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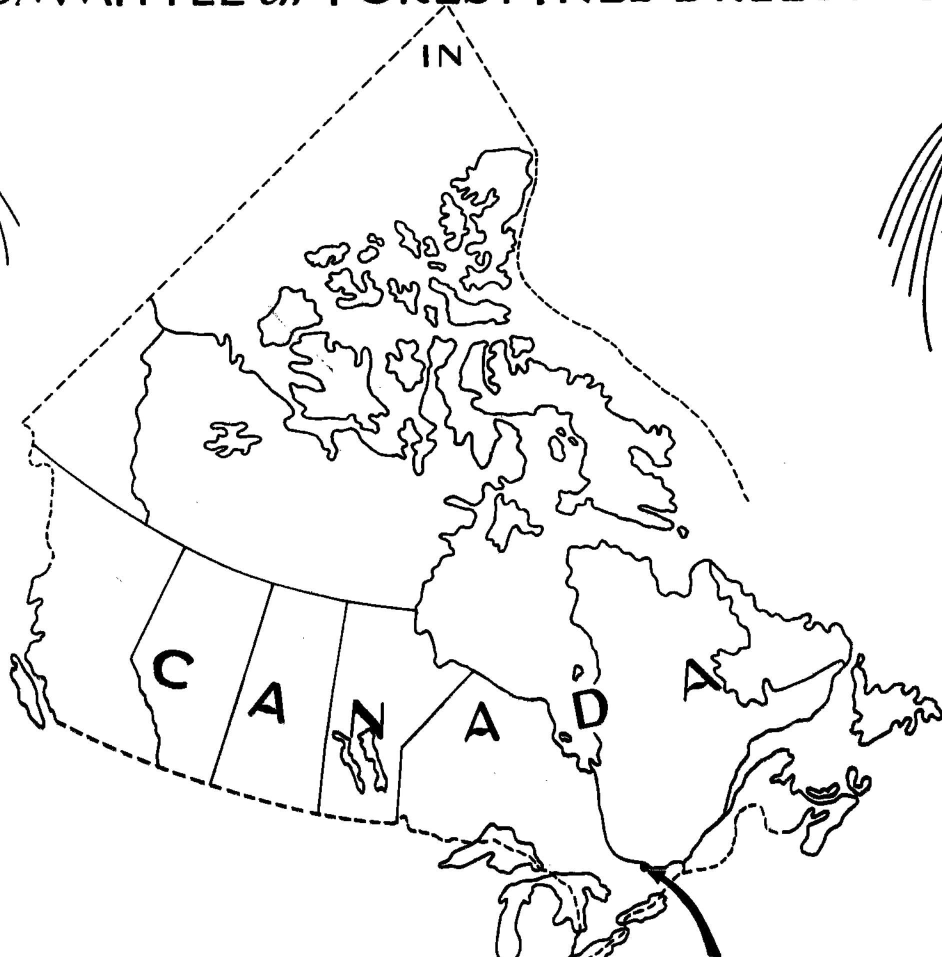
OF THE

COMMITTEE on FOREST TREE BREEDING



HELD AT
PETAWAWA FOREST EXPERIMENT STATION
SEPTEMBER 16th.- 18th.
1964

Part II

Reports and Papers

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PROCEEDINGS OF THE NINTH MEETING OF

THE COMMITTEE ON FOREST TREE BREEDING

IN CANADA

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

The Tenth Meeting of the Committee will be held at the University of British Columbia, Vancouver, B.C., in August, 1966. Canadian and foreign visitors will be welcome. Upon request, further information will be distributed early in 1966.

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

To: Secretary, Committee on Forest Tree Breeding in Canada,
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PART 11

REPORTS AND PAPERS

Assembled and distributed by the
Department of Forestry of Canada, Ottawa

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

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LIST OF ACTIVE MEMBERS OF THE COMMITTEE ON FOREST TREE BREEDING IN CANADA, SEPTEMBER 1964

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MEMBERS' PROGRESS REPORTS

The incidence of apparent recovery from blister rust in white pine seedlings from resistant parents

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Documented recovery of trees from infection by wood rusts has been reported in the literature for both white pine infected with blister rust (Hirt, 1948; Riker, et. al. 1943; Struckmeyer and Riker, 1951), and slash and loblolly pine infected with fusiform rust (Snow, et. al. 1963). In the case of white pine recovery was due to the formation of wound periderm (Struckmeyer and Riker, 1951) which resulted in the expulsion of the fungus from the cortical tissue of the host, while in slash and loblolly pine, resistance appeared to be the result of increased development of the host which more or less enclosed the fungus (Snow, et. al. 1963). While these reports suggest that recovery from disease has a genetic basis, evidence in white pine clearly shows (Patton and Riker, 1960; Rhoads, 1920) that host vigour also markedly affects susceptibility or resistance. Whether host vigour is altered by environmental (predisposing) factors or by other agencies such as inbreeding (Heimburger, 1962). It is of importance to the tree breeder and the forest pathologist especially, to be able to separate genetically based resistance from induced resistance which may exert only transitory effects.

Some information in relation to this subject was observed in a study of 157 seedlings[1] representing eight crosses from naturally resistant parents.

[1] Seedlings were kindly provided by Dr. C. Heimburger, Ontario Dept. of Lands & Forests. The male parent was the same in all cases. Parent trees were located in Pointe Platon, P.Q. Each selection consisted of 20 seedlings except for two, one of which has 19 seedlings and another 18 seedlings.

After two series of inoculations, two seedlings were still uninfected, four died prior to recording susceptibility and 151 developed cankers. Living seedlings were maintained for a period of one year to determine if any recovery from disease existed.

Seedlings were assumed to have recovered when the cankers appeared shrunken and dried out and when growth was normal. Of the 151 seedlings, 8 gave initial evidence of recovery. Five of these seedlings came from one cross. Portions from the canker margins of all resistant seedlings were then fixed and embedded in wax and sectioned in order to determine, if possible, the reasons for recovery. Of the eight seedlings, five had produced an active wound periderm which eliminated the fungus and of these, four were produced by one cross (Population 737). The remaining seedlings could not be classified with certainty and have been retained for further study. The preliminary data, however, suggest that as indicated previously by Struckmeyer and Riker (1951) wound periderm formation may be an active stem resistance factor present in some selections but not in others.

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Quality wood study

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Three symposia on wood quality were held in 1959 to determine the future needs of the wood-using industries, particularly the pulp and paper industry. In brief, the results of these discussions indicated that for certain uses it was still necessary to provide ample supplies of quality woods.

Mainly as a result of these symposia the Ontario government undertook a quality wood research program, in which the Research Branch, Dept. of Lands and Forests; the Ontario Research Foundation; and the Faculty of Forestry, University of Toronto, were to be closely related. The general objectives of these studies is to define more specifically those wood characteristics which form the basis of superior quality in end-use products and endeavour to relate these characteristics to hereditary and environmental factors.

The Ontario Research Foundation obtain an annual grant from the provincial government to carry out a quality wood program directed by a Steering Committee comprising Dr. J.W.B. Sisam, Dean, Faculty of Forestry, Mr. R.N. Johnston, Chief, Research Branch, and Dr. S.G. Reid, Director, Organic Chemistry, Ontario Research Foundation. Their program is divided into two spheres of activity: anatomical studies under Dr. J.L. Ladell, and studies of wood chemistry under Dr. G.H.S. Thomas.

The function of the Quality Wood Unit is to ensure that the program carried out by the Ontario Research Foundation is directed to the aims of the Steering Committee, and to relate these findings to field applications, thus providing an improved wood supply for industry. In addition, trials will be run to assess the natural variations found in specific wood properties such as wood density and spiral grain.

During 1961 and 1962 a program was organized at the Ontario Research Foundation and Dr. Thomas prepared a series of reviews relating to the evaluation of wood species for their pulping characteristics. At this time, trials were conducted to develop techniques for pulping small wood samples and testing their paper strength. Aspen (populus tremuloides) wood samples were used in this preliminary work. Black spruce (Picea mariana) was accepted as the significant species for study in 1963.

WOOD FIBRES

Dr. Ladell is studying relationships between external foliar characteristics and wood fibre morphology. He first assessed the relation between needle spacing on shoots and needle mass per unit length of shoot for black spruce. He found that with increasing needle density, weight per needle tended to decrease, but needle weight per centimetre increased. There was a significant positive correlation between needle weight per centimetre and height or diameter. The study was based on 30 trees in each of four age-classes from 16 to 150 years, in the Cochrane District of northern Ontario.

General verification of this relationship was determined by the Research Branch for a 100 tree samples from a 16 year old black spruce plantation at Moonbeam in Kapuskasing District, belonging to the Spruce Falls Power and Paper Co. A foliage sample was used including 1961-63 internodes from a mid-height branch. In this sample there was a highly significant correlation ($F=8.27^{**}$) between tree diameter at breast-height and needle mass per centimetre of shoot length. There was not a significant correlation ($F=0.97$) between tree height and needle mass.

The objective of the present phase of the investigation at the Ontario Research Foundation is to develop a relationship between needle mass and fibre morphology.

WOOD CHEMISTRY

Dr. Thomas has established a procedure for simultaneously pulping 16 samples of black spruce chips by the sodium bisulphite process, using a wood sample of 5 grams to 20 grams. With this chemical it is possible to duplicate the preparation of pulping liquor, and with the aid of an oil bath having temperature changes controlled by a Temperature Programmer Transmitter to obtain an exact cooking schedule. Other equipment is available to make small sheets of paper and to run standard paper tests such as tensile, burst and tear strength.

One of the defects in paper is caused by compression wood. The chemical section pulped compression wood and non-compression wood samples taken from the same disc. The tests are not yet complete but it is evident that compression wood does not pulp as thoroughly or as quickly as non-compression wood. The chemical differences of these pulps and the quality of the paper they make have yet to be determined. When this has been done, tests can be run to determine the effects on paper strength of various proportions of compression wood. Then in subsequent sampling for particular fibre characteristics, the effect of a proportion of compression wood can be better evaluated.

Interspecific crosses in the genus *Abies*

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The program of crossing foreign species of *Abies* with local *A. balsamea* is still under way. The principal aim of this investigation is still the production of interspecific hybrids that may bring together qualities of growth, resistance, etc., of interest to tree breeders.

Pollen from the following foreign species have been used successfully in crosses with *A. balsamea*: *alba*, *Ernesti*, *fraseri*, *homolepis*, *koreana*, *lasiocarpa* var. *arizonica*, *nobilis*, *nordmanniana*, and *sachalinensis*. These hybrid seedlings are growing in a "natural" environment well suited to the growth of the local species. Possible damage of the severe winter of 1963-64 has not been assessed as yet. A study of these hybrids with respect to morphology, cytology, etc., is being conducted.

1962-63 Biennial progress report
Shelterbelt tree breeding

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Favourable weather conditions prevailed for the 1962 - 1963 nursery programs. The frost free period of 1962 was 117 days (May 9 to September 18), and that of 1963 was 150 days (May 23 to October 19), while the precipitation in the frost free periods was 9.8 and 17.6 inches, respectively. The amount of bloom on Caragana in 1962 was apparently severely reduced by the drought of 1961, whereas the opposite was noted on Colorado Spruce, for which there as an abundance of both male and female flowers on all selections. Following the abundant crop of cones in 1962, very few spruce selections had any bloom in 1963. Shortage of male bloom was especially noted for spruce, consequently all controlled-pollinations in 1963 were performed with stored 1962 pollen.

On April 1, 1963 the former Forest Nursery Stations of Research Branch at Indian Head and Sutherland were transferred to the Prairie Farm Rehabilitation Administration of Canada Department of Agriculture and re-designated "Tree Nurseries". The investigational program has consequently been changed to support increased tree production.

Staff changes included the transfer of Dr. R. Grover, Plant Physiologist, to the Experimental Farm at Regina, Saskatchewan. Mr. P.J. Salisbury, Pathologist, resigned and Mr. A.C. Patterson was appointed Nursery Manager. Mr. C.H. Lindquist has of necessity taken charge of the Tree Improvement Program.

CARAGANA BREEDING

The Siberian pea-tree (Caragana arborescens Lam.), the common caragana, has proved the most reliable species of woody plants for field shelterbelt plantings in the Canadian prairies since 1908.

Evaluation of combining ability for vigour has been the major phase of a breeding program since 1949 to produce more vigorous hybrids of Caragana arborescens Lam. for field shelterbelt plantings. Regrettably, self-incompatible selections to 1953 proved cross-incompatible so that new accessions were sought for genetic diversity. In 1961 and 1962 all vigorous selections of accessions from U.S.S.R., U.S.A., and Europe were evaluated as to their self-compatibility.

The number of ovules per ovary were recorded for 109 selections from seven seed sources. The results, listed in Table 1, indicate that seed source has some influence on the number of ovules per ovary. The accession material originating in the more northern climates apparently has more ovules, indicated by a mean of 19.1 ovules for accessions from Finland and only 11.7 for U.S.A. material.

TABLE 1. Frequency Distribution of Number of Ovules per Ovary for Six Seed Accessions and One Local Hybrid of C. arborescens.

Frequency class (ovules)	Accessions						
	Finland (D138)	USSR (D190)	USSR (D191)	Norway (D142)	Sask. (A101)	U.S.A. (D180)	Hybrid (B24 x V2)
No.							
0 - 1	-	1	-	1	-	-	3
3	-	-	-	-	-	-	-
6	-	-	1	-	-	3	-
9	-	1	5	-	2	7	2
12	-	11	3	1	5	10	14
15	2	43	16	7	9	8	40
18	16	82	36	7	4	2	21
21	15	57	33	3	-	-	2
24	1	32	13	1	-	-	-
27	-	5	1	-	-	-	-
Mean	19.1	18.5	18.5	16.6	14.3	11.7	15.0

In 1963, 22 selections having low self-compatibility were selfed and cross-pollinated with three original self-incompatibles (B2-4, A-1 and V-16) and one self-compatible (V-2) selections. Pollen from each of the 22 selections was applied to one self-incompatible (V16) seedtree. These self-, cross-, and open-pollinations are summarized in Table 2.

It was evident that all the new self-incompatible selections were also

TABLE 2. Self-, Open- and Cross-Compatibility * of Selected Accessions of Caragana.

Seedtree Accessions ♀	Pollens ♂ and Percentage set *						Set(♀)*
	Selfed (%)	B2-4 (%)	A-1 (%)	V-16 (%)	V-2 (%)	OP (%)	V16 (%)
D191-71	0	0	0	0	7	5	0
D143-2	0	0	0	0	2	0	0
D142-6	0	0	0	0	5	2	0
D16-10	0	0	0	0	46	24	0
D180-20	0	0	0	0	15	0	7
D-16-3	0	0	0	0	21	4	7
D180-19	0	0	0	0	0	0	21
D180-12	0	0	0	0	0	0	27
D190-1	0	0	0	0	0	0	29
D180-24	0	0	0	0	14	2	35
D14-112	0	0	0	0	0	-	37
D10-13	0	0	0	0	8	0	39
D180-23	0	0	0	0	0	0	41
D14-12	0	0	0	0	5	17	50
D14-26	4	0	0	0	40	83	21
D191-31	4	0	0	0	0	4	30
D190-6	5	-	10	7	32	0	21
D191-14	6	0	2	0	19	0	31
B14-71	7	12	0	2	0	0	14
D191-49	11	0	0	0	31	12	28
D14-13	11	7	4	6	0	6	56
D11-8	13	0	0	0	0	0	10

*Compatibility expressed as % of pollinated flowers-setting pods.

cross-incompatible when pollinated with the original self-incompatible selections. However, when V16 was used as the seedtree, pollinations by all except four of the 22 accession selections produced a good seed crop. These new 18 self-incompatible selections will be used as seedtrees and pollinated by vigorous self-fertile selections for future progeny tests of the vigour potential for the various combinations.

High general combining ability (C.A.) for vigour has been manifested (Table 3) by the superior mean height of hybrid progenies for one self-incompatible Ⓢ and one self-compatible Ⓧ selection, B2-4 and B2-7, respectively. Maximum specific C.A. for vigour was demonstrated by the hybrid combinations B2-4 x B2-7 and B2-4 x V2. The three selections constituting these superior hybrids must now be propagated vegetatively and paired-planted in isolated crossing plots for the mass production of hybrid seed on the self-incompatible clone.

TABLE 3. Comparative C.A.* of 34 Hybrid Caragana Progenies from Combinations of Self-incompatible Ⓢ and Self-compatible Ⓧ Selections after 4-,6- and 8- Years of Growth.

Pollen of Ⓧ Selections	Ⓢ Seedtrees Selections B2-4 (cm)	21-16 (cm)	A-1 (cm)	V16 (cm)	15-2 (cm)	Mean Heights 4 Yrs. (cm)	6 Yrs. (cm)	8 Yrs. (cm)
B2-7	250	-	233	210	-	114	190	231
V-2	252	227	214	207	220	109	184	224
B2-4B	244	223	216	209	-	112	189	223
B4-2	247	223	234	221	189	88	172	223
B5-1A	224	-	227	214	200	105	181	216
13-5	226	-	205	-	-	100	176	216
10-3	220	211	226	199	-	100	178	214
B5-5	-	-	225	200	-	95	172	212
B4-5	217	224	184	193	207	100	167	205
Means	235	222	218	207	204	103	179	218

*Combining ability measured in terms of linear plant height in centimetres.

Combining ability for vigour when expressed as height, for three self-incompatible Ⓢ selections (A-1, V-16, 15-2) with 13 vigorous Ⓧ selections is summarized in Table 4. The plants were from greenhouse sowings and field planted in 1957. It is evident from the mean height data, that the relative heights change from year to year. In 1958, progeny of the selection 7-9 was ranked eighth, whereas in 1963 it ranked first. Only progeny of selection 10-4 consistently demonstrated the lowest vigour. The most vigorous progeny were

TABLE 4. Comparative Heights* of Eight-Year-Old Progenies of Caragana arborescens from Combinations of Three Seedtrees with Thirteen Selections.

Selections (Ⓧ) ♂	Seedtree (Ⓢ) ♀ and Height (cm) A-1	V-16	15-2	Mean	Annual Growth
7-9	222	216	223	220	43
13-8	201	218	234	218	33
B2-7	220	206	-	213	32
B4-2	211	212	210	211	32
16-1	206	215	-	210	32
10-3	-	-	209	209	33
B3-3	213	201	211	208	33
21-29	209	203	-	206	32
13-1	205	200	-	203	30
8-4	190	208	207	201	30
B3-5	190	204	198	197	30
7-7	198	197	193	196	31
10-4	191	195	185	191	31
Mean	205	206	208	206	32

*Vigour expressed as height of plants in centimetres.

produced by the selection 7-9, which exhibited an annual growth rate of 43.0 cm., compared with a general mean of 32.4 cm. for all progenies tested. Thus the selection 7-9 has high general combining ability for plant vigour. Highest specific combining ability for vigour was demonstrated by progenies of 15-2 x 13-8 and 15-2 x 7-9. Clonal material of the three parental selection (15-2, 13-8 and 7-9) should be vegetatively propagated from cuttings and set out in isolated crossing blocks for natural production of hybrid seed on the self-incompatible clone.

Effect of size of seed on ultimate tree vigour or height was investigated with a 1956 field planting of caragana seedlings from two sizes of seed. Height data are presented in Table 5, for seedlings from seed of two diameters and five inbred progenies as one- to eight-year-old plants. The effect of seed size on progeny vigour differed between seedtrees. Inbred seedlings of V-10 were generally larger for the 3.0 mm. seed, while those of the other four progenies had the most vigorous seedlings from the larger 3.5 mm. seed. The maximum increase in height for seedlings from the 3.5 mm. seed occurred at the fifth year. However, over a period of eight years the average annual growth

TABLE 5. Height* of the One-, Three-, Five- and Eight-Year-Old Seedlings of Five inbred Caragana Progenies from Seed of Two Sizes.

Age of Seedlings	Seed** Size	Inbred Progenies & Heights*					Mean
		V-3	V-10	21-27	B4-4A	B4-4	
(yrs.)	(mm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
One	3.5	20	20	32	17	20	24
	3.0	16	23	26	10	14	18
Three	3.5	53	61	63	63	80	64
	3.0	43	59	64	49	65	56
Five	3.5	137	125	126	140	166	139
	3.0	94	125	120	136	144	124
Eight	3.5	202	194	222	231	261	222
	3.0	180	210	208	211	269	216
Annual Av.	3.5	26	25	27	31	34	28
	3.0	23	27	26	29	36	28

*Vigour or height of seedlings expressed in centimetres.
**Diameter size of seed expressed in millimetres.

was the same for seedlings from both sizes of seed. It appears that seedlings from large seed become established earlier than seedlings from smaller seed, but seedling vigour due to seed size tends to disappear after eight years of growth.

Natural self- and cross-pollinations for C. arborescens have been estimated from self- and open-pollination progenies by use of genetic markers. Two types of such genetic markers have been reported (Proc. Gen. Soc. Can. 3:47-94. 1958) for caragana, namely one simple recessive "p" for the pendula character governing the production of the 'pendula' habit of growth, and another "a" for the albino character governing production of 'yellow-white' chlorophyll-deficient lethal seedlings. In 1962 self- and open-pollinated seed were harvested from one selection, which was heterozygous (Aa) for a chlorophyll deficient factor. Data from greenhouse germination of this seed have been summarized in Table 6.

TABLE 6. Segregation for the Albino character in Self- and Open-pollinated Seedlings of Y26Y.

Seed		Seedlings		X^2	Genotypes of seedlings	
Tree	Pollen	green	yellow	value	green	yellow
Y26Y	self	148	49	.001*	AA,Aa	aa
Y26Y	O.P.	280	48	14.090	AA,Aa	aa

*good fit to 3:1 ratio

From the results listed in Table 6 it is evident that approximately 131 (328-197) of the open-pollination seed or 40% were produced by natural cross pollination and some 60% (190) was the result of natural self-pollination. Further information is required from several trees over a period of years to establish a range of natural cross-pollination for the species. However, for the present it may be assumed that natural cross-pollination of caragana approaches 40%.

SPRUCE BREEDING

Colorado spruce (Picea pungens Engelm.) has proven the most promising spruce species to date for home shelterbelt and park plantings on the calcareous soil of the prairie region. It has demonstrated a resistance to the pine needle scale and spider mite, infestations of which no doubt contribute to losses of white and Norway spruce during drought years. Resistance of Colorado spruce to these insects appears to be related to the intensity of "blue" needle coloration, genetics of which is being investigated.

The drought of 1961 apparently stimulated the development of sexual buds of *Picea pungens* resulting in an abundance of bloom for all selections in 1962. Some 55 seedtree selections were evaluated by self-, cross- and open-pollinations. Self-compatibility ranged from 0 to 59 sound-seed per cone for a mean of 7.2. Cross-compatibility for three pollens ranged from 0 to 101 for a mean of 16.6. Open-pollination ranged from 3 to 156 for a mean of 63.9. Nine selections were self-incompatible, and of these, three were cross-incompatible. The other six self-incompatible selections will be grafted for planting in isolated hybrid seed production plots. Severe insect damage occurred in many isolation bags despite spraying the branches with insecticides prior to isolation. This indicates the need for further research on the control of cone and seed insects of spruce.

The influence of five levels of sucrose, boron and pH on viability of spruce pollen was investigated in 1962 using a basic medium of 1.5% water-agar with the results listed in Table 7. Germination for pollen of Colorado spruce increased from 39 to 71% as sucrose content of the media increased from 0 to 10%, but reduced at higher sucrose levels. On the other hand, germination for pollen of white spruce increased from 4 to 57% as the sucrose level was increased from 0 to 15%, then decreased to 16% at the 20% sucrose level.

Germination of Colorado spruce pollen was not affected by boron at 1 and 5 ppm. Higher boron concentrations actually reduced germination. Germination of white spruce pollen on the other hand, was increased by boron at 1, 5 and 10 ppm with reductions at higher concentrations. Germination for pollen of both spruce species improved by increasing the pH of the media from 2 to 3, but was gradually

TABLE 7. Germination and Growth of Colorado and White Spruce Pollen under Five Levels of Sucrose, Boron and pH.

Species	Level*	Germination**			Growth†		
		sucrose	boron	pH	sucrose	boron	pH
		(%)	(%)	(%)	(u)	(u)	(u)
Colorado Spruce	1	38.8	50.6	0.8	47.4	103.3	5.5
	2	67.1	53.0	61.6	153.0	116.7	96.6
	3	71.0	50.0	60.1	159.9	96.8	143.7
	4	40.9	37.8	56.9	91.2	81.4	136.3
	5	0.8	27.2	39.2	6.5	59.7	77.9
	Mean	32.7	43.7	43.7	91.6	91.6	91.6
White Spruce	1	4.5	30.9	39.4	12.7	41.8	57.2
	2	34.2	45.9	44.6	50.7	86.7	75.5
	3	56.8	40.7	40.5	87.8	64.6	67.6
	4	57.3	34.6	35.3	99.9	56.7	63.2
	5	15.7	16.4	8.6	40.4	41.6	28.0
	Mean	33.7	33.7	33.7	58.3	58.3	58.3

*Levels-Sucrose - 0,5,10,15,20, per cent by weight
-Boron - 0,1,5,10,50 ppm
-pH - 2,3,4,6,8 for Colorado and 3,4,5,6,8 for white spruce.
**Germination as average % for 2 replications of 100 pollen grains.
†Growth of pollen tube in microns.

reduced by higher pH levels. Germination of white spruce pollen was only 8% at a pH of 8.0, whereas that for Colorado spruce was 39% indicating greater tolerance of Colorado spruce to highly alkaline conditions.

The pH of the female flowers of Colorado and white spruce mascerated in distilled water was 3.5 and 4.6 respectively. The pH of the pollens in solution was found to change and become constant at about 6.5, irrespective of the initial pH of the original solution (Table 8). It is apparent that although

TABLE 8. Changes of pH for Solutions with Pollen of Colorado and White Spruce.

Pollen types	original* pH	pH recorded after			
		10 min.	2 hrs.	6 hrs.	24 hrs.
Colorado Spruce	8.0	7.00	6.00	6.05	6.50
	5.0	5.51	5.45	5.80	6.30
	3.0	3.40	4.75	5.60	6.20
White Spruce	8.0	6.70	6.02	6.25	6.70
	5.0	5.70	5.72	6.00	6.60
	3.0	3.40	4.90	5.70	6.20

*pH adjusted with Hydrochloric acid or Sodium hydroxide.

the pH of the germination media for pollen will change, the initial pH is important to effect good germination as illustrated in Table 7. Buffer solutions were tried to overcome this phenomenon, however the pollen failed to germinate on any of the buffers tested.

Cross- and self-compatibility determinations were continued in 1963 for 'blue' selections of Colorado spruce (*Picea pungens* Engelm) with the objective of mass production of 'blue' seedlings. Scarcity of male and female bloom for Colorado spruce prevailed in 1963, evidently due to unusual climatic conditions or the abundant seed-crop of 1962. This situation seriously limited the breeding program for 1963 and necessitated the use of stored 1962 pollen from one 'blue' and one 'green' selection. Viability of the stored 1962 pollen from these two 'testers' varied as to the type of storage. Pollen stored at 0°F in sealed jars manifested germination of 85.5% on water-agar in 1963, whereas that stored in open jars gave 71.6% germination. On the other hand, pollen stored at 41°F in sealed containers germinated 46.1% and in open jars 0%. Controlled pollinations as conducted for 16 'blue' selections of Colorado spruce have been summarized in Table 9. Extremely low seed sets were general for Colorado spruce in 1963

TABLE 9. Open-, Self-, and Cross-Compatibility* of Sixteen Colorado Spruce Selections.

Selections ♀	Pollens ♂ and Seed Set*			
	Open (NO)	Self (NO)	XNC4-16† (NO)	XRC-1† (NO)
NC2-135	2.2	22.0	-	24.9
NC4-110	0.0	-	184.0	24.0
NC4-5	-	-	-	21.2
NC2-142	18.2	-	18.4	16.9
NC7-3	1.3	-	25.0	15.0
NC7-2	0.0	0.0	-	6.8
NC2-141	10.0	7.7	44.9	6.5
NC5-112	0.0	-	-	3.9
NC4-122	0 0	0.0	-	0.0
NC4-60	0.0	0.0	-	0.0
NC4-96	0.0	0.0	0.0	-
NC4-121	-	0.0	-	0.0
NC7-1	0.0	-	-	0.0
NC4-125	0.0	-	-	0.0
NC4-126	0.0	-	-	0.0
NC5-15	0.0	0.0	-	0.0

*Compatibility expressed as number of seeds per cone harvested. - Not pollinated due to scarcity of stored† or fresh pollen.

even for natural open-pollinations, and also following artificial self- and cross-pollinations. Nevertheless, the results in Table 8 demonstrate that hybrid seed was obtained from both crosses on four trees for subsequent genetical analysis. Only one of the new selections appears to be both self-incompatible and cross-compatible; as required for mass production of the hybrid seed.

Seed from 67 self-, cross-and open-pollinations of the 1962 breeding, was sown in a seedbed in 1963. Severe damping-off losses (78.9%) occurred in some rows despite two fungicidal drenches of Captan. Survival in August of this sowing was only 35% (2937 seedlings).

Hybrid seedlings from 24 Colorado spruce selections were transplanted in 1963 from the seedbed to the transplant plots. This material will be field planted in 1965 to evaluate vigour and 'blue' color characters for the various hybrid combinations and for future seed production.

