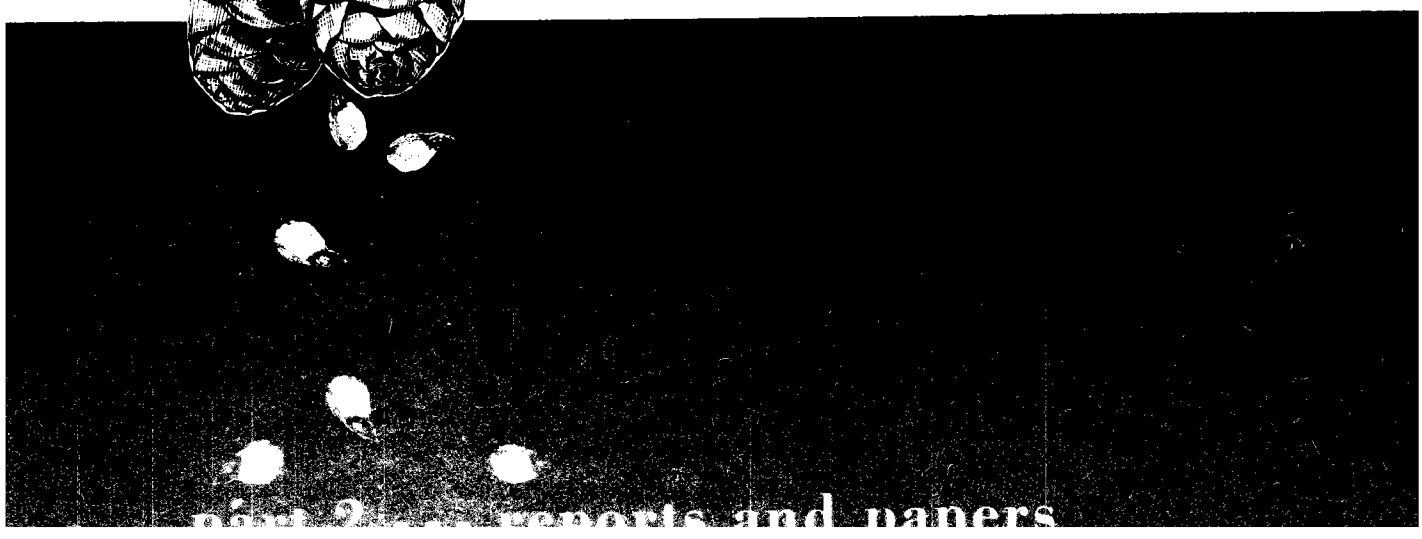
PROCEEDINGS of the ELEVENTH MEETING of the COMMITTEE ON FOREST TREE BREEDING IN CANADA

HELD JOINTLY WITH THE
NORTHEASTERN FOREST TREE IMPROVEMENT CONFERENCE
AT MACDONALD COLLEGE, QUEBEC,
AUGUST 8-10TH, 1968.



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THE COMMITTEE ON FOREST TREE BREEDING
IN CANADA

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

The Twelfth Meeting of the Committee will be held at Laval University, Quebec, P.Q. in the summer of 1970. Canadian and foreign visitors will be welcome. Detailed information will be distributed early in 1970 to all members and to others upon request.

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PROCEEDINGS OF THE ELEVENTH MEETING OF THE COMMITTEE ON FOREST TREE BREEDING IN CANADA

PART 2

REPORTS, PAPERS, AND ABSTRACTS

Editor: C. W. Yeatman

Published by the Forestry Branch,
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Part 1, Minutes and Discussions, received restricted distribution to Committee members only.

Part 2 received wider distribution to persons and organizations actively engaged or interested in forest genetics and tree improvement.

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MEMBERS' PROGRESS REPORTS

TREE IMPROVEMENT PROGRAM IN THE MANITOBA-SASKATCHEWAN REGION

F.B. Armitage
Forest Research Laboratory, Winnipeg, Manitoba

Tree improvement work in the Manitoba-Saskatchewan regional laboratory began when the first scientist was appointed for the purpose in 1964. By 1967 two additional professional personnel had joined the staff. A plant physiologist is expected to join the group in mid-summer 1968.

