axis of the bed. All six blocks are of the California B11 soil mix. Provenance data for the 12 provenances is given in Table I and arranged in order of increasing elevation.

In the fall of 1964, the 12 provenances were sampled by placing a board with 10 teeth alongside each row of seedlings and taking that seedling which was closest to each of the 10 teeth to give 10 seedlings per row. Since there were four replications; each provenance was represented by 40 seedlings. Shoot length (SL), root collar diameter (RCD), and the ratio of these two measurements (SL/RCD) were obtained for every seedling and the mean of all measurements calculated for the 12 provenances (Table II).

During the early spring of the second year a plastic greenhouse was placed over two blocks, one of California mix and the other of local soil. A similar sampling and measuring procedure was followed in assessing the second year's growth, the results of which are given in Table III. In addition, shoot extension was measured every 2 weeks during the growing season so that it was possible to construct a growth curve for each provenance (Fig. 5). Dates of flushing and dormancy are given (Table IV).

The differential growth behaviour of the 150 spruce provenances during the first year in the nursery is currently being assessed.

In addition to the work reported above, which is being conducted at the Cowichan Lake research nursery, provenance investigations have been carried out in co-operation with the Reforestation Division of the B. C. Forest Service. These investigations, which are referred to below, represent an extensive survey of gross differences in growth behaviour of spruce in four widely separated Forest Service nurseries. Measurement is confined to a yearly assessment of growth, and no attempt is made to make detailed assessments of provenance differences in the nursery.

Thirteen white and Engelmann spruce provenances were sown at the Telkwa and Duncan Nurseries in the spring of 1963, and another 40 provenances were sown in the fall of 1963 at Telkwa, Duncan, and Cranbrook Nurseries, and in the spring of 1964 at Aleza Lake Nursery. The provenances are randomized in each of four blocks and sown in rows at right angles to the long axis of the bed. The geographic location of all 53 provenances, and the four nurseries is given in Fig. 6. The 13 provenances referred to have now been outplanted in two locations, one on the coast, and the other in the interior of the Province. The 40 provenances from the Telkwa and Aleza Lake nurseries will be outplanted in the spring of 1966.

From the provenance investigations reported above some general trends are apparent, and may be reported here. However, all conclusions must remain tentative until a comprehensive analysis of results has been carried out.

(1) Variation in growth of diverse white and Engelmann spruce provenances exhibits a clinal trend in a coastal nursery during the first and second year (Tables III and IV and Fig. 7).

(2) This trend is habitat-correlated in that it appears to vary negatively with elevation and positively with the number of days in the growing season.

(3) The variation pattern in growth behaviour is similar to the variation pattern in cone scale morphology in natural stands of the white-Engelmann spruce complex.

(4) In British Columbia spruce populations which occupy an ecological niche transitional between montane and sub-alpine forest regions exhibit a pattern of variation which is intermediate between that of populations from the montane and the sub-alpine regions.

(5) These "intermediate" populations may be the product of introgressive hybridization in white and Engelmann spruce.

(6) Spruce populations from above 4,000 feet enter dormancy in mid-June in a coastal nursery when temprature is increasing and photoperiod approaching maximum. If production is the objective such populations should not be grown on the coast, for, even if they flush again, growth is negligible in comparison to that of low elevation provenances from the same latitude.

(7) Populations from low elevations but northern latitudes generally behave similarly on the coast to high elevation provenances from southern latitudes.

(8) Growth response of high elevation provenances to increased temperatures appears to be enhanced in the presence of good soil conditions, i.e. high fertility and high moisture regime (California mix inside greenhouse, Fig. 5:5) and depressed in relatively poor soil, i.e. low fertility and low moisture regime (Robertson Valley soil inside greenhouse, Fig. 5:6).

TABLE I

Provenances sown at Cowichan, 17 May, 1964

Provenance No.	Latitude	Longtitude	Elevation in thousands of feet	Locality
12	54° 06'	122° 03'	2.0	40 miles east of Prince George.
2	52° 20'	121° 40'	2.2	30 miles north-east of Williams Lake.
8	54° 30'	122° 40'	2.3	40 miles north of Prince George.
4	54° 22'	122° 30'	2.6	35 miles north of Prince George.
6	53° 40'	122° 25'	3.0	35 miles south of Prince George.
7	53° 20'	122° 10'	3.4	40 miles south of Prince George.
1	49° 00'	116° 45'	4.0	30 miles south-east of Nelson.
3	49° 49'	116° 16'	4.5	50 miles north-east of Nelson.
9	49° 14'	115° 58'	4.7	25 miles south of Cranbrook.
10	49° 45'	117° 00'	4.8	30 miles north-east of Nelson.
11	49° 20'	116° 08'	5.3	20 miles north-east of Creston.
5	49° 35'	117° 48'	5.7	25 miles north-west of Nelson.

TABLE II

First year's growth of 12 provenances on an artificial soil mix (California mix) and a local soil (Robertson Valley soil)

P	SL(mSL(mm.)		RCD(mm.)		SL/RCD	
	RVS	CM	RVS	CM	RVS	CM
12	16.0	26.1	0.67	0.89	23.4	29.2
2	13.9	24.6	0.64	0.87	21.6	28.5
8	16.6	23.3	0.73	0.87	22.4	26.4
4	13.3	26.8	0.69	0.91	18.9	29.2
6	15.9	27.4	0.70	0.92	22.2	29.4
7	14.8	23.3	0.69	0.92	21.1	25.1
1	10.2	21.6	0.78	0.98	12.9	22.1
3	16.4	27.4	0.85	1.03	18.9	26.3
9	13.3	24.3	0.72	1.06	18.0	23.0
10	13.0	24.0	0.79	1.09	16.1	21.8
11	13.4	24.2	0.78	1.04	16.9	23.2
5	10.7	20.0	0.69	0.95	15.6	21.1

Each figure is the mean of 20 seedlings. Note that in every instance growth is superior on the California mix. P - provenance (arranged in order of increasing elevation); RVS - Robertson Valley soil; CM - California mix; SL - shoot length; RCD - root collar diameter.

TABLE III

Second year's growth of 12 spruce provenances on two soil types both inside and outside plastic greenhouse

P	E	SL(CM)				RCD(CM)				SL/RCD			
		RVS		CM		RVS		CM		RVS		CM	
		I	O	I	O	I	O	I	O	I	O	I	O
12	2.1	11.04	5.35	12.42	8.03	.384	.237	.379	.277	2.875	2.257	3.277	2.899
2	2.2	17.95	5.71	17.59	10.09	.415	.223	.401	.299	4.325	2.561	4.387	3.375
8	2.3	19.97	6.41	13.23	9.04	.460	.250	.413	.299	4.341	2.564	3.203	3.023
4	2.6	14.77	5.53	11.44	8.34	.373	.222	.350	.296	3.960	2.491	3.269	2.818
6	3.0	12.27	5.92	14.70	8.24	.396	.260	.399	.306	3.098	2.277	3.684	2.693
7	3.7	9.23	4.79	12.11	10.04	.365	.223	.362	.298	2.529	2.148	3.345	3.369
1	3.9	5.33	3.20	9.88	7.09	.317	.215	.356	.315	1.681	1.488	2.775	2.251
3	4.5	9.10	5.06	9.95	7.92	.360	.241	.365	.297	2.528	2.100	2.726	2.667
9	4.7	11.99	5.05	12.62	10.64	.394	.223	.413	.349	3.043	2.265	3.056	3.049
10	4.9	6.30	5.69	11.84	7.31	.387	.260	.393	.316	1.628	2.188	3.013	2.313
11	5.3	6.76	4.90	11.11	8.29	.352	.250	.452	.292	1.920	1.960	2.458	2.839
5	5.7	5.76	4.58	11.32	7.82	.284	.232	.393	.291	2.028	1.974	2.880	2.687

P - Provenance (in order of increasing elevation), E - Elevation, RVS - Robertson Valley soil (local soil), CM - California mix, SL - Shoot length, RCD - Root collar diameter. Each figure is the mean of 10 seedlings.

TABLE IV

Dates of flushing and dormancy of 12 spruce provenances on two soil types both inside and outside plastic greenhouse

		CM inside greenhouse			RVS inside greenhouse			CM outside greenhouse			RVS outside greenhouse			
		Block 1			Block 2			Block 3			Block 4			
P	E	F	D	No. of days between F & D	F	D	No. of days between F & D	F	D	No. of days between F & D	F	D	No. of days between F & D	Average no. of days between D & F in all four environments
12	2.1	Mar 16	Jun 2	78	Mar 16	Jun 2	78	Apr 12	Jun 24	73	Apr 9	Jun 17	69	74.50
2	2.2	Mar 16	Jun 30	106	Mar 16	Jul 30	136	Apr 12	Jun 30	79	Apr 6	Jun 17	72	98.25
8	2.3	Mar 16	May 25	70	Mar 16	Aug 13	150	Apr 12	Jun 24	73	Apr 6	Jun 24	79	93.00
4	2.6	Mar 16	Jun 2	78	Mar 16	Aug 5	142	Apr 12	Jun 24	73	Apr 15	Jun 17	63	89.00
6	3.0	Jun 16	Jun 10	86	Mar 16	Jun 2	78	Apr 15	Jun 17	63	Apr 9	Jun 10	62	72.25
7	3.7	Mar 16	Jun 2	78	Mar 16	May 25	70	Apr 21	Jun 30	70	Apr 9	Jun 10	62	70.00
1	3.9	Mar 16	May 25	70	Mar 16	May 25	70	Apr 12	Jun 24	73	Apr 2	Jun 10	69	70.50
3	4.5	Mar 16	May 25	70	Mar 16	May 25	70	Apr 12	Jun 17	66	Apr 9	Jun 10	62	67.00
9	4.7	Mar 16	May 25	70	Mar 16	May 25	70	Apr 12	Jun 10	59	Apr 9	Jun 17	69	67.00
10	4.9	Mar 16	May 25	70	Mar 16	May 25	70	Apr 21	Jun 17	57	Apr 6	Jun 10	65	65.50
11	5.3	Mar 16	May 25	70	Mar 16	May 25	70	Apr 12	Jun 10	59	Apr 12	Jun 10	59	64.50
5	5.7	Mar 19	May 25	67	Mar 16	May 25	70	Apr 15	Jun 24	70	Apr 12	Jun 10	59	66.50

RVS - Robertson Valley soil, CM - California mix, E - Elevation, P - Provenance, F - Flushing, D - Dormancy.

A provenance was considered flushed when more than 50% of seedlings scored were flushed. Dormancy was similarly assessed. Since flushing and dormancy in each environment was assessed on the basis of only 10 seedings, it is likely that assessments based on a larger sample would exhibit a period of growth (last column in above table) more strongly correlated with altitude than that indicated in table.

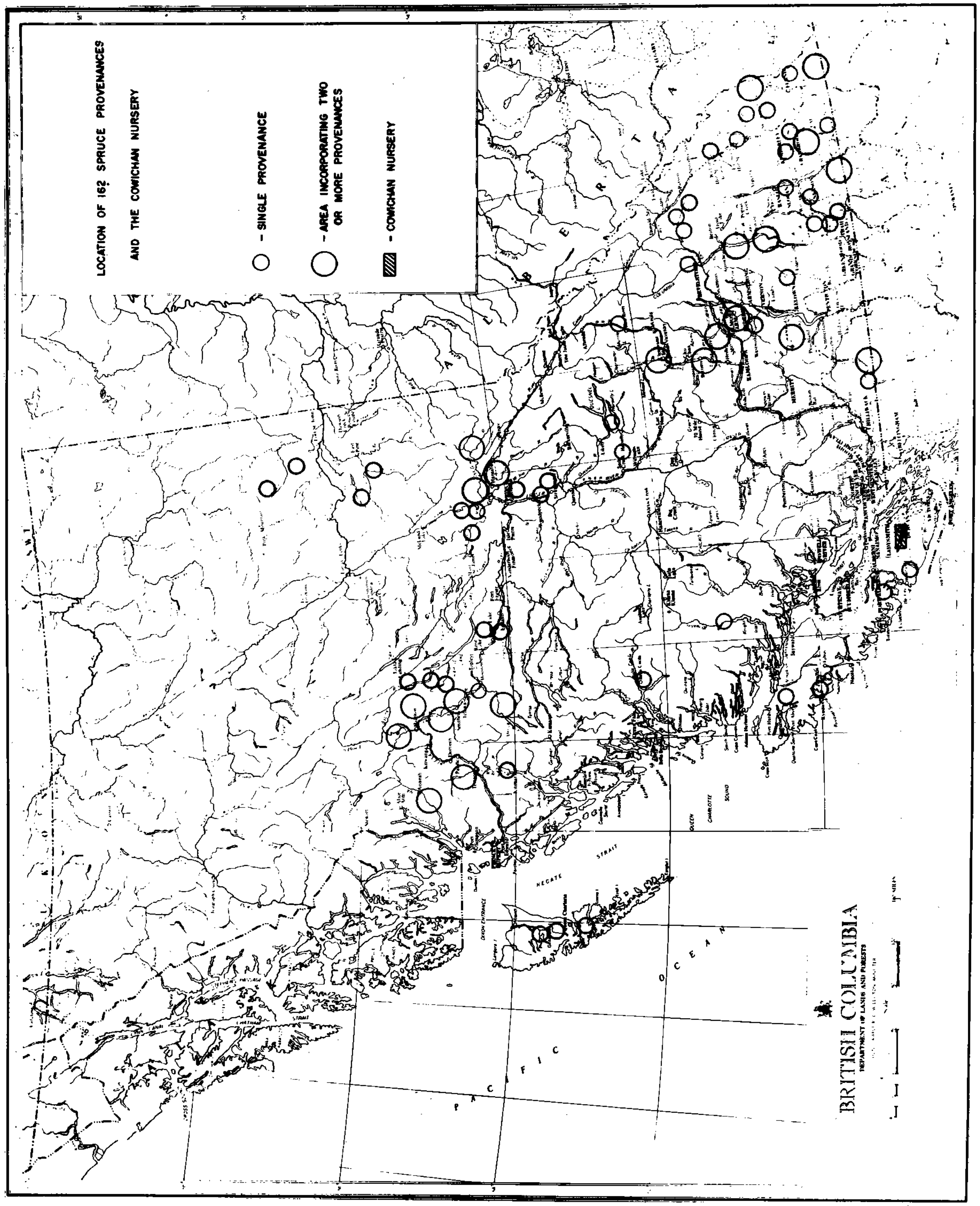
LOCATION OF 162 SPRUCE PROVENANCES
AND THE COWICHAN NURSERY
- SINGLE PROVENANCE
- AREA INCORPORATING TWO OR MORE PROVENANCES
- COWICHAN NURSERY
BRITISH COLUMBIA
DEPARTMENT OF LANDS AND FORESTS
PACIFIC OCEAN
HECATE STRAIT
QUEEN CHARLOTTE SOUND
DIXON ENTRANCE

Fig. 4.

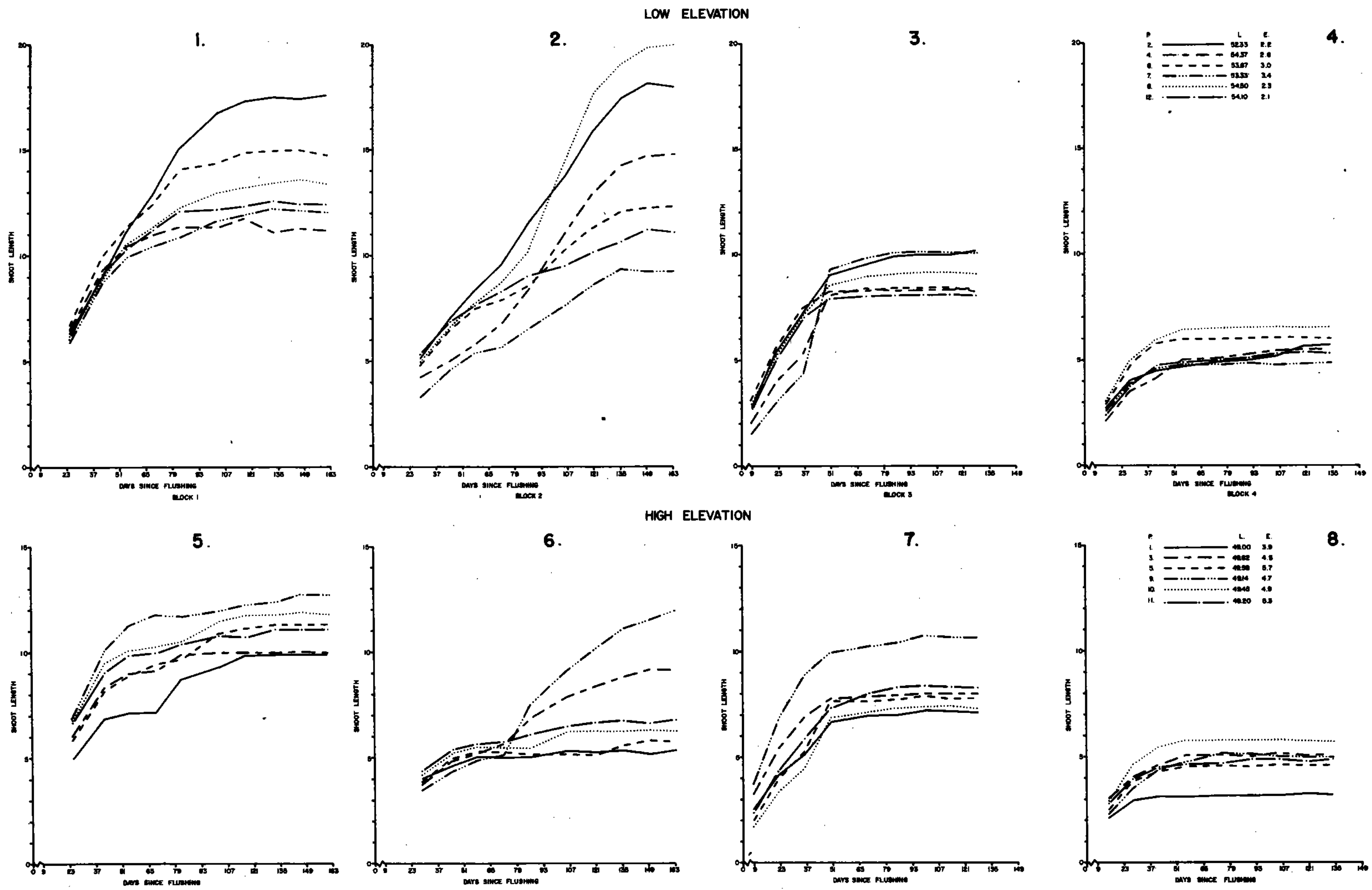

Fig. 5. Second year's growth of 12 spruce provenances (6 low elevation & 6 high elevation) in 4 environments; (1 & 5) California mix inside greenhouse, (2 & 6) Robertson Valley soil inside greenhouse, (3 & 7) California mix outside greenhouse, (4 & 8) Robertson Valley soil outside greenhouse.