ELM BREEDING

The Siberian elm (Ulmus pumila L.) has demonstrated a resistance to drought and rapid growth as plantings in the drier regions of the prairies. Regretably it is very susceptible to damage from 2,4-D, and as a seedling manifests an indeterminate type of growth in the nursery row.

Inbreeding studies were initiated in 1961, when 22 selections of the Siberian elm were self-pollinated. Seven of the 22 selections appeared self-incompatible, whereas the remainder produced from 0.5 to 43.1% sound seed per isolated branch. The respective set of sound seed per branch on open-pollination varied from 0 to 99%. These results suggest that some degree of self-incompatibility may exist within the species. Germination capacity of the open-pollination seed was 70.9%, and that of the inbred seed was 62.2%. Fifteen of the resulting inbred progenies were field planted in 1963 to evaluate the genotypes of the original selections. Segregation within these inbred progenies may permit selection of earlier defoliating lines which would be valuable to facilitate harvesting of nursery seedlings.

Maturity, storage and viability of elm seed were investigated from 1959 to 1962. Seed of Siberian elm (*Ulmus pumila* L.) are dispersed by wind if matured on the tree, and the viability deteriorates rapidly during storage. An index of seed maturity was required to identify the time of harvest and optimum storage conditions necessary to retain seed viability for two or more years to replace failures due to spring frosts. Seed was harvested from several trees at consecutive intervals in 1959, 1961 and 1962. Moisture content and germination capacity of the seed was determined at time of harvest. Seed samples from the last date of harvest in 1959 were stored for two years at 65°F and 0°F in cotton and polyethylene bags. Seed samples from the last harvest in 1961 were adjusted to 5 and 15% moisture content and stored for one year in polyethylene bags at 65°F, 41°F and 0°F. From the moisture content and germination data it was evident that viability of elm seed increases with ripening and the seed attains full maturity at 30 to 40% moisture content. Thus moisture content can be used as an index of maturity for Siberian elm seed, which should be harvested at a moisture content of 40% or less. Moisture content of stored elm seed and temperature for storage are critical for the maintenance of viability. Studies to date suggest a moisture content of 5% and temperature of 0°F provide excellent conditions for the storage of elm seed. Polyethylene bags proved efficient containers for the storage of elm seed.

POPLAR BREEDING

Poplar breeding was continued in the greenhouse in 1963. Pollen from Northwest, Saskatchewan and Tristis poplar clones was applied to a selection of *P. deltoides* (44-52) whereas pollen of Tristis and Saskatchewan clones was applied to the BNW-4 clone. Seedset was good on 44-52 with all pollens, whereas only a few seeds set on BNW-4. The resulting hybrid seedlings were planted in 1964 to determine vigour, rooting ability, growth habit, disease resistance and suitability for future shelterbelt plantings. Six hundred hybrid seedlings, which resulted from hybridization of four poplar clones in 1962, were also field planted in 1963.

TABLE 10. Source, Survival and Height of 5-year-old Scots Pine Seedlings in 1960 Test.

Accession		Source of Seedlings		Survival	Height (cm)	
NO.	Code	1957 seed from	(long-lat)	%	1961	1962
E142	S.2345	Prov. of Orel, Russia	(37°-53°)	82.6	32.5	63.0
E143	S.2346	Prov. of Woronesh, Russia	(39°-52°)	64.9	28.3	58.8
E138	S.2341	Kiev, Russia	(30°-50°)	78.6	28.7	56.5
E145	S.2348	Prov. of Molotow, Siberia	(57°-58°)	54.0	26.1	49.0
E140	S.2343	Smolensk, Russia	(32°-54°)	80.1	23.0	48.4
E139	S.2342	Smolensk, Russia	(32°-54°)	74.3	24.4	47.8
E141	S.2344	Prov. of Kaluga, Russia	(36°-54°)	62.8	21.5	45.9
E147	S.2361	Prov. of Chkalov, Russia	(52°-53°)	34.2	21.7	43.4
E144	S.2347	Beloneskig, Bashkiria, Russia	(51°-55°)	46.2	19.7	40.1
E146	S.2349	Tobolsk, Siberia	(65°-51°)	28.0	18.9	36.8
E137	S.2287	Niska, Finland	(26°-64°)	57.1	10.6	22.4
	Mean			60.2	23.2	46.6

COOPERATIVE CONIFER PROVENANCE TESTS

A provenance test of Scots pine was planted in 1960 as a co-operative study with Mr. Mark Holst of the Department of Forestry of Canada, Petawawa, Ontario. The material was received in the spring of 1960 as 3-0 plants. Two types of planting designs, 20 replications of single plants and three replications of 50 plants, were followed, with plants spaced at four feet in rows ten feet apart. Survival and growth records have been summarized in Table 10. Survival of seedlings was generally associated with longitude of the original seed source, whereas height of growth tends to be associated with latitude of source. Plants from seed of Orel, Russia, displayed outstanding survival and vigour, while those from Finnish seed the lowest vigour. Subsequent performance data for ten to twenty years are required to complete this study.

Another provenance test for Scots pine, which was planted in 1962, constitutes a co-operative test with Dr. P.E. Slabaugh (U.S.D.A. Forest Service). Plants from 31 Russian seed sources were originally received and planted in 1961, but this planting was essentially a failure due to the extreme drought. Hence the provenance was re-planted in 1962, as 25 replications of single plant plots at 12-foot spacings in rows 18 feet apart. Survival of the 1962 plantings was 92% in 1963.

A Norway spruce test involving 600 seedlings each of 13 Norway spruce provenances from M. Holst, was planted under irrigation in 1960 with only 1.9% survival to date. These results demonstrated that even Russian, Swedish, Siberian and Polish strains of Norway spruce rarely survive the extremes of a mild winter (1960-61) and drought (1961) in the prairies.

Nineteen provenances of white spruce from H. Nienstadt of the U.S. Forest Service were transplanted under irrigation in 1960 with an average survival of 17% to date. This material was severely damaged by mild winter and extreme drought. Some provenances from Quebec, Ontario and New York evidently have greater tolerance to adverse climatic conditions than those of Saskatchewan and Manitoba, when propagated in the United States.

Seed orchards and seed production areas in Ontario

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PROVENANCE TESTS - RED PINE

Measurements of total height, after 10 growing seasons from seed, were made in the fall of 1963 at Swastika and Kenora Districts in northern and western Ontario. These are sections of Experiment 96 established for the Forest Research Branch, Department of Forestry, Canada, in 1958. Six Ontario, three U.S., two New Brunswick and one Quebec seed sources were included. The information was forwarded to M. Holst, Petawawa Forest Experiment Station, Department of Forestry, Canada, for comparison with other sections of the test.

No new provenance tests were established in the two year period. Routine removal of competing vegetation was carried out on a number of other Ontario provenance tests.

SEED ORCHARDS

Five seed orchard sites were selected and established in the past two-year period, as shown in Table 1.

It has been found that for white and red pine, grafts which are 3 years old have grown to a satisfactory size and can be successfully transplanted to the orchard site. The increased grafting target and survival in 1960 and 1961 resulted in the largest movement to date of grafted stock to the seed orchards: in the spring of 1964, a total of over 2100 white and red pine grafted trees.

In spring 1963 the first use was made of "Whalehide" pots for transporting and planting grafted stock. The trees are lifted at the nursery and placed immediately in the pots. Loading, transporting, unloading and spotting

TABLE 1. Establishment of seed orchards.

SPECIES	LOCATION	PLANTED			
		1963		1964	
		No. of Clones	Acres	No. of Clones	Acres
White Pine	Lindsay District Orono Nursery	X	2.3	X	0.9
White Pine	Parry Sound District Gurd Twp.	nil		20	3.5
Red Pine	Port Arthur District Fort William Nursery	nil		12	1.5
Red Pine	Parry Sound District Gurd Twp.	nil		22	2.0
Red Pine*	Swastika District Grenfell Twp.	25	3.8	47	2.0
Black Spruce	Parry Sound District Gurd Twp.	nil		nil	

* Previously established.

the trees in the planting pattern is facilitated and cost savings are realized. In the red pine seed orchard in Swastika District, a loss of only 2 trees out of 708 occurred in the first year when whale-hide pots were used. The cost of approximately 8¢ per pot is more than recovered in reduced handling and planting costs and improved survival. It was found that the pots were not deteriorating in the ground as rapidly as expected. The pots retain the soil around the roots in a compact condition during handling, but the material also acts as a barrier to water and nutrients in and out of the pot. As a result of the slow deterioration, for the 1964 plantings, each pot was slit from top to bottom at four places around the pot immediately prior to placing in the planting hole.

In spring 1964, 258 red pine grafted trees were available from four southern Ontario nurseries for the seed orchard at Fort William nursery. Costs of shipment by rail or truck transport in pots (av. 25 lbs. each) were obtained and considered to be prohibitive. The trees were therefore shipped loose in crates, "bare-root", wrapped in burlap with a good supply of moss. The planted trees have flushed well and are a good colour. No losses have occurred to date. Excellent survival appears possible using this method of shipment.

UNDERSTOCK FOR RED PINE

The program of production of material for seed orchards by the grafting of scions from selected plus trees commenced in 1954-55 at the Ontario Tree Seed Plant at Angus. Since that time both Scots pine and red pine have been used as understock for red pine scions.

The grafting of red pine commenced in 1960 at the Forest Station at Midhurst, where each year, except in 1961, the records have been kept separate as to rootstock. Table 2 provides information on the comparative survival on Scots pine and red pine rootstock.

The improved survival on Scots pine is evident. This becomes particularly important in the production of sufficient ramets, for instance the need for 20 ramets in a block pattern planting of 20 clones. It appears that survival on Scots pine after the third year, when most grafted stock can be moved to the orchard, is at least more than three times the survival on red pine. A scion collection program may have to be adjusted on the basis of rootstock to be used.

TABLE 2. Comparison of Survival on Scots Pine and Red Pine Rootstock

Year	No. of Grafts	No. of Clones	% Grafted		% Survival after year on Pr				% Survival after year on Ps			
			on Pr	on Ps	1	2	3	4	1	2	3	4
1960	422	17	40	60	23	16	11	11	46	40	39	38
1962	1036	23	39	61	45	29			80	63		
1963	925	29	41	59	76				87			

For any planned production of ramets, perhaps four times as many scions should be collected for grafting on red pine as would be required for Scots pine understock.

The indication of possible incompatibility between Scots pine and red pine after eight years grafted, was pointed out by M. Holst in his report to the 1962 meeting of this Committee. We now have grafts in the 1959 planting in the red pine seed orchard in Swastika District, the majority of which were grafted in 1955. After nine growing seasons there is no evidence through death, loss of vigour or discoloration which could be ascribed to incompatibility. The records do not indicate which trees in this planting have Scots pine understock. It is now difficult to distinguish Scots pine from red pine understock. This matter is being investigated in the hope that the rootstock species can be determined from bark characteristics. Then records would be kept of future death or loss of vigour which might be ascribed to incompatibility.

FACILITIES

A new plastic-covered greenhouse was completed at Angus in time for the 1963 grafting program. This is a two-level structure providing a cool, below ground level for the introduction of understock to break dormancy and for holding stock following grafting, and an upper, heated level where the temperature and humidity can be controlled as the scion growth develops.

A large number of flower buds were evident on the white spruce scions collected from northern Ontario in 1963-64. These are removed in the greenhouse as they develop. However, many of the scions have succumbed through lack of vegetative buds. Also the buds, in many cases, were found to be brown and rotting inside. The condition was noted on scions shipped to both Fort William and Angus, so that the "blight" could not definitely be ascribed to conditions during shipment or in storage. Most of the fungi isolated were considered secondary, the results were not conclusive and the possibility of climatic injury exists. Another small collection of scions from a few of the same trees has been taken in the field, to determine whether fungi are present to the same extent on forest trees and the possible effect of these on bud development.

This condition is not only serious because of reduced survival in grafting, but the presence of numerous diseased flower buds also indicates the importance of climatic or other injury to flower buds in a developing seed crop year.

SEED PRODUCTION AREAS

Eight seed production areas have been established in the past two year period (see Table 3).

TABLE 3. Establishment of seed production areas.

Species	Location	Site Region	Acres	Development
White & Red Pine	Sault Ste. Marie (Twp. 1A)	4E	10.0	Crop trees marked. Releasing 1964.
Red Pine	North Bay (Cook's Mills)	5E	7.0	Thinned 1963.
Red Pine	Parry Sound (Chisholm Twp.)	5E	8.0	Thinned 1964.
Red Pine	Sault Ste. Marie (Twp. 4D)	4E	8.8	Thinning 1964.
Red Pine	Port Arthur Fort William Nurs.	4W	4.9	Thinning 1964.
Red Pine	Swastika (Larder Lake)	3E	10.0	Crop trees released 1963.
White Spruce	Parry Sound (Gurd Twp.)	5E	8.0	Releasing 1964.
Black Spruce	Geraldton (Jean Lake)	3W	39.0	Strip-cut, scarified 1962-63

WHITE SPRUCE SEED PRODUCTION AREA - PAGWA - GERALDTON DISTRICT

In the fall of 1960 an area of 13 acres in three blocks was partially logged leaving marked seed trees. The blocks were scarified to promote natural regeneration. Table 4 shows the average seedling count per acre on mil-acre plots established on two of the blocks, for assessment purposes.

TABLE 4. Average seedling count on two blocks in white spruce seed production area, Pagwa.

	Seedlings per acre			
	July, 1961	June, 1962	October, 1962	May, 1963
Block II	48,800 (6 plots),	17,300 (6 plots)	22,200 (6 plots)	22,500 (6 plots)
Block III	53,900 (17 plots)	26,700 (10 plots)	18,200 (17 plots)	17,200 (17 plots)

The number of seedlings present will permit ample opportunity for selection of seedlings of superior growth rate and form. Within the next few years the number of seedlings will be reduced to form a sampling stand of about 1,000 trees per acre.

Physiology of flowering and cone production in Douglas fir, 1962-64

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Sugar, starch and hemicellulose analyses have been completed for twig tissues from cone-bearing, girdled Douglas fir and from non-cone-bearing, control stems of double-trunked trees. Further compilation and analysis of the data is required before conclusions can be obtained. Douglas fir seedlings ranging from germinants to the 2-0 development stage were collected at bi-weekly intervals, dissected and freeze-dried. The material will be used to investigate the seasonal carbohydrate economies of the various tissues, including roots. Growth and development data have indicated that there is no period of root dormancy, even under conditions of frozen surface soil.

Cone induction responses from previous fertilization trials appeared to run out in the fourth year after the final fertilization. A 20-year-old stand in the vicinity of Victoria, B.C. has been developed for new cone-inducing experiments. Biochemical changes accompanying floral induction responses to various nitrogen fertilizer treatments will be studied. Consideration will be given to effect of rates of application, the effect of nitrate vs. ammonia formulations, various re-treatment schedules and dates of application, all shown to be important factors influencing responses in previous work.

Two of six Douglas fir clones established by grafting in 1959 have flowered extensively for the past three years. Some individuals have flowered in successive seasons. These clones represent reliable, cone-producing, parent trees. A third clone from a non-cone-producing parent has produced cones for two seasons. Ramets from two reliable and one barren parent have not yet flowered. A distinct environmental response is evident in that cone production has been confined to material planted or held outside in pots, while no flowering has yet occurred in greenhouse material. A reciprocal transfer experiment with potted material under two levels of soil moisture supply is presently being conducted. Investigations of temperature effects are planned when growth chambers become available. Further spring air-layering trials are underway to determine whether the time required for rooting can be reduced to a single season.

Brief report on forest tree breeding

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The following publication was issued: "Introgressive hybridization in red spruce and black spruce" by E.K. Morgenstern and J.L. Farrar with a foreword by M. J. Holst. University of Toronto, Faculty of Forestry Technical Report No. 4, 46 p.

The study indicated that *Picea rubens* sarg. and *P. mariana* (Mill.) B.S.P. are two distinct species, in which introgressive hybridization has occurred since Pleistocene glaciations.

Hard pine breeding at the Southern Research Station, Maple, Ontario, 1962 and 1963

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The objectives of the hard pine breeding program continue to be 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. Red pine, Pinus resinosa Ait., continued to receive most of the program's attention in 1962 and 1963. During this period, the studies of the effects of inbreeding in red pine were largely completed.

Efforts have recently been intensified to produce a rapid growing, southern pine hybrid that can be grown in southern Ontario. Northern sources of pitch pine, P. rigida Mill., are crossed with southern pines and the resulting hybrids tested under southern Ontario conditions.

Effects of inbreeding in red pine

Inbreeding was used as a technique to determine the quantity and quality of genetic variation in red pine. Self-, cross- and interracial pollinations were made on over 50 trees, representing a large part of the species range in the U.S. and Canada (See Fowler 1960-61 Biennial Report). The effects of inbreeding were examined on conelet, cone, seed, seed germination and seedling characters. Similar but less extensive studies were carried out with jack pine (P. banksiana Lamb.) and white pine (P. strobus L.). Provenance test materials were used to study variation in leaf, conelet, cone seed, seed germination and seedling characters of red pine.

It was concluded that red pine is genetically quite uniform. The species is self-fertile, self-compatible and seedlings resulting from self-fertilization are normal. On the other hand, jack pine and white pine were found to be heterozygous in respect to many alleles, partially self-fertile, partially self-compatible, and seedlings resulting from self-fertilization often exhibit depressed growth.

Several factors which might affect natural self-fertilization were examined. It was found that phenology of flowering, parthenogenesis, and selective fertilization were of little importance, while the presence of a high proportion of functional (although not genetic) male trees and the position of male and female strobili in the tree crown affect the amount of natural selfing. Marker genes were used to estimate the pattern of self- and cross-fertilization within individual trees. It was found that approximately twice as much self-fertilization occurred in the lower part of the tree crown as in the upper part. The results of the inbreeding studies are presently being prepared for publication.

Estimates of natural selfing in jack pine

Natural selfing was studied in three jack pine trees with the aid of "marker genes". These trees were of unknown origin and located in a single row at the Southern Research Station. It was estimated that, on the average 20% of the seeds produced by these trees had been self-fertilized. It was also estimated that twice as much selfing occurred in the lower half of the tree crown as in the upper half. A paper resulting from this study is being prepared.

Acquisitions

The following new clones and populations were acquired in 1962 and 1963:

Species	Origin	No. Clones	No. Populations
P. resinosa	Kapuskasing & Vivian, Ont.		2
P. silvestris	Ukraine		1
P. silvestris	Finland	3	
P. Hwangshanensis	S.R.S.		1
P. Mugo (erect form)	Switzerland	6	
P. nigra cebennensis	Turkey Point selections	37	
" "	University of Washington	1	
P. nigra poiretiana	Turkey Point selections	4	

Species	Origin	No. Clones	No. Populations
P. nigra austriaca	Turkey Point selections	5	
P. rigida	New York	14	
"	S.R.S. selections	5	
"	Midhurst, Ont. selections	6	
"	Korea		1
P. rigida x elliottii	"		1
P. rigida x radiata	"		1
P. rigida x echinata	Pennsylvania	4	1
P. banksiana	S.R.S. selections	5	

Hybridization

With the possible exception of Pinus nigra var cebennensis (and some other P. nigra varieties), most of the species tested for shoot moth resistance would appear to be of little direct use value for reforestation in southern Ontario. In an effort to produce genetically variable material, from which to select shoot moth resistant individuals, several hybrid crosses were attempted in 1962. The following pollinations yielded seeds and seedlings in 1963:

Cross	Number Crosses Made	Number of Seeds	Number of Full Seeds	Number of Seedlings (in Green-house - Fall, 1963)
P. densiflora x silvestris	2	1100	2	2
P. hwangshanensis x silvestris	1	157	11	11
P. (densiflora x austriaca) x mugo	1	85	12	12
P. (densiflora x austriaca) x (silvestris x mugo)	1	142	70	69
P. nigra x (austriaca x densiflora)	3	-	467	434
P. (silvestris x mugo) x silvestris	1	38	29	28
P. (densiflora x silvestris)x(sil-vestris x mugo)	1	510	56	56
P. (densiflora x austriaca) x wind	1	-	257	242
P. (austriaca x densiflora) x wind	1	-	260	253

In 1963 an intensive effort was made to produce interspecific hybrids between Pinus resinosa 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.

The following hard pine pollinations were made in 1963:

Cross	No. Trees	No. strobili Pollinated
P. resinosa x resinosa (all combinations)	4	150
P. resinosa x leucodermis + 5% resinosa	3	105
P. resinosa x thunbergii + 5% resinosa	3	109
P. resinosa x (austriaca x densiflora + 5% resinosa	3	106
P. resinosa x (densiflora x austriaca) + 5% resinosa	3	74
P. resinosa x (densiflora x silvestris) + 5% resinosa	4	121
P. resinosa x (silvestris x mugo) + 5% resinosa	4	126
P. densiflora x resinosa + 5% densiflora	1	221
P. hwangshanensis x resinosa + 5% densiflora	2	101
P. nigra x resinosa + 5% nigra	2	54
P. silvestris x resinosa + 5% silvestris	6	267
P. tabulaeformis x resinosa + 5% densiflora	2	158
P. (austriaca x densiflora) x resinosa + 5% densiflora	1	104
P. (austriaca x densiflora) x resinosa + 5% nigra	1	95
P. (densiflora x austriaca) x resinosa + 5% densiflora	1	92
P. (densiflora x austriaca) x resinosa + 5% nigra	1	113
P. (densiflora x silvestris) x resinosa + 5% silvestris	1	52
P. (silvestris x mugo) x resinosa + 5% silvestris	15	860
P. nigra x leucodermis	2	51
P. nigra x thunbergii	1	28
P. rigida x pungens	2	35
P. rigida x pinaster	3	39
P. pungens x pinaster	1	41
P. tabulaeformis x pungens	1	28
<u>Pinus silvestris</u>		
early flowering x early flowering (same population)	16	232
early flowering x late flowering	18	230
early flowering x early flowering (different populations)	23	226
P. montana uncinata x montana uncinata	14	53
P. montana uncinata x mugo	14	57

Turkey Point planting area

The following seedling populations were planted at Turkey Point, Ontario in 1962 and 1963:

Species	No. Populations	No. Plants	Purpose
P. nigra	14	152	Provenance test
P. nigra	1	2,916	Observation
P. ponderosa	5	1,179	Provenance & Observation
P. resinosa	16	800	Provenance
P. resinosa	1	17	Observation
P. silvestris	3	868	"
P. thunbergii	1	1,099	"
P. silvestris x mugo	1	112	"
P. densiflora x nigra calabrica	1	1,671	"
(P. nigra x densiflora) x wind	1	233	"
P. rigida x taeda	1	43	"

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Respiration, growth substances, histochemistry, nitrogen metabolism and growth of white (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) BSP)

Advances in Tree Physiology Research at the
Petawawa Forest Experiment Station, Chalk River, Ontario, 1962-1963

D.A. Fraser,
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Department of Forestry, Canada.

The tree physiology program concentrated on seasonal changes in respiration of shoot tips, growth substances, free amino acids and total vegetative and reproductive growth of white and black spruce growing under various experimental treatments. The Ph.D. thesis of W.H. Vanden Born on the histochemistry of shoot tips of white spruce was published, and the Ph.D. investigations by D.J. Durzan on nitrogen metabolism, in cooperation with Prof. F.C. Steward of Cornell University, was completed in May, 1964. A new Ph.D. study by J. Balatinecz on auxin metabolism, in cooperation with Prof. J. Farrar of the Faculty of Forestry, University of Toronto, was commenced in May, 1964. A National Research Council Post-doctorate Fellow, Dr. V. Chalupa, will commence his work at the Petawawa Forest Experiment Station, in October, 1964.

The oxygen uptake of shoot tips from a 20-metre high, open-grown white spruce tree was reduced in late summer and reached the low winter level in late November. This low level was maintained until April, when the gradual vernal increase began. A mid-June maximum oxygen uptake was followed again by a progressive decline as the season proceeded. This general trend was followed in all material with some modifications: in the black spruce tree grown in a semi-closed stand, maximum respiration of the upper shoot tips preceded by a few weeks that at the lower levels; continuous light stimulated leader growth and induced a longer period of maximum oxygen uptake in early summer. Moisture content reckoned as a percentage of the dry weight of the terminal shoots, was correlated with their oxygen uptake and could be used as an index of respiration rate except in root-pruned saplings where a single maximum peak occurred rather than a month-long period of high moisture content.

A growth promoting substance (assayed by the straight-growth Avena coleoptile test) tentatively identified as b-indole acetic acid, showed seasonal fluctuations in various parts of the white spruce trees. It decreased in activity into late summer in shoot tips and needles of trees growing under natural photoperiod but remained high in those trees where apical growth was prolonged by artificial illumination during the "night" period, of June-August. Although the growth promoting substance disappeared in the buds of mid-winter, it was still present in the needles at that time. A growth inhibiting substance appeared in the buds of mid-winter and continued to be present although in somewhat lesser amounts, in early summer when apical growth occurred. It was apparent that the Avena coleoptile tests do not necessarily portray the best interpretation of the growth regulating substances extracted from spruce tissues and new techniques using spruce pollen, seed germination rates, and tissue culture are being utilized.

The relationship between morphological and metabolic or enzymic differentiation in shoot tips of white spruce has been investigated by histochemical methods revealing the distribution of several enzymes and other cellular constituents in tissues of the shoot tip at different times during the growing season. Most of the enzymes studied showed well-defined distribution patterns which varied with the stage of development of the shoot tip. Less seasonal variation was observed in the distribution of the other substances included. Activity of cytochrome oxidase and succinic dehydrogenase was high in the shoot apex during the flush of growth in the spring, indicating a high level of respiratory activity in that region, consistent with the rapid growth of the shoot. Peroxidase activity was associated particularly with meristematic or potentially meristematic tissue regions. The evidence substantiates the view that mitotic activity is greatest on the flanks of the apex and supports the existence of a quiescent center with relatively low activity in the apical mother cell zone, classically the origin of the primary stem tissues. High phosphatase activity was observed in the crown region and at the bases of needle and cone scale primordia. Young cones in fall or spring exhibited enzyme distribution patterns distinctly different from those in vegetative shoot tips. No evidence was obtained to indicate what enzymes might be particularly involved in the differentiation of reproductive buds, but the results provide a basis for a further critical investigation of this differentiation by histochemical means.

The free arginine-N as a percentage of total soluble-N increases in all parts of the shoot (buds, stem, foliage) during its active growth. When apical growth ceases, arginine-N is greater than can be accounted for as proline. In winter, shoots are characterized by a low content of soluble-N which is rich in proline. In the spring, a flush of arginine-rich soluble-N occurs, and the percentage of proline declines. These seasonal trends have been correlated with data which show the mean monthly temperature. Late in the season, when shoot growth normally subsides, renewed growth may be stimulated by supplemental artificial light. Under the additional illumination the percentage of arginine in the soluble-N tends to be maintained at a time of the year when it would normally be on the decline. When the supplemental light is removed and the light-induced growth stops, the shoots return toward winter dormancy and their free-arginine-N declines and proline-N increases in the normal way. If C^{14} is applied to the shoot apex late in the season, when proline-N accumulates, some C^{14} definitely passes to proline. However, C^{14} also passes to Sakaguchi-positive guanido compounds, to glutamic acid and generally into the insoluble-N (protein) fraction. Whereas others have invoked a Krebs-Hanseleit cycle in conifers, and have even implicated it, in the control of dormancy, this study did not reveal evidence which demanded this conclusion.

Apical and radial growth in trunk and branches, and needle distribution were studied in a white spruce tree 11 metres high and 36 years old. Growth was summarized according to (1) years of formation (Oblique Summation), (2) transversely by trunk internodes (Horizontal Summation) and (3) position of the annual rings and branch internodes (and needles) relative to the pith or trunk respectively (Vertical Summation). In this study summations 1 and 3 were considered to reflect internal (nutritional and hormonal) controls of growth, whereas summation 2 represented the effect of environmental factors including periodicity of flower and seed formation. The tree studied possessed 5¼ million needles when sampled in 1961, two-fifths of which were formed during the last 2 years of growth. The percentage of ash in the needles varied from 4 in the new needles to almost 8% in those 10 years old. The productive capacity of one "average" needle in terms of apical growth, trunk wood, and new needle formation was estimated.

Apical growth of the leader and lateral branches as well as radial increment at the top and bottom of the trunk were studied in two black spruce trees during 1960-1962, along with the developmental anatomy of the buds from adjacent trees for the period 1955-1962. Time of initiation of apical growth varied from the third week of May in 1960 and 1962 to early June in 1961. Termination of apical growth extended from early July in the lower branches until about two weeks later in the upper branches and leader. Reproductive buds could be recognized by early August, but the formation of bracts and ovuliferous scales, or pollen sacs did not occur until several weeks later. The male cones differentiated about one week before the female ones. The consistent production of flower buds in black spruce compared with their sporadic formation in white spruce is partly attributed to the difference in time of initiation of apical growth in black spruce; there the development of buds occurs about two weeks later, usually during a warmer part of the summer when conditions are considered more conducive to reproductive growth.

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Study of individual tree variation of Douglas fir

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The objective is to explore the intraspecific variation of Douglas fir and to determine whether these characteristics are inherited or controlled by environments.

A total of 155 open-grown young Douglas fir trees were selected at the University Research Forest in 1956. Age, height, d.b.h., crown length and width and growth rate were described. Phenological observations on radial and vertical growth, flowering characteristics, cone production were observed from 1956 every year.

Controlled crosses were attempted by O. Sziklai in 1962 and in 1964 to determine how the different characteristics are inherited. These trees also are being studied by A. Kozak to determine factors governing the incidence of attack by cone and seed insects.