Proposals recently made for the development of a regional program were influenced by many factors, the most important of which were recognition of needs for genetically improved materials in the agricultural as well as the forested zones of the region, the diversity and harshness of the silvicultural environment and the paucity of native species or suitably adapted exotics. Wherever possible genetics research and breeding will be conducted simultaneously in broadly based projects. Simple breeding methods that fully exploit native species will be favored and progeny testing will receive due emphasis.

The program has six specific objectives:

1. By applying selective breeding methods, improve indigenous species in relation to requirements of the region.
2. Sustain and increase the effectiveness of (1) by studying genetic variation, correlation and inheritance of traits.
3. Augment the native species by introducing, testing and breeding exotics.
4. Diversify available types through hybridization.
5. Contribute to knowledge of forest genetics and breeding and of the characteristics of the species in use.
6. Disseminate information among resource managers.

Priorities have been assigned and an assessment has been made of the facilities necessary to implement them. Studies in progress include breeding and geographic variation of jack pine; variation and inheritance patterns in native poplars; testing of poplars introduced as seed from Europe; screening trials of poplar clones in current use; hybridization and selection among adapted poplars and spruces and interim measures to improve seed sources of native species used in reforestation.

Land for a nursery and tree bank has been acquired near Winnipeg. The first of a number of field experiment sites that will be required throughout the region has been obtained. Further increase in professional strength is not anticipated until these and other facilities required by existing staff have been adequately developed.

QUALITY WOOD PROGRAM

A.J. Carmichael
Southern Research Station, Maple, Ontario

Forest industries prefer certain wood species. We should understand, therefore, the specific physical and chemical wood characteristics which provide the basis for this preference. The purpose of the studies on wood quality is to define those characteristics which contribute to superior quality in end-use products and to relate these characteristics to heritable and environmental factors.

In 1963, the Advisory Committee for the Wood Quality program accepted black spruce [*Picea mariana* (Mill.) BSP.] as the most significant species for study, with primary concern to be given to the black spruce-newsprint relationship. The production in the laboratory of mechanical pulp (70% - 80% of the pulp furnish for newsprint must be mechanical pulp) has been impossible previously because of the absence of suitably designed equipment. This deficiency was remedied, and disc refiners have been installed to defibrate wood chips.

CHEMICAL PULPING

Wood Density

The determination of mean basic density and compression wood per cent has been calculated for the complete bole of mature black spruce trees. Measurements are completed for a 120 tree sample from six site classes, in which one disc was collected at each 10% height level. Preliminary assessment indicates a range and distribution of these features similar to preliminary tests with Challies Township material (Table 1, Fig. 1). Using the 120 tree sample, Dr. Raymond has developed a computerized plot for the stem analysis of each tree and a record of decadal changes in total stem volume.

The prediction of basic density of the tree stem from core samples is being tested for the 120 tree sample. Preliminary statistical analysis indicates a linear relationship for trees from either lowland or upland sites.

Compression Wood

Wood density and compression wood estimates for 68 core samples were verified by chemical pulping (Brajsa and

Table 1. Mean values for disc samples from the 10% height level of black spruce trees in northern Ontario.

Site[1,2]	No. Trees	Height	Age	Basic density	Compression wood %	Rings per cm
S.I.55	20	22.16m	87	.394	11.8	7.5
S.I.50	19	19.96	92	.414	7.8	8.6
S.C.O.	19	20.24	134	.429	12.1	11.4
S.C.1	19	17.85	103	.422	23.0	9.8
S.C.2	19	15.74	107	.435	20.0	11.6
S.C.3	20	10.74	140	.500	14.9	28.0

[1]Site Index (S.I.) ratings were used for well-drained upland sites (Lake States Tech. Note 473, Jan. 1957).

[2]Site Class (S.C.) ratings were used for lowland sites (Normal Yield Tables, W.L. Plonski, 1956).