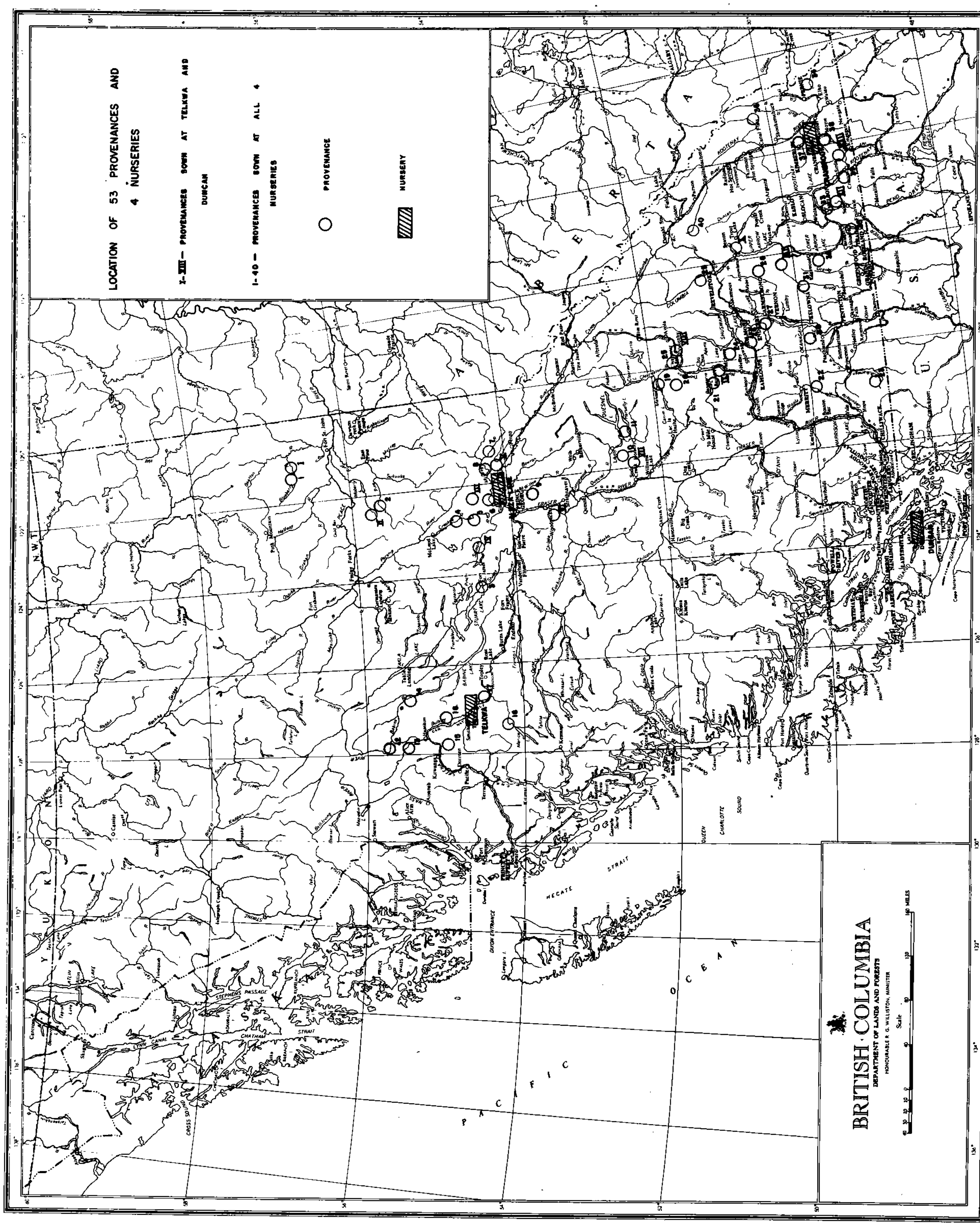
LOCATION OF 53 PROVENANCES AND 4 NURSERIES
I-XIII — PROVENANCES SOWN AT TELKWA AND DUNCAN
1-40 — PROVENANCES SOWN AT ALL 4 NURSERIES
PROVENANCE
NURSERY
BRITISH COLUMBIA
DEPARTMENT OF LANDS AND FORESTS

Fig. 6.

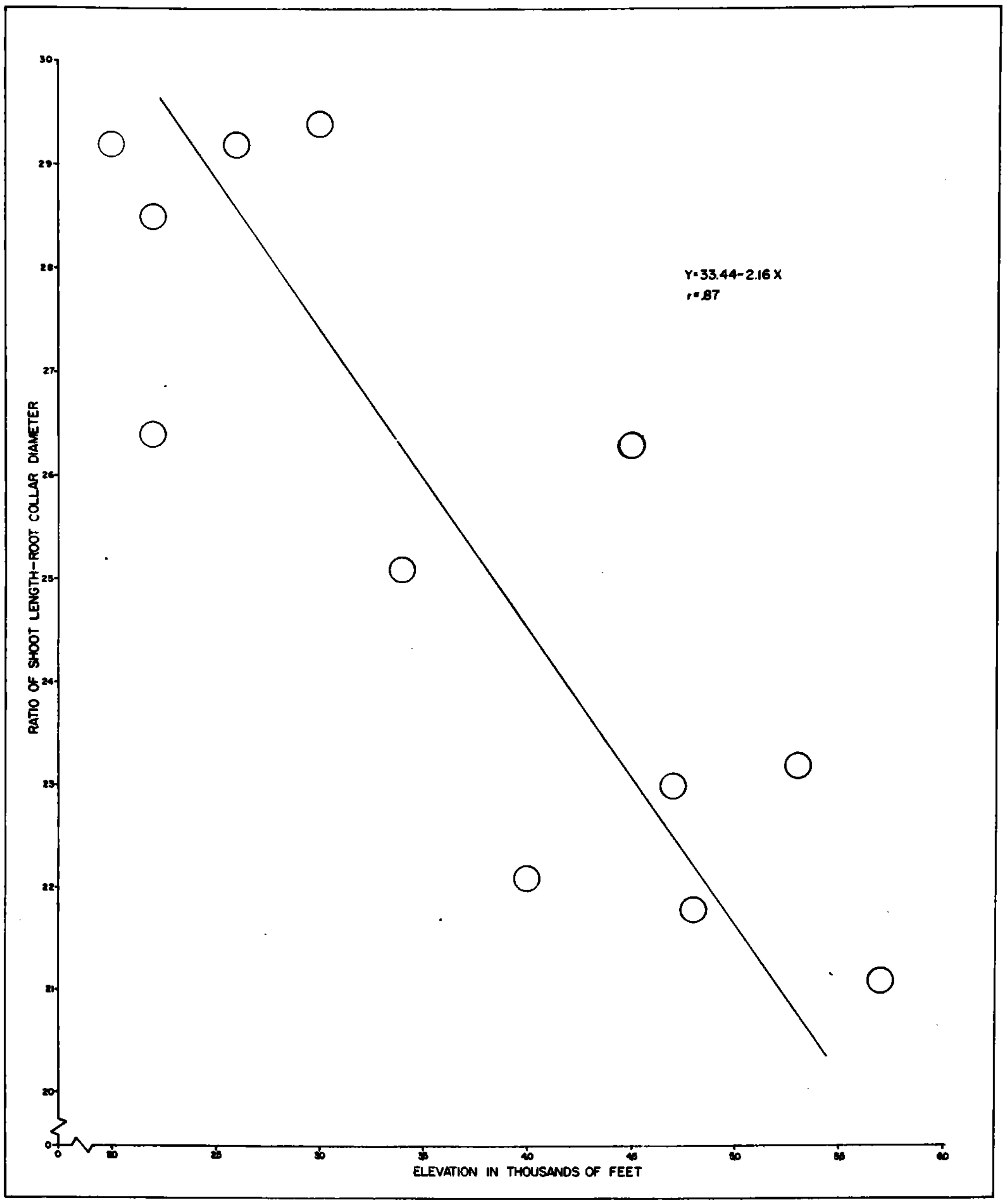

Fig. 7. Relationship between elevation and growth behaviour (on California mix) of 12 provenances of one-year-old white and Engelmann spruce seedlings. Each point on the curve is the mean of 20 seedlings.

VARIATION IN EMBRYO DEVELOPMENT IN DIVERSE SPRUCE PROVENANCES AND ITS EFFECT ON GERMINATION BEHAVIOUR AND EARLY GROWTH

Using x-ray techniques, Scandinavian workers have demonstrated that embryo development in spruce and pine seed in highly correlated with germination behaviour. It is also possible that embryo development may influence early growth in the nursery. Consequently provenance differences in germination behaviour and even early grwwth - differences which, unlike embryo development, are genetically based - may be obscured if no account is taken of this factor.

For these reasonf four replications of 100 seeds of each of the 150 provenances referred to in the last section have been x-rayed in order to determine the extent to which embryo development varied between provenances. The percent of embryo class four in each provenance (embryo fills embryo cavity) was used as a measure of embryo development. The x-rayed seed was subsequently germinated at 25°C and grown to the cotyledon stage. Hypocotyl and radical length, and dry weight was obtained for 60 seedlings of each provenance. Separate samples of 400 seeds of each of the 150 provenances were germinated at 15, 20, and 30°C.

The method followed in assessing embryo development in this instance is similar to that described by Roche (1965). References to the pertinent Scandinavian literature are also given in this latter publication.

A complete analysis of this work is currently underway and no details are yet available. However, a preliminary assessment of the x-ray data indicates that the index of embryo development referred to above varies from 0 to over 90 in the 150 provenances under test.

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TREE IMPROVEMENT IN THE MANITOBA-SASKATCHEWAN REGION

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Department of Forestry of Canada

In 1964 , a geneticist and a technician were appointed at the Winnipeg laboratory to start a tree improvement program for the prairie region which includes the provinces of Manitoba and Saskatchewan.

When preparing the tree improvement program for the Manitoba-Saskatchewan (MS) Region, the following circumstances were considered:

(1) The boreal forests cover the northern part of the region in a continuous zone from east to west. The forests are primarily coniferous: white spruce (Picea glauca (Moench) Voss), black spruce (Picea mariana (Mill.) BSP), balsam fir (Abies balsamea (L) Mill.), jack pine (Pinus banksiana Lamb.) and tamarack (Larix laricina (Du Roi) K. Koch) but there is a general admixture of broad-leaved trees such as white birch (Betula papyrifera Marsh.), aspen (Populus tremuloides Michx.) and balsam poplar (Populus balsamifera L.).

In the southern part of Manitoba, largetooth aspen (Populus grandidentata Michx.) and eastern cottonwood (Populus deltoides Marsh.) are native. Red pine (Pinus resinosa Ait.), white pine (Pinus strobus L.) and eastern white cedar (Thuja occidentalis L.) reach their western limit in the Sandilands Provincial Forest, southeastern Manitoba.

Increased tree growth to be expected through selection and breeding is limited by the rigorous climate. The winters are long and cold, and the growing seasons short, hot, and relatively dry.

(2) Forest lands within provincial boundaries are administered by provincial governments with the exception of two national parks, some Indian reserves and one federal forest experimental area on the Riding Mountain. The Department of Forestry has no nursery facilities, which are a primary requirement for a program in tree breeding.

(3) The wood-using industry is interested in an adequate supply of pulpwood and improved dimension and quality of white spruce, black spruce, jack pine, aspen and poplar for pulp mills and sawmills.

On this basis, the following breeding program was suggested:

Species	Breeding emphasis	Wood use	Site
White spruce	quality	lumber	fertile upland, boreal
Black spruce	volume	pulp	wet lands, boreal
Jack pine	volume	pulp	infertile, dry sand, everywhere
Aspen	quality and volume	pulp and veneer	fertile upland, boreal
Poplar hybrids	quality and volume	pulp and veneer	fertile lowland and irrigated areas

In addition, numerous exotics such as Norway spruce (Picea abies (L.) Karsten), Scots pine (Pinus silvestris L.), larches (Larix spp.), and several poplar hybrids from Japan, Poland, Germany, and Hungary, and other broad-leaved species are under consideration.

Methods include testing of provenances, ecotypes, and progenies of selected stands and individual trees from across the region. Tests are made of the rooting ability of poplar cuttings and of the value of hybrid poplars.

Selecting of superior variants and assessing their hereditary value is an important part of the work. Trees proven to be genetically superior will constitute the basic material used in future tree improvement. The first sifting of a large number of selected trees will be based on open pollinated single-tree progenies. When breeding values have been estimated, controlled hybridization will secure a greater concentration of the desired characteristics in the progenies.

In the international field there is an increasing co-ordination of research activities and exchange of technical information and breeding material. There is an exchange of poplar and aspen materials with the Tree-improvement Institute at Poznania, Poland, and the Forest Genetics Institute at Schmalenback, West Germany. Correspondence in exchange of ideas and information concerning exotic tree species is underway with the Botanical Garden, Göteborg, Sweden.

Co-operative research is being done with the Wood Technology Laboratory of the University of California, Berkeley, to distinguish the true fir species and variation occurring in North America.

The program outlined above will require more personnel and space than are available at present but it is hoped that these requirements will be fulfilled as the program expands.

Discussion of the proposed program is still in progress. The director of the Manitoba-Saskatchewan Region recognizes that any allocation plan must be kept as flexible as possible, and must be continuously reappraised in the light of changing conditions.

The work from 1964 to the present is summarized in the following sections.

White Spruce

The purpose of the experiment is to study the variability of provenances grown from seed collected at a number of locations in eastern Canada. The experiment was begun in the spring of 1955 by R. M. Waldron when seeds of various provenances were collected in Manitoba and Saskatchewan, and expanded in the spring of 1956 to include white spruce seeds from Ontario and Quebec. Seedlings from Manitoba and Saskatchewan were set out at the Riding Mountain Forest Experimental Area, at Moodie, Manitoba, and at Big River, Saskatchewan, and seedlings of Ontario-Quebec origin were field planted at the Riding Mountain Forest Experimental Area in 1959.

Details of the early work carried out on this project have been fully described in the reports prepared by Wheaton (1960) and Waldron (1963).

In October of 1965 a survey of the condition and total height was carried out for the Big River experiment (Table 1).

In addition to the observations presented in Table 1, winter browning, snow mold (Phacidium infestans Karst.) infection, tent caterpillar (Malacosoma americana (F.)) damage, bushy forms and dead leaders were noted. Snow mold forms a harmless crust on lower portions of the trees. The numbers of seedlings affected, included in these categories, were insignificant.

The highest mean of height and the high survival percentage demonstrates the superiority of the local provenance to the introduced provenances. However, the somewhat higher survival percentage of the seedlings from Kississing, Malaneck, Prairie River, and Torch River suggest that they may have greater tolerance to adverse climatic conditions than those of the local provenance.

Grafting of white spruce from selected seed-trees on the Riding Mountain was performed in the greenhouse in March 1966 with potted seedlings for stocks. The scions were collected from the east, west, and south sides of the trees to test the effect of crown position on graft survival. Only 20% of the grafts of 100 white spruce selections survived due to poor scions. The difference of successful grafting between the crown positions was not significant, or at least cannot be proved because of the insufficient samples.

Norway Spruce

This project is a part of an international Norway spruce experiment and was established in co-operation with the Petawawa Forest Experiment Station of Chalk River. The provenances, set out at Riding Mountain Experimental Area in 1963, are of potential interest for the northern area of the Canadian Plain.