Studies of Douglas fir provenances, with special reference to British Columbia

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The objective is to supplement studies under way in coastal Douglas fir provenances, by the Oregon Forest Lands Research Center. Thirteen provenances were included, mostly from the Interior regions of the Province. The seedlings were observed in the first two years in the nursery bed. Seedlings were transplanted to the University Research Forest in the spring of 1961. Phenological observation and growth characteristics were recorded from 1962. Further observations on phenology and growth characteristics are continuing.

Report to Committee on Forest Tree Breeding in Canada

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Victoria, B.C.

Selection of plus trees for use in the Douglas fir breeding program

There is still strong emphasis on the selection of superior phenotypes throughout the coastal range of Douglas fir. Selection is being concentrated in areas for which seed orchards are being planned but at the same time an effort is being made to sample as widely as possible over the entire species range on the coast. All the selected trees are being propagated in clone banks and material for future breeding studies is being assembled. The Plus Tree Register now contains two hundred and fifty-eight selected phenotypes in addition to individuals retained as "special trees". First priority had been placed by the B.C. Forest Service on a seed orchard to produce seed for reforestation at higher elevations on Vancouver Island, and so cruising for plus trees has been largely concentrated in this region. However, the clones for this orchard have been selected and increasing emphasis will now be placed on obtaining trees from higher elevation areas on the mainland. Selection methods still entail a one hundred percent visual cruise of selected stands of immature Douglas fir. A three-man crew is involved in this work throughout the summer months.

The Tree Improvement Sub-committee of the Tree Farm Forestry Committee, which has now replaced the Plus Tree Board as the cooperative body in this field, is still active. Plus Tree Week, the instructional joint cruise in which industrial and Forest Service foresters combine for plus tree selection has become an annual event. Clone banks are being established by seven companies and seed orchards have already been initiated by four of these. Some independent cruising by companies continues. A field trip to visit work of particular interest to the group is arranged annually.

The establishment of the first B.C. Forest Service seed orchard

The first B.C. Forest Service Douglas fir seed orchard is being established at Campbell River. In all, twenty-six acres have been cleared and fenced. Rootstock has been established as areas have become available and this spring planting was completed. Forty-two clones are being used in the orchard, as it is felt that comparatively large clonal numbers are essential at this stage of the program when so little is known about the genotypic qualities of the selected trees. Selection of the clones has been based on some quantitative and qualitative phenotypic characteristics and a distribution over the provenance zone in which the seed will be used. This orchard is intended to produce seed for use in reforestation projects at elevations above fifteen hundred feet on Vancouver Island. Some trees from outside Vancouver Island have been included as the limits of provenance zones are still uncertain and seed from this first orchard may have to be used for projects outside these limits until more suitable seed becomes available. Propagation was started in 1963 and will continue as rootstock become suitably established. By May 1964 over fifteen hundred grafts had been made.

The study of anatomical characteristics of the wood of selected trees

The project in which the Forest Products Research Laboratory and the B.C. Forest Service were cooperating to determine some of the internal characteristics of the selected trees has now been terminated. The final report is in draft form and will be published in due course. For the last two years work on this topic has been coordinated by the Tree Improvement Sub-committee. Five millimetre cores have been collected by members of the sub-committee and analysis of specific gravity and a wood production factor have been made by a technician employed by the Pulp and Paper Research Institute of Canada. He has been working under the direction of Dr. Wilson of the Faculty of Forestry at University of British Columbia. Analysis has been carried out on some three hundred cores and a report will be forthcoming.

Provenance research in Douglas fir by the B.C. Forest Service

The B.C. Forest Service is at present cooperating in the Pacific Northwest Douglas fir provenance study which was originated by the Oregon Forest Research Centre at Corvallis and is being coordinated by Dr. Kin Ching. All information and reports on the project, which involves plantations of Douglas fir from sixteen localities in Oregon, Washington and B.C. will be published by the Oregon Forest Research Centre. There are five test sites in British Columbia and a report has been written summarising some of the information on the project at these sites up to the end of 1961. The Forest Service test plantations are located in the Robertson Valley, near Cowichan Lake and have suffered from exceptionally severe frost damage. Two of the four replications have had to be abandoned but although the remaining two have also been severely damaged they will be retained, since they are slowly becoming established.

Provenance research in Douglas fir is now being handled by R.L. Schmidt of the Research Division, and plans have been made for an intensive study in the immediate future.

Selection in species, other than Douglas fir

As yet, although there is an increasing demand for intensive selection and breeding work to be started in species other than Douglas fir on the coast, only a few western hemlock have been selected and propagated. No cruising has been carried out with the intention of finding plus trees of this species, but some trees with interesting characteristics have been met in the course of the Douglas fir selection program and have been retained.

Grafting methods for Douglas fir

Although the present grafting methods being used for Douglas fir are comparatively successful, it is felt that a study into these and particularly an investigation into the causes of failure in some unions, would be well worthwhile. Although clones showing the extremes of delayed-graft incompatibility which have been found in other places, have not yet appeared in the Forest Service clone banks, several undesirable characteristics and failures are already present. Overgrowth of the scion over the rootstock is increasing and some clones are clearly harder to propagate than others. Material and records are being collected and it is hoped that with the help of anatomical studies some information will be obtained on the causes and means of reducing graft failures.

PUBLICATION

Heaman, J.C. Tree Improvement. For. Chron. 1963, Vol. 39, No. 2.

Summary report on forest tree breeding 1962 and 1963

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Breeding work with white pine, aspen poplars and hard pines was continued. Work with chestnut and white cedar was reduced to a maintenance basis in 1961 and 1963 respectively.

WHITE PINE

Resistance to blister rust and weevil, and satisfactory growth form and growth rate are the main objectives in breeding. At present, the active use of breeding materials and testing of their progenies in respect to resistance to blister rust is the most important phase. Work with resistance to weevil attack is beginning to show promising results and is increasing in importance.

Acquisitions

The following materials were acquired in the form of scions:

Species and origin	Clones	Successful grafts
strobus, England	4	38
strobus, Wisconsin	3	45
strobus, British Columbia	27	484
strobus, Ohio	10	98
strobus, Midhurst, Ont.	31	323
strobus, Seattle, Wash.	1	2
strobus, Heron Bay, Ont.	1	29
monticola, Naples, N.Y.	6	39
peuce, England	1	15
peuce, Finland	8	40
peuce, Cloquet, Minn.	1	2
peuce, Seattle, Wash.	1	16
griffithii, Michigan	13	251
griffithii, Seattle, Wash.	1	7
griffithii, Annapolis, Md.	1	25
koraiensis, Turkey Point, Ont.	1	20
koraiensis, Cloquet, Minn.	2	22
cembra, Duluth, Minn.	1	21
lambertiana x koraiensis, Placerville, Calif.	1	14

Species and origin	Clones	Successful grafts
monticola x strobus, Seattle, Wash.	1	11
monticola x ayacahuite, Seattle, Wash.	1	16
	116	1518
pumila, Poland - one population		3

The following populations were obtained in the form of seeds:

strobus, Moose Lake, Manitoba
strobus, Laurie Lake, Valcartier F.E.S., Quebec
strobus, Cains River, Sunbury County, N.B.
strobus, Hayward, Sawyer County, Wis.
strobus, Connaught Ranges, Ont. open-pollinated
" Chicoutimi, P.Q.
" New Jersey, N.B.
" Camp Gagetown, N.B.
" Prince Edward Island
" Rackeve, Hungary
griffithii, Rackeve, Hungary
" Annapolis, Md., 2 populations
" Solomons Island, Md.
monticola, Nakusp, B.C.
" Rackeve, Hungary
peuce, Rackeve, Hungary
koraiensis, Orono, Ont., 2 populations

The greater proportion of these seeds has been sown at the Provincial Forest Nursery Station, St. Williams, Ont. to produce seedlings for future screening for resistance to blister rust, prior to selection for other important characteristics.

Selection

The following materials, found resistant to blister rust, were selected for further propagation and testing:

origin	number
strobus, first generation seedlings	53
monticola, " " "	1
strobus x peuce	2
peuce x strobus	2
peuce x (flexilis x griffithii)	2
strobus x (flexilis x griffithii)	1
strobus x peuce, precocious	2
parviflora x griffithii	1
cembra x armandi	1
griffithii	1
strobus, second generation seedlings (from resistant parents)	32
monticola " " " " " "	1
	99

Hybridization

Two of 38 wide interspecific crosses made in 1961 yielded full seeds and seedlings of P. koraiensis x albicaulis. Their hybridity has not been ascertained, as yet.

The following crosses were made in 1962:

Parentage	crosses	bags	1964 seedling populations
strobus (resistant) x (peuce x strobus)	6	17	2
strobus (resistant) x monticola (resistant)	9	29	
(strobus x peuce) x (peuce x strobus)	1	7	1
peuce x strobus (resistant)	29	133	12
peuce x (peuce x strobus)	3	11	
peuce x peuce (susceptible)	3	12	
(peuce x strobus) x (peuce x strobus)	2	16	2
monticola (resistant) x monticola (resistant)	4	22	1
griffithii x monticola (resistant)	2	10	
(griffithii x strobus) x (griffithii x strobus)	10	27	6
(griffithii x strobus) x lambertiana	1	6	
(griffithii x strobus) x albicaulis	1	7	1
(griffithii x strobus) x strobus	1	6	1
(griffithii x strobus) x cembra	1	5	
parviflora x albicaulis	14	90	
parviflora x lambertiana	3	29	
armandi x lambertiana	1	10	
flexilis x cembra	1	9	
koraiensis x lambertiana	13	41	1
koraiensis x flexilis	4	16	
cembra x lambertiana	3	12	
	112	515	27

The following crosses were made in 1963:

Parentage	crosses	bags
strobus (resistant) x strobus (resistant)	62	183
strobus (resistant) x (strobus x monticola)	5	11
strobus (resistant) x (peuce x strobus)	5	7
(griffithii x strobus) x (griffithii x strobus)	12	18
(strobus x griffithii) x (griffithii x strobus)	2	14
(strobus x parviflora) x strobus (resistant)	1	5
griffithii x strobus (resistant)	2	11
(peuce x strobus) x (peuce x strobus)	4	28
(griffithii x strobus) x strobus (resistant)	3	7
	96	284

Blister rust

A new variety of black currants was obtained from Finland, as a possible additional source in the breeding of the alternate host for improved performance for our purposes and climatic conditions. A plantation of P. strobus was examined near Ekanas, Finland and 3 trees found to be free from blister rust under heavy natural infection conditions. Scions from these trees were subsequently incorporated into our collection of breeding materials. Additional P. peuce materials were examined at Arboretum Mustila in Finland, for scion and pollen collection in the future.

Weevil

A cooperative project with the Forest Insect Laboratory at Sault Ste. Marie in screening white pine materials for resistance to weevil attack was initiated in 1957. In 1947 a plantation of Scots pine was established within the Kirkwood Management Unit near Thessalon, Ont. and in 1957 a part of this plantation was top-grafted with various P. peuce and P. strobus materials initially selected as being heavily weeviled and free from weevil under conditions favourable to weeviling. The grafts have been inspected annually for weevil injury and a recent report by Dr. C.R. Sullivan presents an ample summary of the results obtained thus far.

In 1955 a plantation of white pine was established adjacent to the plantation of Scots pine used in the studies above. In 1961 the planted white pine were top-grafted with scions of various white pine materials previously screened for resistance to blister rust. The top-grafting was continued in 1962 and finished in 1963. Most of the grafts were successful and are growing vigorously.

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 aspen-like materials with good rooting ability from stem cuttings.

Acquisitions

The new acquisitions were as follows:

Species	Origin	Clones
alba	Germany	5
alba	Yugoslavia	1
canescens	Germany	1
trichocarpa	British Columbia	2
tremula	Norway	1
tremula	Yugoslavia	1
alba x tacamahacca	Japan	1
auramericana	Holland	1
tremula x tremuloides	Norway	4
		17

		Populations
alba	Yugoslavia	1
canescens	Yugoslavia	1
alba x grandidentata	Hungary	1
tremula	Norway	2
tremula x tremuloides	Norway	1
tremuloides	British Columbia	1
		7

Hybridization

The following successful crosses were effected:

Origin	Number of Crosses
alba x trichocarpa	1
alba x tremula erecta	2
alba x sieboldii	2
alba x maximowiczii	1
alba x tremula	1
alba x alba	4
grandidentata x alba	2
tremula x tremuloides	1
	14

Selection

The following clones were selected from populations under test:

Species	Clones
alba x adenopoda	5
alba x canescens	2
alba x (canescens x tremuloides)	2
alba x grandidentata	27
(alba x grandidentata) x canescens	8
alba x tremula	12
alba x tremuloides	32
(alba x tremuloides) x grandidentata	9
canescens	4
canescens x grandidentata	23
canescens x tremula	1
canescens x tremuloides	4
canescens x trichocarpa	2
davidiana	5
davidiana x nigra italica	4
davidiana x tremuloides	5
deltoides x grandidentata	1
grandidentata	1
grandidentata x adenopoda	4
grandidentata x alba	2
grandidentata x (alba x grandidentata)	2
grandidentata x glandulosa	5
grandidentata x tremula	12
(grandidentata x tremuloides) x grandidentata	1
hybrida x grandidentata	4
maximowiczii	5
sieboldii	1
tomentosa x tremuloides	5
tremula	42
tremula x alba	1
tremula x (alba x tremuloides)	2
tremula x canescens	6
tremula x grandidentata	3
tremula x petrowskyana	16
tremula x tremuloides	37
tremuloides	15
tremuloides x alba	2
tremuloides x (alba x grandidentata)	2
tremuloides x (alba x tremuloides)	2
tremuloides x davidiana	16
tremuloides x tremula	58
	390

Rooting ability tests

It has in recent years been possible to test poplar clones for rooting ability by planting cuttings in especially prepared rooting beds in the nursery in the fall. By following a planting plan which includes replication and randomization of the clones tested, a reasonably reliable indication of the total rooting ability of the tested materials is obtained. Total rooting ability in such tests constitutes not only root formation by the cuttings but also the ability to survive and to grow into an acceptable poplar plant during one growing season. The results vary with the original position, physiological age and size of the cuttings and with the weather during the year of testing.

To arrive at an estimate of the genetic component of such rooting ability, it has been necessary to repeat the tests of any given poplar clone for three years, and to use cuttings of comparable size and physiological age. The performance of the clones being tested is compared with that of standard clones with known rooting ability from former tests. Such standard clones also serve in the total evaluation of the growing conditions of any given year in relation to the over-all performance of the poplar materials tested in that year. This method has been found superior to the beaker tests used previously and to the greenhouse tests currently in use in Italy in that it evaluates the total performance of planted cuttings in terms of nursery stock production and thus more directly indicates propagability of the materials under test.

Seedling populations of aspen hybrids are screened for rooting ability by planting one cutting from the basal part of each seedling of acceptable size at the end of the second growing season. The seedlings are then at the 1-1 stage. The remaining stumps of such seedlings are used in evaluating the field performance of the populations in question in test plantations. The cuttings are bulk-planted at a rather close spacing in rooting beds and the number of acceptable plants in the following year is tallied in relation to the total number of cuttings originally set out in the beds. Cuttings are again made from all acceptable plants, as above, and the process is repeated for two years. During this period there is a steady increase in the proportion of cuttings yielding acceptable plants within populations containing good rooting ability.

In other populations there is a steady decrease in the total number of plants, until after three years of mass selection, there are either no plants left or the few remaining plants show rather poor rooting ability when tested individually. This is interpreted as being caused by insufficient rooting ability in such populations. After three years of mass selection in the above manner, the rooted cuttings are made into clones. This is the stage we have reached at present with some of our hybrid aspen populations. The best result obtained thus far with such materials is 91 percent rooting in a population. This means that there undoubtedly will be individuals with an average rooting ability below 91% as well as some with an average rooting ability of above 91%. These latter represent the result of over 20 years' breeding of aspen hybrids for good rooting ability from stem cuttings.

The successful production of aspen-like hybrids with good rooting ability from stem cuttings will lead to the increased use of the kind of crosses that yielded these hybrids, in the future. This will make possible the simple and rapid propagation of any promising individuals obtained and to produce new materials of this kind in sufficient numbers for further selection in respect to growth rate, growth form, wood quality, resistance to disease and site adaptation under field conditions in southern Ontario and eventually also further to the north. The possibility of rapid and simple clonal propagation will also make breeding for wood quality in aspen poplars more realistic and promising than it has been thus far.

Raising of seedlings

The raising of aspen seedlings has for many years been a very difficult and uncertain procedure. Damping-off and other seedling diseases have taken a heavy toll and often the results have been discouraging after considerable effort in producing hybrid seeds. Numerous references can be cited suggesting different improvements in the methods of raising aspen seedlings. Most of these have proven unsuitable to our growing conditions, although more careful attention to soil texture and acidity in the seed beds has gradually improved our results.

In 1963 it was found that much earlier seed sowing than usual, in carefully prepared seed beds outside, yielded results in terms of survival and growth that were far superior to any heretofore obtained. The seeds used for these sowings were in part harvested in the greenhouse from winter-crosses and in part collected outside in 1962 and stored over dry silica gel in a deepfreeze. This method will be repeated in future sowings and, if found consistently successful, will constitute a major breakthrough in our aspen breeding program.

Dieback

Heavy attacks by a fungus believed to be a Gnomonia species continues to be a serious problem in aspen breeding. Asiatic aspens and their hybrids seem to be particularly susceptible to attacks which ultimately cause dieback of branches and tops. In extreme cases older trees become stagheaded and are killed. New observations were made on the severity of attack and extent of damage in our entire poplar collection in the fall of 1963. Several P. alba x aspen hybrids show some individual variation in susceptibility depending on the reaction of their parents to attacks by this fungus, indicating at least some genetic background of possible resistance.

HARD PINES

See report by D.P. Fowler.

WHITE CEDAR

The production of improved types of this species and of western red cedar hybrids, hardy in southern Ontario, is the aim of this project. The survival of some western red cedar populations set out in a plantation was tallied. Several populations contained a relatively high proportion of plants winter-hardy in southern Ontario. In 1963 another small provenance test plantation of eastern white cedar was established. In other respects, this project is at present being continued on a maintenance basis, with periodic examinations and evaluation of provenance and other test materials.

CHESTNUT

The aim of this project is the production of hardy dwarf types, resistant to blight and suitable as dwarfing stock in a breeding program with timber-type chestnuts. In 1963 the larger plants in a testing area of native sweet chestnut, chinkapin and Chinese chestnut have been artificially inoculated with the chestnut blight fungus. The project is at present being continued largely on a maintenance basis.

PUBLICATIONS

Heimburger, C. 1962. Breeding for disease resistance in forest trees. The Forestry Chronicle 38(3): 356-362.

———————— 1963. The breeding of white pine for resistance to weevil. Presented to World Consultation of Forest Genetics and Tree Improvement, Stockholm, August 27, 1963. FAO/FORGEN 6b/5.

Forest tree breeding and genetics at the Petawawa Forest Experiment Station

Biennial Report
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INTRODUCTION

This report briefly outlines the work of the Tree Breeding Group at the Petawawa Forest Experiment Station, Chalk River, Ontario. It is not intended to include a detailed description, but rather to present the main aspects of our recent research activity.

The emphasis continues to be placed on provenance investigations and questions of population genetics rather than on tree breeding, a policy made necessary by the scanty information available on basic variation patterns within Canadian tree species.

Results from our provenance experiments should indicate in which populations we should start breeding and what breeding methods should be employed. More detailed experiments are being conducted, mostly from local sources, for population studies and progeny tests to determine the heritability of both desirable and undesirable characteristics. These include stem form, branching habit, wood quality, disease and insect-resistance, and wood production in relation to growth rate and adaptation to climate and soil. The characteristics being emphasized vary with the species.

RESEARCH PLANNING AND REPORTING

On March 26-27, 1963, a meeting was held at the Petawawa Forest Experiment Station to review the tree breeding program of the Forest Research Branch of the Department of Forestry, Canada. Mr. A. Bickerstaff was Chairman, Dr. J.S. Rowe attended from Ottawa and Dr. I.C.M. Place from the Petawawa Forest Experiment Station. Mr. H.G. MacGillivray represented the Maritimes District, Mr. J.D. MacArthur the Quebec District, while Messrs. M.J. Holst, C.W. Yeatman and E.K. Morgenstern represented different aspects of the all-Canada (East of the Rocky Mountains) tree breeding effort.

Regional problems were reviewed. Much attention was given to spectacular disasters that call for the reforestation of burned-over and barren lands, mainly because they pose immediate problems for the Forest Research Branch. The question of seed origin will be very important in the establishment of productive forests on degraded and barren lands, but problems in ecology (species selection), seedling establishment, and silviculture are the first consideration here. Tree breeders should first concern themselves with the improvement of valuable insect- and disease-resistant species and with normally good conditions of site. Later, when sufficient staff is available, a concentrated effort can be made to deal with carefully chosen problems concerning insect and disease resistance.

Reports were made on the current status of research and on plans for the immediate future. It was clear that more professional and subprofessional staff are required to handle the present program. Plans had been proposed for substantial increases in personnel but the recent austerity program restricted further development. It was also difficult to decide on any specific policy for research and staff allocation as the Forest Research Branch is in a state of reorganization.

A proposal to establish a Canadian Institute of Forest Genetics within the Forest Research Branch was discussed. This would include a nucleus of specialists dealing with provenance studies, tree breeding, population genetics, statistics, physiology, cytology, taxonomy and wood technology. The Institute would be based in Ottawa or at the Petawawa Forest Experiment Station when facilities and staff become available, with regional programs operating within the district organizations.

In 1963, reporting and accounting of the tree breeding program was simplified by reducing the number of projects from 26 to 5. Following are the numbers and titles of the new projects:

P-153 Service work in the tree breeding program.

P-154 Research in tree breeding techniques.

P-155 Provenance studies, progeny tests and breeding in spruce.

P-156 Provenance studies, progeny tests and breeding in pine.

P-157 Provenance studies, progeny tests and breeding in genera other than *Picea* and *Pinus*.

PERSONNEL

Mr. C.W. Yeatman spent this two-year period at Yale University where he conducted research for a Ph.D. thesis.

In September, 1963, Dr. K.J. Roller joined us at the Petawawa Forest Experiment Station, prior to taking up his duties as tree breeder in the Manitoba-Saskatchewan District in 1964.

Early in 1964 Mr. E.K. Morgenstern was granted educational leave to study towards a Ph.D. at Hamburg University.

The Tree Breeding Group is seriously short of staff. We have many experiments that need detailed study and attention. Research workers, technicians and a remeasurement unit with a modern approach to statistics and data processing are all badly needed--and will have to be provided for in the near future.

WHITE SPRUCE

The purpose of this program is to produce fast-growing high-quality white spruce suitable for lumber and/or pulpwood. This is accomplished by investigation of the provenance problem, at first on a local scale within the Great Lakes - St. Lawrence Forest Region (Rowe, 1959) and later on a range-wide scale. By studying the population structure in more or less local populations and by a controlled breeding program to study heritability of quality factors we will learn what can be accomplished in this direction and models for improvement in the species can be established.

We have already established 53 provenance experiments, mostly within Canada, and are presently working on a major co-operative effort to establish another set of white spruce provenance experiments in the Great Lakes - St. Lawrence Forest Region (Exp. No. 194). The western series consisting of five plantings of this experiment was field planted in the spring of 1963. Eleven acres were planted at Petawawa Forest Experiment Station, and an additional 38 acres by co-operators in the Fort Frances, Kapuskasing, Swastika, and Owen Sound areas of Ontario. The Owen Sound experiment failed and had to be replanted in the Spring of 1964. Additional plantations were established with surplus plants on a limestone soil near Lake Dore, Renfrew County, Ontario (3 acres); near Quebec City by Université Laval (4 acres); and in observation plots not far from Gander, Newfoundland (7 acres). Thus a total of 63 acres were planted with this material.

In the spring of 1962 seedlings were distributed to nurseries for the five experiments in the eastern series. These were field-planted in the spring of 1964 at Dorset, Ont., Harrington Forest Farm, P.Q., Baskatong Lake, P.Q., Grand'Mere, P.Q. and Plaster Rock, N.B.

Sixty-six thousand plants for the last series of this experiment (four plantings with 49 provenances) were distributed to nurseries in the spring of 1963. These experiments will be field-planted in the spring of 1965 at Acadia Forest Experiment Station in New Brunswick, near Quebec City, on the Petawawa Forest Experiment Station, and in the vicinity of the Thunder Bay Nursery, Fort Frances, Ont. The summer drought in 1963 took a heavy toll of this material in the P.F.E.S. nursery, while it seemed to survive well in the other nurseries.

A provenance experiment with northern and western provenances (Exp.No.218) was planted at four locations in the Station area. The experiment is an extension of a white spruce study conducted by the Northern Institute of Forest Genetics, Rhinelander, Wisconsin for which we originally supplied most of the provenances.

An older series of white spruce provenance experiments has been measured. The nursery provenance experiment (No. 93-A) was analysed for growth rate, phenology, branch length, and wood density. The field planting at the Petawawa Forest Experiment Station (Exp. No. 93-B) was measured when 9 years old, in the fall of 1962. The lattice design with only three replications made 11 per cent height differences significant. This experiment shows that the white spruce provenances from the Ottawa Valley and from low elevations in eastern and south-eastern Ontario are generally fast growing types and not significantly different from the local Petawawa control. The exception to this general rule is one relatively isolated stand from Vankleek Hill where white spruce is found in a long growing season but on somewhat limey soil; this provenance is 24 per cent shorter than the Petawawa provenance and seems to be especially frost susceptible. In extreme southwestern Ontario are found some relatively slow growing types (11 to 26 per cent shorter than Petawawa white spruce) that may be the result of a general adaptation to limestone in that area. South of Petawawa, white spruce is found in slightly cooler upland climates and are represented by the Denbigh and Maple Leaf provenances; these are 15 per cent shorter than the Petawawa white spruce. In the Haliburton and the Algonquin Park areas of Ontario are types that are surprisingly slow-growing, being on an average 24 per cent shorter than the Petawawa provenance. In a northwestern direction from Petawawa, the provenances come from colder climates and are understandably slower growing. The Nipissing provenance is 19 per cent, Dane 28 per cent, Potter 41 per cent, and Kapuskasing 17 per cent shorter than the Petawawa control. Of these Potter is the slowest growing provenance in the whole experiment, while the Kapuskasing white spruce seems to be relatively fast growing considering its northern locality and cold climate. The white spruce provenances from Quebec are a mixed lot and all significantly smaller than the Petawawa provenance. L'Anonciation is closest to Petawawa; the height difference being 17 per cent. One lot from the Gatineau River (Maniwaki) is 26 per cent shorter. So are the two provenances from the

St. Maurice River (Riviere aux Rat with 21 per cent and St. Maurice River with 26 per cent). The surprise was the provenance from Harrington Forest Farm that was 34 per cent shorter than Petawawa; it is fairly frost-susceptible here. Trois Pistoles from the Gulf of St. Lawrence was also 34 per cent shorter than the Petawawa control.

This experiment is one of 21 experiments established in Canada and the U.S.A. - located mostly on acid sites. These are due for measurement in the fall of 1964. The following conclusions are made, with the understanding that they are based only on the early (9-year) results at one locality (Petawawa Forest Experiment Station):

1. The pattern of growth in the field experiment agrees in a general way with that in the nursery provenance experiment. (Small changes do occur as could be expected now that the trees are above the snow line).
2. The provenances that were the fastest growing at Petawawa came from areas with relatively long growing seasons and from acid soils; some of these were also frost susceptible.
3. Limestone ecotypes are apparent, although not all of them have been slow growing on acid soils.

Should the other experiments in this series confirm our findings it would be advisable to make more detailed population studies of the white spruce in southeastern Ontario. Such a study (Exp. No. 292) was initiated in the fall of 1963 when cones were collected from 7 trees in each of 6 stands. This material will be supplemented with collections from other stands in the fall of 1964. At a later date we should make extensive plus tree selections and carry out testing in the same general area.

In 1962 12 Petawawa white spruce trees were selfed to continue our studies of inbreeding depression and to establish selfed lines for further selection and breeding.

A systematic study of white spruce wood characteristics is urgently needed to establish suitable sampling techniques for the study of tree to tree variation. The selection of superior trees based on external characteristics of growth and form reveal nothing of the internal wood structure or properties. In particular, a non-destructive sampling technique for the assessment of spiral grain is required.

Wood density is an important factor as a general measure of wood quality and pulp yield. High wood density and a small fibril angle should be combined to produce high wood quality.

There are only few studies that indicate how much of the natural variation is due to genetics and how much wood density could be improved. Keith (1961) studied 15 white spruces from Peace River and found that ring width was influenced by specific gravity up to 60 years of age but the effect was not so pronounced after that age. About 40 per cent of the variation in specific gravity could be related to variation in ring width inside the 60th ring, and 30 per cent for outer wood. This means that 60-70 per cent of the variation may be under genetic control. If we compare this with the 1,873 logs from 400 white spruce from Manitoba and Saskatchewan studied by Hale (1952), we find that the highest density recorded was on the average 22 per cent above the mean. This would indicate that by breeding and selection we could increase wood density roughly 13-15 per cent. In a study of 110 young white spruce at Petawawa Forest Experiment Station, Jones (1958) found one tree that was 29 per cent above average. This might indicate an even higher potential for increase.