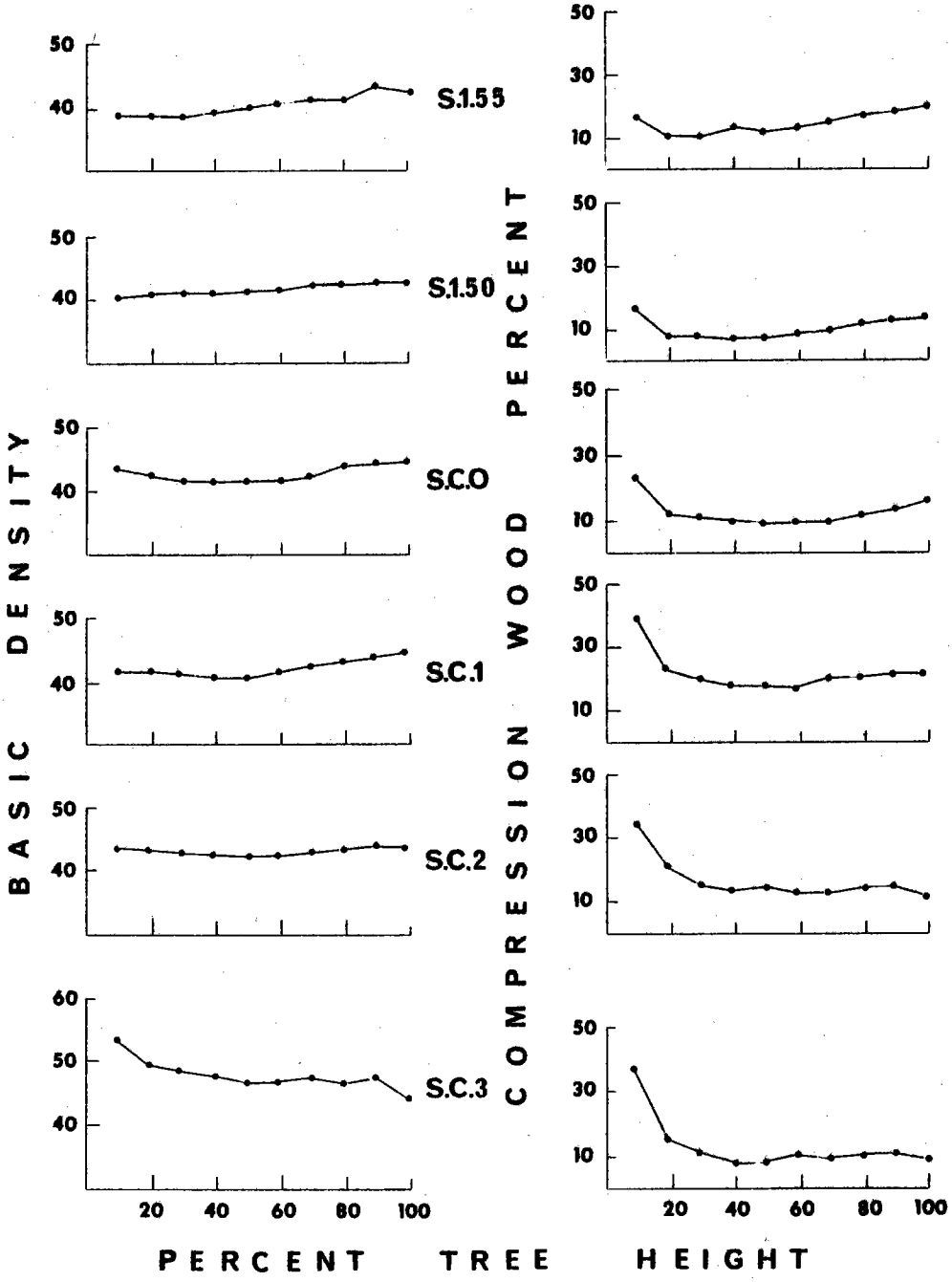

Figure 1. Mean values for basic density and compression per cent in 119 black spruce on six sites.

and Thomas 1966). Earlier trials by Thomas (1964) had charted pulp yield for wood of known density and compression wood content, and these were used to compare estimates and actual pulp yield for core samples.

In this test, the average compression wood content within 11 trees from a good lowland site was found to be 13.9% by volume, with individual trees ranging from 5.3% to 26.1%. Patterns of variation within trees were found to vary, but there was some indication of high compression wood contents at the base of trees and in their upper crowns.

Complementary studies (Ladell *et al.* 1967) of the effect of varying amounts of compression wood on (chemical) pulp yield and paper strength showed that, if a value of 15% was taken to represent the normal amount of compression wood in stands, the loss in pulp yield might be as high as 1 ton per acre. The effect of compression wood in this amount on paper strength, however, would probably be insignificant.