The experiment consists of 8 blocks, each containing one 9-tree plot of each of 12 provenances. The trees were planted at 8 x 8 foot spacing.

The location of each provenance lot was randomly assigned within each block. A 2-row surround of (2-2) white spruce was planted around the outside boundary of each block.

Differences in the size and condition of the various provenances were noted at the time of planting. There was a wide range in size even though all stock had been grown under similar conditions in the nursery. However, the count in 1965 does not show significant differences between the mean heights of the various provenances, except between the Norway spruce and the local white spruce. The survival of the Norway spruce provenances is higher than that of the white spruce.

A ranking system was used to evaluate the observations. For that purpose, the percentages characterizing the various conditions such as height, mortality, health, infection of snow mold, frost damage, browsing and fork were transformed to numerical values and summed for each provenance (Table 2). The rank totals under each provenance in Table 2 give the array of evaluation. The first in the rank is the provenance originating from a plantationat the Petawawa Forest Experiment Station (Code No. 2365). It appears to be adequately established in the Petawawa environment, and is quite tolerant to the extreme climate in Manitoba. The provenance from Bauske, Latvia (2351), is ranked very close to it but the provenances from Sweden exhibit very poor performance, the local white spruce presents the poorest growth. The slow growth is characteristic in the first period of white spruce development here.

During the course of the survival count it was noted that one of the chief causes of mortality was trampling by elk or moose. Dead leaders and/or colour (yellowish) were observed quite frequently among the survivors, but no record was kept of the numbers affected.

Jack Pine

This project is a part of the all-range jack pine provenance experiment (Exp. No. 255-A) initiated by M. J. Holst at the Petawawa Forest Experiment Station in 1962 and 1963. More details of the project are published in the Proceedings of the 9th Meeting of the Committee on Forest Tree Breeding in Canada, 1964, pp. 82-84.

In 1965, two experiments were undertaken in the nurseries at Marchand, Manitoba (Lat. 49.4°, Long. 96.2°) and at Spruce Home, Saskatchewan (Lat. 53.5°, Long. 105.7°). Fifty-three seedlots were received from the Petawawa Forest Experiment Station and sown in May in the above-mentioned two nurseries. One seedlot was added to them from local sources.

Drill sowing method was used in nursery beds. The arrangement of the rows in each plot was the following: 1 local-2 provenances- 1 local-2 provenances-1 local. The length of plots was 10 feet. Each plot includes two seed lots, i. e., 20 feet linear row for each provenance. Ten replications were used.

In July, the survival was recorded in each nursery. Expected seedling number was 500 for each seed plot (25 seedlings per foot). The deviation from the expected seedling number is demonstrated in Figure 1. The highest number of seedlings were obtained from the seed of provenance numbers 3277 and 3237. Both had very low germination percentages on the list sent by the P. F. E. S. After the survey in July a germination test of the surplus seeds was made in the laboratory and much higher germination percentages were found for the seed lots. The differences ran to 20-30%. On the other hand, many seed lots had lower germination capacities than expected. These differences led to uneven spacing in the seedbeds, since the rate of sowing was based on the original list of germinative capacity.

Analysis of variance on germination shows high variability between provenances and between replications which suggests soil interaction or site effect in the germination process. Moreover, several other factors affected the different germination, e.g., in the first 4 weeks the area was irrigated by sprinkler which did not water the blocks evenly. Those blocks which fell into the perimeter of the area seeded was unevenly irrigatedand resulted lower percentage in germination. It is obvious that the factors which controlled the germination

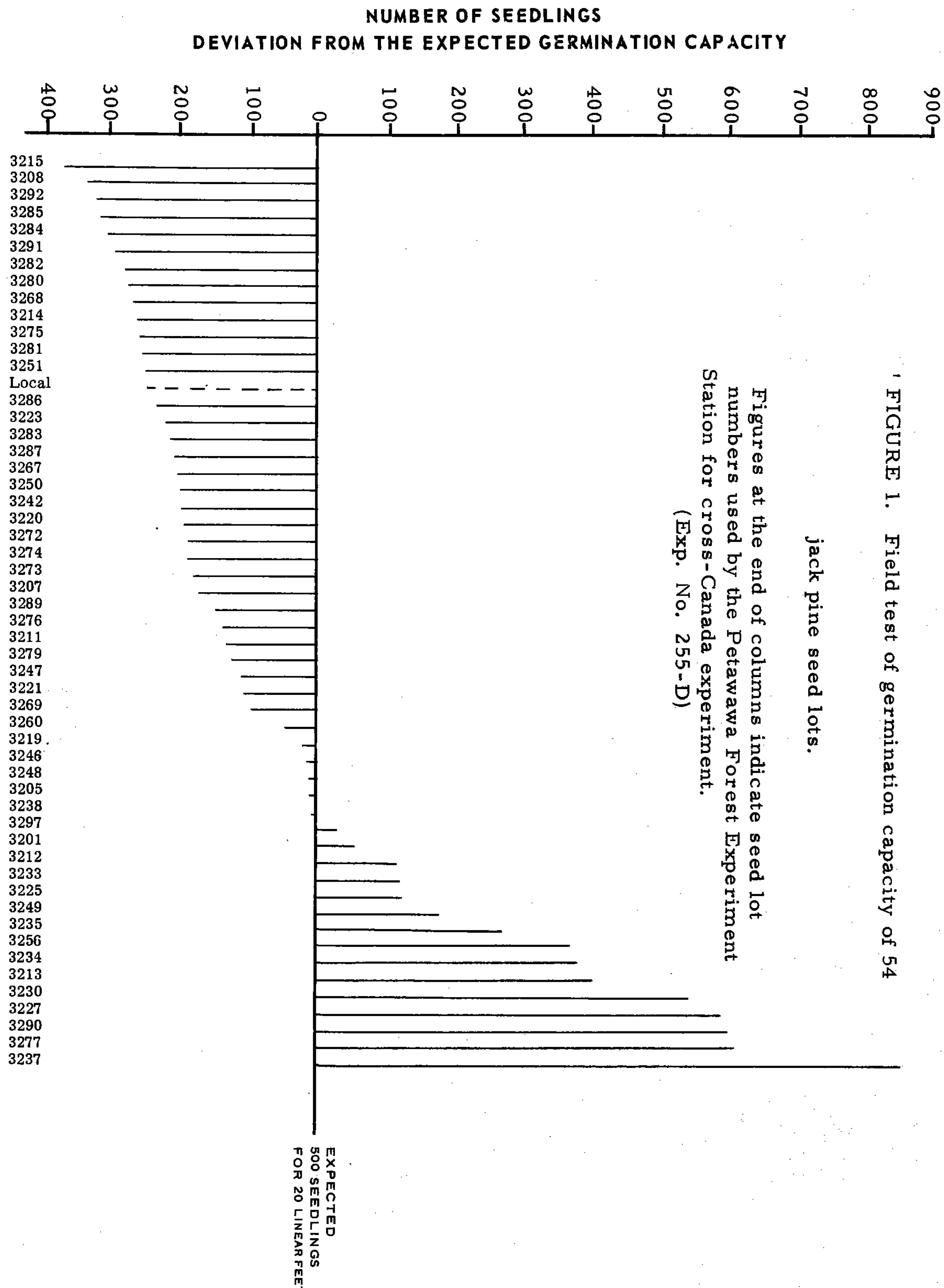

FIGURE 1. Field test of germination capacity of 54 jack pine seed lots.

Figures at the end of columns indicate seed lot numbers used by the Petawawa Forest Experiment Station for cross-Canada experiment. (Exp. No. 255-D) were ecological rather than genetic. The variation of germination is discontinuous and a conclusion cannot be drawn regarding the viability of the provenances.

The experiment at Spruce Home was essentially a failure due to severe weed competition during the period of germination. However, the surviving seedlings were measured for height in October 1965. The seedlings of No. 3279 from Cloquet, Minnesota, exhibited the highest growth, 2.2 cm in the first year, the poorest, 1.7 cm, was No. 3283 seed lot from Sprague, Manitoba. Significant differences were not found between the height of the provenances.

Scots Pine

Eleven provenances from the Petawawa Forest Experiment Station were planted at Carberry and at Piney, Manitoba, in 1960. The experiment was laid out in a randomized block design and in each locality there were four blocks. Each block was divided into 11 contiguous plots. Each plot contained 49 plants, arranged in a 7 x 7 square. The plots were divided by single division rows, and two rows formed a surround on the outside border of the plantations. The Manitoba Forest Service provided 2-2 stock of unknown origin for the surround and division rows.

Survival and height data were recorded in October 1965. The data are summarized in Table 3. At Carberry, the growth records demonstrate that the local seed lot is superior to the introduced provenances but the survival percentage is very low. The mortality is higher in the surround rows than in the division rows of the local lot and it is due to the side effect. The plantation is located in an open area and is exposed to drying winds, snow storms and damage by animals.

At present, the trial demonstrates better results at Piney than at Carberry. Both the growth and survival exhibit higher values. The missing trees were killed by the collar weevil (<u>Hybobius radicis</u>) and damaged by pine rust (<u>Peridermium harknessii</u>). Collar weevil and pine rust are very common on jack pine and red pine in this area and endanger the existence of Scots pine plantations.

In both trials, plants from seed of Kaluga and Kiev, Russia, displayed outstanding survival and vigor, while those from Niska, Finland, were lowest in vigor. The day length difference between Niska and Carberry and Piney may explain the difference between the growth rate of the two seed lots. The seedlings from the local source represents at least the second generation of the introduced Scots pine, which appears to be well adapted to extreme climatic condition.

True Firs

In 1959, Dr. A. H. Hutchinson, Professor of Botany at the University of British Columbia, suggested an investigation be made of morphological variation within and between alpine fir (<u>Abies lasiocarpa</u> (Hook) Nutt.) and balsam fir (<u>Abies balsamea</u> (L.) Mill.). The financial assistance for the project was given by the National Research Council until 1963. After 1963, the project was undertaken by the Department of Forestry, Winnipeg, and more specific objectives were designed to learn as much as possible about these two species.

The main objectives of the project were to determine the variability of needle and cone characteristics and to ascertain whether alpine fir or balsam fir is essentially one population and whether the phenotypic variation of each species follows certain environmental gradients.

Sixty-five stands of alpine fir, located in the Yukon Territory, British Columbia, Washington, Montana, and Oregon were sampled.

The following characteristics were recorded for the study of variation: needle length, width and apex form; present of groove and ridge; colour of foliage; stomatal distance on the adaxial needle surface; stomatal distribution on the adaxial needle surface; stomatal structure; seed wing area; seed weight; length of scale; length of bract; difference between scale, and bract; and resin canal position. Mean, standard deviation and range were calculated from tree means, and stand means were computed. Correlation analyses and 't' tests were used to show the association between several traits and environmental factors such as precipitation, temperature, and altitude. The correlation coefficients prove significant differences between the stand means.

All traits showed higher variability between stands than between trees sampled. The variability of traits is apparently largely due to the environmental factors. Nevertheless, they sometimes suggest casual associations.

Stomatal distance was directly associated with precipitation. Therefore, stomatal frequency increases with higher precipitation. Analysis of variance showed that the difference between cone scale and bract lengths was highly significant between the different stands. These differences indicate actual variations in the cone collection. Cones were collected from mature trees of 50 stands located in British Columbia. Twenty randomly selected scales and bracts were measured for each stand.

Varieties and clines are suggested to exist in the natural range of alpine fir. Eastern and western varieties and high-alpine and sub-alpine type alpine firs have been described in a manuscript prepared for publication.

The study of balsam fir has not been completed. However, the existence of some putative hybrid trees between alpine fir and balsam fir at Lesser Slave Lake, Alberta, may be mentioned here. Several traits such as resin canal position and hypodermal tissue in the needle cross-section, thickness of the needle, distribution of stomata on the upper surface of the needle, size of the parenchyma extension in the bundle, length and number of the lenticels on the middle-age bark, and finally the percentage of β-pinene and β-phellandrene in the resin, show intermediate characteristics between alpine fir and balsam fir. Alpine fir has not been found in this area as yet and it is assumed that the hybrid seeds were carried by the flood of Lesser Slave Lake from those regions where the ranged of the two species overlap. Further investigation is underway on this subject.

Poplars

In the past, extensive work has been done by federal agencies to select clones, hybrids, and cultivars of various poplars for shelterbelts and ornamental purposes at Brooks, Alberta, at Indian Head, Saskatchewan, and at Morden, Manitoba. Now it is pertinent to select good material of all available promising poplars for the forest industry and propagate them on a large scale. Good poplar material means clones, hybrids, and cultivars capable of high survival and growth on various sites, resistant to diseases, frost hardy and suitable for timber and pulpwood.

In the early spring of 1965, 180 rooted 2-year-old cuttings comprising 12 different cultivars were received from the tree nurseries of the Prairie Farm Rehabilitation Administration of Canada Department of Agriculture Forest Tree Nursery at Indian Head, Saskatchewan (Table 4). The rooted cuttings were set out in three plantations in May 1965, at the Riding Mountain Forest Experimental Area, Pineland Tree Nursery at Hadashville and

Lake St. George in the Interlake Area. Soil at Hadashville was prepared by common nursery cultivation for producing seedlings. At the Riding Mountain Experimental Area the site was bulldozed and raw humus pushed from the soil surface. At Lake St. George no preplanting site preparation was undertaken. The cuttings were planted in the rough; grasses and Ledum sp. were the main ground species present. Each plantation consisted of five replications with each replication containing one cutting of each of the 12 cultivars. Cuttings were planted at 4' x 4' spacing in pits.

In October 1965, heights, survival, and pest resistance were recorded. Height growth was best at Hadashville, next best at Riding Mountain and poorest at Lake St. George. The difference between the means of height in the three plantations was highly significant according to the 't' test. An analysis of variance of survival did not exhibit significant differences among the plantations.

Strong infection of Septoria musiva and S. marsonina, conidial stage of Drepanoperiza popedorum (Desm.) Hoehn. on leaves, Cytospora chrysosperma on the dead cuttings and Phyllosticta brunnea on the petioles were observed. Other infections such as leaf spots Cladosporium subsessile and Discosia atracreas have been found on the cultivars in the experiment located at Riding Mountain.

It was found that the best three cultivars prove to be Populus x cardeniensis (mislabeled canadensis), P. x petrowskyana, and P. x Brooks No. 1. Their superiority to the others is certainly encouraging. It is of interest that certain differences of cultivars in their reaction towards climatic, edaphic, and genetic influences were indicated.

Exotic Species

The number of tree species occurring in the boreal forest region of the Manitoba-Saskatchewan Region is very limited and those which are growing in the South, in the parkland and prairie areas are not productive. It is pertinent to consider increasing the number of tree species in the Manitoba-Saskatchewan Region by introduction of new species from other provinces, countries and continents. Species, which can be utilized by the wood-using industry, are considered first. Spruces, true firs, frost hardy pines, larches, lodgepole pine and jack pine hybrids, birches, oak, maples, and poplars are such tree species. Secondly, consideration is given to several shrub species which are able to improve the condition of the recent forest stands located under extreme climatic conditions.

The first approach was to obtain some exotic materials, and to estimate the breeding value of the exotic trees established in the Skinner's arboretum for 50 years. The inventory of trees and the estimation of their breeding value is presented in Table 5.

The arboretum is located at Dropmore, Manitoba, on the border of the Aspen Grove and Mixedwood sections at 1800 feet elevation and 51° 10' latitude and 101° 20' longtitude. The topography of this region is generally rolling. Mainly clay-loam covers the deep glacial till which is moderately calcareous. The climatic data are the following: annual total precipitation 18 inches, with nearly equal distribution of rain through the growing period; average annual temprature 33°F, January is the coldest (-11°F average) and July is the warmest (78°F) month; the number of days when mean temperature exceeds 42°F is 170, starting on April 28 and ending on October 15; the number of days between the first and last frost are eight (8), from July 12 to 20.

This climate provides an excellent environment for the selection and breeding of frost hardy trees. Any trees hardy at Dropmore should grow anywhere in the grain belt of middle Canada where soil and moisture conditions are favorable.

In 1965, the author began testing some poplar hybrids provided by Mr. Skinner, for rooting ability, growth, and fibre content. In addition, a population study was undertaken of the spruce hybrids listed in Table 5 under 15.

In co-operation with the University of Manitoba, anatomical studies were made of a number of tree species from Egypt. The trees were: Ficus glumosa (Moraceae); Khaya grandifolia C. Dc., Mysore (Dandeli) (Meliaceae); unidentified Eucalyptus species (Myrtaceae); Jacaranda (Dalbergia) latifolia Roxb. (Bignoniaceae); unidentified Tamarix species (Myricaria); Cedrela toona (Meliaceae); and an unidentified Casuarina species.

The prepared and stained slides were examined under microscope and a study was made by Mr. Samir F. A. Tewfick in his master's thesis at the University of Alexandria, Egypt.

These species are not hardy in the extreme climate of this continent, with the exception of Tamarix which appears to be suitable for introduction in the salty soils of Manitoba and Saskatchewan. Tamarix species are growing as small trees in their natural ranged. They are very frost hardy trees and have modest requirements for nutrition. The wood of tamarix is insignificant for the wood-using industry, but tamarix should be considered for use on saline and alkali soils, as shelterbelt or protective plantation against the dry winds of the prairie.