Based on the average wood density for white spruce given by Besley (1959), it is estimated that the listed increases in wood density and a 10 per cent increase in volume would have the following effects on pulp yield (thousands of pounds of pulp per acre for a stand with a normal volume of 2000 merch. cu.ft. per acre (22 cords per acre)):

	Pulp yield	
	Normal Volume	+ 10% Volume increase
Wood of average density (Besley, 1959)	23.0	25.3
15 per cent increase in wood density	26.5	29.2
25 per cent increase in wood density	28.6	31.4

With such gains in sight we should not wait much longer to begin basic studies of methods and variation. From such studies, specifications of wood quality could be drawn up for plus tree selection.

RED AND BLACK SPRUCE AND THEIR HYBRID SWARMS

The objectives of the breeding program in red and black spruce are:

1. to explore their geographic ranges for fast-growing provenances and to determine the ranges of adaptation,
2. to produce provenance and species hybrids for the testing of possible hybrid vigour,
3. to study and describe the taxonomy of the species and the extent of the introgression that has occurred between them.

The range of red spruce extends south along the Appalachian Mountains to the Great Smoky Mountains in North Carolina. These potentially fast-growing races may be of direct value in the moister and cooler parts of eastern Canada. This hypothesis is being tested in 21 red spruce provenance plantations established from Nova Scotia to the Lake States and also in grafted population-samples planted at Petawawa.

Black spruce has received less attention to date, but in view of its Canada-wide distribution in the boreal forest and economic value as a pulp species, it will receive more attention in the future. A few small provenance experiments have been established and seed collections from a narrow latitudinal transect from Lake Erie to James Bay (Exp. No. 289) have been made. In this study six regions were sampled, including 21 stands and 126 single trees. The progenies were sown in a greenhouse for the early evaluation of seed and seedling characteristics. This material is being studied by Mr. E.K. Morgenstern, and will be evaluated in his Ph.D. thesis (to be submitted to the University of Hamburg). A more extensive study covering the full range of the species will be carried out when time permits.

The relationship between red and black spruce has long puzzled taxonomist and forester alike. Sargent (1898) was the first to realize that there were two species involved, but stated that "Forms intermediate in character between the black and red spruces are known to exist".

Heimburger (1939) was no doubt the first to recognize "that these transition forms are natural hybrids between black and red spruce". I have therefore suggested honouring this outstanding ecologist and geneticist by naming these hybrid swarms after him: <u>Picea</u> x <u>Heimburgeri</u>.

Three fortuitous F_1 hybrids between Quebec red spruce and Petawawa black spruce have grown exceptionally well in a plantation planted at the Petawawa Forest Experiment Station as may be seen from the measurements listed below. The data were collected 23 years after sowing, and all species are growing in adjacent rows in the same plantation.

Species	Height (feet)	D.B.H. (inches)	Volume (cu.ft.)	Volume relative to black spruce
Red spruce	22.6	3.2	0.63	59
Black spruce	26.5	3.9	1.07	100
Red x black spruce	30.0	5.4	2.27	212
White spruce	27.2	4.2	1.23	

This is a very promising lead and may result in a major break-through in spruce breeding.

The red x black spruce problem is complicated by several factors, some of which have been studied in established plantations, while others require further experimentation. Black spruce is a shade-intolerant and cold-hardy species that typically grows rapidly from germination but slows down in later years. Although it is normally confined to swamp lands, in plantations it is relatively tolerant to drought and root competition and has a wide latitude in nutritional requirements. Red spruce is a shade-tolerant tree that normally grows to large dimensions in association with hardwoods. But it grows slowly in its early years, is susceptible to frost injury when planted in the open, and is intolerant of drought, root competition, and low levels of nutrition. When the F_1 hybrid is planted on an open site, intermediate with respect to climate, moisture and nutrition, it grows rapidly due to the combination of fast early growth, tolerance to root competition, (e.g. grass), and ability to utilize fully the nutrients available in the soil.

Within the areas where the ranges overlap, natural hybrids commonly occur but do not show any pronounced hybrid vigour, although they usually grow on intermediate habitats. These hybrids form introgressed populations in which few, if any, F_1 hybrids are to be found, and where relatively free gene exchange within and between populations has eliminated the opportunities for novel recombinations of complete genomes. A further levelling influence results from the genetic adaptation over many generations of both parental and hybrid populations to the same regional climate, although their specific site preferences are quite different.

It may be expected that hybrids between geographically separated parental populations would exhibit heterosis when planted in an intermediate habitat (in terms of geography, climate, and site). To test this hypothesis, crosses were made between pure black spruce in northern Ontario and Manitoba and pure red spruce from the southern Appalachian Mountains. Other species and provenance hybrids have been produced using the southern red spruce pollen on black and red spruce growing at Petawawa.

The resulting hybrids are to be tested at Petawawa, which in many respects may be considered intermediate between the parental locations. In 1962 three controls and 16 combined provenance and species hybrids were sown, and in 1963 a further nine progenies from red spruce provenance crosses, 26 lots of F_2 hybrids and 40 control (open pollinated) lots were sown. We are not fully satisfied with the results. The quality of the red spruce pollen is suspect as it had to be stored (frozen) for one or two years after collection. It is also possible that species incompatability is a factor when populations outside the overlapping zones are crossed. A further approach will be to use red spruce as the female parent rather than black spruce.

Taxonomic studies of red and black spruce are continuing, together with the description and mapping of introgressive populations. In the summer of 1956 T. Mosquin and I studied and described all the samples we had of natural red, black, and red x black spruce populations, as well as the hybrids produced in the late 1930's by C. Heimburger and L.P.V. Johnson. We adopted Anderson's (1949) methods of describing introgressive hybridization, using pictorialized scatter diagrams as well as hybrid indices. Twenty-five characteristics were scored, eight of which were used in our final score. Flower colour and needle colour were the best discriminants. Twig colour, sterigmata form, pubescence, hair type, hair length, and cone scale form were used as additional characteristics. These gave reasonably descriptive scatter diagrams and hybrid indices.

The three main accomplishments of this study were: 1)the development of suitable techniques for the description of red x black spruce hybrids, 2)the demonstration of the occurrence of introgressive types in natural populations, and 3)the demonstration that the two species did not originate as separate ecotypes from existing common parental populations, but are well defined and recognizable botanical species, although closely related.

In the early 1950's, I collected seed for both red and black spruce provenance experiments. Some of the provenances showed signs of introgression while in the nursery, where it was obvious that established methods of describing and measuring them would be inadequate.

The opportunity was given to Mr. E.K. Morgenstern to use this material for his M.Sc. thesis at Toronto University, with the objective of determining introgression from branch samples of young seedlings.

He studied the 12 black spruce and the 14 red spruce populations that are part of broader Departmental studies of red and black spruce provenances mentioned above. Mr. Morgenstern visited and scored an additional five black spruce and six red spruce stands, and has published his findings (Morgenstern and Farrar, 1964).

It is intended to use the scoring techniques developed in these studies to explain some of the variability within the populations represented in the established provenance plantations of red spruce. As the experimental plantations have been established in both coastal and continental climates, a descriptive hybrid index may explain each plant's reaction to climate and site.

NORWAY SPRUCE

Norway spruce has been widely planted in the cool temperate climate of the North East of North America where it grows well on moist, cool, acid sites. It is slower growing in the drier, more continental and boreal climates. As is to be expected with an exotic species, Norway spruce presents particular problems of adaptation and selection. Only the most promising provenances are of interest, and within these, rigid selection is exercised for growth, frost hardiness, and resistance to the white pine weevil (Pissodes strobi).

IUFRO provenances of Norway spruce were planted at Petawawa in the early 1940's by Dr. Heimburger. The seedlings were selected for frost resistance and vigour in the nursery, and the plantation has been thinned to remove weevil-susceptible trees. A report based on measurements in this and other experiments in Canada and the U.S.A. (Holst, 1963) was presented at the World Consultation on Forest Genetics and Tree Improvement in Stockholm, August, 1963, in a supplement to the extensive review of Norway spruce provenance research made by Professor O. Langlet.

I summarized the results of the Norway spruce provenance experiments planted at Petawawa Forest Experiment Station, Chalk River, Ontario; Manistee National Forest, Wellston, Michigan; Eagle River District of the Nicolet National Forest, Wisconsin; Harvard Forest, Petersham, Massachusetts; Fox and Vincent State Forests, New Hampshire; Ontario, Schoharie and Otsego Counties, New York; and the Acadia Forest Experiment Station, Fredericton, New Brunswick.

In the western half of the Great Lakes - St. Lawrence Forest Region, with its somewhat continental climate, provenances from countries around the southeast corner of the Baltic Sea and from Poland, and White Russia have been best. One Canadian plantation of unknown origin that was heavily graded for winter-hardy trees produced progeny that have shown much promise. Other progenies from comparable plantations in which no selection had been exercised show intermediate or poor growth. In the moister and milder climate along the Atlantic Ocean (New England States, and New Brunswick) generally fast-growing provenances, such as Crucea, Valdu Rau, Stolpce, Svinosice, Dolina and Istebna, have grown very well.

In all areas, white pine weevil causes considerable damage. In the coastal United States and Canada, Norway spruce is more productive than the native spruces. In the Great Lakes - St. Lawrence Forest Region, Norway spruce may grow slightly faster than white spruce on good fresh spruce sites, but white spruce is better on poorer sites and in frost pockets, and is practically free of weevil injury.

Many Norway spruce plantations derived directly from seed of European origin show great tree to tree variation because the specific genotypes are adapted in varying degree to the new environment, often including a shorter day-length. In this case, mass selection through the severe culling of poorly adapted and weevil-susceptible individuals will give rise to a much superior second generation.

Further populations for mass selection may be derived from isolated seed orchards composed of individuals selected for growth rate, cold and frost hardiness, and weevil resistance (or the ability to recover satisfactorily from occasional attack). The testing of individual clones or progenies may be included in the objectives of such seed orchards. Such a scheme has also been advocated for the improvement of Douglas fir in Europe.

This approach is presently being applied at three locations in eastern Canada. The first is in the Hudson's Place plantation at the Petawawa Forest Experiment Station and was mentioned above. The stand is apparently of southern (German?) origin and was thinned from an original 1500 to 27 trees that are winter-hardy, including some that are also weevil-resistant. Open- and control-pollinated progenies have proved to be cold-hardy and vigorous, but it is too early to estimate their relative weevil resistance. A general seed collection was made from this stand before the final thinnings were made. It was sown in the nursery in 1942 and 1943, from which selected seedlings were planted beside the IUFRO provenances. I have selected 40 of these trees for further testing and breeding.

The second family is derived from trees growing around the Proulx nursery near Grand'Mere, Quebec. Dr. Heimburger selected a number of superior trees in 1937 and their progeny were included in the Petawawa IUFRO provenance plantation where they have grown somewhat less than the Hudson's Place provenance. Seventeen trees were selected and clones propagated for the establishment of seed orchards and the production of a third generation for further testing and mass selection.

The third family is also from the Proulx plantations, derived from trees selected by myself and Mr. Arne Rosholm in 1962 from stands growing within and beside the well known manurial trials. J.B. Santon scored these different Proulx families for twig pubescence. Those from the manure plots are of northern origin, probably Jämtland, Sweden, as they are 98 per cent pubescent, and 92 per cent of the hairs are glandular. The Proulx nursery family growing at Petawawa are only 84 per cent pubescent, with 73 per cent glandular hairs. According to Lindquist (1948) such types are found in some parts of Switzerland but it may be the result of contamination of a southern type with pollen from the Jämtland spruce that grows nearby. In the future, the earlier collection (Heimburger) will be referred to as the "Proulx provenance" and the later collection (Holst and Rosholm) as the "Jämtland provenance".

Further selections of promising types have been made in the Petawawa IUFRO plantations from within Roumanian, Latvian, and Russian provenances. Dr. Hans Nienstaedt, Northern Institute of Forest Genetics, sent scions from trees selected in the Bryansk, Mozyr and Gomel provenances (U.S.S.R.) growing in the Nicolet National Forest in Wisconsin. We also obtained scions from Michigan from two provenances, Dolina, Ukrainian S.S.R., and Svinosice, Czechoslovakia, that grew well in the IUFRO experiment at the Manistee National Forest, but which were not represented in the Petawawa plantation.

We feel that the hardy and relatively fast-growing types from the Baltic, Poland, White Russia, and European Russia should be extensively tested in eastern Canada, as should also the fast-growing but cold-susceptible types from the Carpathian Mountains. We have therefore started to collect Norway spruce provenances from Roumania, Ukraine, Latvian S.S.R., Lithuanian S.S.R., and White Russian S.S.R. (Exp. No. 277). It has been difficult to obtain seed as cone crops in these regions have been poor in recent years.

A plantation containing 15 progenies of Norwegian Norway spruce plus trees were rated for winter damage (Exp. No. 75). There was relatively little injury (27 per cent), but another experiment with 11 central European provenances (Exp. No. 80-A) had 80 per cent winter damage. All damaged (cold-susceptible and weevilled) trees were cut from these plantations. An experiment in the same locality (Exp. No. 78) shows that the Colorado provenance of blue spruce suffered only slight winter damage (8 per cent), while the Wyoming provenance was heavily injured (40 per cent).

N.H. Grace and J.L. Farrar (1947) grew a number of clones of Norway spruce in the course of their investigations of rooting hormones during the mid-1940's. These were planted in the Petawawa arboretum and are now being used for studies of variation in wood properties. Prof. R.W. Kennedy, Toronto University, took wood samples from four ramets in each of four clones in the spring of 1963. It was hoped that the sample (4 inch x 1 inch) would not weaken the tree trunks unduly, but unfortunately several have broken during the last year.

OTHER SPRUCE

A number of exotic spruces have been sown during the period under review. For breeding in white spruce, the following are of special interest: _Picea bicolor_, Fusiyama, Japan; _P. jezoensis_, Hokkaido, Japan; _P. jezoensis v. hondoensis_, Saitama, Japan; _P. polita_, Saitama, Japan; _P. pungens_, Arizona and Utah.

Other species sown to supplement our black and red spruce breeding program were: P. glehnii, P. omorica and P. orientalis.

We think that some interesting hybrids can be made between the black-red spruce group, and P. glehnii, P. omorica and perhaps also P. orientalis. From the Northern Institute of Forest Genetics we obtained 10 clones of P. omorica that had survived in a test planting in Wisconsin. We also received scions from some interesting plantations of Picea glehnii I saw during a visit to Finland.

A number of western white spruce provenances from British Columbia, South Dakota, and Montana were sown. These will be compared with Engelmann spruces from British Columbia, Montana, Idaho and Utah, mainly to study the extent of the introgression between these species (Exp. No. 223).

RED PINE

The red pine breeding program continues to emphasize the provenance problem and population structure.

A single tree progeny test with Lake States red pine, conducted in co-operation with the University of Wisconsin was field planted in the A.E.C.L. area near Chalk River, (Exp. No. 215-B). The nursery test of this material (Exp. No. 215-A) was measured annually and is being retained as a demonstration plot.

Also in co-operation with the University of Wisconsin, 25 red pine provenances (from Lake States, Ontario, Quebec, New Brunswick and Nova Scotia) were established in five locations in Ontario, two in Quebec and one in each of Nova Scotia and Prince Edward Island (Exp. No. 216).

Our early provenance experiments were made with seed provided by the Ontario Department of Lands and Forests. These experiments have been very valuable but at the same time it is admitted that the information to be gained from "regional collections" of red pine is limited. Clearly identified seed sources (stands) will be required in future experiments. Our experiments to date have been based on a system of seed collection areas ranging in diameter from

50 to 100 miles which seems to be a practical and useful unit, but which is too broad for an accurate estimate of population structure. Also, it has been quite difficult to match climatic data to collection areas.

Even with these deficiencies of the provenance material, the results obtained so far indicate that there are significant differences in height and frost susceptibility associated with seed origin.

In eastern Ontario where red pine occurs more or less continuously, there is a significant association between growth and length of growing season. The scatter about the regression is wide, indicating that stand differences are important. One stand from some limy sands near Castleton, Ontario, appeared to be poorly adapted to an acid soil.

The red pine from western Ontario varies widely in growth. The differences between provenances are significant, but they are not associated with length of growing season. Three different collections from the same general area (Eagle River) include almost the complete range of variation. If this picture is true, then the red pine of western Ontario, because of its somewhat spotty occurrence, is divided into more or less isolated families where genetic drift is pronounced. Only careful stand testing could show the nature and range of variation within this region.

In terms of frost resistance, the western Ontario red pine is significantly less damaged than red pine from eastern Ontario. Furthermore, within the eastern Ontario provenances tested, those from milder climates show more frost damage than those from colder climates.

There were no significant differences in frequency of prolepsis.

There was little association of height with phenological data (period of shoot growth). This may have reflected the narrow range in growth-period, or was possibly the result of the difficulties encountered towards the end of the growing season in determining the position of the growing point.

In a few of our field tests, large height differences are apparent due to differences in site. When red pine is planted on marginal sites, it is very sensitive to micro-site variation. This must be accounted for before differences due to seed origin can be demonstrated.

On the better sites, provenance differences may not be apparent, but on the poorer sites there appears to be an interaction between starvation, frost susceptibility, and seed origin. Thus different experimental sites may lead to apparently conflicting conclusions.

We are co-operating with Dr. D.P. Fowler, Ontario Department of Lands and Forests, in his study of population structure in red pine (Exp. No. 207-B). Selfings, and within- and between-stand breeding were employed. Fifty-two seed lots were sown at the Petawawa Forest Experiment Station: 5 are selfings, 18 within stand crosses, and the remainder are hybrids between stands (provenance hybrids). Some of the crosses sown in the nursery are listed below:

Petawawa, Ont.	x	Cadillac, Mich. Cass Lake, Minn. Maine Bancroft, Ont. (tassel pine)
Swastika, Ont.	x	Pennsylvania Maine New York Itasca Park, Minn. Trout Lake, Wis.
Lake Abitibi, Ont.	x	Pennsylvania Maine New York Trout Lake, Wis. Petawawa, Ont.
Winchedon, Mass. Kilburn, Wis	x	Maine

After two years' investigation, Dr. Fowler found no detectable inbreeding depression. There were no differences due to the pollen parents (stand pollen mixtures), whether of local or distant origin. Only the mother trees contributed significantly to the variation. This appears to be an instance of maternal inheritance.

The seedlings were raised in a somewhat artificial environment that may have reduced the potential genetic effects due to differences in the male parents. Further observations of these seedlings will clarify this question.

The results of experiments in Canada and the Lake States indicate that testing single trees and stands (families) may be more important than regional testing. To gain further information of within- and between-stand variation, seed and scions were collected from ten trees within each of five local stands, (Exp. No. 238). The seedlings were transplanted in 1963, and a clone test was established in our Pine Graft Arboretum.

In another experiment (Exp. No.257), cones were collected from 32 single trees of red pine scattered in the lower Ottawa River Valley to test whether one tree per family would be enough to identify fast-growing families. Unfortunately chipmunks spoiled the seed beds and the test had to be cancelled. This test will be repeated.

Some of our experiments suggest that it is important to distinguish between seed collected from fast- or slow-growing trees or stands in a given area. If this is so, we should confine future single tree tests to fast-growing types only.

JACK PINE

Jack Pine is widely used in the reforestation of large areas of sandy soils of low fertility. The establishment problems are minimal on these sites owing to the lack of competition from other vegetation, and, apart from fire protection, the management and harvesting costs are low.

Rapid juvenile growth, variability in growth and form, early flowering, and obvious need for improvement in stem form, branch size and branch angle, make it an interesting and promising species for genetic improvement.

Three lines of approach are being followed in jack pine: provenance research; provenance hybridization; and heritability studies.

Provenance research

Over the last few years attempts have been made to analyse several of our older jack pine provenance experiments (Exp. Nos. 40, 41, 42, 70 and 83).

Most of these contain Ontario provenances mainly, supplemented with a few from Quebec. They show that most of the variation in height is clinal and is highly correlated with both length of growing season and May - September mean monthly temperature.

We have also investigated the relationship between growth rate and Hills' Site Regions for Ontario (Hills, 1952). Comparisons within and between western Ontario regions are rather inconclusive because of insufficient sampling, but the eastern regions differ significantly in height and phenology (period of shoot growth). Provenances from continental western Ontario and cold northern Ontario start growth early in the spring, finish early in the fall, and have short growth-periods. Provenances from the milder parts of middle and southern Ontario start growth late in the spring but finish much later in the fall and therefore have longer growth periods.

Hills' Site Regions are important indicators of potential yield and may be adequate first approximations for the delineation of seed collection zones. In an eleven-year-old provenance experiment, mean height differed significantly between regions, e.g., when comparing three provenances from the Georgian Bay Site Region with four provenances from the Lake Abitibi Site Region we find that 7 of 12 possible differences were significant. On the other hand it could be shown that significant height differences occurred which demonstrated the influence of local climate within a site region. The Lake Abitibi Site Region is a case in point. The Stevens provenance (short growing season) is 11 per cent shorter than the other three provenances (Timmins, Swastika and Connaught) from this site region.

In 1955, 16 provenances of Lake States jack pine were planted at the Petawawa Forest Experiment Station (Exp. No. 125). This is an extension of a 29-provenance test sown in 1952 by the Lake States Forest Experiment Station and established in 17 permanent outplantings in the Lake States. Our experiment was measured in 1958, 1960, 1961 and 1962. The ranking of provenance height is similar to that found in the Michigan experiments. The exceptions to this rule are Manistee from the Lower Peninsula that gained 10 ranks, Otonagon Co. that fell 8 ranks, Cass Co. that fell 6 ranks, and Becker Co. that fell 5 ranks. Significant differences in susceptibility to the white pine weevil were not found in the Petawawa experiment. The lattice-square design resulted in a gain in precision of 34 per cent. Keul's Studentized Range Test at the 5 per cent level showed only the highest and the lowest mean heights to be significantly different. When calculated as a randomized block design, Duncan's Multiple Range Test at the 5 per cent level indicated the existence of three distinct means.

Seed beds and nursery provenance experiments containing our all-range jack pine provenance experiment (Exp. No. 255) were established in 1962 and 1963 at six locations in eastern Canada, two locations in the Lake States, and four locations in the eastern United States. A western series containing some 15 field plantings is planned, but seed for only two were sown in 1964 (near Edmonton, Alberta and Fort Smith, N.W.T.). An additional 10 field tests are to be established in eastern Canada from seed sown in 1964 in the Petawawa Forest Experiment Station nursery. Another 8 experiments have been started in Europe (Scotland, Holland, Finland, Denmark, and Czechoslovakia) and in New Zealand.

Preliminary results from the nurseries in Scotland show a very high correlation between growth rate and length of growing season of place of origin for the provenances coming from western Ontario and further West (west of longitude 90°W), while the provenances from eastern Ontario and Quebec (between longitude 70°W and 90°W) are more variable (Table 1). The same trend is found in T. Schantz-Hansen's (1954) provenance experiment that was planted on the Cloquet Experimental Forest and which contained 10 Canadian provenances and 12 American provenances. This could be interpreted in terms of more genetic variability towards the middle of the range or a poorer relation between climatic station and collection site. The growth rate in the western part of the range is closely related to climate (clinal variation), while in the extreme eastern part of the range there seems to be a wider scatter. This may be a simplified version of the actual variation, and better estimates will be forthcoming in the future.

Table 1. Correlation Coefficients for length of growing season and jack pine growth rate.

	Scottish nurseries		Cloquet Experimental Forest Average annual growth for 15 & 16 year old saplings
	2 yrs. old	3 yrs. old	
Western part of range (west of longitude 90°W)	+ .994***	+ .969**	+ .785***
Middle part of range (between longitude 70°W and 90°W)	+ .894***1/	+ .878***	+.462 n.s.
Eastern part of range	-	-	only two provenances - variable

1/ Oconto, Wis. excluded

Levels of significance: ***, 0.1%; **, 1%; *, 5%; n.s., not significant.

An explanation of results obtained in nursery and field experiments exposed to natural conditions of site and climate can sometimes be answered in growth-chamber experiments where it is a relatively simple matter to investigate certain interactions of temperature and daylength.

Such experiments were carried out by Mr. C.W. Yeatman while studying towards a Ph.D. at Yale University. Seed of 87 provenances was given to Mr. C.W.. Yeatman for investigation of genetic and environmental effects on seedling development. These studies were conducted in controlled environment facilities provided by Prof. F. Mergen at Yale University. Mr. Yeatman has given a summary of the results of his research in a separate report published in these proceedings.

Prof. F. Mergen, Yale University, conducted detailed morphological and chemical (mineral) analyses of samples of seedlings grown by Mr. Yeatman. Two seedlings from each of the 50 sources that had been grown under 12 different environmental conditions were measured and evaluated in detail (e.g. number of stomates, length of needles, number of serrations, and number of secondary needles)

The data were transferred to I.B.M. cards for statistical analysis. Information was obtained on the genetic variation in these characteristics that is due to geographic origin of the seed, as well as on the relative rigidity of genetic control.

Nine seed sources, chosen from the eastern, central and western parts of the natural range of the species, were analyzed for nitrogen, phosphorus, potassium, and ash content.

The results of these studies are in preparation for publication by Prof. Mergen.

Prof. Mergen further investigated the variation in photosynthesis and respiratory responses between 17 seed sources of jack pine. Seedlings were grown under a constant temperature but with varying photoperiods, and their relative rates of photosynthesis and respiration were measured in a closed system using an infra-red gas analyzer. Differences between treatments and sources were found.

Provenance hybrids

Provenance hybridization seems a particularly promising technique for raising quality and production, and to combine traits such as growth rate and hardiness, but which may also produce monstrosities.

Experience elsewhere with other species indicates that hybrids between northern and southern provenances are inferior at the parental locations and may or may not be superior to local populations at intermediate locations. Knowing this, it is possible to suggest combinations capable of producing fast-growing and adapted hybrids for a specific area and to test the hypothesis. Some of the hybrids in some of the habitats may prove to be superior to the parents (heterotic) and/or to local populations. Although the F_1 may be heterotic, performance may be expected to break down in the F_2, but through further selection within the F_2, F_3 and F_4 it may be possible to fix combinations of several valuable traits.

Even if the provenance hybrids are intermediate or inferior to the parent provenances, selection and breeding for desirable traits should be continued and the F_3 may be used as foundation stock for a new race.

The vigour of a provenance hybrid may result simply from increased genetic diversity (highly heterozygous) or from specific combinations of genotypes. In this latter case, it may be of advantage to breed between small isolated populations where mild inbreeding and genetic drift have occurred.

Provenance hybridization may not always have beneficial effects. Super-heterotic hybrids of great vigour, but of very poor form, may result if quality traits, such as small branch size, depend on recessive genes. Complementary genes may also be encountered that give unwelcome traits in the hybrid that could not be foreseen. Furthermore, genetic homeostasis may result in resistance to breeding and selection.

Success in provenance hybridization may depend upon the use of selected parents that have proven to be superior in progeny tests. This would be so if the desired traits were dominant (which does not seem to be the case), or if the quality traits are recessive and located in the same loci, or if they are not dependent on complementary effects. All these possibilities will have to be investigated eventually.

The provenance hybrids made to date have been between average populations and if some of these exhibit heterosis much will be gained.

In 1960 a number of jack pine provenance hybrids were made by removing the male flowers and pollinating the open flowers with Petawawa pollen. This technique can be very successful in young grafts and seedlings where male flowers are not abundant and can be removed before the pollen is shed. Thirteen such provenance hybrids were made. Provenances from North West Territories, Alberta, Manitoba, Ontario, Wisconsin, Michigan, Quebec, New Brunswick, Nova Scotia and Maine were crossed with pollen from Petawawa. This seed was sown in 1962, together with 12 control seed lots of original provenance collections (Exp. No. 268-D).

Fifty jack pine provenance hybrids were sown in 1963, derived from controlled pollinations made in our provenance experiments and graft arboreta (Exp. No. 268-E), (Table 2).

Table 2. Fifty Jack Pine provenance hybrids sown 1963 at the Petawawa Forest Experiment Station.

Female	Male								
	N.W.T.	Alta.	Man.	Ont.	Mich.	Que.	N.B.	N.S.	Maine
N.W.T.				2					
Alberta				2				1	
Manitoba				1			1		
Ontario				2					
Minnesota				4		1			
Wisconsin				7		2	1		
Michigan				4		1			1
Quebec		1		7	2				
New Brunswick		1		2	1				
Nova Scotia	1			2					
Maine		1	1	1					

Species hybrids

The jack x lodgepole pine hybrid has been tested on a very limited scale in eastern North America. Most of these hybrids were made at Placerville where they showed pronounced hybrid vigour. On the sandy acid sites in the East, jack pine has been superior, the hybrid intermediate, and lodgepole pine the poorest. However only few combinations have been tried. In those I know of, the lodgepole pine parent came from Eldorado Co., California and the jack pine parent came from the "East". Better combinations with jack pine may be expected from fast-growing and well-formed types of lodgepole pine originating from acid or sandy sites or perhaps from mid-elevations or even coastal areas.

Some evidence of the gains to be expected is seen in the introgressed lodgepole x jack pine populations from Alberta planted at the Petawawa Forest Experiment Station. The lodgepole pine types are slow growing and of good form, but the jack pine types are more vigorous and typically of undesirable form. It is noteable that the trees in these populations are all resistant to sweet-fern blister rust (Cronartium sp.), although they originated in an area free of the disease because sweet fern is absent.

Blister rust killed most of the pure lodgepole pines planted on deep acid sands at the Petawawa Forest Experiment Station. The same provenances were less susceptible at Valcartier F.E.S. and nearly resistant at the Acadia F.E.S. Hence, there appears to be an interaction between environment and rust susceptibility. The mass introduction and inoculation with Cronartium would be the first stage in the introduction and selection of lodgepole pine for the production of species hybrids with jack pine.