Previous analyses had shown that there was a highly significant negative correlation between (chemical) pulp yield and compression wood content, with per cent compression wood accounting for 55.3% of the variability in pulp yield. Such a correlation could arise through an underlying positive association between compression wood and its lignin content. This possibly misleading effect was taken into account by introducing lignin content into the regression as a concomitant variable. The result was to increase the proportion of the variability in pulp yield accounted for to 73.7%, while still indicating a very strong negative correlation between yield and compression wood.

Unexpectedly, specific gravity was not found to be as useful as compression wood per cent as an indicator of pulp yield. However, the subjective nature of compression wood estimates indicates the need for a better means to evaluate this factor in core samples.

A literature review is planned with the University of Toronto, to assess the methods available for scanning wood cores by means of X-rays, radio frequency waves, and other forms of radiation, to obtain a charted record of variations in cell substance along a radial traverse.

Rate of Growth

The effect of rate of growth on pulp yield and paper properties is being assessed as part of a study involving four mature trees from Parnell Township, Ont. Four trees were selected to include slow and rapid growth rates, and subsamples

were excised from discs at the 25% height level to include groups of 25 growth rings. Subsequently, an additional 14 trees in the Parnell group will be analysed with subsamples taken from four height levels.

In the 116 tree samples described in Table 1, there was a trend on all sites toward higher basic density and compression wood per cent when the number of rings per centimeter increased. Multivariate analyses have yet to be made to illustrate this relationship. However, it would appear that on wetter sites there is reduced growth rate and an increase in basic density and compression wood per cent.

Lignin and Extractive Chemicals

A study of the extractive chemicals of black spruce was undertaken initially to determine the extent to which the presence of extractives could affect the accuracy of specific gravity determinations (Ladell 1967). The scope of the work has been broadened to include the distribution of total extractive content (as against the alcohol/benzine solubles only) and to work on the interrelations between extractive content and such factors as growth rate and the distribution of resin ducts and the effect of seasoning on extractive content.

During the year, variations in total extractive content of black spruce were investigated at the 25% level in four trees. Overall averages for trees weighted for wood volume ranged from 2.5% to 4.6% with an average of 3.6%. These results, in combination with those obtained earlier and evidence from the literature, suggest that the gradient from the pith may be a very steep one.

THE ASSESSMENT OF PLUS TREE SELECTIONS

Wood Samples

The power coring tool for collection of 18 mm cores has been fitted with a more powerful motor and will be operable this year. It will be used to obtain core samples from all the black spruce plus trees in Ontario, and for stands representative of the major commercial black spruce site classes.

Basic density measurements have been completed for samples from four height levels in nine white spruce removed in cleaning of the Pagwa seed production area. The basic density weighted by bole volume for six selected plus trees averaged 0.345 and ranged from 0.328 to 0.385, compared with three control trees on the same site which had an average value of 0.344 and ranged from 0.333 to 0.354.

Although these trees represent the fastest natural growth for spruce in Ontario, they do not appear to have excessively low wood density. Pulping and paper tests for these samples are continuing. Individual measurements of tree size are not available for these specimens. However, when measured in 1960, two of the select trees, adjacent to the group sampled for density measurements, had the following dimensions:

389 was 118 feet high and 23.5 inches dbh at a breast-height age of 112 years;

396 was 107 feet high and 20.2 inches dbh at a breast-height age of 110 years.

The modification of laboratory procedures for the processing of larger numbers of wood samples is being planned with the Ontario Research Foundation. This would enable general testing of core or disc specimens from selected and comparison trees obtained by the Timber Branch, Ontario Department of Lands and Forests, in their Tree Improvement Program.

Needle Frequency in Black Spruce

One hundred black spruce were randomly selected from a 16 year old plantation on Spruce Falls Power and Paper Co. limits at Moonbeam, Ontario. Needle frequency was assessed and cuttings obtained from 30 trees for rooting to verify the hypothesis that trees of higher needle frequency would grow larger.

Additional cuttings will be collected from selected trees of high and low needle frequency to assess the hypothesis that those trees with higher needle frequency and more medullary ray tissue root better.

During earlier tests to establish the relationship between needle frequency and tree size, in Parnell Township, Kapuskasing District, seeds were obtained from the trees being sampled. These were sized, weighed and germinated during the winter of 1967-68. Preliminary results indicate that there was a characteristic size of seed common to each tree, with the highest germination from small seeds and the lowest from large seeds. Seedling hypocotyl and epicotyl length and cotyledon number were greatest from larger seeds.