TABLE I

Condition of white spruce provenances
in the plantation at Big River, Sask.
1965

Provenance	No. of seedlings planted	Height	Survival	Browsed	Forked	Frozen in 1965
		cm.		%		
Longlac, Ont.		29	72	20	11	4
Sandilands, Man.		33	61	19	17	3
Hodgson, Man.		34	87	19	21	7
Riding Mt., Man.		33	69	10	17	5
Kississing, Man.		37	99	12	27	12
Maloneck, Sask.		35	93	10	19	12
Prairie River, Sask.		37	99	7	22	10
Torch River, Sask.		37	99	10	17	10
Candle Lake, Sask.		32	85	17	19	7
Bitter Creek, Sask.		33	72	11	12	5
Local (Big River), Sask.	878	42	93	6	24	15

TABLE 2

Condition of Norway spruce plantation
at Riding Mountain Experimental Area

Observations	2312-Ossjo, Sw.	2313-Skone, Sw.	2314-Maltesholm, Sw.	2315-Olsztyn, Po.	2350-Bashkiria, Ru.	2351-Bauske, Lat.	2352-Minsk, Ru.	2353-Kaluga, Ru.	2354-Magaiski, Lib.	2365-P. F. E. S., Ont.	2366-P. F. E. S., Ont.	2289-Bialostock, Po.	Local W. sp.
Height (cm)	45	52	50	59	48	55	51	53	42	55	57	49	36
Mortality %	1	22	1	4	4	1		4	3	3	3		9
Healthy %	37	6	36	36	79	65	50	27	23	70	40	56	49
SM %	19	48	37	39	4	12	6	46	30	10	23	10	12
Brow. %	11	13	7	11	-	16	6	5	22	11	17	12	7
Fork %	22	10	16	7	12	6	8	7	4	3	10	19	17
Frost %	10	1	3	3	1	-	2	11	12	3	7	3	6
	Numerical value of measured data for ranking of provenances												
Height	9	16	14	23	12	19	15	17	6	19	21	13	0
Mortality	21	0	21	18	18	21	22	18	19	19	19	22	12
Healthy	7	1	7	7	15	12	9	5	4	13	7	11	9
SM	6	0	2	2	9	7	8	0	4	8	5	8	7
Brow.	11	9	15	11	22	6	16	17	0	11	5	10	15
Fork	0	12	6	15	10	16	14	15	18	19	12	3	5
Frost	1	11	9	9	11	12	10	1	0	9	5	9	6
Total Score:	55	49	74	85	97	93	94	73	51	98	74	76	54

TABLE 3

Source, survival and height of 8-year-old Scots pine
seedlings at Carberry and At Piney
1965

Seed lot number	Origin		Carberry		Piney	
	Seed from	Long. - Lat. o	Survival %	Height cm	Survival %	Height cm
2287	Niska, Finland	26 - 64	6	41	37	44
2341	Kiev, Russia	30 - 50	57	74	84	154
2342	Smolensk, Russia	32 - 54	31	74	78	132
2343	Smolensk, Russia	32 - 54	50	69	82	130
2344	Kaluga, Russia	36 - 54	59	71	77	113
2345	Orel, Russia	37 - 53	37	74	75	127
2346	Voronesh, Russia	39 - 52	50	76	70	129
2347	Beloneskig, Bashkiria	51-- 55	31	56	74	102
2348	Molotow, Siberia	57 - 58	20	71	62	112
2349	Tobolsk, Siberia	65 - 51	40	66	72	103
2361	Chkalov, Russia	52 - 53	26	64	62	126
Local	Manitoba*	98 - 50	32	85	75	132

* The origin of Manitoba provenance is unknown.

TABLE 4. Hybrid parents and source of clones in study

Code No.	Clone - Name	Type of origin	Parents	Source
1	P. Northwest	N	P. deltoides Marsh. x P. balsamifera Duroi non L.	Prairie Nurseries Northern Alberta
2	P. tristis Fisher	N	Unidentified hybrid, Tacamaha section	Kew, England Through the Skinner Nursery
3	P. FNS #44-52	N	P. deltoides Marsh. x ?	(FNS) by J. Walker
4	P. Saskatchewan	N	P. deltoides Marsh. x ?	(FNS) ?
5	P. berolinensis Dippel	N	P. laurifolia Ledeb x P. nigra L. cv. 'italica'	Berlin, Germany
6	P. euramericana (Dode) Guinier cv. 'gelrica'	N	P. deltoides Marsh. x P. nigra L.	G. Houtzagers Germany
8	P. volunteer	N	P. Petrowskyana Schr. x ?	(FNS) by W. L. Kerr
9	P. Sargentii Dode	S	American sp. native in Alberta and Saskatchewan	Central Plains
10	P. euramericana (Dode) Guinier cv. 'vernirubens'	A	P. deltoides ssp. angulata Ait. x P. nigra plantierensis L.	Kew, England by Henry (1914)
11	P. x cardeniensis (?)	?	There is no certain identification for the name and origin	Exp. Farm, Morden, Manitoba
12	P. Petrowskyana Schr.	N	P. x berolinensis Dippel, natural variation	Maine, U.S.
13	P. Brooks #1	N	P. deltoides Marsh. x P. Petrowskyana Schr.	E. Griffin, Brooks Alta.

Explanation of (Figures): (S) species, (A) artificial, (N) natural hybrid
(symbols) (FNS) Forest Nursery Station, Indian Head

TABLE 5

Introduced tree species other than poplars in the Skinner's Nursery at Dropmore

	Species	Native of	Source	Years of Intro-duction	Age	No. of Trees	Breeding Purpose	Remarks
1.	BASSWOOD Hybrids between *Tilia americana*, *L.* x *T. cordata* Mill.	E. and Cen. N. America N. Europe	Portage la Prairie, Man. Uppsala, Sweden	1920 1930	10	$\frac{1}{4}$ acre plantation	Frost hardy, fast growing and resistant trees for the farmers	The hybrids raised from the mixed plantation. *T. cordata* produced higher % of hybrids. The hybrids increased faster than the parents and immune to the leaf mites.
2.	BIRCH *Betula* Albo-*Sinensis* Burkill.	Hueph, Szechuan Kansu in W. China	Arnold Arb. U.S.	1926	10-38	Scattered at different places	Selection of the best strains for crossing the native species	Very decorative tree, suitable for parks and gardens.
3.	*B. davurica*, Pallas	Manchuria N. China Korea	A. E. Volicoff Manchuria	1930	25	Some trees	Crossing material for upland species	In Kew, England was cut back by frost.
4.	ELM *Ulmus pumila*, Lin., Dwarf Elm	N. Asia from E. Siberia to N. China	A. E. Volicoff Manchuria	1937	28	Some trees	Crossing with native elms	Resistant to elm disease (Bea Swartz like).
5.	MAPLE *Acer platanoides* Lin. Norway Maple	Continental Europe, from Norway southwards	Uppsala, Sweden	1958	6	Some trees	Further investigation	Immatured trees, just for progeny test.
6.	OAK *Quercus mongolica*, ?	Manchuria	?	1930	25	Some trees	-	There is a hybrid with *Q. macrocarpa*. Fast growing and frost hardy. Unknown in the literature.

TABLE 5 (continued)

	Species	Native of	Source	Years of introduction	Age	No. of Trees	Breeding Purpose	Remarks
7.	WALNUT Juglans mandshurica Maximowicz.	Manchuria in the region of Amur and Ussuri Rivers and N. China	A. E. Volicoff Manchuria	1934	30	Some trees	Further investigation	
8.	WILLOW Salix alba var. Chermasina ? x S. vitellina, Lin. x S. amygdalina, Lin. x S. nigra Marshall x S. pentandra, Lin.	Asia	Morton Arb. Chicago, U. S. A. (Roy Nordine)	1958	6	One shelter-belt, 100 yards, 2000 trees.	Selection for the best growth rate	The trees are uncontrolled hybrids of the species involved in column 2 and show high variability in growth rate, form, color. All the trees are hardy and resistant.
9.	DOUGLAS FIR Pseudotsuga Duglasii var. taxifolia, Britton.	North America	High Buttes of South Dakota U. S. A.	1937	25	20 trees scattered	Further breeding for hardy trees	There are some hardy trees between them which bore seeds in 1964. All were sown in the nursery in 1965. 25 ft. high trees, 1961 started to bear seeds.

TABLE 5 (continued)

Species	Native of	Source	Years of introduction	Age	No. of Trees	Breeding Purpose	Remarks
LARCH 10. Larix kurilensis, Mayr. Kurile Larch (L. dahurica var. japonica, Maxim.)	Kurile Isl. Japan (Iturup)	Yokohama Nursery Co. Japan	1952	12	Some trees	Cross pollination between other larches available in the nursery	Hardy and resistant to sawfly but very poor growth rate.
L. Europaea, De Candolle	S. and central Europe	John Rafn Copenhagen	1913				
L. sibirica, Ledebour	Siberia, East Russia	John Rafn Copenhagen	1910				
L. americana, Michaux	North America	In a swamp area, 20 mi. north of DM.	1913		Pure stand about ½ acre	Selection for plantation, further cross pollination and research on population genetics	The stand is invaluable for the further breeding of larch. Sawfly attacks are not present there. The trees are 50 ft. high, 10-12 inches b. d. h.
11. Natural hybrids between the above trees		Dropmore	1940	24			
PINE 12. Pinus sylvestris, L. Scots pine	Nearly all Europe extending across Siberia to the Amur River Region	Rafn and Shon seed collected from Sweden and Finland	1912	45	In mixed stand on one acre 15-20	Progeny test and introduction in various regions of Man. and Sask.	Healthy, well-developed trees almost rarity in this country. 2000 seedlings were sold to Mr. Reine, Foxwarren, Man.

TABLE 5 (continued)

Species	Native of	Source	Years of Intro-duction	Age	No of Trees	Breeding Purpose	Remarks
13. P. resinosa, Ait.	S. E. Canada, Sandilands the western limit	Black Island L. Winnipeg	1925	30	10 trees	Study on population genetics and the effect of self fertilization on the progenies	Valuable group of trees, mixed with scots pines. A natural cross ferti-lization could happen giving hybrids, which never occurred as yet.
14. P. murrayana, Balfour. (P. contorta var. Murr., Engelm.)	Sierra Nevada and West Coast Mountains	?	?	Est. 8-10	4 trees	Cross pollination with lodgepole and jack pines	This tree attains to a considerably larger size than L. p. p. and hardy in this region.
SPRUCE							
Picea pungens, Eng.	Colorado, U. S. A.						
Colorado sp.		?			Some mother trees in one group		In 1964, Skinner collected 60 different cones in length and scale type. Seeds were sown in the fall of 1964 and the progenies can be checked in the following years.
P. obovata, Ledebour	Siberia and North-east	J. Rafn,) Copenhagen)	1913				
Siberian sp.	Russia.	)					
P. abies, Mill. Norway sp.	Mts. of North and Central Europe	J. Rafn,) Copenhagen)	1913			Study on hybrid variations, selection and propagation of the best individuals	

TABLE 5 (continued)

Species	Native of	Source	Year of Introduction	Age	No. of Trees	Breeding Purpose	Remarks
15. Natural hybrids of the above trees Norway sp. is the mother tree		Nursery, DM	1938	25	200 yards shelter-belt		
16. P. likiangensis var. purpurea, Masters	W. Szechuan China	Arnold Arbor. U. S. A. Boston	1930	30	Some trees	Cross pollination with W. sp. for hardiness and late flushing	Quite hardy trees. Its growth rate poorer than the W and N. sp.

TABLE 6

Introduced poplars in the Skinner Nursery at Dropmore

	Species and Sex	Native	Source	Year of Intro-duction	Age	No. of Trees	Breeding Purposes	Remarks
1.	Populus tristis, Fisher (Balsam Poplar) ♀ ?	Inner North-western Himalaya	Kew, England	1935	5-30	Scattered trees in the arboretum	Propagation for ornamental plantation and use for cross pollination with aspen species	The old trees never had leaf rust and frost damage.
2.	P. songarica, ?, ♂ putative natural hybrid between balsamifera and ?	Manchuria	Kew, England cuttings	1958	16	Some trees in a group	Cross pollination other native poplars and aspen	Unknown in the literature. One of them is 40 ft. tall, 26 cm b.d.h. No leaf trust and disease
3.	P. monilifera, Aiton Black Poplar ♀	East N. America	Kew, England North Dakota	1930	25-30	Several trees scattered	Cross pollination	Known as P. canadensis, Michaux or P. deltoidea, Marshall - in the literature.
4.	P. laurifolia, Ledebour (P. bals. var. viminalis Loudon, male.)	Altai Mts. Russia	Kew, England	1930	25-30	Several trees scattered	Cross pollination	Hardy but poor growth.
5.	(P. monilifera x bals) ♀ x P. songarica ♂ Artificial Hybrid	-	Nursery DM	1960	4	100 yard shelter-belt inc. 172 trees	Cross pollination, variations study, propagation after progeny test, provenance exp. in diff. regions	Cross pollination was made under glass and colhichine used for indication of better growth. Growth rate 5 ft. per year. Hardy and resistant as yet although canker occurs naturally in the area.

TABLE 6 (continued)

	Species and Sex	Native	Source	Year of Intro-duction	Age	No. of Trees	Breeding Purposes	Remarks
6.	P. tristis ♀ ? x P. balsamifera ♂ Artificial Hybrid	-	Nursery DM	1940	24	Trees in shelter-belt	Sex definition, cross pollination with aspen	Many of its offsprings have been sold to different pulp mills for testing and propagation.
7.	(P. monilifera x P. balsamifera) ♀ x P. laurifolia ♂ Artificial Hybrid	-	Nursery DM	1950	13	Trees in shelter-belt	Further breeding and propagation	Fast growing but not rot resistant. Because of the low ratio of balsamifera genes, may be good for further crossing with not resistant clones, like P. songarica.
8.	(P. monilifera x balsamifera) ♀ x P. tristis ♂	-	Nursery DM	1950	14	Trees in shelter-belt	Progeny test and further breeding	One of the trees has extremely thick leaves. Never been bothered by any leaf rust or canker.
9.	P. simoni, Carriere (Balsam Poplar)	N. China	Kew, England (Kew's No. 209)	1947	17	Trees in shelter-belt	Further testing	It shows a high degree of resistance to disease. Early flushing species.
10.	P. octorabdos?	Central Asia	Kew, England	1947	17	Some trees	Further testing	Unknown in the literature. It has the same qualities as No. 9.
11.	P. Koreana, Rehder (Balsam Poplar)	Korea	Kew, England Bot. Gard. Stockholm	?	?	Some trees	Further testing	It shows rapid growth at Dropmore.

Legend: DM - Dropmore, Manitoba.
x - Cross pollination (hybridized)

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TESTING PRE-SELECTED PINE GRAFTS FOR RESISTANCE TO THE WHITE PINE WEEVIL, PISSODES STROBI PECK

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In an earlier report to this committee (Sullivan, 1964) I discussed the results of a field experiment on weevilling of 400 scions of Pinus strobus L., and P. peuce Griseb., selected specifically for resistance or susceptibility to weevil attack and grafted on Scots pine. The investigation was carried out in co-operation with Dr. C. Heimburger, Southern Research Station, Ontario Department of Lands and Forests, Maple, Ontario, who provided the material and carried out the grafting at the Kirkwood Management Unit, Thessalon, Ontario. Very briefly, the results were as follows. Scions selected for susceptibility to weevil attacks were, indeed, more susceptible than scions selected for resistance to attack. Greater differences in susceptibility occurred between clones of P. strobus than between clones of P. peuce and, in general, the latter species was much less susceptible to weevil attacks than the former. However, when the records were examined in terms of individual clones of both species, it became evident that differences occurred between clones within and between the classified groups. Whereas certain clones contained scions with leaders unsuitable for weevil selection, others contained scions with leaders suitable for attack. Within the former group, the lack of weevil attack may be attributed to the physical qualities of the leaders. Within the latter group, however, failure of the weevil to attack certain clones while others were heavily attacked, indicated that some factor or factors, unrelated to leader vigour, influenced the selection.

In a second experiment, 2,324 scions were grafted on white pine in the Kirkwood Management Unit during the period 1961-63. All scions were selected as being resistant to blister rust. They were provided by Dr. Heimburger who also performed the grafting operations. At the time of grafting, all scions were covered with a protective bag to prevent weevil damage during the establishment year. These bags were removed in June after the weevil had ceased ovi-position. Each year thereafter, the individual scions were examined to determine their growth performance and the incidence of weevilling. The following text summarizes the results obtained to date. It should be pointed out that these results are based only on a few year's data and that more reliable information must await the results of annual surveys extending over many more years.