In 1960, a number of the jack x lodgepole pine hybrids from Placerville and from the natural hybrid swarms in Alberta were crossed with Petawawa jack pine on open flowers after the male flowers had been removed. Fifteen such crosses were sown in 1962 (Exp. Nos. 87 and 268).

In 1961, three of the Placerville hybrids and four groups, based on cone type, of the Alberta hybrids were crossed in a similar manner to Petawawa jack pine. Sufficient seed resulted from these crosses for distribution to cooperators in Alberta and Manitoba, where the influence of the fast-growing Petawawa type may be an advantage. We also plan to plant the jack x lodgepole pine hybrids on a heavy soil in northern Ontario where the lodgepole genes may be an advantage, as some shore and lodgepole pine provenances are notable for their ability to grow on soils of low fertility as well as on poorly aerated acid soils.

The effort in the United States to improve upon the somewhat weedy Virginia pine and the prospect of success is followed closely here. We should very much like to cross Virginia pine with jack pine. Virginia pine has the advantage of being an eastern pine as well as a "southern pine" adapted to an eastern climate and eastern soils and may therefore be a better crossing partner for jack pine than the western lodgepole pine.

Earlier attempts to cross jack pine with Virginia pine failed. New and more extensive crosses were made in 1962 when we crossed five different jack pine provenances with Virginia pine pollen obtained from North Carolina.

Heritability studies

Although we are mainly looking for increases in growth rate (and in form, in a general way) in our provenance experiments, we are concerned with the inheritance of specific quality factors in a single tree progeny test.

The inheritance of cone serotiny in jack pine is of more than academic interest. An open-coned type could be of great value to the silviculturist who does not wish to burn and who would like to depend on advanced regeneration. Apparently the open-cone type is in some way dominant over the closed-cone type, and the latter may be dependent on recessive and relatively homozygous genes. However, it would be desirable to know more about the correlation between parent and progeny in this characteristic so that the probability of obtaining open-coned types in a given progeny could be calculated. This information will be useful in the establishment of seed orchards.

Inheritance of straight or curved cones and of cone angle is a more academic question, but this information could help in the interpretation of results from the range-wide provenance experiments.

There is much variation in the stem form of jack pine and it may best be observed in 15- to 20-year-old plantations. The forms observed will include trees with straight and symmetrical boles (at least as straight as one can expect from a multinodal pine), trees with slight but consistent "waves" up through the stem, trees with crooked stems, and trees with very crooked stems twisted like a corkscrew.

Jack pine typically has a very small branch angle. It may have evolved from a type that had the multinodal characteristics in a moderate and more congenial climate. A tree with a small branch angle maintains living branches low on the stem. The branches are long, larger in diameter and are retained for a long time. This is one of the reasons why jack pine appears to be limby and why self-pruning is slow. Another reason is, perhaps, that the branch-stubs are resinous and do not decay readily. Thus a jack pine type with a large branch angle would be desirable.

In the fall of 1961 collections consisting of 15 cones from each of 300 jack pine trees were made. Records were kept of cone type, stem form and branch characteristics. None of the trees was marked permanently in the field. The cones were harvested before the open-coned types had begun to release their seed. Most of the sample trees were found in Exp. No. 192, which contains both provenance material as well as seedlings derived from bulk seed lots from straight trees. The rest was natural jack pine from the Orange Road at Petawawa. The seed was sown without replication in the spring of 1962. Somewhat over 100 plants per seed lot were grown, and the 2-0 stock was out-planted in the spring of 1964. At that time the number of progenies that could be tested had fallen to 255. The design includes 10 replications of 10 plant plots and the spacing is 6' x 6'.

This experiment will be rated for cone characteristics, stem form and branch angle when 10 years old. The experiment can also be used for rating insect and disease resistance, as well as for wood quality, should the opportunity arise.

A further study of the heritability of stem form was initiated in 1964 when crosses were made between trees with straight, average, and crooked stems. Ten to fifteen trees were chosen within each of several populations sampled.

SCOTS PINE

Our work with Scots pine has the following aspects: 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 root stock.

As seed becomes available from plus stands selected in Europe, it should be tested in North America in preference to seed from unselected stands. Such plus stands are being tested in Exp. No. 266 where nine stands from Scotland, Sweden, Germany and Czechoslovakia have been selected for trial.

One lot of Ukrainian Scots pine was added to the provenance experiment with Russian and Siberian Scots pine. This lot came from Kozinsky, Kiev Forest District, an area known for its high resin production. This type may also prove to be a high-resin yielder in Canada and thus show promise as a provenance relatively resistant to shoot moth. It was planted in the shoot moth test area at Turkey Point in southern Ontario (Exp. No. 201-T). An observation plot was planted with the remaining stock which was graded for presence and absence of proleptic shoots (Exp. No. 201-U).

Five Scots pine plus trees were selected in the Proulx Plantation near Grand'Mere, Quebec. The grafts will be isolated in a small seed orchard, the objective being the production of adapted, fast-growing and well formed progeny for timber production.

Some of our earlier plantings of provenances suitable for Christmas trees were heavily damaged by pine grosbeaks. These birds eat the buds during the winter and can seriously deform Christmas trees.

Seed from 17 clones selected as superior Christmas trees was sown in 1962. However, viability was extremely poor due to lack of pollen, a common occurrence in young seed orchards.

In 1963, 63 different crosses were made in our Christmas tree selections, to test both the heritability of the selected traits and the combining ability of the various clones. Characteristics such as needle colour, needle retention, needle form, resistance to winter-burn, branch angle, number of branches, resistance to snow breakage, symmetry, prolepsis, and age of flowering will be studied. In addition, the heritability of weevil resistance will be studied in these crosses. Broad sense heritability estimates will be made from twenty clones grafted from apparently weevil resistant and weevil susceptible selections. The grafts will be planted in a randomized clonal test (Exp. No. 280).

LARCH

A number of seed lots were sown of larch species of botanical interest

(Exp. No. 252). Some of these lots were large enough to provide plants for replicated experiments. They were:

- 7 lots of *L. decidua* from Czechoslovakia
- 2 lots of *L. decidua* from Denmark
- 1 lot of *L. sibirica* v. sukatchewii from Sokol, U.S.S.R.
- 1 lot of *L. sibirica*, Siberia, U.S.S.R.
- 1 lot of *L. Gmelini* v. principis ruprechtii, Chansi, China
- 1 lot of *L. koreana*, Kankyo-Hokudo, Korea

Only small seed samples were obtained of the following lots, but sufficient for planting in the arboretum:

- 2 lots of *L. decidua*, Galicia, Ukrainian S.S.R.
- 10 lots of *L. sibirica* v. *sukatchewii*, Siberia
- 12 lots of *L. japonica*, Sakahlin
- 1 lot of *L. gmelini*, Sakahlin

Seedlots from arboreta of various open pollinated progenies of unusual larch hybrids were field-planted for further observation and selection (Exp. No. 35-B and 35-C). They were: *L. decidua* x *sibirica*; *L. gmelini* x *leptolepis*; *L. laricina* x (?).

Some of these lots should be tested in colder climates and on different sites. Other lots will be kept in test and arboretum areas at the Petawawa Forest Experiment Station to serve as a nucleus for future breeding work in *Larix*.

BIRCH

In 1962 several types of birch material were sown. Some of this was an addition to our provenance experiment with exotic species. A total of 12 lots were sown that included the following species: *Betula platyphylla*, *B. maximowicziana*, and *B. ermani*. All of the *B. maximowicziana* were killed the first winter. The *B. ermani* is small, while *B. platyphylla* seems to be more hardy.

Also in 1962, 75 lots of Dr. W.H. Brittain's range-wide material of Canadian white birches (*Betula* spp.) were sown. An additional 43 lots were obtained as 1-1 seedlings (Exp. No. 267). These were supplemented with botanical collections made by Dr. T.C. Brayshaw. This forms a nucleus of material for taxonomic as well as for breeding studies.

Various *Betula verrucosa* x *papyrifera* and *B. pubescens* x *papyrifera* hybrids were produced. Six lots were sown in 1962 and 17 lots in 1963 (Exp. No. 285-B).

OTHER SPECIES

There are several provenances of *Abies Fraseri* in the *Arboretum*. Seed was collected from seventeen of the most winter-hardy trees. These selections may eventually produce a winter-hardy Christmas tree type (Exp. No. 284).

Two small experiments were planted with *Alnus glutinosa*. Five European provenances were tested.

PLANT FORCING

The seven-month period between seed harvest and spring sowing is wasted when normal outdoor nursery procedures are followed in raising seedlings. In some species, the stratification requirement of the seed prevents its satisfactory germination when sown in the greenhouse during fall or winter.

An investigation of the chilling requirement of fresh seed of a number of spruce and pine species was made in 1962 by Mr. J.B. Santon. Mature cones were harvested in the autumn and stored in an open shed until the seed was extracted during October and November. The seed was stored at room temperature before it was sown on moist soil in pots on four dates at one week intervals. The chilling treatments were applied by placing the pots in cold storage (34-38°F) for one, two, three and four weeks. The control (no chilling) was sown on the same date as that for one week chilling but was kept in the greenhouse. All chilled pots were moved from cold storage to the greenhouse on January 19. Total germination relative to that after four weeks' chilling is listed below.

The results indicate that without stratification, germination is

Species	Weeks chilling				Control (No chilling)
	4	3	2	1	
Jack pine	100	97	99	85	77
Red pine	100	100	95	81	58
White pine	100	48	26	9	4
Black spruce	100	127	87	64	29
Red spruce	100	81	49	48	19
White spruce	100	85	88	54	8
Norway spruce	100	82	48	40	23

lowered in all species and such losses could not be permitted in breeding material. For maximum germination, the following periods of chilling are recommended: red and jack pine, two weeks; white pine, at least four weeks (probably six weeks); black spruce, three weeks; red and Norway spruce, four weeks; and white spruce, at least four weeks.

ROOTSTOCKS AND PRUNING

As mentioned earlier we have made some crosses to study the precocious flowering habit of Scots pine. We hope to produce an early flowering and slow growing rootstock. This should not be difficult if cone sickness is dependent on a few dominant genes. We will still have to prove that these precocious and slow-growing seedlings also will induce early flowering and reduced growth in clones (and grafted seedlings) that are normally fast growing and late flowering. We had originally hoped to use this Scots pine rootstock to induce early flowering in red pine. It seems, however, that there is graft incompatibility between Scots and red pine. When developed, the Scots pine strain may still be of value for use with other species than red pine.

Young red pine grafts have an unsatisfactory form for flower production. The growth rate is very fast, only one whorl of branches is produced per year, the number of branches per whorl is low, and the branches are short in relation to the height. This gives a very open crown having relatively few sturdy branches with a limited development of the secondary branch system. Few female flowers, and no male flowers, are borne on this branch system. The long internodes characteristic of vigorous growth are associated with a tendency to prolong this combined vegetative and female-flower stage. The lack of pollen in many pine seed orchards, at least in the early stages, is due to lack of branches small enough and sufficiently suppressed to produce male flowers. It is desirable to have many branchlets in the lower part of the crown for abundant pollen production.

It is necessary to find, first a treatment which will increase the number of branchlets in the crown, and second a means of inducing these branchlets to bear male flowers. An approach to these problems based on past experience is suggested in the following discussion.

As soon as the graft starts to produce a long leader (with few side buds) the leader and the upper strong branches should be cut back. The beginning of July is the proper time for this. The shearing is done in more or less the same manner as a Christmas tree grower shears a pine Christmas tree. This shearing will produce new branch buds from the needle fascicles. Scots pine reacts very well to this shearing and may produce as many as 15 to 30 buds on one main shoot. Red pine does not produce as many buds and the timing of the shearing is more critical. If properly timed, the shearing of the leader will produce many times more buds than the 3 to 6 buds normally formed in a whorl. Some of the branchlets formed will be small enough to become potential locations for male flowers. The pruning of the leader and/or the upper whorl should be done every year or every second year depending on development.

After a dense crown has been formed, the lower part of the crown may be induced to produce male flowers by removing the buds in early spring (at the time of bud swelling) the year before flowering is required.

Any kind of pruning or shearing will temporarily reduce female flowering, because the number of buds is reduced. However, over several years this light pruning method should provide many more medium sized branches suitable for female flower development.

Female flowers may be induced on pruned red pine grafts by giving them an application of ammonium nitrate in June. As ammonium nitrate inhibits male flowering, it must not be applied to the grafts from which pollen is to be collected.

VEGETATIVE PROPAGATION

A study (Exp. No. 241) was initiated several years ago by J.B. Santon concerning the influence of scion topophysis (i.e. primary, secondary or tertiary branchlet position), graft position, and rootstock pruning on the development of grafts produced with scions cut from <u>mature</u> white spruce. Standard 2-2-1 potted rootstocks and ordinary winter grafting techniques were used. The scions were cut from 40, 80, 100, and 120 year old trees. Topophysis influenced the growth of scions taken from younger trees but had little effect on material from older trees. In grafts made with branchlets from older trees, the rejuvenation of the scion is most rapid when grafted high on the rootstock. The lower branches of the rootstock are retained and only pruned to prevent them from competing with the graft. Grafting in the high position induced the grafts to lose the branch habit, a characteristic maintained for many years by scions from old trees when grafted low on the rootstock. After five growing seasons in the nursery, the high grafts are many times taller than the low grafts and growing straight and vigorously. Because the foliage of the rootstock is maintained for a longer period, and because both rootstock and grafts grow rapidly, the plants produced by this high-grafting method will need either particular care in handling or an easily identifiable rootstock. This might be the place for a rootstock with a marker gene.

A total of 2,924 grafts of pine and spruce were made during the two year period (Table 3). Most of these have been dealt with under the different sections.

Table 3. Summary of grafting during the spring of 1962 and 1963.

Project or Exp. No.	Material	No. Grafts
	1. SPRING 1962	
10,275	17 clones, Proulx Pt. via P.A. 103	425
119	30 " of 3 provenances from Russia via Wisconsin	600
	10 clones of P. omorika via Wisconsin	138
	Total Grafts 1962	1,163
	2. SPRING 1963	
275	22 weevil resistant Norway Spruce from Proulx Pltn., Grand'Mere, Que.	550
119	38 selected clones from I.U.F.R.O. experiments in Michigan and Petawawa	510
280	20 weeviled and non-weeviled clones of Scots pine	500
	5 selected Scots pine clones from Proulx Pltn.	87
	3 blighted and not blighted clones of white pine	99
P-144	2 clones of P. nigra x P. resinosa	15
	Total Grafts 1963	1,761

NURSERY WORK

The many co-operative obligations and inadequate labour has made the nursery work difficult. Sufficient time cannot be spent on each of the many experiments that require special care.

The unusually hot and dry weather experienced in the summer of 1963 caused heavy losses of seedlings. Thirty-five per cent of spruce and ten per cent of the pine transplants died during this period.

Fifty-one new Dunemann beds were installed in spring, 1964.

About 156,000 seedlings were transplanted (Table 4)

Table 4. Transplanting of tree breeding material.

Project or Exp. No.	Material	No. Plants
	1. SPRING 1962	
194-D-1	Picea glauca provenance experiment	72,080
208	Spruce hybrids	5,920
	Spruce rootstocks	1,040
176-B	Abies balsamea and other Abies species	9,690
244	Picea species	740
238	Red pine one parent progeny test	2,700
211,291	Red pine, controlled pollinations and hybrids	3,960
264	3 Jugoslavian P. nigra provenances	2,150
	Total transplanting 1962	98,280
	2. SPRING 1963	
194-M	Picea glauca provenance experiment	21,465
	Spruce hybrids	4,892
	Pine hybrids	572
238	Pinus resinosa one parent progeny test	26,510
	P. glauca for reforestation	4,000
	Total transplanting 1963	57,939

PLANTATION WORK

Twenty-five experiments included 32,570 plants covering 25 acres were field-planted at the Petawawa Forest Experiment Station. This figure includes 1,069 grafts (Table 5).

Another 29 experiments were planted by co-operators in Canada and the United States. These included 106,589 plants and covered 90 acres. Seed for the jack pine provenance experiment (Exp. No. 255) was sent to nine co-operators for sowing in their nurseries, an additional 2.25 acres. Another 41 red pine grafts were sent to Maple, bringing the total area up to 93 acres (Table 6).

Some 200,000 2-0 white spruce were sent to various co-operators for transplanting in their nurseries (Table 7).

Table 5. Spring planting 1962 and 1963 by the tree breeding Group, Petawawa Forest Experiment Station.

Exp. No.	Description	No. of Plants	Area Acres	Plantation Area
	Seed Plants 1962			
35-B	Observation of various provenences and single tree progeny of Larch for further selection.	50	0.06	P.A. 101
35-C	Ditto	1,326	1.10	P.A. 114
201-U	Provenance experiment with Ukrainian Scots pine	407	0.34	P.A. 121
215-B	Single tree progeny test in Lake States red pine conducted in co-operation with The University of Wisconsin	2,928	2.40	P.A. 120
216-B	Red pine provenance experiment including Lake States and Canadian provenances in co-operation with Un. of Wisconsin	5,286	1.94	P.A. 120
255-A-2	All range jack pine experiment	seeded	0.25	P.F.E.S. Nursery
270 open	Selfing of Scots pine	450	0.37	P.A. 121
	Total 1962	10,447	6.46	
	Seed Plants 1963			
6-C	Breeding of weevil resistant and weevil susceptible Norway spruces by means of intraspecific hybridization of the Norway spruces on Hudson's Place.	37	0.03	P.A. 114
194-D-1	Provenance experiment with 25 races of white spruce from the Great Lakes-St. Lawrence Forest Region.	13,464	11.14	P.A. 125
200-P	Provenance experiment and observation plots including North European and Russian Norway spruce.	2,039	0.75	P.A. 114
218-F-1	Provenance experiment with Northern white spruce	920	0.53	P.A. 114
218-F-2	Ditto	812	0.45	P.A. 114
218-F-3	Ditto	812	0.45	P.A. 114
218-G	Provenance experiment with Northern white spruce	94	0.30	P.A. 116

Table 5 (Cont'd.)

Exp. No.	Description	No. of Plants	Area Acres	Plantation Area
	Seed Plants 1963 (Cont'd.)			
244 open	Selection and testing of exotic spruces	50	0.17	P.A. 116
263-A-1	Provenance experiment with South European, Russian and Siberian Scots pine	1,184	0.68	P.A. 124
263-A-2	Ditto	1,373	0.78	P.A. 124
263-B	Ditto	170	0.56	P.A. 115
283-A	Testing of 5 European "Alnus glutinosa" provenances	99	0.33	P.A. 116
	Total 1963	21,054	16.17	
	Total 1962	10,447	6.46	
	Seed Plants, Grand Total 1962-1963	31,501	22.63	
	Grafts 1962			
85 open	Selection of early flowering Scots pine for rootstock purposes	100	0.33	P.A. 115
85 open	Ditto	102	0.15	P.A. 114
86 open	Selection of the perfect Scots pine Christmas tree	80	0.26	P.A. 115
128 open	Grafted red pine population samples intended for provenance hybridization	380	1.25	P.A. 115
128 open	Ditto	381	0.63	P.A. 104
187-B	Grafted population samples of Norway spruce provenances	26	0.09	P.A. 116
	Total 1962	1,069	2.71	

Table 6. Plantations established in 1962 and 1963 by co-operating agencies.

Exp. No.	Description	No. of Plants	Area Acres	Agency and Location
	Seed Plants 1962			
183-E	Testing of single tree progenies of high resin yielding Austrian pine for shoot moth resistance	520	0.11	Ont.Dept. of L. & F., Maple, Ont.
200-B-1	Provenance experiment and observation plots including North European and Russian Norway spruce	6,528	6.20	Dept. of Forestry, Man.
200-C	Ditto	6,900	5.70	Dept. of Agri-culture, Indian Head, Sask.
200-E	Ditto	7,000	5.80	Kimberly-Clark Pulp & Paper Co., Longlac, Ont.
200-H	Ditto	3,000	2.50	Northern Inst. of For. Genetics, Rhinelander, Wisconsin.
200-I-1	Ditto	100	0.15	Univ. of Min-nesota, St. Paul, Minn.
200-I-2	Ditto	1,250	2.00	Univ. of Min-nesota, St. Paul, Minn.
200-I-3	Ditto	25	0.04	Univ. of Min-nesota, St. Paul, Minn.
200-N	Ditto	300	0.25	Dept. of N.A.& N.R., Northern Adm. Br., Fort Smith, NWT.
200-O	Ditto	300	0.44	Mr. L.S. Paterson, Fort Frances, Ont.
201-T	Provenance experiment with Ukrainian Scots pine	860	0.71	Ont. Dept. of L. & F., Maple, Ont.
209-I	Provenance experiments and observation plots including Larix decidua, L. leptolepis and L. eurolepis.	200	0.40	Mr. L.S. Paterson, Fort Frances, Ont.

Table 6 (Cont'd.)

Exp. No.	Description	No. of Plants	Area Acres	Agency and Location
	Seed Plants 1962 (Cont'd.)			
216-C	Red pine provenance experiment including Lake States and Canadian provenances in co-operation with Un. of Wisconsin.	3,065	2.53	Dryden Paper Co. Ltd., Dryden, Ont.
216-D	Ditto	3,065	2.50	Université Laval, Quebec City, Que.
216-E	Ditto	3,065	2.53	Dept. of For., Fredericton, N.B.
216-F	Ditto	3,244	2.68	Dept. of For., Fredericton, N.B.
216-G	Ditto	1,100	0.90	Ont. Dept. of L. & F., Maple, Ont.
253-G	Picea abies x asperata hybrids suitability for warm summers	100	0.08	Mr. L. S. Paterson, Fort Frances, Ont.
255-A-1	All range jack pine experiment	seeded	0.25	Kimberly-Clark Paper Co. Ltd., Longlac, Ont.
255-A-3	Ditto	seeded	0.25	Lake States For. Exp. Station, Rhinelander, Wis.
255-A-4	Ditto	seeded	0.25	Mich. State Univ., East Lansing, Mich.
255-A-5	Ditto	seeded	0.25	Université Laval, Quebec City, Que.
255-A-6	Ditto	seeded	0.25	Acadia For. Exp. Station, Fredericton, N.B.
255-A-7-1) 255-A-7-2) 255-A-7-3	Ditto	seeded " "	0.25) 0.25) 0.25)	New Hampshire For. & Recr. Commission, Concord, N.H.

Table 6 (Cont'd.)

Exp. No.	Description	No. of Plants	Area Acres	Agency and Location
	Seed Plants 1962 (Cont'd.)			
255-A-8	All range jack pine experiment	seeded	0.25	School of For. N.C.State College,Raleigh
255-A-10	Ditto	greenhouse & growth chamber tests		Yale Univ., New Haven, Conn.
255-C-1 255-C-2 255-C-3 255-C-3-1 255-C-3-2 255-C-3-3 255-C-3-4	Ditto	seeded		For.Commission, Edinburgh, Scotland
264-open	Provenance experiment with Pinus nigra from Mich.State University	432	0.33	Ont.Dept.L.& F., Maple, Ont.
	Total	41,054	38.10	
	Seed Plants 1963			
194-A	Provenance experiment with about 25 races of white spruce from the Great Lakes-St. Lawrence Forest Region	6,982	6.48	Ont.-Minnesota Pulp & Paper Co. Ltd., Fort Frances, Ont.
194-B	Ditto	9,480	7.50	Spruce Falls Power & Paper Co., Kapuska-sing, Ont.
194-C	Ditto	13,464	11.40	Ont.Dept.L.& F., Swastika Dist.
194-D-2	Ditto	6,048	2.77	Mr.J.B.Santon, Wilberforce Tp., Renfrew Co., Ont.
194-E	Provenance experiment with about 25 races of white spruce from the Great Lakes-St.Lawrence Forest Region	13,464	11.40	Ont.Dept.L.&F., Huron Distr.
194-U	Ditto	4,500	3.70	Université Laval, Quebec City, Que.

Table 6 (Cont'd.)

Exp. No.	Description	No. of Plants	Area Acres	Agency and Location
	Seed Plants 1963 (Cont'd.)			
194-V	Provenance experiment with about 25 races of white spruce from the Great Lakes-St. Lawrence Forest Region	8,424	6.96	Dept.of For., Distr.Office, Newfoundland.
200-B-2	Provenance experiment and observation plots including North European and Russian Norway Spruce	2,464	3.61	Dept.of For., Distr.Office, Fort Garry,Man.
216-H	Red pine provenance exp. including Lake States and Canadian provenances in co-operation with Un. of Wisconsin.	600	0.50	Université Laval, Quebec City, Que.
278-A	Selection of hardy plants in Douglas fir provenances	25	0.08	Université Laval, Quebec City, Que.
283-B	Testing of 5 European "Alnus glutinosa" provenances	84	0.12	Mr.J.B.Santon, Wilberforce Tp., Renfrew Co.,Ont.
	Total	65,535	54.52	
	Grafts 1962			
128-open	Grafted red pine population samples	41	0.07	Ont.Dept.L.& F. Maple, Ont.

Table 7. Distribution of plants to outside agencies in 1962 and 1963.

Exp. No.	Agent and Planting Site	No. of Seedlots	No. of Seedlings
194-G	Canadian International Paper Co., Harrington Forest Farm Nursery, Calumet, Que. (white spruce, 2-0 stock for transplanting). To be field planted 1964 in the Grenville-Harrington Area.	28	34,000
194-H	Canadian International Paper Co., Harrington Forest Farm Nursery, Calumet, Que. (white spruce, 2-0 stock for transplanting). To be field planted 1964 near the Baskatong Lake Area	28	34,000
194-I	Consolidated Paper Co., Grand'Mere, Que. Nursery at Grandes Piles, Que. (white spruce, 2-0 stock for transplanting). To be field planted spring 1964.	28	34,000
194-J	Fraser Companies, Ltd., Edmundston, N.B. (white spruce, 2-0 stock for transplanting). To be field planted spring 1964 in the Plaster Rock Area.	28	34,000
194-K	Dept. of Forestry, District Office, Fredericton, N.B. (white spruce, 2-0 stock for transplanting). To be field planted spring 1965.	53	21,850
194-L	Dept. of Forestry, District Office, Sillery, Que. (white spruce, 2-0 stock for transplanting in the Valcartier Nursery). To be field planted by Université Laval spring 1965 in the vicinity of St. Raymond Co. of Portneuf, Que.	53	21,750
194-N	Ont. Dept. of Lands & Forests, Fort William, Ont. (white spruce, 2-0 stock for transplanting in the Thunder Bay Nursery, Fort William, Ont.) To be field planted spring 1965.	53	22,200
	Total		201,800

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Tree improvement work in the Maritimes District,

APRIL, 1962 TO MARCH, 1964

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Work at the Acadia Forest Experiment Station and elsewhere in the Maritime Provinces involved seed-source studies in Pinus resinosa Ait., Pinus banksiana Lamb., Picea glauca (Moench) Voss., Picea rubens Sarg., Picea abies (L.) Karst., and Larix leptolepis (Sieb. and Zucc.) Gord., Larix decidua Mill., and Larix laricina (Du Roi) K. Koch. Trial plantations of native and non-native Larix Mill. and Abies Mill. were also established.

Pinus resinosa seed-source tests were established in 1962, in cooperation with Mark Holst, Petawawa Forest Experiment Station. These are located on the Garden of Eden Barrens, Nova Scotia, and at Iris, Prince Edward Island and involved 25 and 16 seed-sources respectively. The first was laid out according to a 5 x 5 balanced lattice square with three replications, and the second according to a 4 x 4 balanced lattice square with five replications. Twenty-five trees per plot, 6-foot x 6-foot spacing, single rows of division trees, and double rows of surround trees were used in each plantation.

Pinus banksiana seed lots from 96 sources, supplied by the Petawawa Seed Bank were sown during the spring of 1962 in a nursery experiment using 10 randomized blocks, 10 seed spots per plot, and 1-foot x 1-foot spacing. The seed spots were thinned to one seedling per spot during 1963 and each blank seed spot was replanted using 1-0 seedlings from the same seed-source. Heights of the seedlings were measured after growth stopped in the autumn of 1963. Some phenological observations were also made about this time.

A *Picea glauca* seed-source test conducted in co-operation with Dr. Hans Nienstaedt, Lake States Forest Experiment Station, was established during the spring of 1962. Four-year old (2+2) trees representing 26 seed sources were planted in 10 randomized blocks: five on a rich moist site and five on a drier and poorer site. Four-tree plots and 6-foot x 6-foot spacing were used. Four rows of trees surround each plantation. A record of dead and missing trees was taken in 1963.

Tests of *Picea rubens* from 30 seed sources, mostly in the Maritime Provinces and Maine, were established at Green River, the Acadia Forest Experiment Station and Fundy National Park in New Brunswick; near Baddeck and at East Kemptville in Nova Scotia; and at Iris in Prince Edward Island. Co-operators established two tests in Newfoundland and one in Maine. All plantations were laid out using 10 randomized blocks, four-tree plots, 6-foot x 6-foot spacing and rows of surround trees.

Height measurements were made in unreplicated plots of 10-year old *Abies balsamea* (L.) Mill., *Picea glauca*, *Picea rubens*, and *Picea mariana* (Mill.) BSP. at the Acadia Forest Experiment Station. Several seed-sources were represented within each species. With the exception of *Picea mariana* the trees from seed collected locally produced the greatest average height growth within each species. The average height of *Picea mariana* from local seed was slightly less than that of trees from seed collected at Musquodoboit, Nova Scotia, but the difference was not significant.