REFERENCES

Brajsa, Miss B. and Thomas, G.H.S. 1966. Ont. Res. Found. Carbohydrate Res. Rep. 66-1. 8p.

Ladell, J.W. 1967. The amount and distribution of extractives in black spruce. Ont. Res. Found. Res. Rep. 67-2, 25p.

Ladell, J.W., Carmichael, A.J. and Thomas, G.H.S. 1967. Current work in Ontario on compression wood in black spruce, in relation to pulp yield and quality. Lake States Tree Improvement Conference, Madison, Sept. 1967.

Sugden, E.A.N. 1967. Mechanical pulping - A review of selected references, 1957-1967. Ont. Res. Found. Res. Rep. 67-3, 43p.

Thomas, G.H.S. 1964. Ont. Res. Found. Res. Rep. 64-2, 25p.

SHELTERBELT TREE BREEDING

W.H. Cram and C.H. Lindquist
Indian Head, Saskatchewan

Since 1965 tree improvement programs have of necessity been assigned a lower priority than investigations to resolve nursery production problems. Nevertheless, work is being continued to improve and mass produce superior hybrids of caragana and spruce, and also to evaluate poplars, willows, shrubs, and various species of conifers for shelterbelt plantings.

CARAGANA IMPROVEMENT

Investigations were initiated in 1949 to produce more vigorous caragana seedlings for field shelterbelt planting by cross-pollination of selections showing superior vigor. Parental selections demonstrating superior combining ability for vigor are being propagated by cuttings to establish natural hybrid seed orchards of one self-incompatible and one self-compatible pollen selection. One such planting consisting of 125 rooted cuttings of self-incompatible selection and a self-fertile selection was established at the nursery in 1959. This produced 10 lb. of hybrid seed in 1966, which was field sown in 1967 with standard seed for comparison to determine the relative nursery vigor of the hybrid seedlings in 1968. Fourteen pounds of hybrid seed were harvested in 1967.

Self-compatibility Determinations

These studies were conducted for 152 new vigorous selections, which originated from six Russian and three European seed sources. Self-compatibility of the 152 selections ranged from 0% (pods-per-flower-tripped) to 89%, of which 32 appeared self-incompatible. It was apparent that pollen with only 8% viability is efficient for pollination as indicated by seed source Denmark (D227) which set 26%. Inbred seed of 1965 from 28 selections germinated in the greenhouse revealed that none of the selections carried the deleterious albino character.

Cross-compatibility Determinations

This work was limited to three self-incompatible selections with nine vigorous self-compatible selections as pollen parents. Good cross-compatibility was evident for all combinations as indicated in Table 1. Pollen abortion was estimated by culturing for 24 hr on 2% water-agar media with

Table 1. Cross-compatibility[a] for Three Self-incompatible Caragana Selections with Three Self-compatible Selections

Pollen parents ♂	Abortive[b] pollen	Self-incompatible Selections ♀ V-16	B2-4	D191-1	General mean
		(%)	(%)	(%)	(%)
D26-2	11	28.7	17.5	4.7	17.0
B5-1A	1	34.7	14.7	8.5	19.3
B2-7	4	35.7	13.0	17.5	22.1
V-2	31	47.1	17.1	10.0	24.8
V-15	20	59.2	9.1	8.9	25.7
7-9	26	55.9	8.1	25.6	29.9
13-8	100	34.0	16.8	53.1	34.6
V-14	17	65.7	23.1	16.7	35.2
H-1	53	59.1	47.9	13.7	40.9
General combining ability		46.7	18.6	17.6	27.6

[a]Percentage of pods set for flowers tripped.

[b]Mean for three fields on one petri dish of agar.

10% sucrose added. However, pollen from selection 13-8 did not produce any tubes on the artificial media, indicating pollen sterility, but seed set was good for three combinations. Selection D191-1 (of a Russian seed source) had lower cross-compatibility than B2-4 (a local selection), except when in combination with pollen of 13-8 and 7-9. Selection V-16 demonstrated the highest cross-compatibility for all combinations, except D191-1 X 13-8.