Table I shows the source and performance of the scions of specific clones from the time they were field-grafted until Autumn, 1965. The average mortality for scions of all species and clones is approximately 29% with considerable variability between species and between clones. In general, clones of P. peuce exhibited significantly less mortality than those of P. strobus and the variability in mortality between clones of the former species was less than that in others. In addition, the P. peuce X P. strobus hybrids show considerably less mortality than all other hybrids and species top-grafted. About 5% of the observed mortality can be attributed to the death of trees containing scions and to severe weevil damage. The remaining 95% of the dead scions died from unknown causes. A small proportion of this may be

TABLE I

Clone number	Species	Source of material	Number scions grafted	Scion mortality Number	Scion mortality %	Scion-years of growth	Scion-years with lineal growth > 8 inches (%)
		Field grafted during May, 1962					
56	Pinus strobus	Pointe Platon, P. Q.	50	3	6.0	189	118 (62.4)
229	" peuce	Rochester, N. Y.	50	5	10.0	185	40 (21.6)
230	" "	" "	51	7	13.7	185	79 (42.7)
362	" koraiensis	Orono, Ont.	50	23	46.0	145	30 (20.7)
369	" "	Asheville, N. C.	49	39	79.6	82	12 (14.6)
500	" strobus	Pointe Platon origin	49	6	12.2	176	100 (56.8)
512	" "	" " "	52	8	15.4	185	100 (54.1)
519	" "	" " "	50	13	26.0	153	93 (60.8)
539	" "	" " "	50	13	26.0	155	82 (52.9)
541	" "	" " "	51	13	25.5	157	91 (58.0)
546	" "	" " "	48	12	25.0	154	60 (39.0)
616	" "	" " "	50	15	30.0	144	85 (59.0)
622	" "	" " "	50	11	22.0	163	99 (60.7)
624	" "	" " "	50	7	14.0	177	93 (52.5)
625	" "	" " "	49	18	36.7	129	75 (58.1)
644	" "	" " "	50	11	22.0	160	95 (59.0)
645	" "	" " "	50	16	32.0	153	82 (53.6)
646	" "	" " "	52	22	42.3	127	52 (40.9)
683	" "	" " "	51	13	25.5	157	98 (62.4)
740	" peuce	Ottawa, Ont.	50	10	20.0	181	59 (32.6)
741	" "	" "	48	11	22.9	163	43 (26.4)
		Field grafted during April, 1963					
28	Pinus peuce x strobus	Charlottenlund, Denmark	25	2	8.0	46	37 (80.4)
30	" strobus	Kroglund, Denmark	25	0	0.0	50	34 (68.0)
55	" "	Pointe Platon, P. Q.	25	5	20.0	38	32 (84.2)
94	" peuce	Jamaica Plain, Mass.	25	2	8.0	47	22 (46.8)
120	" strobus	Wisconsin Rapids, Wis.	24	17	70.8	11	9 (81.8)
196	" peuce	Rochester, N. Y.	24	2	8.3	45	22 (48.9)
198	" "	" "	25	0	0.0	49	18 (36.8)
262	" peuce x strobus	St. Williams, Ont.	25	2	8.0	46	38 (82.6)
263	" "	" " "	25	6	24.0	32	23 (71.9)

attributed to poor grafting success, but in only one case, that of clone 120 grafted in 1963, was extreme mortality observed before de-bagging. It is suggested that most of the mortality attributed to unknown causes may have occurred as a result of environmental stress (physical condition of the trees, inability to take up and utilize soil nutrients, adverse weather conditions, etc.) or lack of compatibility between the host trees and scion species.

Field observations of the linear growth of the living scions of each clone were made annually, to provide an assessment of their growth performance. The linear growth of the scions was compared with the growth of ungrafted native white pine, located near the experimental site, and was considered satisfactory if it exceeded about 8 inches. The results in Table I show that the clones varied greatly in their ability to add satisfactory linear growth - a further reflection of their response to environmental stress.

TABLE II

Comparison between the number of living scions, the number of scions suitable for attack, and the number of suitable scions with leaders selected by *Pissodes strobi* for attack. Records accumulated during the period 1961-65.

Clone number	Number of living scions inspected	Number and percentage of living scions suitable for attack		Number and percentage suitable scions selected by weevil for attack	
		Number	%	Number	%
		Field grafted during April, 1961.			
56	140	92	65.7	2	2.2
60	161	95	59.0	8	8.4
62	177	123	69.5	6	4.9
92	181	156	86.2	27	17.3
153	180	115	63.9	6	5.2
154	147	104	70.7	12	11.5
157	152	79	52.0	5	6.3
307	131	87	66.4	13	14.9
308	133	89	66.9	16	18.0
315	154	101	65.6	13	12.9
319	84	52	61.9	9	17.3
326	147	108	73.5	25	23.1
346	61	50	82.0	0	0.0
349	98	76	77.6	7	9.2
350	124	104	83.9	13	12.5
689	184	150	81.5	22	14.7
691	191	151	79.1	17	11.3
693	184	150	81.5	25	16.7
700	187	179	95.7	57	31.8
709	195	174	89.2	61	35.1
739	72	50	69.4	6	12.0
		Field grafted during May, 1962			
56	142	104	73.2	3	2.9
229	140	107	76.4	25	23.4
230	141	126	89.4	31	24.6
362	118	80	67.8	22	27.5

TABLE II (continued)

Clone number	Number of living scions inspected	Number and percentage of living scions suitable for attack		Number and percentage suitable scions selected by weevil for attack	
		Number	%	Number	%
369	72	45	62.5	16	35.6
500	133	81	60.9	19	23.5
512	141	96	68.1	10	10.4
519	116	76	65.5	9	11.8
539	118	83	70.3	10	12.0
541	119	84	70.6	10	11.9
546	118	52	44.1	13	25.0
616	109	69	63.3	12	17.4
622	124	97	78.2	25	25.8
624	134	78	58.2	14	17.9
625	98	69	70.4	12	17.4
644	121	85	70.2	18	21.2
645	118	70	59.3	9	12.9
646	97	56	57.7	15	26.8
683	119	95	79.8	14	14.7
740	141	121	85.8	21	17.4
741	126	104	82.5	30	28.8
		Field grafted during April, 1963			
28	48	21	43.8	4	19.0
30	50	16	32.0	1	6.3
55	42	8	19.0	2	25.0
94	48	20	41.7	3	15.0
120	14	4	28.6	0	0.0
196	47	19	40.4	0	0.0
198	50	19	38.0	3	15.8
262	48	14	29.2	4	28.6
263	36	10	27.8	1	10.0

The method for determining the suitability of leaders for attack was described in an earlier publication dealing with weevil feeding and oviposition behaviour (Sullivan, 1961). Weevil attack is confined chiefly to the leading shoot and to the previous years' growth on this shoot. Feeding and oviposition is initiated at the top of the leader and extends downward as the season progresses. In its initial attack, the insect exhibits a definite preference for leaders with upper diameters (measured 1 inch from the top) exceeding 5 millimeters. Selection is not related to the length of the leader, nor to the incidence of needle clusters per unit area of the leaders, but it appears to be influenced by bark thickness. Leader mortality occurs when the feeding larvae ring the stem. Larval survival and adult emergence is dependent upon resin flow within the attacked stem as well as on competition for space and food. These observations have shown that in terms of the external physical attributes of a leader, its suitability for attack by the insect is related primarily to its upper diameter. Therefore, this is the main factor used throughout this study to classify leader vigour and susceptibility. In addition, since some leaders exhibit a strong tendency to throw off weevil attack, the records have been analyzed to separate the number attacked but not killed from the number killed by the insect.

Table II shows a comparison between the number of living scions of each clone inspected since the top-grafting operation, the number considered suitable for attack by the weevil, and the number actually attacked by the insect. A high percentage of the living scions of most of the clones established in 1961 and 1962 contain leaders suitable for attack, but large differences in the percentage of suitable leaders actually selected by the insect are clearly evident. For example, of the material grafted in 1961 and exposed to the insect over a 4-year period, at least three categories of selections are apparent, 0-9%, 11-18%, and 23-35%. These broad groupings indicate the beginning of a gradation among the clones ranging from low to high susceptibility to weevil attack. The significance of this cannot be adequately assessed until more data similar to that in Table II is available and the investigation is extended to embrace variations within clones. It is significant, however, that at this stage in the investigation the insect's preference for specific clones is evident. Although results indicate that scions of specific clones tend to be rejected by the insect, additional data are required to determine if this tendency will be maintained over a longer period of exposure.

TABLE III

Incidence of weevil attack on clones obtained from various sources. Clones grouped by species and ranked according to the percentage killed by the insect. (Percentage values in brackets)

Species and Source		Clone number	Number of scions suitable for attack	Number attacked but not killed	Number killed
Pinus strobus					
Wisconsin Rapids,	Wis.	120	4	0 (—)	0 (—)
Pinus strobus					
Kroglund,	Denmark	30	16	0 (—)	1 (6.3)
Pinus strobus					
Midhurst,	Ont.	153	115	2 (1.7)	4 (3.5)
		157	79	0 (—)	5 (6.3)
		154	104	2 (1.9)	10 (9.6)
Pinus strobus					
Pointe Platon,	P.Q.	56	196	0 (—)	5 (2.6)
		62	123	0 (—)	6 (4.9)
		60	95	2 (2.1)	6 (6.3)
		55	8	0 (—)	2 (25.0)
Pinus strobus					
Origin - Pointe Platon,	P.Q.	539	83	4 (4.8)	6 (7.2)
Outplanting - Connaught		512	96	3 (3.1)	7 (7.3)
Ranges		624	78	8 (10.3)	6 (7.7)
		541	84	3 (3.6)	7 (8.3)
		519	76	2 (2.6)	7 (9.2)
		645	70	1 (1.4)	8 (11.4)
		616	69	4 (5.8)	8 (11.6)
		683	95	2 (2.1)	12 (12.6)
		625	69	2 (2.9)	10 (14.5)
		644	85	4 (4.7)	14 (16.5)
		546	52	4 (7.7)	9 (17.3)
		500	81	2 (2.5)	17 (21.0)
		622	97	4 (4.1)	21 (21.6)
		646	56	0 (—)	15 (26.8)

TABLE III (continued)

Species and Source		Clone number	Number of scions suitable for attack	Number attacked but not killed	Number killed
Pinus peuce					
Jamaica Plain,	Mass.	92	156	17 (10.9)	10 (6.4)
		94	20	1 (5.0)	2 (10.0)
Pinus peuce					
Rochester,	N.Y.	196	19	0 (—)	0 (—)
		230	126	14 (11.1)	17 (13.5)
		198	19	0 (—)	3 (15.8)
		229	107	6 (5.6)	19 (17.8)
Pinus peuce					
Ottawa,	Ont.	740	121	6 (5.0)	15 (12.4)
		741	104	4 (3.8)	26 (25.0)
Pinus peuce					
Havelock,	Ont.	700	179	11 (6.1)	46 (25.7)
		709	174	7 (4.0)	54 (31.0)
Pinus monticola					
Garibaldi,	B.C.	346	50	0 (—)	0 (—)
		349	76	1 (2.2)	6 (7.9)
		350	104	0 (—)	13 (12.5)
Pinus griffithii					
Jamaica Plain,	Mass.	315	101	2 (1.9)	11 (10.9)
Pinus griffithii					
Elmhurst,	Ill.	326	108	0 (—)	25 (23.1)
Pinus koraiensis					
Orono,	Ont.	362	80	1 (1.3)	21 (26.3)
Pinus koraiensis					
Asheville,	N.C.	369	45	0 (—)	16 (35.6)
Pinus peuce x strobus					
Petawawa,	Ont.	691	151	2 (1.3)	15 (9.9)
		689	150	4 (2.7)	18 (12.0)
		693	150	1 (0.7)	24 (16.0)
Pinus peuce x strobus					
Charlottelund,	Denmark	28	21	1 (4.8)	3 (14.3)
Pinus peuce x strobus					
St. Williams,	Ont.	263	10	0 (—)	1 (10.0)
		262	14	1 (7.1)	3 (21.4)
Pinus griffithii x strobus					
Toronto,	Ont.	739	50	1 (2.0)	5 (10.0)
Pinus strobus x parviflora					
Wellesley,	Mass.	307	87	2 (2.3)	11 (12.6)
		319	52	2 (3.8)	7 (13.5)
		308	89	0 (—)	16 (18.0)

WORK ON FOREST GENETICS AND TREE IMPROVEMENT AT THE FACULTY OF FORESTRY, UNIVERSITY OF BRITISH COLUMBIA

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The program on forest genetics and tree improvement is three pronged:

1. Academic program: instruction in forest genetics at the undergraduate level, within the third-year forestry curriculum; graduate work is offered at the Masters and Ph. D. levels.

2. Research projects in the field of forest genetics, mainly concentrating on geographical, morphological and physiological variations of provenances and progenies of the important timber species.

3. Close co-operation with industries on the field of tree improvement, mainly concerning plus tree selection, and the establishment of clone banks, seed orchards and seed-production areas.

Academic Program

The undergraduate course is given during the second term with two hours lecture and two hours laboratory. Twenty-six and twenty-three students took this course during the 1964-65 and the 1965-66 school year respectively.

In the graduate program we have presently two Ph. D. candidates. One of them is working on geographic variation of cone and seedling characteristics of Picea, while the other is studying cone, seed and seedling variation in Pseudotsuga.

Research Project of the Field of Forest Genetics

a) Provenances studies. Investigation of the effects of various environmental conditions simulated in growth chambers to provenances of different species was extended during the past two years. Fourth-year forestry students working on their B. S. F. thesis showed great interest in such studies. Besides Pseudotsuga menziesii (Mirb.) Franco, Picea sitchensis (Bong) Carr, Pinus contorta Dougl., Thuja plicata Donn and Swietenia macrophylla King were included in the program.

Besides these growth chamber studies, Hennig's (1966) work recommending Douglas-fir provenances for French conditions based on climatic comparisons is presently under trial.

Seed germination was investigated by three students. Jukes (1965) employed different methods to break dormancy in western white pine (Pinus monticola Dougl.); Vink (1965) embarked on the relation of seed-borne micro-flora and their beneficial effect on the germination of Douglas-fir seed; and Flowers (1966) studied different storage methods of Caribbean pine (Pinus caribeae Morelet.) seed.

b) Studies on half-sib progenies. Although seed production during the last two years was negligible, collection of Douglas-fir cones still proceeded slowly. Presently 42 provenances represented by 439 trees are in our collection. Study of cone-, seed-, and seedling-characteristics on selected provenances and trees is in Mr. Gy. Kiss's Ph.D. research program. Seedlings are presently in their first year of growth in the nursery. A cytological study of development of micro- and mega-sporangiate stroboli of Douglas-fir was completed on four trees, one from U.B.C. Campus and three from Haney Research Forest. Generally the foliar initiation of reproductive buds was detected at the end of July. A difference of one week occurred among trees from the same location, demonstrating the extensive variation in Douglas-fir (Kiss and Sziklai, 1965). Clark (1965) found cone and seed variation of Sitka spruce on 37 trees from 6 provenances just as great within provenances as among provenances. Addison (1966), working on nutrient requirements on Sitka spruce previously collected by Clark, further substantiated Clark's findings on high variability of this species. Bunnell's (1965) study on variation in pollen morphology of selected conifers in B.C. provided dimensional and morphological values for five species.

c) Studies on full-sib progenies. Seedlings from a polyallel cross of four Douglas-fir trees were planted for progeny testing at U.B.C. Research Forest during spring 1964. As a result of the limited cone production during the last two years, it was possible to repeat only a few crosses. Seed is stored until a sufficient quantity is available for further experimentation.

Tree Improvement

Close co-operation with forest companies on their tree improvement program is beneficial to both parties. Information collected by company field foresters on seed production areas and clone banks is used by fourth-year forestry students in their B.S.F. theses. During the last two years three students worked in the field of tree improvement; Benn (1965) studied the effect of crown pruning on 35 Douglas-fir trees, McIntyre evaluated the effect of artificial wet pollination in Mt. Benson seed production area, and Spencer (1966) investigated the results of grafting Douglas-fir in the clone banks.

Other projects indirectly related to forest genetics and tree improvement are also under investigation by the different faculty members.

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ENVIRONMENTAL CONTROL IN RELATION TO FOREST GENETICS RESEARCH AT THE PETAWAWA FOREST EXPERIMENT STATION

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This report describes the new controlled environment laboratory and experimental nursery being developed for forest genetic research at the Petawawa Forest Experiment Station. Also a summary is given of the results of an investigation of the growth of seedlings of jack pine (Pinus banksiana Lamb.) provenances in relation to photoperiod and temperature. Variation in the development of cold hardiness was demonstrated in some of the same jack pine provenances. .

Environmental control in forest genetics - A discussion

Most of the work in forest genetics at the Petawawa Forest Experiment Station has involved experiments with tree material established in nurseries or field plantations at this station and elsewhere in Canada east of the Rocky Mountains. The information gained is essential in determining broad patterns of genetic variation within species and the adaptibility of populations, progenies, hybrids, and clones to particular environments and forms the basis for a sound program of selection and breeding for improved productivity. Problems of both a practical and a theoretical nature are dealt with in field tests, but many questions remain unanswered owing to intrinsic limitations of space, time, money, and confounding biological and physical variables.

Experimental efficiency can be increased and the yield of information extended by the use of more intensive experimental methods designed to provide early estimates of genetic parameters and of geno-type x environment interactions. By controlling the cultural environment, environmental components of variation that are not of direct interest can be optimised or held at uniform levels, while others of direct interest can be tested singly or in combination. Environmental control can be complete, as in enclosed growth cabinets or growth rooms, or the natural environment may be more or less modified, as in a greenhouse or nursery. Through choice of sites, field plantations can be established in a range of selected environments, but major environmental modifications at a given location are not practicable. Each level of control, from artificial environment to field plantation, is capable of answering different questions concerning a common problem. An important advantage of complete environmental control is that given conditions can be repeated for testing new material.