Three-year old (2+1) *Larix leptolepis*, *Larix decidua*, and *Larix laricina* from 20, three, and two seed-sources respectively were planted at the Acadia Forest Experiment Station in the spring of 1962. The plantation was laid out according to a 5 x 5 balanced lattice square with three replications. Forty-nine trees per plot, 10-foot x 10-foot spacing, single rows of division trees, and double rows of surround trees were used. Unreplicated observation plots were planted by co-operators at various points in the Maritime Provinces.

Native and non-native *Abies* as well as putative hybrids from crosses made in 1957 were planted in observation plots. Non-native *Abies* scions were grafted for future tree-breeding material. Plant material was exchanged with organizations and individuals in Europe, Asia, and North America.

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Cytogenetic studies in Caragana

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Tetraploid Caragana arborescens

The production of a tetraploid branch on a diploid bush of *C. arborescens* by the use of colchicine-agar capsules in 1954 was described in the 1957 report and in 1958 it was reported that this branch had borne seed which germinated into tetraploid plants. Six tetraploid seedlings from open-pollinated seed of 1959 and 1960 have survived and in May, 1964 one of the bushes flowered for the first time. This bush from 1959 seed, germinated in early 1960, was set out in the arboretum beside the "parent" diploid in 1961. Thus it has required four years to flower whereas normal diploid bushes flower in the third year and occasionally in the second. All the tetraploid seedlings have been slower growing than diploids. The flowering bush is 90 cm tall, the others, even slower in growth, are 20-30 cm tall. Average diploid seedlings would be at least 120-150 cm tall in their fourth season. Thus the tetraploids hold no promise as plants of superior growth rate.

The tetraploid bush differs from the diploid most obviously in greater pubescence of leaflets and calyx, which in the tetraploid, are sericeous, in the diploid, glabrate. The oblong-ovate leaflets are slightly thicker in texture and slightly broader in the tetraploid; length/width ratio is approximately 1.6 in the tetraploid, 1.8-2.0 in the diploid. Flowers of the tetraploid differ only slightly from those of the diploid -- being about 1 mm (5%) longer and the calyx slightly broader and more pubescent. Pollen of the tetraploid was 97% normal, full grains measuring 25-30μ in diameter (20μ in diploids). Some partially full smaller grains and empty micro-grains were also present.

Caragana aurantiaca X C. frutex hybrid

This hybrid was made by Miss I. Preston, a former employee noted for her lilac breeding, in 1930, and three bushes have since been growing almost forgotten at the Central Experimental Farm. After detailed study, it was concluded that the bushes are actually hybrids and they were described as C. X prestonae (Can. J. Genet. Cytol. 5,119-126. 1963). The parent species are not closely related and C. frutex is tetraploid (2n=32) whereas C. aurantiaca is diploid. The hybrid plants are tetraploid and it is believed that they resulted from the fertilization of unreduced eggs of C. aurantiaca. In general appearance the shrubs seem to be a small form of C. frutex, differing in that the leaves are smaller, the flowers are slightly smaller, unusually abundant and a deeper orange-yellow colour. The hybrid has ornamental value superior to that of C. frutex. A similar bush from a commercial source has been seen and it is possible that the hybrid has arisen in cultivation and has been propagated by nurseries.

Report to Committee on Forest Tree Breeding 1964

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B.C. Forest Service,
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As much of the tree improvement program as possible is now consolidated at the Cowichan Lake Experiment Station. The existing office building has been enlarged to allow space for two small laboratories and an office for the technical forest officer in charge of the tree breeding. A five-acre nursery site is being prepared and the first seed beds were established in 1963. A small seed extraction plant will be installed in due course. This consolidation will allow much better supervision of the three clone banks, progeny tests and experimental plots which are located in the Cowichan Valley. The clone banks alone contain grafts from 388 selected and special Douglas fir.

Inbreeding experiments with Douglas fir

The results on inbreeding studies with the Douglas fir to date would indicate that there is much variation between S_1 inbred lines as some are relatively easy to establish and others much more difficult. There is also a great deal of variation within an inbred line but this is not unexpected at such an early stage of inbreeding. By the use of fertilizers, inbred lines of Douglas fir have produced both staminate and ovulate strobili in varying amounts at ages as early as six years. Successful single crosses have been made between such lines with much variation in the early growth of the progenies. Both backcrossing and further inbreeding to an S_2 generation have been successfully carried out in some lines. This study has now been written up for publication.

The Pseudotsuga Arboreta at Lake Cowichan and Kennedy Lake

Two small arboreta containing all the known species of Pseudotsuga were established on Vancouver Island in 1960 in order that material would be available for future breeding work with the Douglas fir. The Asiatic species, in particular, Record of the Pseudotsuga arboreta at Lake Cowichan and Kennedy Lake three years after planting, 1963

Species	Country of Origin	Seed source particulars			Plantation	No. trees planted	Survival per cent
		Elevation in feet	Latitude	Longitude			
<u>P. sinensis</u> Dode	China	3,940	30°	120°	Cowichan	25	93
"	"	"	"	"	Kennedy	42	90
<u>P. forrestii</u> Craib.	China	9,840	27°	100°	Cowichan	25	76
"	"	"	"	"	Kennedy	52	86
<u>P. wilsoniana</u> Hayata	Formosa	4,920	25°	121°	Kennedy	48	96
"	"	2,950	24°49'	121°25'	Cowichan	25	72
<u>P. japonica</u> Beissner	Japan	2,620	33°33'	133°52'	Cowichan	8	75
<u>P. macrocarpa</u> (Torr) Mayr.	U.S.A.	7,000	34°17'	117°36'	Cowichan	25	96
"	"	"	"	"	Kennedy	22	95
<u>P. menziesii</u> Mirb. Franco <u>var. glauca</u>	U.S.A.	9,850	33°54'	109°07'	Cowichan	26	100

are rare and seldom found together in western arboreta. The lake Cowichan arboretum is at an elevation of 550 feet, latitude 48° 50', longitude 124° 07' while the Kennedy Lake arboretum on the west coast of Vancouver Island is at an elevation of 100 feet, latitude 49° 05', longitude 125° 32'. A summarised account of these two arboreta three years after planting is given in the accompanying table.

The two most vigorous species at the present time are P. macrocarpa and P. menziesii var, glauca. All the Asiatic species have suffered to some extent from frost and as further seed supplies are very difficult to obtain, scions from the most vigorous trees are being grafted on to local Douglas fir.

In 1963, Pseudotsuga seedlings from Mexico, elevation 7,500 feet, latitude 29° 10' and longitude 108° 10' were added to the arboreta. This particular seed lot was recognised as a distinct species in Mexico and is known as P. flahaulti, Flaus.

Inter- and intra-specific crosses within the genus Pseudotsuga

Some inter-specific pollinations were made with P. macrocarpa from California in 1963 and repeated in 1964. Other pollinations in 1964 were made with pollen from P. menziesii in Oregon and California. In North America P. Menziesii has a range of more than 2,000 miles from north to south and almost 1,000 miles from east to west. British Columbia occupies only a relatively small part of its range. Efforts are, therefore, being made to increase the breeding potential of the clone banks at Cowichan Lake by propagating scion material from trees selected in the United States and Alberta. At the present time, the Cowichan clone banks contain the clones of 43 and 14 trees selected respectively in Washington and Oregon. In addition, there are three clones from Alberta and eleven from interior British Columbia. In situations where neither pollen nor scions are procurable, small plantations are established from seed. This has been already done with the Asiatic and Mexican Pseudotsuga which are now growing at Lake Cowichan.

Progress report on tree breeding

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Breeding of Juglans

Selection of Juglans nigra, cinerea and sieboldiana gave the opportunity to study hydridization between the Canadian, Japanese and European species (J. regia). Some Juglans nigra, almost a hundred years old, have their progeny growing in the vicinity and their adaptation to hard winter conditions is already evident.

Crosses were made this spring between the four above-mentioned species to study different characteristics in the hybrids.

This study was made in cooperation with "La Station d'Amélioration du Noyer et du Châtaigner, Corrèze, France.

A provenance study was also prepared in cooperation with The Conservation Commission of Missouri, the former "Institut Agricole d'Oka" and la Seigneurie de Lotbinière, Qué.

Breeding of Acer

A collection of seeds was made to establish a provenance study in cooperation with The N.E.F.E.S. Burlington, Vermont, U.S.A.

Breeding of Fagus

Fagus grandifolia pollen was collected to send to Yugoslavia for crossing with Fagus silvatica. The study was made by the "l'Institut de Recherches forestières de Belgrade, Yougoslavie".

Study on conifers

Other provenance plantations were established in the spring of 1964 to continue a program started in 1962 and 1963, in cooperation with Michigan State

University (Douglas fir, Scots pine) and with the Petawawa Forest Experiment Station (white spruce, red pine).

Some provenances of <u>Larix</u> will be planted next spring in cooperation with the Division of Lands and Forests, Conservation Department, New York State.

Studies in *Abies* species and *Pinus resinosa*
Progress Report 1963-64

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Manitoba-Saskatchewan District, Winnipeg.

Two specific studies were undertaken, the first is a continuation of research in *Abies* species.

Leaf structure of Abies species

It was found that the position of the resin canals in leaves of alpine fir (*A. lasiocarpa*), balsam fir (*A. balsamea*) and Frasers fir (*A. Fraseri*) changed with the age of the tree. In all three species, the resin canal is marginal in the juvenile stage and shifts to a medial position in the mature tree. This similarity between these species is taken as evidence that the three species are more closely related in origin than had been previously supposed. A similar change in position was not observed in other species investigated, *e.g.*, red fir (*A. magnifica*), noble fir (*A. procera*), white fir (*A. concolor*), silver fir (*A. amabilis*), and shasta fir (*A. magnifica* v. *shastensis*). The marginal position of the resin canal is considered to be a primitive feature associated with juvenility.

This characteristic of the shift in position of the resin canals may be useful for distinguishing hybrids and species in *Abies*. Earlier studies of putative *Abies* hybrids did not take this into account. A paper was written concerning the variability in the leaf structure of balsam fir, Fraser fir and alpine fir.

In another study of alpine fir, needle samples were collected from sixty-five locations covering Yukon Territory, British Columbia, Washington, Oregon and California. The number of stomata were counted on the adaxial side of the leaf and the data subjected to statistical analysis. Stomata frequency was correlated with precipitation, latitude, altitude, and leaf width, which together accounted for 20 per cent of the variation. Precipitation alone accounted for about 16 per cent of the variation. Fifty per cent of the variation was of genetic origin, and the remaining 30 per cent was unaccounted for.

A red pine provenance experiment in Manitoba

A replicated experiment was planted at the Sandilands Forest Reserve in 1958. Observations were made in 1958, 1959, 1960 and 1963, including mortality counts, the occurrence of winter injury to the foliage (winter browning), and height growth. The following conclusions were reached from analyses of the data.

The Raco, Michigan, provenance was the best and the Stanley, Nova Scotia, provenance the worst. The two provenances differed significantly in both survival and maximum height growth. The Stanley provenance was particularly susceptible to winter browning. The performance of the local Sandilands provenance was close to that of Raco.

Sandilands is on the edge of the dry prairie region at the western limit of the range of red pine. It is in the forest-grassland transition zone that is more suitable for jack pine.

Because the Sandilands plantation site is marginal for red pine, it was of particular interest to compare the results with data obtained from five parallel experiments established on better sites in Ontario. In all cases, both Raco and Stanley provenances retained their respective positions, but the differences between them were smaller in magnitude.

Clinal variation in relation to continuous climatic or geographic variables was not evident in these data, which suggested rather that growth potential varies on a stand to stand (family to family) basis. A paper on this investigation is being prepared.

Selection and testing of variation among poplar species

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Native cottonwood from several sources are being compared with the hybrid poplars Populus grandis, populus robusta and Populus regenerata on a commercial scale on about 600 acres of plantations.

Populations containing 69 of the Oxford hybrid poplars, 10 Italian hybrid poplars, and a limited number of native black cottonwoods were established at the University Research Forest and on the Harper property near Agassiz. Growth measurements were summarized in 1962-63 Annual Report of the University Research Forest.

Testing pine grafts for resistance to the white pine weevil, *Pissodes strobi* Peck

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This work began as a field investigation in 1957 to examine the resistance and susceptibility of grafts of numerous five-needle pines to attack by the white pine weevil. Grafts used were selected specifically for their resistance or susceptibility to weevil attack and, in most instances, for their resistance to white pine blister rust, and satisfactory growth form and growth rate. All materials used were provided by Dr. C. Heimburger, and all grafting was carried out at the Kirkwood Management Unit, Thessalon, Ontario.

In the first experiment, 400 grafts of *Pinus strobus* and *P. peuce* were established on Scots pine in 1957 and examined annually for weevil damage. Records obtained over a five-year period were combined in an effort to assess the degree of resistance or susceptibility of the grafts over an extended period of time. As a result of earlier studies, the limitations on weevil attack, imposed by leader vigour, were considered in establishing resistance or susceptibility.

The results have shown that grafts selected for susceptibility to weevil attack were, indeed, more susceptible than the grafts selected for resistance to weevil attack. However, when the records were examined in terms of individual clones, it became evident that individual differences occurred between clones within and between the classified groups. Greater differences in resistance to weevilling occurred in clones belonging to two different populations of *P. strobus* than in those belonging to a single population of *P. peuce*. Moreover, early selection for resistance to weevilling was observed, even within a single population of *P. peuce*. Apparently, some factor, or factors, other than the physical qualities of the leaders of certain clones were instrumental in influencing selection by the white pine weevil.

In the second experiment, about 5,000 grafts were established on white pine during the period 1961-63. Materials grafted include *P. strobus*, *P. peuce*, *P. griffithii*, *P. monticola*, and *P. karaiensis*, in addition to hybrids of *P. strobus* crossed with *P. parviflora*, *P. griffithii*, *P. monticola*, and *P. peuce*. Methods of observation and recording of information were formalized in 1963. Surveys and preliminary analysis of graft vigour and weevilling will be carried out annually until sufficient data have been collected to provide for a critical description of the resistance, tolerance, or susceptibility of the clones to weevil attack. Until such time, the records of the annual surveys will be examined to maintain, in tabular form, the annual progression of graft vigour and weevil damage. The results of observations made to date indicate that, for the most part, the grafts are quite hardy and can withstand the climatic conditions characteristic of the Kirkwood area. In addition, differences in weevil attack, and leader mortality due to weevil attack, have been observed that are not associated with any obvious difference in leader quality.

Variation and inheritance of some physiological and morphological traits in Douglas fir

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The objectives of this study were to describe the variability, to evaluate the combining ability, and to calculate the heritability values for certain characteristics of Coastal Douglas fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii). Four trees (A, B, E, and 11) were selected on the University of British Columbia campus. Three of them were selected from the local natural population while the fourth came from an unknown provenance. The investigation of variation included phenological observations on flushing and flowering times, and quantitative descriptions of pollen, seed and cone size.

A survey of campus trees showed that Douglas fir is extremely variable in the time of flushing and flowering, the size of pollen, seed and cones, and the total number of filled seeds. Times of flushing did not determine times of flowering. There was a strong negative correlation between pollen size and time of flowering. This suggests existence of adaptive significance to adverse climatic condition. Variation in width of the cone was greater than in cone length.

Seed germination percentage appeared to be inherited on a single factor basis, and the results from F_1 crosses substantiated the suggestion that tree E might possess a homozygous dominant state. Filled seeds had not been obtained from tree B when it was self-pollinated. This supports Orr-Ewing's theory, that self-sterility might be an inbreeding effect caused by the action of lethal genes, when brought together in a homozygous state.

Combining ability of the four study trees was tested by a polyallel cross with all sixteen possible combinations. The cross was completed in 1962, using three different pollination methods; dry, wet and dry-wet. Mortality of conelets was lowest in the case of wet pollination. Losses were doubled with dry pollination. Of 302 seed conelets pollinated, 201 were collected and 8,004 seeds were extracted from them. The number of filled seeds per cone was lowest in the cases of self-pollination (1.91) and wind pollination (3.05). Cross pollination on the average surpassed wind pollination by 4.6 times, and the self-pollination by 7.3 times, producing 13.81 filled seeds per cone.

In order to minimize and test the variability due to environmental effects, the seedlings were grown under controlled environmental conditions. Two Percival (PGC-78) units were employed, one of them simulated long-day (15 hours illumination) and the other short-day (10 hours illumination) effects for 132 days.

Tree 11, which was different in origin from the local provenance trees, showed the best combining ability as a seed parent. Progeny from crosses between trees from the same populations showed smaller values compared to progenies from crosses between trees from different populations. Epicotyls, for example, were 73-78 per cent longer in seedlings from tree 11 compared to seedlings from trees B and E, when pollen from tree A was applied. Obviously, further investigation of intra-specific crosses has practical merit.

Heritability values in the narrow sense were calculated for twelve different juvenile seedling characteristics.

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The selection and testing of Douglas fir and western hemlock plus trees

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The objective is to locate and propagate superior phenotypes of Douglas fir and western hemlock. 2,250 acres were reconnoitred and 812 acres were cruised 100 per cent on the University Research Forest in 1959. Field data were collected on 16 Douglas fir and on 20 western hemlock trees, which included: age, height, d.b.h., growth rate, stem form, crown form, length of live crown, branching habit, branch size, bark type and thickness, cone production, resistance to insect and disease. Sites were described, and photographs were taken.

Wood samples were collected for laboratory analysis: fiber length, specific gravity, fibril angle, sapwood-heartwood ratio, springwood-summer-wood ratio, and cellulose content were defined.

Scions from 4 plus Douglas fir and 4 plus Western hemlock were grafted in clone bank in 1962.

Genetic variation in seedlings of jack pine provenances grown in controlled environments

PROGRESS REPORT

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The investigations reported here were conducted at Yale University, School of Forestry, Greeley Memorial Laboratory, while I was on educational leave of absence from the Petawawa Forest Experiment Station. I am very grateful to Prof. François Mergen, Yale University, for the free use of his laboratory facilities and for his continuing advice during the course of preparation of my Ph.D. dissertation. The full results will be incorporated in the dissertation and will be submitted for publication in due course.

Genetic variation in jack pine has been demonstrated in plantation and nursery experiments. Rudolf (1958) summarized the studies reported up to 1957, in which were shown differences associated with seed origin in growth, form, winter hardiness, winter coloration and insect damage. Schoenike et al., (1959), and Arend et al., (1961), described differences in cone characteristics, height growth, and susceptibility to insects that were related to seed origin. Holst and Yeatman (1961) reported that height growth of Ontario provenances was positively related to length of growing season of the area of origin, and Mergen (1961) showed that there are local ecotypes within the natural range of jack pine that produce reproductive structures at an earlier age. Giertych and Farrar (1962) studied the growth of jack pine seedlings of nine provenances in relation to photoperiod and nitrogen level. Total dry weight, height, dry weight of leaves and roots, and dry weight per unit nitrogen content were all positively correlated with number of growing degree days.

In any field study, major factors of the environment, such as light and temperature, are largely confounded with each other and difficult to measure precisely. Thus field studies designed to separate the genetic and environmental components of variance are subject to large error variances from uncontrollable variations in important environmental factors.

Basic studies of tree seedling growth and development may be carried out in artificial environments, where one or several factors may be controlled within close limits, while others not of immediate concern may be held constant and at as near optimal levels as possible.

The following studies of genetic variation in jack pine seedlings in relation to seed origin and environment of culture began in July, 1962. Seed of 87 provenances was supplied by Mr. M.J. Holst, who has reported elsewhere in these proceedings on the broad program in jack pine provenance research initiated by him some years ago. The seed samples included collections from the entire natural range of the species, from the coast of Maine and Nova Scotia to the MacKenzie River Valley in northwest Canada, and from the Lake States to northern Quebec. This material was used for the following studies: a) growth of jack pine seedlings in controlled environments in relation to seed origin, photoperiod and temperature; b) comparisons between the same provenances grown in controlled environments, in a greenhouse and in field nurseries; c) winter hardiness and initiation of growth in the spring in relation to seed origin.

a) Growth of jack pine seedlings in controlled environments in relation to seed origin, photoperiod, and temperature. Seedlings of 50 provenances were grown for three months at three photoperiods (20, 15 and 10 hours) and at three temperatures (27°/19°C, 21°/13°C, and 15°/7°C, light period/dark period, respectively). With proper attention to statistical design and analysis, it was expected that close estimates could be obtained of the relative contributions of the genetic and environmental components of variation, and of the significance of their interactions.

The data recorded at the end of a three-month treatment period included fresh and dry weight of crowns, dry weight of roots, and ratings of bud, secondary needle and secondary shoot development. In addition, detailed measurements of crown and needle lengths for individual seedlings of six provenances were made. The data were processed by the Yale IBM 709 computer where each provenance was subjected to multivariate analysis of variance leading to estimates of significant parameters for environmental effects and their interactions. These sets of parameters were further analyzed by canonical analysis to provide two significant linear compounds which were used to discriminate between the 50 provenances.

Marked differences in reactions appeared between provenances. On the average, the southern sources grew more than the northern sources, but the relative reaction of the northern sources to photoperiod and temperature was greater.

Photoperiod accounted for the greatest proportion of the variance within provenances, the longest photoperiod generally leading to greatest development. Temperature had a marked effect within photoperiods; the warmest regime resulted in more rapid and complete maturation during the growing period than did those at lower temperatures.

b) Comparisons between controlled and natural environments. Seedlings of the same 50 seed sources were grown in a greenhouse under the daylengths used in the controlled environments. Daylength in the greenhouse was controlled by supplementing the normal daylight with artificial light of relatively low intensity. In a favourable photoperiod, shoot growth in the greenhouse was much greater than that in the growth cabinets, apparently due to the lower average light intensity in the greenhouse, although the possible influence of other variables such as light quality and temperature cannot be discounted.

In a parallel experiment, the development of seedlings of 87 provenances grown on a greenhouse bench for four winter months were compared with those grown during four summer months. Relationships similar to those in the first experiment were observed, but the differences between replicates of the same seed lot (error variance) were greater.

Collections of one-year-old seedlings of the same geographic seed sources were made from three nursery provenance tests established in Canada. In these collections, the error variance in dry weight measurements was excessively large.

c) Winter hardiness and initiation of growth in the spring in relation to seed origin. Seedlings were grown under the natural daylength for the observation of cold resistance and spring growth initiation. Seedlings of 15 provenances, five each from a southern, central, and northern latitudinal zone, were grown in the greenhouse during the summer of 1962. In September, potted seedlings were placed in the nursery and in the greenhouse.

On four dates (between September 27 and December 14), sample seedlings were subjected to a series of low temperature tests to determine comparative levels of cold hardiness. Observations were made of foliage colour, bud development, and needle characteristics. Samples of needles were analyzed by paper chromatography for quantitative estimates of soluble sugars.

Differences due to latitude of origin were demonstrated in cold hardiness, sugar concentration, and winter coloration (anthocyanin). Values for all characteristics increased with time during the autumn, and earlier in seedlings of northern origin than in those of southern origin. This differential was directly related to the earlier maturation of the northern provenances as indicated by earlier bud formation that was followed by secondary needle growth.

Cold hardiness was not directly related to sugar concentration or to winter coloration, but all were considerably higher in the seedlings from the nursery than those from the greenhouse.

In the nursery seedlings, the development of cold hardiness coincided with the appearance of raffinose, which disappeared by April when cold resistance was again at a low level.

Seedlings of the same 15 provenances that had overwintered in the nursery were subjected to a series of controlled environments in the growth rooms for eight days beginning April 10. Three temperatures (21°, 16°, and 10°C) were maintained and three photoperiods (20, 15 and 10 hours) were applied to groups of seedlings (15 provenances) within each cabinet. At the end of the treatment period measurements were made of shoot growth and secondary needle growth. Sugar levels were assayed and a single low temperature (-25°C) test was applied to the seedlings.

The low temperature test proved to be too severe, but some seedlings from both the lowest temperature and the shortest photoperiod escaped complete necrosis. There were no significant differences in this respect due to seed origin.

High temperature greatly stimulated both shoot growth and growth of secondary needles, the former chiefly in seedlings of southern origin, the latter mostly in seedlings of northern origin. The development of shoots and needles was directly related to photoperiod, but this accounted for a lower proportion of the variance than either temperature or latitude of origin.

Sugar concentrations after the eight-day treatment period were compared with those measured in a comparable sample of seedlings at the beginning. Sugar level varied inversely as temperature, while photoperiod had a minor effect of doubtful significance. The level in northern seedlings was depressed less at the highest temperature and elevated more at the lowest temperature than that in seedlings from central latitudes or of southern origin.

Temperature was shown to be the major factor controlling growth initiation and sugar concentration of jack pine seedlings that had been subject to several months of winter chilling. The type and amount of growth, whether predominantly of shoot or needle, depended on latitude of origin and was in turn related to the type of bud formed before winter dormancy set in the previous autumn. Longer photoperiods resulted in earlier growth initiation and more rapid growth independently of temperature, but the effect of photoperiod was less than that of temperature over the ranges employed.

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Introduction

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The meeting of this panel was arranged because the time is ripe for a discussion of red pine breeding and related provenance research. The early series of red pine provenance experiments planted in the Lake States have been remeasured and reviewed. Younger provenance experiments planted in the United States and Canada have supplied additional information of performance related to geographic origin. More recently a number of detailed experiments have been carried out to study population structure and breeding patterns within the species.

We cannot expect to cover the whole field in detail, but we can present the results of specific experiments and discuss the implications that arise from them. We should also discuss our results in practical terms and give those who are responsible for the procurement of red pine seed a chance to weigh our arguments. Are we in a position to recommend limitations on seed collection in terms of provenance, seed production areas (native and plantation) or seed orchards?

Each member of the panel has first hand knowledge of some aspect of red pine breeding and it is expected that this exchange of ideas will provide some answers from past experience and pose specific questions for future research in the breeding of red pine.

Some evidence of racial variation in red pine (Pinus resinosa Ait.)

by

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(Maintained in St. Paul, Minn., by the Forest Service, U.S. Dept. of Agriculture in cooperation with the University of Minnesota).

Red pine, according to Shaw, is a member of the section Lariciones which represent the first stage in the evolution of the hard pines. It is the only member of this section in North America except for Pinus tropicalis which is limited to a restricted range in Cuba and the Isle of Pines in the Caribbean region. Other members of the group are found in Europe, Siberia, and various parts of Asia down to and including the Phillippines, East Indies, Burma, and Indo China.

Morphologically, red pine is a very uniform species. Apparently it also is a very old species. Fossil records from Dakota Sandstone show that an upland pine (Pinus clementsii and/or Pinus resinosipites) markedly resembling red pine occurred in southern Minnesota during the Cretaceous period. During periods of glaciation red pine along with other species was forced to migrate to the South and then returned North with the retreat of the glaciers. Some red pine may have migrated northward to the east of the Great Lakes and some to the West, thus laying the foundation for some possible racial differentiation.

DISTRIBUTION

The present natural range of red pine includes a relatively narrow zone about 1500 miles long and 500 miles wide around the Great Lakes and the St. Lawrence River. It extends thus from Newfoundland and Quebec west to Ontario and southeastern Manitoba, and south to northeastern Minnesota, Wisconsin, Michigan, northern Pennsylvania, New York, Connecticut, and Maine. Red pine also occurs locally in northeastern West Virginia and in northeastern Illinois. Except for the West Virginia outliers, the present range from southeastern Wisconsin eastward lies within or closely adjacent to the area glaciated during the late Pleistocene period. The species was formerly most abundant and grows to the largest size in the northern parts of three Lake States.

The native range does include some considerable variation in winter temperatures and precipitation, but in general the conditions probably are not nearly as variable as are those represented by the native ranges of such species as Scots pine and ponderosa pine which also have been studied and found to display considerable racial variation.

RACIAL VARIATION STUDIES IN THE UNITED STATES

Several agencies have undertaken studies of racial variation in red pine in the United States. The Lake States Forest Experiment Station began this as one of its earliest projects and made field plantings representing a considerable number of seed sources in 1931, 1933, and 1937. In 1937, also, the Northeastern Forest Experiment Station obtained stock of some 50 sources of red pine from the Lake States Station and outplanted them on the Kane Experimental Forest in northwestern Pennsylvania. In 1948 the University of Wisconsin began some studies of racial variation in red pine, and in 1954 the Nekoosa-Edwards Paper Company began a study of variation of red pine within the Lake States. More recently, Michigan State University has begun a study of variation in this species also.

The Lake States Station studies

The sources assembled by the Lake States Forest Experiment Station pretty well bracketed the natural range of red pine within the United States with the exception of the West Virginia outliers. Only a few Ontario sources were included, and the range in Canada was not, therefore, well represented. Seed of a West Virginia source was obtained, but somewhere along the line it apparently had been injured, and it failed to produce seedlings. It was impossible to obtain another collection before the time that the nursery sowings were made for the main studies. One set of plots was established in 1931 with 37 sources, a second set in 1933 with 140 sources, and a single planting in 1937 with approximately 50 sources. For the first two sets, plantations were set out in at least 3 localities within the Lake States, but the combination of severe drought, fire in one area, and an errant plowman in a third area combined to reduce the 1931 and 1933 plantings to one locality, northeastern Minnesota. The 1937 planting on the Chippewa National Forest in northeastern Minnesota escaped injury, but it was set out on an emergency basis and was not well laid out for analysis.