Progress in breeding of conifers (and most hardwoods) is limited by the time between generations which varies from a minimum of 6 years, e.g., jack pine, to 15-20 years, e.g., red pine and white spruce. The initial delay is caused by a relatively slow rate of growth and by the short growing season of the Canadian environment. A tree must achieve a minimum size in order to provide sufficient sites for floral initiation and subsequently it must have sufficient foliage to manufacture photosynthate for normal cone and seed development. A further lapse of time occurs in many species because of slow sexual maturation. The first problem may be alleviated by speeding up the rate of growth through artificially extending the growing season and/or promoting more than one growth cycle in each 12-month period. The question of sexual maturity is also related to species and environment but if flower promotion is to be of practical value, the yield of seed must be sufficient for genetic evaluation. Thus reliable methods of growth control and plant forcing are urgently required in forest genetics.

New facilities being provided at the Petawawa Forest Experiment Station will permit intensive studies of populations and orogenies under controlled or semi-controlled environments for the evaluation of the effects on seedling growth and development of genotype and factors of the environment and of their interactions.

In addition, these facilities will be used to determine the degree to which manipulation of the environment can be used to maximize the growth of seedlings of the tree species employed in the breeding program, and thereby minimize the period between generations.

New Facilities for Control and Modification of the Environment

The facilities under development at Petawawa include a controlled-environment laboratory and two analytical laboratories in a new building adjacent to the existing greenhouse, and an experimental nursery about 1 mile from headquarters near Thomas Lake. The controlled-environment laboratory will be equipped with six growth cabinets including: 1) three 36-sq.-ft. growth cabinets with control over photoperiod, light intensity (three levels), temperature (-15 to 35°C), humidity (above 5°C and above the limits of ambient moisture content), wind speed, and, of course, rooting medium; and 2) three 18-sq.-ft. growth cabinets with photoperiodic control, broad flexibility in light quality (spectral distribution of radiant energy) as well as light intensity, temperature control (-5 to 35° C), humidity control above and below the ambient condition, control of carbon dioxide content between the ranges of 0.03 to 1%, variable wind speed, and choice of rooting medium.

The analytical laboratories will have standard research facilities and will include ample desk space for technicians and student assistants. One laboratory will be specially adapted for seed and germination studies, under the direction of Mr. B. S. P. Wang, and will be equipped with seed germination cabinets and an X-ray machine for evaluating seed quality. The other laboratory will be used for seedling analyses (e. g., measurements of seedling size, bio-mass, phenology; micro-morphology; biochemical and nutritional analyses; wood property evaluation; anatomical studies; etc.), and for investigations and operations related to controlled breeding (e. g., pollen extraction and viability tests; cytological aspects of sexual incompatability).

Thomas Nursery is a 5-acre area on till soil rising to the west of Thomas Lake. Water for sprinkler irrigation is supplied from the lake, and a grid of 18 60amp/110V electrical power panels services two thirds of the nursery. An area has been set aside for mixing bulk lots of soil for special seed- or transplant-beds. The work building is designed as a field laboratory and for storage of equipment, and is the centre of distribution of electrical power. The building is heated and has an independent water supply for year-round use.

The natural daylength can be extended by illuminating seedlings in the nursery beds with lights controlled by time clocks. The quality and intensity of supplementary light can be altered by the appropriate choice and arrangement of light source. Soil temperatures can be modified by heating cables, and the growing season extended by covering seed beds with plastic greenhouses. Electrically operated recording instruments can be set up in the field. Seedlings may be grown in the existing soil, or particular rooting media can be uniformly mixed and set out in beds.

These facilities will provide opportunities for a wide range of genetic and genecological studies, both short- and long-term, and either narrow or broad in scope. While their operation and use will remain primarily the responsibility of the members of the tree breeding section, other research scientists from the station and visiting graduate students and scientists will find unique opportunities to conduct special studies of the growth of tree species in relation to genotype and environment.

Geographic variation in jack pine (Pinus banksiana Lamb.)

A progress report of this study was presented at the last meeting of this Committee (Yeatman, 1964). The following is the summary of a Ph. D. dissertation[1] presented to the Graduate School of Yale University in June 1966 (Yeatman, 1966). Sections of the dissertation will be submitted for publication in due course.

"Seedlings representative of jack pine (Pinus banksiana Lamb.) provenances from the entire range of the species were grown in growth cabinets, a greenhouse, and in three nurseries for the evaluation of genotype x environment interactions on seedling growth. Investigations were also made of relative cold hardiness of jack pine seedlings during the autumn and early winter, and of growth initiation and frost hardiness in the spring.

Following germination in the greenhouse, 76% of the variation in seedling size was accounted for, with about equal weight, by seed weight and number of growing degree-days at the place of seed origin.

Seedlings were grown in growth cabinets for 3-month periods under three photoperiods and at three temperature regimes. Two very highly significant, and independent, compound variates were derived by a canonical analysis of dry-weights of tops and roots over all controlled environments. The first variate was highly correlated with growing degree-days at the place of seed origin, the second was significantly related to seed weight. The mean response over all environments provided the main basis for discrimination among provenances. Over the ranges employed, photoperiod affected growth more than did temperature, and the interaction of provenance with photoperiod was the second important source of discrimination among provenances. The patterns of seedling response in the greenhouse and nurseries were closely parallel to those in comparable controlled environments. The median controlled environment provided the best conditions for genetic differentiation among populations. The analyses demonstrated an overall clinal pattern of genetic variation due to environmental adaptation.

Northern populations were hardier than southern, and degree of hardiness was positively associated with foliar sugar-content, needle coloration, and phenology of bud formation in late summer and autumn. Temperature was more important in controlling spring growth initiation than photoperiod.

These experiments demonstrated the potential value of intensive seedling studies for genetic differentiation among populations of a tree species. Interpretations of the adaptive nature of population differentiation were clarified by the use of a series of controlled

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[1] The work was supported by National Science Foundation grants G-8891 and G-19973 awarded to Prof. François Mergen, Yale University.

environments. These results will be compared with the performance over a number of years of the same populations grown in nursery and field experiments. From these comparisons, estimates will be made of the predictive value of similar seedling tests of jack pine."

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WESTERN FOREST GENETICS ASSOCIATION

REPORTS

A POSSIBLE APPLICATION OF INBREEDING IN FOREST TREE IMPROVEMENT

(Abstract)

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When breeding value is poorly defined on the basis of a single phenotype, information from relatives can be used as a more accurate means of identification. When selecting on the basis of family means, the amount of gain expected usually increases as the within-family genetic correlation increases. Selfing is one method of developing a high within-family genetic relationship. However, selection between selfed families may be biased because of inbreeding depression. An intuitive approach to reducing this bias was tested experimentally. Mimulus guttatus, Fisch. was used as a convenient test organism.

Selection for "tall" height to first flowering node was carried out in a base population. The selected parents were selfed and also intercrossed. In the S-1 generation, the poorest 50% of each selfed family was culled. Intuitively, these "short" individuals would be those most adversely affected by inbreeding. A final selection of the best selfed families, based on the "improved" family means, was then made. The selected families were then outcrossed. In the F-1 generation, simple mass selection was practised. The mean of the outcrossed selfed-family offspring was compared with the mean of offspring from the mass selection experiment. Six replications of these two procedures were pooled and compared.

The actual gains obtained were compared with gains predicted from idealized genetic models. Despite the considerable amounts of mortality and sterility that were encountered, the actual and predicted gains corresponded surprisingly closely.

It is concluded that where inbreeding depression is not excessive, and where heritability is low, selection using selfed families is a method that is worthy of serious consideration.

THE SECOND STAGE OF A DOUGLAS-FIR CLONAL SEED ORCHARD DEVELOPMENT AT ROW RIVER

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A clonal seed orchard development is generally a continuous project with no sharp division lines between stages; therefore, my topic is perhaps misleading when I talk about first and second stages. Joe Wheat[1] made a suggestion in one of his newsletters that the first stage of a clonal seed orchard development is completed with the completion of grafting. This is called the establishment stage.

The second stage is centered around seed production and is called the production stage.

Before I go into discussing this stage, let me give you a brief review on the history of the Row River seed orchard.

This Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) clonal seed orchard was started eight years ago on a seven-acre tract by the Booth-Kelly Lumber Company, and at present it is owned and managed by the Georgia-Pacific Corporation.

The seed orchard was planned to provide seed with improved qualities to reforest the cutover land on the company's Springfield Division.

Originally 15 plus trees were selected mainly on company land to supply the scionwood for grafting.

The ramets of the 15 clones have been distributed at random with a spacing of 12 feet between rows and ramets. Consideration was given for two later thinnings whenever it will become necessary to make the final spacing 24 feet by 24 feet.

The first six years' activity was mainly concentrated around grafting. By 1964 all the rootstocks were grafted at least once, but some even two or three times. After a complete graftability study, it was found that some of the clones are very poor grafters and that they are not worth regrafting.

In order to replace the grafts lost and to raise the number of clones in the orchard, seven new plus trees were located in 1964. The scionwood from these trees was grafted onto 2-1 rootstock as bench grafts in 1965 and planted out in the I. F. A. Canby nursery for two years. They should provide enough grafted material to fill all the blank spots in the seed orchard next spring; so there is a good chance to achieve an all-grafted stage again at least for a while.

With this the establishment stage will be complete, although the second stage of development started already in 1963 when the first control pollination was made and a handful of seed harvested. The seedlings raised from this first crop show a promising result, but it is far from being enough material to evaluate all the clones' genetic worth in the orchard.

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[1]Director of I. F. A. Tree Improvement Laboratory at Nisqually, Washington.

Since 1963 the flower production is getting heavier every year, but the ultimate goal is far away yet, namely, the production of seed with improved qualities for reforestation purposes. At present we are mainly engaged in producing enough seed as soon as possible to be able to complete all the crosses needed for progeny testing. In the meantime, the search goes on to find ways to produce a large amount of seed as frequently as possible for reforestation purposes.

There are several approaches which show some promise in inducing flower production. Among these are cultivation, pruning, irrigation, and commercial fertilization. The last one is perhaps the most promising, but a great deal of experimental work is still required to find the right mixture of fertilizer, application time, and application rate for the best result. In order to come closer to solving this problem, the first trial was made in September, 1964 with a fertilizer mix of ammonia nitrate and 16-16-16. Using one-half pound of fertilizer per tree on the average as a ground application, the result showed some promise. Percentagewise, more than twice as many trees had flowers out of the fertilized trees as did those out of the controls.

Based on this result, another trial was set up for the spring of 1965. The fertilizer used was again ammonia nitrate and 16-16-16. This time three applications were given. Each time a tree received one-half pound of fertilizer, on the average, as a ground application.

The first application was given two weeks before general budburst, the second at general budbursting time, and the third application followed two weeks later.

The year 1966 is producing a bumper cone crop in this area. This is also noticeable in the seed orchard; however, while comparing the fertilized trees to the controls, the result shows that percentagewise more than four times as many fertilized trees produced cones than those left for controls.

It was found last year and also this year that there is a large variation (six weeks) in vegetative budbursting time among clones. Therefore, it is impossible to handle the orchard as one group when fertilizing.

It is believed that timing the fertilizer application is one of the most important factors in inducing flowering. In the 1966 trial this was incorporated by dividing the clones into smaller groups. The experiment was also designed to find out from the three application dates which brings the best result. For the result we have to wait until next year or the following years.

A flower-bud study was also conducted this spring which is a vital part for a successful control pollination program. The variation among clones was only 10 days, but the majority of the clones were only one or two days apart.

According to this observation and pollen-flight studies from last year and this year, the peak of pollen flights from outside sources closely coincided with the receptivity of female flowers within the orchard. There is not much we can do about this because the orchard is located in a narrow valley 900 feet above sea level, and there is an elevation change of more than 2,000 feet within a mile. The clones are also originated from an elevation range of 1,000 feet to 2,300 feet. The only possible way to avoid contamination from outside pollen source would be to use some artificial means to induce flowering in the off years. The large amount of pollen from outside sources might be undesirable as far as contamination is concerned, but it could be very helpful in seed production with somewhat lower genetic gains.

Control Pollination and Progeny Testing

While developing a seed orchard, it is important to evaluate the genetic worth of the breeding stock used in the orchard. This is done by comparing the progeny of the control pollinated crosses to open pollinated stock from the orchard and to regular planting stock from a nursery used for routine annual reforestation.

The increasing flower production at Row River made it possible to embark on an over-all control pollination and progeny testing program.

Control Pollination at Row River

A crossing plan was worked out for all 22 clones, although the seven new clones will not have enough flower for control pollination for some time. Most of the parent trees were located in groups of two or three in one stand near each other and some of them show signs that they might be half sibs; therefore, these were grouped and used as one pollen group. This resulted in 12 pollen groups. By crossing these 12 pollen parents individually with all the clones except with themselves, 242 combinations can be produced. This is still a high number of combinations, but quite possible to follow through. It will give a good test on general combining ability and also some result on specific combining ability.

In order to carry out this work the control pollination program was started in 1965. Twenty-three combinations were made, but only seven produced a sufficient number of seed to complete the test. The seed is kept in cold storage until there is enough seed from the other combinations to make an outplanting for a meaningful progeny test.

The flowering was considerably better this spring. This made it possible to make another 50 combinations. The cones look really good so far, and we might get enough seed to be able to start progeny testing next spring. The work will start with raising the seedlings at the nursery. The earliest possible date for outplanting could be in 1969. For this purpose a 30-acre tract was located this spring and set aside.

The following considerations were given when making the land choice:

1. The area represents a natural wild condition and is located on company land similar to areas where most of the seed from the seed orchard will be used.

2. The area has a fairly uniform topography with a good deep forest soil.

3. It compares favourably with the elevation of the parent trees.

4. It is near an all-year-around road for good access.

5. The land is partially cleared already, and plans are made to build a fence around the area to protect the trees from wild-life damage. This land is probably far from being ideal for such a purpose, but we feel this is the best we can find, and it is quite suitable for progeny testing.

Progeny testing is a long-range program. The final results will not be available for at least 40 to 60 years. In the meantime, a seed orchard will be producing seed and the seed will be used to reforest cutover lands.

During the years of cultivation to control the weeds and preserve moisture, pruning to aid graft development is a routine practice. Along with these measures, fertilization to induce flower production has the effect of increasing the height growth which is undesirable in an orchard because lower tree heights make cone collection easier and cheaper. Don Copes[2] initiated a shearing study last year to find some ways in slowing down the growth rate on these fast-growing trees and improving their branching habits. This program is designed to cover several years. The results after one year

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showed very good success. With this encouragement and also as a precautionary measure, to avoid a future disaster from a storm, we decided to shear the entire orchard.

The experiment showed that the trees sheared in the middle of July in the succulent stage developed a better top and stronger side branches than those sheared in the middle of September.

The shearing was generally done on this year's leader. In some cases we went back into last year's growth. A strong bud was located on the terminal leader approximately a foot from the last whorl; then the cut was made about one-fourth inch above the selected bud. The top whorl was trimmed back to eliminate competition for the new leader. The last year's result showed a strong side branch development. This was particularly noticeable on the internode branches. Shearing so far has shown neither positive nor negative effects on flowering. This, of course, has to be investigated further.

By reviewing the past eight years' work at Row River, it becomes more obvious that our efforts to establish a clonal seed orchard were not fruitless. There are still many problems waiting to be solved, but with a united effort such as this meeting and many other opportunities of exchanging ideas, we will certainly find a way to overcome some of these difficulties.

GEOGRAPHIC VARIATION IN WHITE FIR

(Abstract)

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Seedlings representing 45 geographic locations within the western half of the range of white fir (Abies concolor (Gord. and Glend.) Lindl.) were grown for two years at the Institute of Forest Genetics, Placerville, California. Results of measurements made upon 15 morphological and growth characteristics indicated that white fir is a highly variable species. It was concluded from results and also from field observations, that white fir has three morphological forms within this half of its range. The three forms are designated as (1) Cascades - North Coastal California; (2) Sierra Nevada; (3) Southern California. The results also indicate that the Cascades - North Coastal form has probably resulted from hybridization and introgression of white fir with grand fir.

CALIFORNIA REGION SUPERIOR TREE SELECTION PROGRAM

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A long-range goal of the California Region tree improvement program is to produce quantities of superior seed at favourable prices. The program will provide species improvement through selecting outstanding individuals, testing their ability to transmit their desirable characteristics and establishing seed orchards from the selected trees.

Superior Tree

A superior tree is defined by the U.S. Forest Service, California Region, as:

> A phenotypically outstanding tree that has no undesirable characteristics and produces more cubic volume per year when compared to its immediate even-aged neighbors.

A distinction is made between "superior" and "plus trees" in California. A plus tree connotes a high selection intensity where many man days are spent to find one tree in several thousand. In selecting superior trees, there is little attempt to find those rare individuals, but if one is located, it is recorded and used.

A tree to qualify as superior may be from 20 to 120 years old, but most selections should be in the 60- to 90-year age class. Typical wolf trees, even though they are great volume producers, are not selected. A good rule-of-thumb to follow is: Select trees that will make good sawlogs. (Saw timber for the next rotation will average about 30 inches and these trees will not have the high quality lumber found in old-growth trees.)

Superior trees are found on all sites and are not graded one against another. A superior tree on Site 1 will obviously appear "more superior" than an equal-age tree growing on poor site.

Summary of Selection Work

Superior tree selection began in California in 1964. To date there are over 120 Douglas-firs and 90 ponderosa pines selected. The bulk of the selections were made by two-man teams that averaged about two selections a day. A two-man student team was used this summer on a trial basis in the Douglas-fir selection program. The quality and quantity of their work was such that college students will undoubtedly be used in the future.

A COMPARATIVE KARYOTYPIC STUDY OF PSEUDOTSUGA SPECIES

(Abstract)

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Of the six recognized species in the genus Pseudotsuga, only two of them, Douglas-fir (P. menziesii) and bigcone Douglas-fir (P. macrocarpa) have been used for karyotype analysis. Comparative karyotypic study of Formosan Douglas-fir (P. wilsoniana) and Douglas-fir is now being conducted in the Forest Research Laboratory. In the study, we have found that the basic chromosome number of the Formosan Douglas-fir is 12, different from Douglas-fir, which has a number of 13 (The basic number for bigcone Douglas-fir is 12, as reported by Christiansen in 1962.) Moreover, the study confirms work of Barner and Christiansen in 1962 on the chromosome morphology of Douglas-fir. Of the 13 chromosomes, five have been found to have median centromeres; six, subterminal centromeres; and two, telocentric centromeres. On the other hand, Formosan Douglas-fir has six chromosomes with median centromeres and six with subterminal centromeres. The possible modes of origin and the implications of the differences in chromosome number are being investigated.

PONDEROSA PINE SEED ORCHARD IN IDAHO

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ABSTRACT: Three seed orchard plantations were established in 1966 for the genetic improvement of ponderosa pine in southern Idaho. The general plan is essentially a form of half-sib family selection. A new approach was adopted in parental selection and seed production for the early production of genetically improved seed in commercial quantities. Parent trees to be included in the seed orchard plantations were selected on the basis of general phenotypic characters of the natural even-aged stands. Improved seeds will be produced from two sources. The stands of best parent trees, as recognized by the performance of their progenies in the plantations, will be managed as seed production areas for immediate seed production in commercial quantities. At the end of the testing period, when satisfactory between-progeny differences are obtained, the plantations will be managed as seed orchards to produce seed from the best individuals of the best progenies.

The ponderosa pine seed orchard project in Idaho is conducted as a cooperative effort between the University of Idaho, U.S. Forest Service, Bureau of Land Management, and private industry (Wang, 1963). Three seed orchard plantations were established in 1966. A fourth will be planted in the spring of 1967. Each of the plantations is approximately 14 acres in size. Each plantation contains 11,360 seedlings representing 284 one-parent progenies in four-tree plots arranged according to a ten-replicate randomized complete block design. Plantation sites are located at different elevations between approximately 3,000 feet and 5,000 feet in Boise and Payette valleys. This is the altitudinal range of the general area where the improved seed produced from the seed orchards will be used. The best seed sources and best parent trees for the different site conditions will be isolated through the performance of their progenies.

Early Production of Improved Seed

A major objective shared by all cooperators in this project is the early production of genetically improved seed in commercial quantities. Although this is one of the common aims of nearly all tree improvement endeavours of sexually reproduced species, seed production is a serious problem of ponderosa pine in southern Idaho for several reasons. (1) Ponderosa pine seed production is sporadic. Good cone crops are few, far between and not predictable. Only one good seed crop occurred in Montana over an observed period of over 23 years (Boe 1954). (2) Seed production age is late. It has been observed that ponderosa pine bears cones at as early as 16 years and continues to produce viable seed when 350 years old (Curtis and Lynch, 1957). Cone crops, however, are usually light in the early years. The newly established seed orchard cannot be expected to produce seed in commercial quantity until 30 to 40 years after planting. Early quantity production of improved seed is obtained from the mother trees of the best progenies. Their superiority is proven by their progenies. They are in the prime of seed production age. This is the approach adopted in this project.

Parent Tree Stands

The parent materials to be included in the seed orchard plantations are selected from the ponderosa pine region of southern Idaho. This region comprises approximately six counties of mountainous country. Pure stands of ponderosa pine are found in this region generally between 3,000 and 7,000 feet, above the sagebrush of the lower slopes and the spruce-fir type of higher elevations.

Characteristically, ponderosa pine appears in patches of even-aged stands. The broad and usually highly dissected expanse of natural ponderosa pine forest is actually composed of a mosaic of many small stands of even-aged trees. But the difference in age class of adjacent stands is usually great.

These patches of natural stands were established in a fortuitous combination of abundant moisture, cleared ground, and viable seed. Natural seed dispersal of large seeded ponderosa pine is not great. The effective range of pollen dispersed is also limited. The differences in age class, time and year of flowering and the physical handicap of local topography are all effective breeding barriers conducive to the development of a heterogenous local population as evidenced by the obvious phenotypic differences between adjacent stands.

The patches of natural stands of even-aged trees are in reality "progeny test" stands of the local population. They represent the progenies of possibly only a few trees that happened to be close to the newly created forest openings and produced seed in a wet year. For the phenotypic selection of parent materials, the general characteristics of trees in the even-aged stands serve as a more reliable basis of selection than the phenotypic characteristics of individual trees. Emphasis was made on desirable tree form characters which are expected to have a higher heritability than volume growth. In a mountainous country, volume growth is very much influenced by site diversities, even in a limited area.

The plan was to subdivide the ponderosa pine region of southern Idaho included in this project into 20 subdivisions. Each subdivision corresponds to approximately the area of a ranger district. Two best stands in each subdivision, one from higher elevations of 4,500 feet and above and one from lower elevations, were to be located. Open pollinated cones were to be collected from the 10 best trees in each stand. A total of 400 trees will be included in the progeny-test plantations. The reason that cones were collected from the best 10 trees and not from random trees is that the less desirable trees and trees of the intermediate and lower strata will be removed when the stand is converted to seed production area. The best formed trees in the crown class are more representative of the parents to be used for seed production purposes.

This project was initiated in 1960. Field selection and cone collection was made in 1961-62. Through the joint efforts of all cooperators, cones were collected from 284 trees in 35 of the selected stands. Trees from higher and lower elevations, and from the "basaltic" and "granitic" areas were about equally represented. Seeds were kept separate by parent. Seed trees were marked with conspicuous metal signs for protection.

Establishment of Plantations

Seed size and seed weight of the 284 seed lots were measured before they were stratified for sowing. The seeds were sown in regular seed beds of the U.S. Forest Service Lucky Peak Nursery according to a four-replicated randomized complete block design. Regular nursery care was given. Seedlings were raised to 2-0 stage for outplanting. The seedlings were labelled with numbered sticker tape before lifting. They were then sorted according to seed sources into four-seedling bundles. The four-tree bundles were then distributed into replicate bundles and kept in cold storage until planting.

The planting sites were selected to represent the altitudinal range in which ponderosa pine was to be planted. The sites were originally ponderosa pine land with gentle 10% slopes of average or slightly above average site quality in the "granitic" region. The sites were cleared the year before planting and disked and contour-furrowed in the spring shortly before planting.

Planting was done by hand with planting bar and "little beaver" power planter. In addition to the progenies, each plantation included four, four-tree plots of ordinary local 2-0 nursery stock to serve as controls. The four seedlings in each plot were planted at five-foot intervals in a single row at the bottom of furrows which ran in parallel lines 10 feet apart along the contour. The 5 x 10-foot spacing was used for the purpose of planting a larger number of seedlings in the early stages for the observation of juvenile characters, and of maintaining the plantation at 10 x 10 to 20 x 20-foot spacing by successive roguing. The first plantation was completed in mid-April (Idaho City) and the last one (Boulder Creek) was planted from the end of May to the first week of June when the ground was cleared of snow. At the end of the first growing season, with the exception of a few marginal severe site plots, an over-all initial survival of 90% was expected.

The Progeny-Test Seed Orchard

The plantations will be used in the early period as progeny tests. Observations will be made for evidence of genetic differences between progenies. As early as the 2-0 stage, obvious differences were observed, especially between progenies from different elevations in the four-replicate seed beds. First mortality count and frost damage observation will be made at the end of the first 12-month period after planting. Any indication of genetic differences in the capability to withstand transplanting shock will be highly useful for the possible development of resistant trees for the more severe sites.

The plantations will be protected from fire, rodent damage, and grazing. Excessive weed and undergrowth will be controlled by chemical spray.

Thinning of the stand will be made at 10-year intervals in conjunction with the measurements for genetic differences between the progenies. Most of the trees will bloom and produce their first cone crop before the end of the second 10-year period. To provide wide spacing for better development of seed trees, the plantation will be thinned to one-fourth of the original stocking in the second thinning. Only the best individuals from the 40 best progenies with overlapping flowering time will be maintained after the third thinning when quantity seed production is expected.

Seed Production Area

Many years will elapse before seed of any appreciable quantity will be produced from the seed orchard. To meet the immediate need, seed will be used from the superior parent trees recognized in the progeny test. Additional seeds in commercial quantities will be produced from the even-aged stands of the superior trees by developing the stands into seed production areas. The trees are within the age classes of 50 to 150 years which are of prime seed production age for ponderosa pine. The stands will be thinned to 50 to 100 trees per acre and heavily fertilized.

The first series of seed production areas will be developed on the basis of genetic superiority observed during the first 10-year period of progeny test. Additional stands for seed production areas will be selected on the basis of the 20-year progeny observations. At the present, several ordinary seed production areas have been established at considerable expense and additional areas are contemplated. They were established from phenotypically selected stands without the benefit of a progeny test. Under these circumstances, the development of the first series of seed production areas on the basis of five years' progeny observation, is fully justifiable. Under similar conditions, ordinary 2-0 nursery stock planted in this area were about four to six feet in height in five years after planting. At this age there will be ample indication of differences in inherent vigour and general adaptability to the tested areas between the observed progenies. The early observation will be verified when the 10-year and 20-year results become available. The seed production areas will be able to produce seed in commercial quantities from the progeny tested superior trees and their stands 20 to 25 years before improved seeds in any substantial quantity will be produced from the seed orchard.

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SEMINAR

SELECTION, SEED ORCHARD ESTABLISHMENT, MANAGEMENT AND FLOWER INDUCTION

SELECTION OF CLONES AND THEIR USE IN SEED PRODUCTION

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A person invited to come to this part of the world, and to this campus, to give an address, should have either the very considerable strength of character to decline, or should have something to say. Obviously I lack the former. I'm not too sure about the latter, but, on the strength of innumerable precedents, I will proceed as far as you allow me.

The scenario for a session such as this calls for a target to be presented to a company of sharpshooters. Hopefully, the target will not be a sitting duck, but will take enough evasive action to cause the sharpshooters to mistake each other for the target. At least this is how I have interpreted Oscar's signals.

Because I have not been engaged in the day-to-day work of tree improvement for several years, I am not qualified to deal with details of technique, but am, I believe, in a position to take a detached view of objectives and general problems. I think this is a good thing for us all to do fairly often, and I suspect such an exercise may be as stimulative to discussion as would a consideration of techniques alone. Although I recognize it as bad procedure, I will apologize in advance for saying many things which are obvious to all of you.

Let us briefly review the rationale of clonal seed orchards as a tool in tree improvement, checking off our assumptions along the way against what we have learned and against what we have not yet learned. Our first assumption is that we are to concentrate our efforts on a given species. To do so seems to be sound and elementary strategy. But what have we learned about this assumption? In the southern pine region, since the inception of tree improvement work, two pine species have, almost overnight, become the objects of the intense attention of practical tree-improvement workers. These are Virginia and longleaf pines.

Not many years ago, Virginia pine was more commonly known as scrub pine and barely received mention in the Forest Inventory statistics. Suddenly it was recognized, by an astute manufacturer, that this pine possessed the principal attributes of a commercially valuable species. That is, it is single-stemmed, not too limby, grows reasonably fast, occurs on a wide variety of sites, and, above all, is widespread and abundant in supply. As a bonus, it was found that this pine usually produces wood of rather low specific gravity and low resin content, and is thus suited to the economical production of groundwood pulp. As a result, by 1965, seven companies in the North Carolina State Industry Cooperative Tree Improvement Program were working with this species, 217 trees had been graded as ortets, and 110 acres of seed orchards had been initiated, as compared with 886 ortets and 658 acres for loblolly pine, the major species.

It may be somewhat surprising to much of this audience to hear that longleaf pine, the predecessor of Douglas-fir as North America's leading structural timber, has only recently engaged the attention of tree improvers. The reason lies simply in the close tie between artificial regeneration techniques and practical tree-improvement possibilities. Longleaf pine seedlings are difficult to plant, and until the recent elaboration of effective direct sowing techniques for southern pines, following developments in the Pacific northwest, longleaf pine did not figure appreciably in artificial regeneration statistics. Meanwhile, in the sandhills region of the Carolinas, where loblolly pine, the generally recognized all-purpose species, does not thrive, plantations of slash pine, an exotic to the area, were beginning to stagnate. Therefore it became urgent to replace slash pine with the better-adapted longleaf. Thus it has been possible to inaugurate a tree-improvement program for a native species of proven adaptability because of a development in artificial regeneration technology.

So, with the southern pines, we have learned that the circumstances affecting the practicability of a program of improvement of a given species may change quite quickly. Therefore, while it may be good strategy to concentrate efforts on one or two major species in an area, the other strategic concept of a secondary objective - in this case a "back-up" species - is also worthy of consideration. Regeneration decisions can be made overnight. If tree improvement is to keep pace with these decisions, we need to be prepared, at least with basic biological and technological knowledge of those species potentially useful in our region, even though we may recognize that it would be hard to justify seed orchard development in anticipation of need.

A second assumption involves the function that seed orchards are expected to play in a given forestry enterprise. Most seed orchards are established with three different objectives in view. These are (1) to produce seed effectively and dependably, (2) to produce seed of a certain provenance, and (3) to use as seed producers trees of superior phenotype and, hopefully, of superior genotype. The relative weights assigned to these objectives, if consistently adhered to, determine the whole course of seed-orchard development. Thus a given seed orchard may be expected to effect considerable genetic improvement, or none at all, either outcome being regarded as successful, depending on the objective.

Multiple objectives can be achieved if they are not in conflict. How do these three relate to each other? None of them is fully compatible with the other two. The provenance objective is compatible with the seed-production objective only if the seed orchard is so located as to favour seed production by trees of a specific race. The North Carolina State Cooperative Program includes one loblolly pine seed orchard apparently located too far north to be an effective producer of seed of the race employed. The seed-production objective is only partly compatible with the genetic-improvement objective, as we will see later. Therefore we have grounds for scrutinizing the assumption, often made, that seed orchards offer multiple benefits. They do, but the conscientious advocate of seed orchards will do well to avoid both self-delusion and the arousing of unwarranted expectations on the part of his clients.

While on this subject, it may be appropriate to mention what is often a fourth objective of seed-orchard programs. This is the public image of the agency involved. No one here is unfamiliar with this aspect. Public recognition is a legitimate by-product of such programs, but, as actors, politicians, and other public figures have often complained, the public is fickle, and the burnishers of the public image are obliged to act accordingly. Their interest in and support of tree-improvement programs may prove short-lived.

Once the decision is made to improve a given species by means of the clonal seed orchard technique, specifications for the proposed improvement must be laid down. Current studies of heritability and correlation are expected to provide guidance with respect to the intrinsic or biological aspects of tree characteristics. The extrinsic aspect, namely, importance, may be a bit slippery, since it is partly subject to human whim or changes in manufacturing technology. An illustration of the difficulty of judging importance of a characteristic is provided by western white pine. Resistance to white pine blister rust has re-emerged, following a brief eclipse by hopes for chemotherapy, to a position of primary importance. Regardless of complexities, decisions with respect to improvement goals must be made early and, once made, cannot be changed without extensive substitution of clones in a seed orchard.

Age at which the characteristics of an ortet can be most effectively evaluated is a dimension of the problem of setting improvement goals and of choosing candidate trees that can sustain lengthy debate. The simplest view is that it need not exceed expected rotation age of the next crop. One difficulty is that expected rotation ages tend to fluctuate rapidly and widely. It seems likely that as the inferiority, for many purposes, of wood produced near the pith is more widely recognized, rotation ages may settle back to a position between the extremely short rotations such as the 15 to 20 years favoured by some southern pine operators, and the long rotations carried over from old growth harvesting.

There seems to be fairly general agreement that ortets should not be selected at less than about half rotation age. This restriction would tend to eliminate "sprinters" that are said to slow down unduly before rotation age is reached. There is less agreement on the matter of selecting rather old ortets. Here, the arguments may have to take account of species and regional differences. In some rather extensive regions, existing age structure of stands determines the choice. Moreover, some species, such as Douglas-fir, do not produce many good scions per unit area of crown on older trees. Further, one may feel more confident about the seed-producing potential of a clone derived from a prolific young ortet than of a clone derived from an equally prolific older ortet.