For the 1931 planting, at the end of 18 years from seed, the ranges in seed source averages for survival, average height, average diameter, basal area per acre, and approximate cubic volume per acre were substantial (Table 1).

Table 1. 1931 Planting, survival, and growth, end of 18th year from seed, northeastern Minnesota.

Category	Survival	Average total height	Average d.b.h.	B.A. per acre	Approx. unpeeled volumes per acre	
					All trees	Satisfactory trees
	Per Cent	Feet	Inches	Sq.ft.	Cu. ft.	Cu. Ft.
Low	42	10.5	1.92	12.1	61	58
High	100	15.3	3.43	75.5	515	514
Average	68	12.8	2.61	31.6	186	184
LSMD, 5%	12	.7	.24	--	--	--

Analysis of variance indicated that there were significant differences due to source. Likewise, considering factors of quality (vigour, form, and soundness), there were also wide ranges by sources. These factors were expressed by percentages of better dominant and codominant trees or premium trees, which combined elements of vigour, form, and soundness. To combine quantity and quality factors, we used the best dominant and codominant trees with crowns over one-third filled with foliage of healthy green color and normal size that were completely sound, had good form, and a well developed crown and computed the volumes per acre of these satisfactory trees. These volumes were only slightly less than those for all trees, which illustrates that there were few poor trees in the planting.

When it comes to picking out a pattern there is some difficulty. The best lots were from northeastern Minnesota, northwestern Minnesota, north-central Minnesota, northeastern Wisconsin, and adjacent southern Upper Michigan. Lots from New England, Lower Michigan, central Wisconsin, and northwestern Wisconsin generally did not perform so well. Within these various regions or subregions, there again was quite a little variation from source to source. The most local subregion, northeastern Minnesota, had some of the very best performing sources and also two of the poorest. This general pattern seemed to hold for the various characteristics measured or computed. Average results for the various subregions gave a clearer indication that the local and near local sources on the average perform best at this age and that those from a further distance, in this instance, central Wisconsin, Lower Michigan, and New England, perform somewhat more poorly.

The larger planting with 140 sources on the same site in northeastern Minnesota displayed somewhat similar results at the age of 23 years from seed. The top 20 per cent of the sources in cubic volumes per 100 trees planted were all from localities in Minnesota, northern Wisconsin, and Upper Michigan. None of the sources from central Wisconsin, Lower Michigan, or the northeastern States were included in this category. One out of three Canadian sources was so included. Survival, after the 1936 drought, was somewhat low but showed a considerable range between sources as did also average d.b.h., average height, and average cubic volume per acre (Table 2). There was also a broad agreement in development considering average cubic volume per acre at 23 years according to the accumulation of degrees above 50°F of the zone of seed origin. The best results came within the zone comparable to that of the planting site and then it decreased in both directions. It increased from 126 for the zones with 11,000 or more cumulative degrees above 50 to 430 for the zone with 8-9,000 cumulative degrees. (Table 3).

Table 2. 1933 Planting, survival, and growth, end of 23 years from seed, northeastern Minnesota (140 sources).

Category	Survival	Average total height	Average d.b.h.	Approx. unpeeled volumes per acre
	Per Cent	Feet	Inches	Cubic feet
Low	8	9.7	1.33	8
High	52	22.9	5.23	910
Average	31	19.6	4.19	341
LSMD, 5%	19	2.5	.79	--
LSMD, 1%	25	3.3	1.04	--

Table 3. 1933 Planting, relation between cubic cubic volume 23 years from seed and cumulation of degrees above 50°F. of the place of origin.

Normal annual cumulation of degrees above 50°F.	Volume per acre
Thousands	Cubic feet
7-8	325
*8-9	430
9-10	339
10-11	233
11+	126

*Planting site is in this zone.

Again we have the picture that there is better development of reasonably local sources in considering this one particular planting area, although the range of results is somewhat narrow and sources from quite a distance away from the planting site still may perform quite well. On the other hand, those from central Wisconsin, Lower Michigan, and northeastern states appear to be a much poorer risk in this section of the Lake States. A further check of the volumes per source according to the average January temperatures of the seed collection area indicated a decreasing volume production with an increase in average January temperature. This ranged from 611 cubic feet for the 0-4°F. zone to 128 cubic feet for the 20-24°F. zone.

The Northeastern Forest Experiment Station tests

At the end of 10 years' growth in northwestern Pennsylvania 50 seed sources of red pine originally supplied by the Lake States Forest Experiment Station showed generally good survival for all sources but showed some significant differences in height growth. Seed source survivals ranged from 79.8 to 93.6 per cent and average heights from 9.4 to 10.9 feet. A narrow range, it is true, yet the analysis of variance indicated a significant difference due to sources and to regions. This study was reported by A.F. Hough in Station Paper 49 of the Northeastern Forest Experiment Station in August 1952. He concludes: "Seed from those regions at the head of Lake Superior and to the north and west in parts of Wisconsin and Minnesota resulted in significantly poorer height growth in the Kane Plantation than did seed from regions south of Lake Superior in the Upper Peninsula of Michigan, from northeastern and central Wisconsin, and from the north-central portion of the Lower Peninsula of Michigan. In other words, seed from sources geographically closer to the point of planting is better than seed from the western limits of the red pine range".

AN INTERPRETATION OF THESE RESULTS

These results from widely separated planting sites in northeastern Minnesota and northwestern Pennsylvania agree in indicating that the response of red pine from seed sources in central Wisconsin, Lower Michigan, and New England differs to a significant degree from those in northern Wisconsin, northern Upper Michigan, and Minnesota. This would appear to be of some significance in indicating racial variation in the species although the races may be rather widely distributed and not sharply defined. The scatter of the results for individual sources, however, makes it difficult to pick out any patterns for determining clinal or ecotypic variation.

Aside from these rather broad indications of racial or ecotypic variation within the species, there are a number of known individual tree variations in growth habit and apparently in resistance to some pests. These differences probably will be covered in more detail by other members of the panel.

The net result of these differences within the species indicate that there is some possibility of improving growth and development by selecting seed origins reasonably close to home until there are demonstrated advantages of certain more distant sources. They indicate further that much of the opportunity for improvement within the species probably must depend on individual tree selections over a good part of the range and the use of these selections in breeding work.

Red pine progeny test 1931 and 1933 Minnesota plantings

by

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Probably the oldest red pine individual-tree progeny test in the United States was established by the Lake States Forest Experiment Station in 1931 and 1933. Of the three original plantings, only one remains today. It is located between Ely and Isabella in northeastern Minnesota and includes 87 individual-tree open pollinated progenies, 56 stand collections and 13 miscellaneous collections. Each collection, whether from an individual tree or stand, was planted in 10-tree row plots with 10 completely randomized replications. This report covers the 1964 measurements of the individual-tree progenies only, and it only includes 69 of the original 87 collection. Eighteen progenies were left out because their survival was zero in many plots. The progenies included in the test were represented by 8-10 plots in most cases, but for a few only 5 could be included.

For the preliminary analysis presented here, the seed sources were arranged by regions according to the seed collection zones described by P.O. Rudolf[1]. The basic data are presented in Table 1.

The outplanting is located in zone 4B and in Table 1 the regions are arranged on the basis of decreasing proximity to the planting site zone. The analysis of variance in Table 2 shows that the differences between seed source in height, diameter breast height and survival all are significantly different at the 1 per cent level; regional differences, however, are only significant for the survival. It is striking that whereas survival for the collections from the

[1] Rudolf, P.O. 1956. A basis for forest tree collection zones in the Lake States. Minn. Acad. Sci. Proc. 24: 21-28, illus.

Table 1. Average annual diameter growth, height growth and survival of 69 red pine single-tree progenies. Collections marked with asterisks (*) were planted entirely in 1931 or in both 1931 and 1933; all other collections were planted in 1933 only.

Region	Coll. No.	Annual Growth DBH in.	Annual Growth Ht. ft.	Surv. %
4A N.W. Minn.	183	.230	1.28	37
	184	.240	1.29	43
	Mean	.235	1.28	40
4B N.E. Minn.	34*	.224	1.26	20
	35*	.245	1.29	22
	37*	.228	1.25	19
	38*	.230	1.26	29
	147	.221	1.26	32
	177	.246	1.29	32
	180	.244	1.26	19
	Mean	.234	1.27	25
3B Cent. Minn.	143	.245	1.29	32
	144	.212	1.24	23
	145	.260	1.29	26
	172	.260	1.35	41
	173	.237	1.29	40
	174	.241	1.25	29
	Mean	.243	1.29	32
4C N. Wis.	46*	.209	1.25	17
	47*	.182	1.21	26
	48*	.214	1.21	24
	49*	.232	1.24	24
	24*	.215	1.25	17
	141	.260	1.34	37
	148	.219	1.23	37
	165	.231	1.26	30
	166	.238	1.24	33
	167	.225	1.25	32
	170	.216	1.25	33
	Mean	.221	1.25	28
3C E.Cent.Minn. & W.Cent.Wis.	12*	.221	1.29	25
	13*	.214	1.27	24
	74*	.198	1.23	29
	75*	.223	1.27	26
	142	.235	1.30	34
	151	.254	1.29	10
	161	.233	1.26	28
	163	.239	1.29	23
	164	.236	1.28	31
	171	.227	1.30	16
	227	.233	1.24	23
	Mean	.227	1.27	26

Table 1 Cont'd.

Region	Coll. No.	Annual Growth DBH in.	Annual Growth Ht. ft.	Surv. %
3D Cent.Wis.	156	.211	1.24	26
	223	.223	1.27	29
	224	.226	1.30	28
	226	.237	1.29	23
	Mean	.225	1.28	26
4D N. Upper Mich.	230	.216	1.22	20
	231	.228	1.21	23
	232	.242	1.29	32
	233	.225	1.21	32
	236	.224	1.27	27
	237	.209	1.23	28
	242	.212	1.19	19
	244	.188	1.14	16
	Mean	.218	1.22	24
4E S. Upper Mich.	229	.201	1.19	21
	249	.195	1.21	13
	Mean	.198	1.20	17
5B-D Keewenau Upper Mich.	238	.236	1.25	14
	239	.231	1.29	32
	Mean	.233	1.27	23
3E E.Wis. & N.Lower Mich.	194	.218	1.25	17
	204	.276	1.36	19
	206	.251	1.31	17
	207	.199	1.15	10
	211	.221	1.22	10
	213	.195	1.25	13
	216	.208	1.23	18
	217	.212	1.29	27
	218	.226	1.32	19
	Mean	.223	1.26	17
3F E.Cent. Lower Mich.	81*	.219	1.23	20
	82*	.210	1.28	21
	192	.199	1.15	18
	Mean	.210	1.23	20
2D S.W. Wis.	152	.206	1.24	10
2C W.Cent.Wis.	64*	.218	1.23	20
	159	.250	1.27	23
	Mean	.221	1.25	22
2F E.Cent. Lower Mich.	189	.209	1.19	22

Table 2. Analyses of variance for 1964 measurements of red pine seed source test in Northeastern Minnesota.

Source of variation	Degrees of freedom	Height	DBH	Survival
Seed Source	68	.01577**	.2721**	5.748**
Region†	13	.02422^{NS}	.3948^{NS}	14.835**
Seed Source within Region	55	.01378	.2431	3.600
Error	517	.00661	.10698	3.229

** Significant at the 1% level.

NS Non-significant.

† Regions based on seed collection zones described by P.O. Rudolf (Minn. Acad. Sci. Proc., 1956, pp. 21-28).

3 zones surrounding the planting site ranges from 19 to 43 per cent; it ranges from 10 to 23 per cent with only one exception (27 per cent) when seed sources from the mildest regions (3E, 3F, 2D, 2C, 2F) are planted in the colder zone 4B.

The growth rates of the different seed sources are relatively uniform; the poorest seed source grew at a rate of 1.14 feet per year, the best at 1.36 feet per year. In terms of site index, the best progeny is 11 feet or 19.2 per cent better than the poorest (57 ft. and 68 ft. respectively). Considering only the regions including and immediately adjacent to the outplanting site, the range is reduced by one-half to 8.9 per cent of 5½ feet (62 ft. versus 67½ ft.) and the best seed source is only slightly over 3½ ft. better than the average for the seed sources representing the three zones: an improvement of approximately 5.5 per cent. For diameter growth, the improvement is somewhat better, the best progeny being about 9.2 per cent better than the average for the seed sources representing the three zones (4A, 4B and 3B).

The data suggest two additional interesting points. The seed sources from the climatically more different zones appear to be more variable than seed sources from zones similar to the planting site. For example, in zone 4D -- northern Upper Michigan -- the best seed source is 13.1 per cent taller than the poorest; in zone 3E -- eastern Wisconsin and northern Lower Michigan -- it is 18.2 per cent taller; and in zone 3F -- east-central Lower Michigan -- it is 11.3 per cent taller. Thus, the variation is as much as twice as great as it is for the zones including and adjacent to the outplanting. It is unfortunate that the Lower Michigan planting of the material failed and it, therefore, is impossible to know whether or not the Michigan seed sources would have been less variable if planted within their own climatic zone. The data do, however, suggest that some genotypes interact with the environment more strongly than others; hence, fail to perform well.

Finally, the relationship between height growth and diameter suggests rather marked differences in tree form; some seed sources appear to be tall with relatively small diameters, others are intermediate in height but have relatively large diameters. The following seed source averages are listed as examples of the extreme types:

Seed Source	Diameter growth/year	Height growth/year
180	.244	1.26
174	.241	1.25
166	.238	1.24
171	.227	1.30
224	.226	1.30
217	.212	1.29

Practical implications of the results

Is a red pine breeding program feasible? The answer is in the affirmative. Small gains can be made, but will be slow and costly compared to other species progress. The gains become more meaningful when we consider that a one foot improvement in site index, from 50 ft. to 51 ft., at standard levels of management approximates a 2,000 bd. ft. increase (4.5 per cent) in yield at the end of the rotations. We are, from the presented data, justified in expecting gains of 3 to 4 per cent in height growth or 1.5 to 2 ft. increase in the site index. This amounts to about 9 per cent increase in board foot yield at rotation age. Add to this the extensive planting of red pine and the increases become considerable. We are talking in terms of 200 to 400 million board feet increases in yields for the Lake States[2] per rotation.

How should the breeding program proceed?

First, phenotypic selection probably will be of little value. Simply select good dominant trees in the best stands.

Secondly, progeny tests should include the largest possible number of progenies representing broad geographical regions climatically similar to the potential planting region. For example, for planting in northern Minnesota, the tests may include northern and central Minnesota and northern Wisconsin.

Thirdly, the tests plantings should, (1) be planted on different sites to permit studies of genotype x environment interactions, and (2) plots should be large enough to permit long term evaluation without between-plot competition becoming a serious problem.

Fourth, measurements must be of sufficient accuracy to permit evaluation of small differences.

What research is needed in order to further a red pine breeding program?

The data presented suggests that genotype x environment interactions may be an important factor in red pine improvement; they must be studied. The results also suggest important genotypic differences in tree form. Research should definitely determine the importance and magnitude of such differences. It should also evaluate the magnitude of variation in wood quality characteristics.

Finally, to write, on the basis of these results, that a red pine breeding program is feasible is perhaps unconvincing. What we need is an analysis of the improvement costs and an evaluation of ultimate economic gains; only by comparing these two factors can we reasonably decide whether to breed or not to breed red pine.

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[2] Figured on the basis of a total annual planting program of 125,000 acres in the three Lake States of which an estimated 75 per cent was red pine.

Summary of comments on red pine breeding[1] [2]

by

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During the past 12 years several provenance and progeny tests of red pine have been established by the University of Wisconsin[3]. In 1963, measurements were made on the older plantings and were analyzed to provide a basis for decisions on a future program of tree improvement with red pine. Data from five of the older tests are discussed here.

Unfortunately, an interpretation of the data is not entirely clear-cut. Certain restrictions of experimental design necessitated assumptions concerning statistical analysis. Each planting was intended to follow the design layout of the triple rectangular lattice. This is an incomplete block design for which variation between blocks within the three replicates can be removed to provide an increased precision on heterogeneous sites. The design requires randomization of blocks within replicates and of plots within blocks. Only the latter randomization was performed in the Wisconsin plantings. The lattice analysis was used, however, as it approximated the actual design more closely than the alternative randomized complete block design with three replicates. In addition, square plots containing 36 or 64 trees were used with the result that the incomplete blocks were relatively long and narrow. The tests were thus probably not as precise as they could have been.

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[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

[2] Additional data and discussion of the work in Wisconsin have been included in a paper submitted for publication to FOREST SCIENCE in 1964.

[3] Plantations discussed here were established by R.G. Hitt. The work was supported in part, by funds from the Wisconsin Conservation Department. Acknowledgement is made of planting sites provided by the Nekoosa-Edwards Paper Company.

Among the plantings is a provenance test including seedlings from 18 seed collections in Ontario and Quebec along with a sample of nursery stock offered by the Wisconsin state nurseries. Many of the seed collections were provided by the Tree Seed Plant at Angus, Ontario. They presumably represent collections from many trees in native stands near the listed seed source. As nearly as can be determined from nursery records, the control stock originated from seed collected in northern Wisconsin. An array of mean heights and mean survival are presented in Table 1. Survival was uniformly high, while height at plantation age six varied significantly among the different seed sources. Two points of interest are suggested by the array of mean heights.

Table 1. Provenance means for height and survival at plantation age 6 in central Wisconsin.

Seed Source	Mean Height (feet-based on 88-95 trees)	Mean survival (%-based on 192 trees)
Angus, Ontario	7.0	95
North Bay, Ontario	6.7	94
Kemptville, Ontario	6.5	96
Mattawa, Ontario	6.5	98
Madoc, Ontario	6.4	96
Control, "Northern Wisconsin"	6.4	93
Hyndford, Ontario	6.2	95
Chapeau, Quebec	6.1	95
Pembroke, Ontario	6.1	95
Wawa, Ontario	5.9	99
Sioux Lookout, Ontario	5.8	95
Douglas, Ontario	5.7	93
Thessalon, Ontario	5.6	95
Batchewana, Ontario	5.4	95
Eagle River, Ontario	5.4	93
Vermilion Bay, Ontario	5.1	94

continued

Table 1 Cont'd.

Seed Source	Mean Height (feet-based on 88-95 trees)	Mean Survival (%-based on 192 trees)
Thessalon, Ontario	5.0	92
Geraldton, Ontario	5.0	94
Kawene, Ontario	4.6	95
$LSR_{.05}$†	1.0	
$LSR_{.01}$	1.3	

†Means which differ by more than the indicated approximate LSR (for 10 means) are significantly different at the probability level indicated. (From Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42).

(1) There are significant differences in total height between seed sources, although no seed source is significantly taller than the controls. In central Wisconsin, seed sources from southern Ontario generally show more rapid early growth in height than seed sources from central or western Ontario. A graphical representation of internode elongation for the tallest and shortest seed source over six successive years showed increasing divergence in elongation. The pattern of internodal elongation for the controls, however, paralleled that of the Angus source.

(2) The height advantage of the Angus source over control stock is about 10 per cent. A figure of approximately 10 per cent appears in the comparison of tallest progenies with control stock in most of the Wisconsin plantings. The Angus source is also the tallest or second tallest in two older Wisconsin plantings.

In the four older plantations, two pairs of identical composition, the variation in height and diameter was analyzed for a total of seven seed sources from Ontario and Quebec, a few collections from stands in northern Wisconsin, and 60 different open-pollinated progenies from individual Wisconsin trees. The selected Wisconsin trees were concentrated in northern Wisconsin, chiefly in the north central area. The basis for selection is obscure. For the purposes of analyzing variation in open-pollinated progenies, the selections were assumed to be essentially random, at least in terms of height and diameter growth.

In the first pair of plantings, 38 open-pollinated one-parent progenies were established in northwestern Wisconsin and in central Wisconsin. The array of measurements from the northwestern planting, at plantation age nine, suggests that improvement of red pine is largely a question of locating the best of several adequate seed sources. The tallest one-parent progeny was practically the same height as the control stock. Seed for the controls came from northern Wisconsin, Cass Lake, or Red Lake, Minnesota. In the same test established in central Wisconsin, the outlook for genetic improvement in growth rate through selection and breeding is more promising. The height advantage of the tallest one-parent progeny is about 10 per cent above the controls. As a measure of the joint effect of variation in height and diameter, bole volume was calculated assuming a conical stem form. Here the range of variation was considerably magnified with volume of the tallest progeny representing a gain of nearly 50 per cent over the controls or the mean of one-parent progenies.

The oldest pair of tests included twenty, one-parent progenies, 5 Ontario provenances, and 2 Quebec provenances with state nursery stock of northern Wisconsin origin as a control. Measurements at age 11 showed that the tallest progenies were again 10 per cent taller than the controls or the mean of one-parent progenies. The average unpeeled volume of the largest seed source in one planting is 70 per cent greater than the controls while unpeeled volume was about 30 per cent greater in the other planting. Peeled volume was calculated for the central Wisconsin planting and showed an advantage of about 30 per cent for the largest seed source. The total range of variation in calculated peeled volume was somewhat reduced as compared with unpeeled volume as the result of a small, yet significant positive correlation of volume and bark thickness.

The results of the Wisconsin tests are interpreted to indicate that a continuation of some plan for intraspecific genetic improvement of red pine is worthwhile in areas where red pine represents the major species for reforestation.

Of the 28 million seedlings planted in Wisconsin in 1963, 20 million (70 per cent) were red pine.

The plan for red pine improvement in Wisconsin has two aspects:

(1) The performance of seed sources from southern Ontario in Wisconsin tests, and the performance of seed sources from central Wisconsin in Wright's[4] range-wide nursery test have prompted plans for seed collections emphasizing trees in southwestern and central Wisconsin. Material from these sources has not been tested in Wisconsin. The test will consist of nursery study followed by field plantings in highly replicated, randomized-complete blocks of small row-plots. The plots will contain open-pollinated one-parent progenies for a progeny test-seedling seed orchard to be represented on one site in each of the four major areas of tree distribution for the state. It is hoped that data from this experiment will provide two things; first, an indication of whether seed from populations in the southwestern and central portion of the state has a general potential for more rapid growth, and second, from the relatively large number of progeny-tested individuals, a breeding population of sufficient size for further genetic improvement should be obtained.

(2) Grafts from the parents of the currently most promising progenies in progeny tests will be established in a breeding collection which may also provide some seed for commercial use. When a sufficient number of parents are collected, controlled crosses will be made to provide estimates of the genetic parameters which are necessary for the prediction of genetic gain and to provide F_2 seed in seedling seed orchards.

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[4] Wright, J.W., W.I. Bull, and G. Mitschelen. 1963. Geographic variation in red pine - 3-year results. Quarterly Bull. Mich. Agr. Expt. Sta. 45: 622-630.

Seedling seed orchards for the improvement of red pine

by

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My colleagues on this panel are presenting data from past experiments on the genetics of red pine (Pinus resinosa Ait.) possibilities. Their general experience indicates that the species is little variable and that accurate experimentation is needed to detect differences.

Continued large-scale planting of red pine in Michigan prompted Michigan State's interest in its improvement, starting in 1959. The first step was a range-wide provenance study, to fill gaps left by older ones. This was studied in the nursery, then outplanted in several north central states. To date it has shown general growth superiority on the part of trees grown from seed collected in southern Michigan and central Wisconsin. Variation in traits other than growth rate was slight or nonexistent.

The second step was a seed orchard program started in 1960. The native southern Michigan red pine population seemed to be the logical basis for that intensive work. The traditional grafted seed orchards seemed ill-fitted for several reasons. Grafting experience in Wisconsin and Ontario was not as favourable as with the European and southern pines. Early fruiting of the grafted trees has been disappointingly light, and there is a possibility that seedlings will produce cones almost as early as grafts. As yet there are no inheritance data to help in making superior-tree selections in the field. Hence there is no guarantee that seed from grafted plus trees will be enough improved to warrent the expense of the grafting. Also, native red pine is an uncommon tree in the state. There are few opportunities to practice strong plus-tree selection of the type needed to make a grafted orchard successful. In the absence of inheritance data it is necessary to estimate heritabilities. They are probably low:

around .05 or .10. With values that low, genetic improvement following mass selection might be undetectable.

For those reasons we chose a very different approach: to collect open-pollinated seeds from hundreds of trees, grow those seedlings in properly designed progeny tests, measure the progeny tests after 8 or 10 years, remove the poorest progenies <u>in toto</u>, and remove some of the poorest trees in the best progenies. This is termed half-sib family selection by crop plant and animal breeders. The genetic improvement does not rest upon the care which went into the original selections. Rather, it depends on the fact that genetic superiority of certain progenies will have been proven by the time of the first thinning. Those superior progenies will function as a seed orchard as well as a breeding arboretum for the continuation of the work into the second and third generations.

As already mentioned, the seedling progeny test-seed orchards were started in 1960. That was a good seed year and both the U.S. Forest Service and the state of Michigan were collecting large quantities for their regular planting programs. They agreed to keep a few cones from each tree separate whenever possible. The collectors practiced some care in the choice of parent trees, but probably too little to be effective. The lack of parental selection is a debatable point and very rightly has been questioned. It can be justified for Lake States red pine but not as a general practice. For one thing, native red pine is uncommon and the stands are uneven. There are few cases where one could select the best tree in 50 with any pretense of having chosen the genetically best type. For another thing, the selection would have delayed the start of the work until another good seed year occurred. This might be a 5- or 6-year delay, long enough to counteract the mass selection gains.

The seeds were extracted in the fall of 1960 and sown in the experimental nursery in the spring of 1961. Their heights were measured but no other data were taken because of the seeming uniformity in other traits. They were raised to 2-1 size and outplanted in the spring of 1964, in cooperation with Jack Pitcher of the Milwaukee office of the U.S. Forest Service.

Five outplantings were made, three in Michigan's Lower Peninsula and two smaller ones in the Upper Peninsula. According to plan there should have been 90 trees (15 replicates X 6 trees per plot) of every open-pollinated progeny in each of the permanent test plantings. However, there were not enough seedlings to do that. Hence, the actual outplanting included up to 40 seedlings (10 replicates X 4 trees per plot) per progeny per outplanting. Over 300 progenies were involved.

These permanent test plantings were established by machine on open, level sites. There was a stipulation that the rows be straight in both directions, that every fourth tree be labelled, that the 4-tree plots line up well with each other, and that the trees be planted well. The stipulation was easily met even though planting proceeded at the rate of one tree every 6 seconds. With a 5-man crew, and with proper preparation beforehand (preparation took two-thirds as much time as planting), the 6 seconds included mapping. There was insufficient chemical weed control in a part of one plantation and resulting high mortality; survival in the others is still over 95 per cent.

During the next year or two we shall practice sufficient weed control to get all trees started well. Then we shall use the best current fertilizer recommendations and apply fertilizer (probably nitrogen) in an attempt to stimulate early fruiting. We are hopeful of duplicating the results in one southern Michigan plantation which coned heavily in its eighth year.

As soon as profuse flowering starts, the plantations will be measured, certainly for height and possibly for other characters which are deemed important at the time. Then the first thinning will remove the poorer 150 progenies and change the spacing from the present 8 x 8 feet to an approximate 8 x 16 feet. Strictly from the improvement standpoint there is no point in measuring earlier. Nor is there any point in thinning earlier. It is that thinning which will raise the genetic average of the plantation and make it a producer of superior seed. Hence, first flowering and thinning should coincide. Subsequent thinnings will remove more progenies until finally only the best trees in the best 20 to 25 progenies remain.

As soon as flowering occurs there will be a two-part schedule for each plantation. One part will be seed production and collection. Action agencies (presumably the Michigan Department of Conservation and the U.S. Forest Service) will treat the plantation as a seed orchard and harvest genetically improved seed. For the second part, a research agency will develop a second-generation progeny test-seed orchard. There will be hundreds of controlled pollinations so that every progeny is identifiable by male and female parent. Controlled pollinations can be accomplished much more easily under the test conditions than in the original wild stands. Per parent tested, they promise twice as much genetic gain.

The second-generation progeny test-seed orchards will go through the same cycle of measurement, thinning, seed production, and breeding as the ones now on the ground. Hopefully, 20 years hence they will replace the present ones; in turn they will be replaced by third-generation ones.

This scheme is offered as a model for improvement in other species. The major deviation would be the addition of careful parental selection in most other trees. The number of parents tested (should be over 100) can vary with the ease of planting. The number and size of the test plantings can vary with the need for testing over a variety of conditions and the amounts of seed needed. If the acreage involved in adequate progeny tests is too small for anticipated seed needs, supplementary unmeasured plantings can be made solely for seed production.

Comparisons are in order between this and other improvement schemes which might have been used. This one is relatively inexpensive and therefore surpasses others with respect to the amount of improvement per unit of effort. Also, it surpasses seed production areas and grafted seed orchards (but not 2-parent progeny tests) with respect to the amount of inheritance data; that is needed to form the foundation for long-term improvement work. If the goal were the quickest possible production of genetically improved seed without regard to cost or amount of improvement, the nod might go to grafted seed orchards; there seems a probable 3- or 4-year differential.

If the comparisons are on the basis of improvement per generation or per unit of time, the choice is between the present 1-parent progeny test and a 2-parent progeny test scheme. Theoretically the 2-parent scheme, which involves controlled pollination, is the best. But in red pine there is some question. A progeny test must achieve a certain size (rather large) before it can function properly as a seed orchard or as a foundation for a many-generation improvement effort. If enough controlled pollinations can be accomplished in one or two years to achieve that size, they should be made. If that work must be spread out over a several-year period, we may have to be content with open-pollinated progenies and their lesser gain. Experience will settle this point.