In some species, such as Douglas-fir, relatively few older trees, short of decadence, show conspicuous stem and branch defects. The greater ease of detecting such defects on younger trees seems to support a policy of seeking ortets in young stands. Finally, in support of this as a general policy, it seems somewhat irrational to select relatively old ortets and then, as is inevitable, to evaluate their progeny at relatively young ages.

Possibly more controversial than age at which to choose ortets is the intensity of the initial phenotypic selection, or the strictness of the grading. In the old-field stands so common in the loblolly pine regions, rigorous adherence to standards of comparison between candidate and adjacent check trees has resulted in early superiority in growth of open-pollinated progeny of candidate trees as compared with progeny of checks and with seedlings from open-market seed. These short-term gains are highly worthwhile, for they maintain support of the programs. It is nevertheless a question worthy of careful study whether better long-term results might be achieved if the same initial selection effort were devoted to finding larger numbers of ortets as a result of less rigorous grading.

Selection is a term we tend to use rather indiscriminately. In the process of improvement by use of clonal seed orchards, we make choices at several stages and tend to lump them all under selection. They are as follows:

(1) Choosing ortets by phenotypic grading in the forest,

(2) Eliminating technically unsuitable clones in the course of seed-orchard establishment,

(3) Eliminating genetically unsuitable clones from seed orchards on the basis of progeny-test results.

Because these choices succeed each other at rather long intervals, we may tend to overlook their exponential effect in reducing the base of genetic variability on which a progeny-tested seed orchard comes to rest.

Turning from selection of ortets to seed orchard establishment, let us consider the case of the clonal seed orchard, with heavy weight given the genetic improvement objective. This is probably the most common situation. The desirable number of clones making up such a seed orchard has been specified by various workers over the range from 15 to 40 or more. Here again, we run into some assumptions, not all of them always stated. These are as follows:

(1) The clones selected will exhibit high enough short-term graftability and long-term stock-scion compatibility to be of practical use.

(2) The clones selected will produce enough pollen and seed, preferably both, to justify the expense of establishing and maintaining them.

(3) The clones selected will be closely enough synchronized in their flowering to permit a reasonably high degree of panmictic crossing.

(4) The clones selected will be sufficiently cross-compatible to permit a high degree of panmictic crossing.

Unless these assumptions are approximately valid, a specification of the number of clones needed to make up a seed orchard may be much too small. As Carl Heimburger put it, in a discussion at the Seattle World Forestry Congress, the seed orchard may wind up as a number of holes in the ground.

These assumptions relate to what might be called the purely production aspects of the clones we have selected. The purpose of controlled-pollination progeny-testing is to evaluate another aspect of our selected clones, namely, their breeding behaviour. Early justifications of progeny-testing were to the effect that only by progeny-testing could we be assured that a "good" phenotype represented a "good" genotype. We have a reasonable degree of such assurance from numerous open-pollinated and controlled pollinated progeny tests, but the latter type of test is now being used to seek the answers to less simple but equally important questions, which may be described loosely as dealing with the breeding behaviour of clones or the nature of the variance their offspring exhibit.

If we conduct, as we do, controlled pollinated progeny tests at great expense, this is done with the expectation that the outcome of these tests will reveal differences in the breeding behaviour of our selected clones. These differences will presumably be such that different clones will be found adapted to different sorts of roles in a genetic-improvement program. Some clones may be discarded. Others, with high specific combining ability, may be useful in specific crosses. Others may prove most useful in various selection schemes which can be carried out on the basis of panmictic seed orchards.

The clonal seed orchard, designed to effect genetic improvement, has usually been established with the recognition that it represents a later stage in an orderly progression from phenotypic selection through progeny-testing to selection based on such testing. However, expediency and the long life cycle of trees has dictated a telescoping of this sequence into nearly simultaneous stages. In this process of telescoping, we have inevitably, in a practical sense, prejudged the outcome of our progeny tests. To oversimplify, our rationale has been something like this: "Our producing seed orchard needs $\underline{n}$ clones. We will establish in it $2\underline{n}$ or $3\underline{n}$ clones so that grafting and reproductive difficulties will leave us with approximately $\underline{n}$ clones, which will then produce panmictically the seed we desire." This rationale overlooks the strong possibility that a scheme of directed crosses between certain of the surviving clones may be indicated as a better procedure by the outcome of progeny tests.

What constitutes adequate pollen isolation is a question that has long nagged at tree-improvement technicians. While we have numerous data on pollen flight under given conditions of laminar air flow, most of us realize, I believe, that it is the turbulent and largely unpredictable winds that effect a great deal of the pollination of conifers. Thus many of us have adopted what might be called practical standards of distance isolation and have fallen back on the pollen produced in seed orchards as a sort of countervailing isolation mechanism. Logical as this rationale may be, I am not aware that we yet have data to support it. Two sorts of questions arise: first, do we in fact achieve countervailing isolation - as a famous Confederate put it, "getting there first with the most" - and, second, do we achieve anything like a homogeneous pollen mix throughout our seed orchards?

This review of some questions and assumptions that are the daily fare of those tree-improvement technicians who work with clonal seed orchards leads me to suggest that we might consider some alternative approaches and procedures. The clone has obvious advantages for conservation of genotypes and of reproductive maturity. The clonal seed orchard, in which ramets of numerous clones are systematically or randomly mixed, has the disadvantage of relative inflexibility once the original layout has been established. Moreover, it now seems doubtful that this sort of seed orchard will achieve the breeding behaviour originally hoped for.

Tree improvement, like most human activities, oscillates from one fad to the next, sometimes in cycles. Thirty years ago the small band of tree breeders devoted much of its effort to development of controlled-pollination techniques, largely in the service of programs of species hybridization. In the last quarter century, progress along these lines has decelerated, while the various technologies, such as air conditioning and refrigeration, which might be called on for support, have flourished. We are now finding, as we return to controlled pollination as a part of our progeny-testing programs, that for many species our techniques of securing, handling, and applying pollen are not really good enough. I believe that it is quite possible to improve these techniques not only to the point where they will adequately serve the ends of progeny-testing, but beyond this to the point where we can replace the haphazard autopollination of our present seed orchards with artificial mass pollination, with a considerable measure of control of parentage on both sides. The technical difficulties would seem less than those encountered either in maize with its short-lived pollen or apples with their relatively hard-to-get pollen. Both of these crops are control-pollinated on a commercial, large-scale basis.

I believe it is quite possible that an effective scheme for production of genetically improved seed in commercial quantities can be worked out using solid clone blocks in which mass controlled pollinations are made as directed by progeny-test results, and that such a scheme might offer more flexibility and more rapid and continued genetic improvement than the current _laissez pollinister_ mixtures of ramets.

SEED ORCHARD PROBLEMS AND PRACTICES IN THE NORTHWEST

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Size of the Seed Orchard Program in the Northwest

To the best of my knowledge, 344 acres are now devoted to seed orchards:

Area	By whom established	No.	Acres	Species*
Oregon-Washington	13 companies, *USFS,BLM	20	232	DF,WWP,SP,NF,PP
British Columbia	5 companies, BCFS	10	60	DF
Idaho	USFS	2	42	WWP
California	USFS	1	10	SP
Totals		33	344	5

(*DF=Douglas-fir, WWP=western white pine, SP=sugar pine, NF=noble fir, PP=ponderosa pine, USFS=U.S. Forest Service, BLM=U.S. Bureau of Land Management, BCFS=British Columbia Forest Service)

Why is the Northwest program so small compared with that of the southeastern United States? I believe it is because many company and governmental officials have been indoctrinated with an old-growth harvesting philosophy. Until forest lands are committed to intensive management under a sustained yield program, it is difficult for officials to recommend investment of thousands of dollars a year on projects which may not pay off for 60 to 100 years.

The rapid changes in climate and soils with a shift of a few miles are other roadblocks to producing all Northwest seed in orchards. This means many small orchards of 5 to 20 acres in size to care for a zone some 50 miles long and 500 to 1,000 feet deep (in an elevation sense). The added cost and manpower required for small orchards have discouraged investment in such long-term projects.

In the southeastern United States improved growth rates of well above 5% are being experienced when seed from orchards is used. When similar results are available in the Northwest, it is expected that more forest managers will recognize the value of a tree-improvement program.

Objectives of Northwest Seed Orchards

Improved growth rate consistent with high quality, and resistance to disease are the two primary tree-improvement objectives in the Northwest. Incorporated in the first is the need to produce ample quantities of seed from a specific climatic zone under semicontrolled conditions.

As used here "high quality" implies straight stems, straight grain, small branches, branch angle approaching horizontal and resistance to frost, snow, insects and disease. High specific gravity and other internally detectable factors are not yet being used in first-generation plus tree selections in the Northwest. Since high specific gravity is desirable for some uses, undesirable for others, tree breeders are not sure which to emphasize. All are agreed on growth rate. Most believe that we should strive to perpetuate the phenotypic qualities cited.

Secondary objectives vary to this degree. One major company has planned its Douglas-fir orchards to produce seed only for high-site reforestation. The Forest Service has generalized their goal. Their orchard seed will be returned to all land within the respective climatic zones from which the bulk of National Forest timber will be harvested during the next 50 years. The second of the two primary objectives deals with production of western white pine and sugar pine seed which is inherently resistant to the imported blister rust disease. In the first selections of rust resistant phenotypes, growth rate and form are secondary considerations. However, many rust-resistant trees are fast-growing desirable phenotypes; so the picture is brighter for first-generation progeny than it may originally appear.

Problems Faced in Selecting a Seed Orchard Site

Primary factors considered to date include favourable local weather conditions (a long growing season, good air, drainage, etc.), minimum chance of contamination from outside pollen, desirable soil conditions, access by labour source, immediate availability for use, and a manageable topography. An available water supply appears desirable, but there are few facts concerning timing and quantities of water needed to produce the maximum number of pounds of Douglas-fir seed per acre.

Compromise has been the key word in the selection of most sites. Some degree of contamination is usually conceded. To avoid this, a Douglas-fir orchard would have to be located in a very wet belt where only Sitka spruce and western hemlock grow, or in a dry area east of the Cascades. Douglas-fir does not thrive even as an ornamental in dry areas. In a wet area the climate is not conducive to frequent seed crops even though the trees grow vigorously. Establishment and maintenance costs would be greatly increased if the site were located a long distance from the forest manager's headquarters.

A search of some 300,000 acres on the Siuslaw National Forest failed to yield even 80 contiguous acres suitable for a seed orchard. High elevation (above 1,000 feet) and steep topography ruled out most of the area. Annual precipitation of 80-plus inches ruled out the rest.

In brief, it is a difficult chore to locate within the Douglas-fir region a seed orchard site which meets minimum standards for growing season, topography and soil conditions.

Establishment and Maintenance of Seed Orchards

A first step in establishment is the selection of better-than-average phenotypes as described above. Selection criteria are about as numerous as tree breeders. In general, most selection systems will designate as plus trees those which are superior to their nearest competitors in growth rate and form. Dr. Robert Campbell, Weyerhaeuser Company, Centralia, Washington, explained his method of selecting one tree in 100 based on taking diameters, height growth, distance from neighbouring trees, age, etc. and analyzing the data by an IBM program. For details, Dr. Campbell should be contacted.

A seed orchard requires intensive management once grafting has begun. Grafts and rootstocks must be pruned, rootstocks fertilized, insecticides applied, and competitive plants controlled by cultivation or other means. In one orchard, failure to cultivate has resulted in an expanding rodent population. I believe it accurate to say that the most successful Northwest orchards have been blessed with talented seed orchard managers who have spent most of their working time in the orchard.

Among the problems in Douglas-fir, flower induction is much talked about. Yet little is known as to thresholds of such factors as moisture, nutrition, temperatures, and length of growing season which must be met to produce a collectible cone crop. Research is sorely needed.

Long-term grafting incompatibility is a problem presently being investigated by the Pacific Northwest Forest and Range Experiment Station. Use of insecticides in orchards has been the subject of several studies the last 10 years. Unfortunately, seed-orchard establishment has been forced to proceed before research could provide the answers to these and other questions.

The rest of my paper is illustrated by coloured 35 mm slides.

1. A picture of Mount Hood showing the transition from timbered to treeless slopes. Why is the dividing line so clear cut? It is obvious that a 400-foot change in elevation is critical when approaching timberline.

2. This illustrates one of the advantages of controlled seed production - known seed source. Here are several sacks of cones without a single label. The buying agent at this gas station told me he did not care where the cones came from - he wanted to buy 3,000 sacks.

3. If seed source is known, the climate of source and reforestation site must be matched. In this 4,000-foot elevation plantation the trees were about 15 years old when a severe frost completely destroyed them. The seed came from 800 feet elevation some 80 miles away.

4. This nursery bed of mixed species illustrates again that seed from orchards would save money in ways not presently thought about. A forest manager would not waste seed from orchards by mixing it with other species for nursery sowing.

5. This is a ponderosa pine seed production area, an interim step between present collection methods and seed orchard development. This natural stand has been thinned and fertilized to encourage cone production.

6. A four-year-old Douglas-fir seed orchard graft is loaded with cones. This dream-come-true was staked to prevent the graft from breaking off.

7. This Douglas-fir graft is covered by a polyethylene tent down to 18 inches above the ground. There was a small air vent at the top of the A-frame cover. This cover sped up pollen production a week to 10 days. If such measures were not used, we would never be able to use fresh pollen from late flowering grafts in our progeny-testing program.

8. A graft which has been bagged for controlled pollination. The gentleman is Virgil Allen, seed orchard manager, who has successfully handled the orchard since its inception.

9. An outplanting of control-pollinated progeny at Dennie Ahl Seed Orchard. This is not a progeny test but will give us a chance to conveniently start producing an F-2 generation. One of the seedlings had two normal cone buds at the end of the third growing season. The buds become conelets, but a frost in late May prevented us from observing further development.

10. A progeny test outplanting on the Olympic National Forest at about 2,500 feet elevation. These are control-pollinated seedlings from the Dennie Ahl Seed Orchard.

11 and 12. Graft incompatibility is shown by yellowing needles in the spring of the second growing season. Whether this is due to the same factor(s) as cause delayed incompatibility, we do not know.

13. An eight-year-old Douglas-fir showing the familiar overgrowth which is an external sign of failure of phloem tissues to form a successful union. We would love a solution. This type incompatibility may eliminate 30 to 50% of the grafts made to date.

14. A disadvantage of using a crown veneer graft - a poor union in which the graft tends to grow away from the rootstock. This also shows need for graft maintenance.

15. An example of the ability of Douglas-fir lateral branches to turn up and assume dominance over a crown veneer graft. Perhaps pruning would have given the scion a chance to survive. The lessons learned from this orchard were largely responsible for our decision to prune lateral branches from the very outset.

16. Another problem - an elk took the entire scion from this rootstock before we erected a fence.

17. A tractor has been used the last three or four years to reduce competition from brush and fern species. It also helps keep the fire hazard within acceptable tolerances.

18. A shallow mantle of porous soil plus the standard application of fertilizer killed a potential rootstock. This happened on the edge of a lodgepole-pine-occupied swale.

19. A few Dioryctria, Contarinia, and Megastigmus were noted in the orchard the first year in unbagged cones. Since then we have been encouraging forest entomologists to develop a control program. We believe an adequate program has been developed for Douglas-fir.

20. Tent caterpillars surprised us by defoliating a number of grafts in 1964.

21. Topophysis has been noted since 1958. Some grafts now in their ninth season are still growing like branches. A very small study indicated that by collecting our scions from the top five whorls we could avoid this in Douglas-fir.

22. Water is dear at Dennie Ahl - even for fire prevention or control. We still do not know if we could increase the cone crop by applying water when the soil moisture content approached the wilting point.

23. Should we top or prune Douglas-fir to keep cone production nearer the ground? This is another answer still evading me. My observations are based on many topped trees in yards, under power lines, etc. I believe we kill the goose by topping a tree. I invite you to check not one but 200 or 300 such trees and draw your own conclusions.

24. Abortion of cone and pollen buds between the primordial and mature cone stage is a field where much work needs to be done. If we could save half of the aborted buds, we could increase the ultimate crop greatly. What are the moisture, nutritional, and climatic thresholds involved?

25. Douglas-fir conelets from one tree may be a dark purplish red, while conelets on its neighbour are lime green. Does this variation have any meaning?

26. A proliferated cone from clone 9 at Dennie Ahl. The same clone produced a hermaphroditic bud (pollen at base, conelet at terminal) in 1959.

27. Rust-resistant tree breeding has led to the development of seed orchards for future mass production of seed from western white pine and sugar pine. On grafts made in 1958 and 1959 we are getting a collectible crop of cones in 1966.

28 and 29. While analyzing the results of artificial inoculation of potentially resistant white pine progeny, attractive assistants have proven very satisfactory.

30. California has a 10-acre sugar pine seed orchard for production of rust-resistant progeny. Cones are being produced on some eight-year-old grafts.

31. How will tree improvement expand in the future? Here is a tree believed resistant to mistletoe. Will there one day be many programs of breeding for insect and disease resistance as well as for such factors as growth rate, quality, and specific gravity?

Seed orchard development in the Northwest is still in its infancy. Solution of the grafting problem and orientation of more forest managers concerning potential gains are expected to increase participation in the seed orchard program.