As others will mention, there is as yet no guarantee of sufficient genetic variability with red pine to warrant a tree breeder's attention. Thus this whole project might fall flat. However, it was intended to be large enough to give a definitive answer. If that answer is "no variation", we can proceed without conscience pangs to other more amenable trees. If the answer is "variation", we will obtain actual improvement and theoretical data at the same time.

The future of red pine - seed supply and breeding

by

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Based upon the results from numerous provenance studies, an inbreeding study and the general lack of phenotypic variation, I guestion if there is enough genetic variation available in red pine to warrant the expenditure of the large amount of time and money required to produce an improved type.

Red pine is genetically the least variable of all the pine species that have been subjected to detailed examination. The species is genetically quite uniform. Undoubtedly some genetic variation does exist, but the magnitude of this variation (at least when compared with that of other pine species) is small.

The tree breeder is dependent upon the presence of detectable genetic variation to produce improved strains or types of trees. Progress in producing an improved red pine, or for that matter the improvement of any organism, depends on the ability of the breeder to locate or produce genetic variants from which to select desirable types. Because of the lack of genetic variation in red pine, it is doubtful if selection of superior individuals or races will be fruitful. Selection is possible, but on the basis of improvement per unit effort, it is probably impractical. It might require 100 times as much effort to locate superior red pine types as it would to select superior types within a variable species such as jack pine.

Hybridization, both on an intraspecific and interspecific level, is a widely used technique for introducing desirable variation into a variety or a species. The slight differences between red pine from widely different origins would tend to preclude intraspecific hybridization as a promising approach for this species. Interspecific hybridization would certainly appear to be promising except for the fact that it is extremely difficult to cross red pine with any other species. Many attempts have been made to cross red pine with supposedly closely related species. Only one successful cross has been reported. This is a hybrid between Austrian pine and red pine, made at Placerville, California. Thus far it has not been possible to repeat this cross. It is probable that this cross will be repeated and that other hybrids will be made using improved techniques such as embryo culture and the use of stimuli to assist fertilization and embryo development.

The production of genetic variation by using mutagenic agents such as irradiation offers some promise. Unfortunately, it is not until the second generation that most of the induced variation can be detected. This would mean at least 10-15 years for red pine. The use of mutagenic agents resulting in polyploidy does not appear promising.

The very things that make the breeding of red pine difficult, simplify the problem of obtaining and distributing red pine seeds and seedlings for reforestation purposes.

There is little, if any, biological evidence to support the establishment of either seedlings or clonal seed orchards of red pine. The chance that seed produced in seed orchards will be genetically better than average is negligible. Seeds obtained from natural stands or plantations will be every bit as good (genetically) as seed produced in orchards. Seed orchards should only be established if it can be shown that seeds can be produced most economically in this manner.

The standards used to determine which stands or plantations should be used for seed collection need not be high. Seed collected from any good healthy stand or plantation should be adequate. If possible and economical, cone collections could be made in conjunction with cutting operations.

Although the genetic variation of red pine is slight, it does exist. The rather broad seed zones, presently used by the Department of Lands and Forests, should be maintained but, in times of seed shortage in one zone, there is little reason why seeds from adjacent zones cannot be substituted.

Lessons learned from some red pine provenance experiments in Canada

by

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The older series of red pine provenance experiments planted in northeastern Minnesota in 1931 and 1933 and in northeastern Pennsylvania in 1937 indicate a small range in height growth between sources.

In the Minnesota experiment[1] (which is of particular interest for Ontario), the occasional lot grew very poorly. Provenances nearest to the planting site were best whereas those from colder or warmer regions were inferior and more variable. There was plenty of variation within regions indicating differences in growth potential between different stands. The best provenances were about 10 per cent higher than the mean.

In the Pennsylvania experiment[2], provenances from Lower Michigan, central and northeastern Wisconsin, and the Upper Peninsula of Michigan ranked highest. The distant provenances from warm regions grew best, while those from the cold and continental (most distant) northwestern Minnesota grew the least. The "eastern" provenances made a surprisingly poor showing. They were found in the middle three-fifths and were quite variable. Of the 50 provenances tested, New York ranked 23rd, Pennsylvania 33rd, Massachusetts 35th and Maine 37th.

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[1] Rudolf, P.O. 1948. Importance of red pine seed source. Proc. Soc. Am. For. Meeting, 1947: 384-398.

[2] Hough, A.F. 1952. Preliminary results of red pine seed-source test in northwestern Pennsylvania. U.S.D.A. For. Serv. Northeast. For. Exp. Sta., Pap. 49. 28 pp.

In this experiment the best provenances were also about 10 per cent higher than the mean.

Since 1955, red pine provenance experiments have been planted in Canada by the Ontario Department of Lands and Forests and by the Forest Research Branch of the Department of Forestry of Canada. Some of the results were discussed in our progress reports in these proceedings (pages 78-81 and 122-123).

In an experiment that included Ontario provenances planted at the Petawawa Forest Experiment Station, 10-year-height was highly significantly correlated with length of growing season. The eastern Ontario provenances were less variable than those from western Ontario. In terms of frost damage the western Ontario provenances (from a more continental climate) were less damaged than the eastern Ontario provenances. When height was plotted over January to July temperature differential (which provides a good separation of eastern and western Ontario provenances) only the western provenances showed significant correlation. In this experiment the best provenances are roughly 10 per cent higher than the mean.

In another experimental series testing red pine from most of the Canadian range with a few U.S. provenances also included, we find a somewhat similar picture. In the experiment planted at the Petawawa Forest Experiment Station, the distant provenances from New Brunswick and Nova Scotia grew poorly. No provenance was significantly better than the local control. Again the better provenances were about 10 per cent higher than the mean.

All of our experiments are young and not all have been analyzed. Whatever data we have suggests that the growth rate of red pine is related to regional climate. We also suspect that both local climate and site have a pronounced effect on vigour and adaptation. The between-stand variation has been difficult to estimate as most of our provenances come from seed collection areas of 50 to 100 miles diameter. Wherever we have been able to pinpoint a stand, our data suggest considerable stand to stand variation, particularly in the western part of the range where stands often are well isolated from each other.

Here the chance for genetic drift must have been considerable. In eastern Ontario where red pine has a more continuous distribution, differences between stands are not so pronounced. But even in eastern Ontario there are exceptions to this rule. A slow growing type from a frost pocket near Griffith has been identified. The relatively slow growth of a southern Ontario provenance (Castleton) from a slow growing stand on calcareous sands might indicate an ecotype unsuitable for the acid sands in our experiments, or possibly the effect of genetic drift in an isolated southern outlier population.

In Canada we have extensive areas where red pine is more or less continuous and where it maintains a prominent position in the forest. In these areas we would expect to find more or less continuous variation. But we also have the extremes of the range (northern cold, western dry and eastern moist) where red pine is confined to small isolated stands. Such stands are either confined to choice sites or have been isolated on marginal sites. Here genetic drift must be considerable and special ecotypes have probably developed. Compared with the extensive areas of uniform sand plains in the Lake States some of our soils seem poorer and more variable. On these marginal soils red pine has reacted violently to as yet unidentified micro site deficiencies.

Differences between provenances have been less pronounced in the experiments planted in regions with congenial climates and relatively fertile and uniform soils. Where the experiments have been established near the edge of the range or on marginal soils, differences between provenances have been more evident. This is an important finding that will be investigated further in other range-wide studies in Canada.

Future experiments in Ontario should investigate variation between stands based on standard sampling techniques. Differences between trees may be discovered through single tree progeny tests.

If our preliminary results are valid I suggest the following for a practical approach to red pine seed collection in Ontario.

1) Do not collect seed for reforestation in plantations.
2) Avoid areas with provenances that have proven slow growing in our provenance experiments.
3) Avoid areas with red pine of variable quality.
4) Avoid slow growing stands.
5) Avoid frost pockets or frost basins - unless such slow growing but frost hardy types are needed for planting in similar areas.
6) Confine cone collections to relatively few areas of good red pine[3] where open grown trees occur that are accessible to local labour for picking cones - and where both are expected to remain for the next 50 years.
7) Test the populations with 50-100 single-tree progeny tests which may eventually serve as a seed orchard of an improved native population.
8) Test all selected stands on different sites in different regions.

Such procedures might eventually secure a 10-20 per cent increase in volume. However, the most immediate benefit would be that cone collection would be forbidden in poor stands, even if cones and cone pickers are both available.

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[3] These stands can be improved somewhat genetically by cutting undesirable trees. As emphasis is on cone production, trees with large crowns should be favoured.

Notes on panel discussion

by

C.W. Yeatman,
Secretary,
Committee on Forest Tree Breeding in Canada.

Following the presentation of the papers, specific points were raised in questions from the floor. Dr. Fowler explained that at least a 15-year delay was involved in the detection of the mutogenic effects of irradiation of red pine because a second generation was required to display the segregation and recombination of the affected genotypes. Dr. Rudolph commented that some irradiation effects may be evident in the first generation,e.g. flowering may be induced earlier. Irradiation of pollen may be a way of making interspecific crosses more probable in red pine.

Mr. Rudolf explained that the low survival in some of the Lake States experiments resulted from the exceptionally severe drought and high temperatures experienced in 1936. Normally, survival in comparable red pine plantations is 80 per cent or better.

Dr. Nienstaedt said that differences in growth due to variations in stocking were compensated for by planting-up the failed spots with jack pine. Survival within provenances from the northern part of the Lower Peninsula of Michigan was substantially lower than the average. The provenance with the lowest survival was also the most variable.

Dr. Wright was asked whether he recommended single-plant plots in preference to four-plant plots. He replied that if 95 per cent survival can be obtained, then 1 or 2 plant plots are to be recommended, but such survival cannot be guaranteed. Dr. Nienstaedt commented that he prefers not to use plots of a very few trees because of the interaction and competition between plots. Furthermore, small plot data are difficult to convert into yields on a per-acre basis.

The use of fertilizers for the promotion of flowering in red pine was discussed. Generally it has been found that fertilization tends to increase the number of flowers, but does not materially reduce the age of flowering.

Dr. Kriebel noted that although there is more inherent variation in white pine, it will still be a long time before improved stock can be placed at the disposal of planters. Will it take much longer for red pine? He suggested that it may be worth the èffort in particular areas where red pine is an important species, e.g. in Wisconsin.

Mr. Salm asked how much attention had been paid to insect and disease resistance in red pine. Dr. Fowler referred to the work on the susceptibility of red pine to European shoot moth. To develop resistance, there must be variation to work from, and all red pine appears to be susceptible in a favourable environment. Pinus nigra is resistant, but as mentioned previously, it does not readily hybridize with red pine. Dr. Heimburger concurred, and noted that the European shoot moth is an exotic species that is not hardy in the colder areas away from the Great Lakes. However, since red pine is so uniform, it is potentially very susceptible to foreign disease organisms, and hence it is imporaant to introduce some variation into red pine if possible. Dr. Heimburger reported that entomologists in the Lake States feel that red pine will frequently form a good stand in spite of attack by shoot moth. In areas of severe injury, alternative species may be planted, but this is a glib suggestion, since other species are not as good on red pine sites.

Dr. Rudolph remarked that too much emphasis was placed on mean values for performance, and that more attention should be paid to variability within provenances. To take another approach, data dealing with the crop trees only, say the upper one third, should be analyzed. Dr. Nienstaedt expressed his agreement and added that the latter point was another reason for having larger plots. Dr. Lester noted that the use of means is obligatory in many cases due to the design of the experiments. Dr. Wright said that if a high correlation is proven between whole- and part-plot values, then limited measurements including only the tallest trees may be made to save time and effort.

VISITORS' PAPERS AND NOTES FROM ILLUSTRATED TALKS

Genetic variation in *Picea sitchensis* (Bong.) Carr [1] [2]

On the basis of the long and continuous latitudinal range of Sitka spruce, an hypothesis was established that this species demonstrates genetic variation in height growth that is related to the pattern of geographic distribution. To test this hypothesis, studies were made of the variation in starting capital of potential growth material, rate of growth, and duration of growth.

For the first growing season, the seed and embryo were considered to form the starting capital. Embryo size, cotyledon number, and cotyledon length were correlated with seed size; there was no relationship between latitude of seed origin and seed size, germination rate or germination capacity.

The terminal bud was considered to be the starting capital for the second growing season. Bud size was correlated with the number of enclosed needle primordia, and large buds were produced on large seedlings; these in turn produced more shoot growth, thus maintaining the growth differential. There was no relationship between rate of growth and latitude, but seedlings of one provenance (glacier valley near Juneau, Alaska) had an exceptionally high growth rate.

The duration of growth was the most important factor influencing provenance variation in height growth. Bud formation and flushing were considered to be adaptations to climatic conditions in the native habitats. Buds formed and terminal height growth ceased in the autumn in response to decreasing daylength, and an essentially continuous relationship was demonstrated between height growth or time of bud formation and latitude. The glacier valley source and one southern provenance formed buds significantly earlier than neighbouring sources. The flushing response was largely controlled by temperature and the variation was

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1 This paper contains preliminary conclusions based on research carried out in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School, Yale University.

2 Paper presented *in absentia*.

associated with the spring temperature regime in the native regions.

Observations on morphological development of the seedling were corroborated by the results of an anatomical investigation. The low degree of differentiation in the mature embryo is suggested as a cause of the slow germination that was observed with seed of this species. However, once the tissue systems and terminal meristems were established, the pattern of development resembled that described for several other coniferous species. The small size of the apex may contribute to slow development in the early seedling stages. The anatomical development of the shoot apex followed the three stages outlined for other conifers, but, in seedlings from southern origins, needle initiation continued late in winter and occasionally was resumed in early spring.

Fundamental to variations in morphology and anatomy are differences in the nucleus. Hitherto, variation in conifers has been considered to arise as the result of single gene mutations, and no systematic patterns of variation in nuclear or chromosomal constitution have been described. In Sitka spruce, however, the continuous pattern of morphological variation was paralleled by variation in the karyotype. Both the volume of the nucleus and the total length of the haploid chromosome complement increased with increasing latitude of seed origin.

Jeffrey Burley,
School of Forestry, Yale University,
New Haven, Connecticut, U.S.A.

Wood quality study - Ontario black spruce

The two main types of black spruce stands found in Northern Ontario were illustrated. A contrast was made between the poorly drained lowland condition common to northeastern Ontario (Cochrane District) and the better drained upland sites of northwestern Ontario (Geraldton District).

Examples were shown of the new equipment in use at the Ontario Research Foundation to pulp small (5 gm) wood samples and to prepare paper sheets for testing. One of these tests, the Ingstrom zero span tensile test, was illustrated.

A.J. Carmichael,
Ontario Department of Lands and Forests,
Toronto, Ontario.

Genetic studies of birch

Betula is the first hardwood genus to be studied at the Institute of Forest Genetics, Rhinelander, Wisconsin. There are three main areas of research: variation, compatibility, and cytology. A provenance study of yellow birch has recently been initiated. Considerable work has been done on self-compatibility, intraspecific and interspecific compatibility within the genus. Cytology has so far received the least attention. Collection of materials for a birch arboretum is well under way. A small experiment on flower induction in birch has shown that it is possible to get female flowers on birch by growing them under continuous light for 27 months.

Knud E. Clausen,
Institute of Forest Genetics,
Rhinelander, Wis.

Scots pine progeny test in Sweden

and some notes on the work of the Department of
Forest Genetics, Royal College of Forestry,
Stockholm, Sweden

A short survey was given of the results obtained from progeny tests with Scots pine, (Pinus silvestris L.) in Sweden. The progenies originated from parent trees selected as extreme plus or minus types in stands at different latitudes. A comparison between the progenies showed that in general the progenies from the plus trees had good height growth and a relatively narrow crown. The "minus-progenies" were lower with longer branches and a more bushy appearance. A conspicuous exception was one progeny from a cross between two minus trees. This progeny was taller than all the other ones in the test whether originating from other minus trees or from plus trees. The shape of the crown, however, was bushy and the branches long. Another exception was found in three progenies from a plus tree growing in the same stand as the above mentioned minus trees. These progenies had a comparatively low mean height independent of the phenotype of the other parent tree - plus or minus. The crowns on the other hand were narrow in the plus x plus combinations and very varying in the plus x minus crossings.

The branch angles seemed to be strongly genetically controlled, the parent trees with acute branch angles giving progenies with distinctly acute branch angles, too. An analysis of variance indicated highly significant differences between the progenies in the above mentioned characters.

Progenies obtained from crosses of widely different provenances had a mean height superior to that of the progenies from the same parent trees after open pollination.

The effect of inbreeding in progenies obtained by self pollination was characterized by a high mortality of the plants, a depressed vigour and retarded growth. The variation in this respect was great within the progenies as well as between them.

Abnormalities in the formation of buds and branches such as forking, fasciation and prolepsis have been found in some of the progenies. These characters seem to be due to one or a few dominant genes. The great influence of the environmental factors was emphasized. Some characters varied more with differences in the environment than others.

A few other projects going on at the Department of Forest Genetics in Stockholm were mentioned. Provenance tests with Picea abies and Pinus silvestris, the two economically most important forest tree species in Sweden are carried out on a large scale. Rapidly growing provenances of spruce have been introduced from eastern and southern Poland, from Germany and western Russia. They grow better than most of the Swedish provenances in southern Sweden and are hardy enough to stand the climate. In Scots pine the problem of transplanting provenances from south to north and vice versa is studied and the limits set for the range within which seeds and plants can be moved without damaging effects on the growth etc. of the material are investigated.

The capability of self fertilization is studied in different forest tree species. Special attention is paid to the embryological side of the problem. The development of the pollen tubes, the zygotes and the embryos and the stages at which the abortion of either of them set in seem to vary immensely between trees.

Irradiation of X-rays and γ-rays is carried out in order to produce mutations and get mutants, the purpose being among others to get individuals resistant to diseases.

Karyotype analyses have been made of a number of coniferous species. On the basis of these analyses common basic idiograms were drawn and the chromosome morphology investigated.

The X-ray method is used routinely in studying seed quality and for special purposes as for instance the study of polyembryony, embryo and endosperm damages, insect attacks etc.

Carin Ehrenberg,
Royal College of Forestry,
Stockholm, Sweden.

Tree seed production in New York State

Slides were shown of New York's tree seed production areas of red, white and Scots pine and of Japanese larch. Plantations from 10 - 15 year old are rogued of undesirable trees leaving 150 trees per acre. In case of red and Scots pine and Japanese larch the trees are topped at about 10 feet. Slides were shown of a European larch tree flowering at 4 years of age in a plantation, also a heavy crop of cones on white spruce in a plantation planted in 1953 - 14 years from seed. The method of moving grafted trees by use of gallon oil cans with both ends removed were shown. Slides of personnel at this conference were shown as they appeared at the World Consultation in Stockholm in 1963.

E.J. Eliason,
Head Research Unit,
State of New York,
Conservation Department,
Albany, N.Y.

Variation in virulence of some strains of *Valsa nivea* Fr. causing crown blight of hybrid aspen

An ascomycete *Valsa nivea*, present as a saprophyte on native aspen in Sweden, appeared as a wound parasite on artificial hybrids between *Populus tremula* x *P. tremuloides*.

Analysis of bark extracts from the hybrid and the parent species pointed out a difference in the content of carbohydrates. The hybrid aspen contains sucrose, which is lacking in the parent species. Thirteen strains of the fungus were tested on their sucrase activity. Two strains were sucrase lacking and they were mostly apathogenic when tested under field conditions.

A great many progenies of hybrid aspen have been tested for natural resistance to *Valsa nivea*. The importance has been determined of time of inoculation, the diameters of the twigs and the genetic influence on the establishment of symptoms.

A. Hyppel,
Royal College of Forestry,
Stockholm, Sweden.

Needle anatomy of soft pine hybrids

A few slides were shown illustrating some of the differences and similarities in needle anatomy among species and hybrids of soft pines. This material is part of a paper to be published in Silvae Genetica.

H.B. Kriebel,
Department of Forestry,
Ohio Agricultural Experiment Station,
Wooster, Ohio.

White spruce - Slide show comments

The Lake States Forest Experiment Station, Institute of Forest Genetics has 3 new and 1 older study of racial variation in white spruce established in the field. Results are very similar to preliminary Canadian results with, in many cases, identical seed sources. Of particular interest is the superior development in the Lake States of certain seed sources from southeastern Ontario.

Recent work with white spruce has shown that trees in the same stand may vary up to two weeks in their time of flushing. Sixteen late-flushing and nine early-flushing trees were selected and cloned in 1962. On May 23, 1962 the young grafts experienced a severe frost in the nursery and many clones were seriously injured. An examination a week after the frost indicated that whereas an average of 13.3 per cent of the buds (range 0.0 to 44.0%) were killed on the late-flushing clones, the early flushers showed an average of 80.4 per cent (range 69.2 to 100%) bud injury. Clearly this variation can be utilized in a breeding program and should be given all possible attention.

White spruce grafts made in 1959 and 1960 produced cones for the first time in 1964. Highly significant difference in production was observed in a randomized test involving 12 clones. The best clone produced an average of 50 conelets per graft; the poorest only 3 conelets per graft. If cone production of this magnitude can be maintained, breeding will be greatly simplified.

H. Nienstaedt,
Institute of Forest Genetics,
Rhinelander, Wis.

The radiation research project at the Institute of Forest Genetics, Rhinelander, Wisconsin

The recently initiated radiation research project at the Lake States Forest Experiment Station's Institute of Forest Genetics in Rhinelander has been planned with four broad, long term objectives in mind. These include:

(1) The fundamental study of acute and chronic gamma irradiation effects in forest trees.

(2) The development of radiation as a possible tool in genetic studies of forest trees.

(3) A comparison of the responses to gamma radiation with those of other types of radiation and chemical mutagens.

(4) The induction of mutations useful in a tree improvement program.

Until now, exploratory studies of the effects of radiation on forest trees have been made at the Institute with the cooperation of the Brookhaven National Laboratory. At the present time gamma radiation facilities are being developed at Rhinelander to facilitate studies designed to meet the above objectives. The major radiation facility, which is nearing completion, is a 6½ acre gamma radiation field in which a 1,500 curie Cs^{137} source will be exposed in the centre for 20 hours each day from about April 1 to October 1 every year. The source will provide a range of dose rates from 10,000 r/day at one meter from the source to less than 2 r/day at the outer edge of the irradiated field.

Trees of various species and provenances within the species will be planted in replicated arc plots at several distances from the source to expose them to a range of chronic gamma ray dose rates. In addition, potted seedlings, cuttings, scions, etc., may be moved into the field for relatively high acute gamma ray dosages and then grown in non-irradiated environments for subsequent study.

Studies currently underway in the radiation research project include a study on the effect of X-irradiation of seed on the mutation rate in the X_1, and X_2 generation in *Pinus banksiana*, the effect of gamma irradiation of pollen on embryo, seed, and seedling progeny development in *Picea glauca*, the effects of gamma irradiation on female gametophyte, embryo, seed, and seedling development in *Pinus banksiana*, and the effect of pollen irradiation on self-fertility in *Picea glauca*. In the studies of jack pine, evaluations of the effects in the second generation after radiation treatment, are now getting underway. The white spruce pollen irradiation studies are being continued on an expanded scale on the basis of early results which indicated a stimulation of seed yield and viability from the irradiated pollen crosses.

Planned future studies will include both chronic and acute irradiation of various types of tree materials from a wide range of species.

T.D. Rudolph,
Institute of Forest Genetics,
Rhinelander, Wis.

Breeding *Thuja* in Denmark

Thuja plicata, Lamb. in Denmark is seriously damaged by the fungus *Didymascella thujina* (Dur.) Maire. This fungus causes complete destruction of the nursery stock in some years.

It was shown that the F_1 between the resistant Japanese *Thuja*, *T. Standishii* (Gord.) Carr., and *T. plicata* was completely resistant and that the backcross F_1 x *T. plicata* gave a 1:1 segregation, which indicated that we are concerned with one pair of genes in the resistance to the disease. It is homozygously dominant in *T. Standishii* and homozygously recessive in *T. plicata*.

It was also demonstrated that cuttings from old trees were resistant to the disease.

Both forms of resistance are employed in forestry in Denmark.

Bent Söegaard,
Royal Veterinary and Agricultural College,
Hörsholm, Denmark.

The forest tree improvement program at the New York State College of Forestry

The overall program in Forest Genetics and Forest Tree Improvement at the New York College of Forestry may be divided into three sections: (1) the academic program, which acts to support the undergraduate curriculum in the area of Forest Genetics and offers graduate work at the Masters and Ph.D. level; (2) a program of College oriented "basic" research and (3) "applied" research in the area of seed production, and seed orchard establishment. The latter program is supported and is in cooperation with Mr. Eliason of the Research Division, New York Conservation Department.

A brief review of current activity in these three sections will be given at this time, those readers interested in greater details of the program are invited to write or visit the College of Forestry at any time.

In the academic program we have at the present time three students studying for the Master of Science degree and one Ph.D. candidate. Thesis topics outlined at the Masters level include: Intraspecific hybridization in tulip poplar (*Liriodendron tulipifera*); Effects of gamma radiation on pollen production in jack pine (*Pinus banksiana*); and a study of genetic improvement in Eastern white pine (*Pinus strobus*). No Ph.D. thesis work is in progress at the present time.

Research in Forest Genetics at the College includes the following projects for the academic year 1964-65:

1. Research on genetic and physiological variation in wood characteristics of three larch species and one species hybrid.
2. Investigation of ion uptake and nitrogen relations of interspecific tree grafts.
3. Diallel crossing results in white spruce (*Picea glauca*)-- germination and first year growth measurements.
4. Physiological studies of vegetative propagation -- root initiation and differentiation in culture solutions.

5. Experimental controlled pollinations planned for the spring of 1965 are to be conducted among selected individuals of Scots pine (Pinus sylvestris), white spruce (Picea glauca), and Japanese larch (Larix leptolepis). In addition work will be continued on controlled hybridization of pitch pine (Pinus rigida) with southern pine species.

6. Mutation breeding work - The use of ionizing radiation to induce mutations in forest trees will be continued as a part of our basic research program. Currently we have irradiated seeds of red pine (Pinus resinosa), white pine (Pinus strobus), white spruce (Picea glauca), and Norway spruce (Picea abies), in the 1-0 nursery beds. In addition we plan to use irradiated pollen in controlled breeding work during the spring of 1965 as a means of mutation induction and/or as a means of overcoming incompatibility in certain crosses.

7. Rhabdocline resistance and provenance studies in Douglas fir -- two studies are currently underway with Douglas fir: (1) a 10-provenance study of the Rocky Mountain Douglas fir type ranging from Arizona to Canada was field planted in 1963 to study growth reactions and susceptibility to Rhabdocline pseudotsugae; and (2) plantation selections of apparently resistant individuals have been selected for additional breeding work in 1965 and 1966.

In the cooperative seed orchard and seed production program the current year's work will be concentrated on Norway spruce (Picea abies), Japanese larch (Larix leptolepis), and Eastern white pine (Pinus strobus).

At this time we may summarize our present seed orchard and seed production program as follows:

White Pine. Both seed production areas (21A) and grafted seed orchards (10A) have been established. The grafted seed orchards are from Northern New York old growth, natural stands. One small orchard of apparent blister rust resistant selections has been established. At the present time we have enough grafts in our transplant beds for two additional orchards;

one of these will contain selections from natural stands in Southern New York, the other plantation selections from the Northern part of the State.

Red Pine. We are presently limiting tree improvement work with this species to seed production areas. The question of relative amounts of genetic variation in red pine requires additional work prior to seed orchard establishment.

Scots Pine. A large number of Scots pine plantations with wide genetic variation are available in New York from which to select. One grafted seed orchard (6A) has been established with selections made on the basis of desirable winter coloration and overall form. Because of the early flowering in this species seedling seed orchards are planned. A seed production area of 6 acres has been established.

Norway Spruce. No seed production areas have been established for this species and only one small (1A) grafted seed orchard. We have had difficulty in grafting this species; present alternative consideration includes seed production areas and seedling seed orchards.

White Spruce. A seed production area has been selected for conversion and one small (1A) grafted seed orchard established. In 1964 a series of controlled pollinations were made to begin a seeding seed orchard; the very early prolific flowering in this species makes it an ideal one for seedling seed orchard work.

European Larch. One grafted seed orchard (6A) has been initiated and a search for a suitable seed production area is underway. Both grafted and seedling seed orchards are planned.

Japanese Larch. A grafted seed orchard (6A) has been established as well as 5 acres of seed production area. An additional seed production area is being converted during the current (1964) growing season. In addition two small hybrid orchards (Japanese x European larch) have been established from selected clones.

Gerald R. Stairs,
New York State College of Forestry,
Syracuse, N.Y.

Studies in Douglas fir at U.B.C.

Experiments carried out in Douglas fir were described. At the provenance level 27 Coastal and Interior sources were used to study the germination behaviour and seedling characteristics in controlled environment. Half-sib progenies were studied of 348 families representing 30 different locations from the west coast of Vancouver Island to the east side of the Rocky Mountains.

The progeny test with full-sibs was explained in more detail. Partial diallel crosses were attempted on four Douglas fir trees on the University Campus from 1958, and complete diallel cross was accomplished in 1962. The seed was germinated and the seedlings were grown in growth chambers. Twelve different characteristics were measured or evaluated and the combining abilities of the four trees and the heritability values for the twelve characteristics were calculated. Seedlings were planted out at U.B.C. Research Forest for further test.

O. Sziklai,
Faculty of Forestry,
University of British Columbia,
Vancouver, B.C.