Propagation of Selections

Propagation of selections which have demonstrated high combining ability for vigor in hybrid combinations, is conducted annually to provide clonal material for isolated seed production plots. Some 2,300 softwood cuttings from four vigorous self-incompatible and nine self-compatible selections were rooted in 1966, and 4,800 cuttings of four selections in 1967, with an average of 38% rooting. One hundred and nine grafts were made on 57 seedlings from 12 selections for a mean success of 80%.

COLORADO SPRUCE IMPROVEMENT

Colorado Spruce

Picea pungens improvement studies have been in progress since 1954, the objective being the mass production of 'blue' trees from hybrid seed for farm shelterbelt plantings.

Table 2. Color Rating and Distribution of Hybrid Colorado Spruce Seedlings Field Planted in 1963 and 1965

Progeny Tree	Progeny Pollen	Planting site	Number plants	Color Rating[a] & Percent of Seedlings Blue	G-B	B-G	Green
			(no.)	(%)	(%)	(%)	(%)
PC-6	RC-1	WL1	65	57	22	17	5
PC-6	RC-1	WL1	96	57	17	18	8
PC6-B	RC-1	ENE	351	21	23	21	35
PC6-B	RC-1	WSE	517	39	13	10	38
PC-7	RC-1	S1S2	455	26	11	23	40
PC-7	RC-1	WL1	30	20	13	37	30

[a]Color classes are blue, greenish-blue, bluish-green, and green.

Hybrid seed of 1965 from 48 crosses were sown on May 30, and damping-off losses of 38% occurred despite Captan drenches. Seedling stand for 71 combinations sown in 1965 was 34%. All seedlings demonstrated good blue needle color. Seedlings from 24 crosses of 1961 were planted as a permanent field shelterbelt in 1966, with a survival of 73%.

Some 1,060 hybrid seedlings (PC6B X RC1) were planted in two locations on the nursery in 1963 and in 1965 some 640 hybrid seedlings from two other crosses (PC6 X RC1, PC7 X RC1) were also planted out at two locations for each progeny. Four needle color classes (blue to green) were utilized to classify each progeny as to color, and the results are summarized in Table 2. The cross combination of PC6 X RC1 appears to produce the highest percentage of blue needle progeny. Characteristics of the planting site appeared to influence the manifestation of needle color as is indicated by progeny of PC6B X RC1.

Self- and Cross-compatibility

Pollinations to determine compatibility were continued in 1966. Female flowers on 47 'blue' selections were isolated in cellulose bags on May 23 and artificially pollinated on June 6. The cones were harvested on September 5, and compatibilities evaluated on a basis of the average yield of seed per cone. Self-compatibility of 43 selections ranged from 0 to 56 seeds per cone and averaged 9.3, whereas mean cross-compatibility ranged from 0 to 90 seeds per cone, average 27.4. Regrettably, five of the apparent self-incompatible selections were also cross-incompatible with RC1 and N4120. On the other hand, one of these (N436) had a cross-compatibility of 14 seed per cone in 1965. Three selections (N436, N424, N422), appeared self-incompatible but one (N4115) set 45 seed per cone in 1966.

Twenty-two selections that demonstrated self-incompatibilities in 1965 and 1966 are potential material for natural crossing blocks to produce hybrid seed. Pollen viability of 34 selections ranged from 1 to 88% and for pollen selections from 94 to 93%. Repeated spraying of trees with insecticides reduced the incidence of insect infestations and permitted harvesting of some 27,832 hybrid and 2,424 inbred seed in 1966.

Only one cross (RC5-89 X S535) of nine attempted crosses of two Colorado spruce selections with pollen from three *Picea schrenkiana* selections, was successful and produced 18 seeds.

Grafting

The grafted orchard of Colorado spruce was increased by 64 grafts of 15 selections with a success of 79%. Success for 35 grafts of *P. schrenkiana* on Colorado spruce and 5 on white spruce, and 10 grafts of white pine on Scots pine was 79%, 57%, and 100%, respectively.

POPLAR AND WILLOW

The 1966 poplar breeding program consisted of crossing *Populus* X 44-52 with *P. petrowskyana* and *P. tristis* in the greenhouse. The seed harvested produced 252 hybrid seedlings from greenhouse sowings.

Rooted Cuttings

Forty-eight selections of poplar hybrids (44-52 X Saskatchewan) were planted in the field as rooted cuttings to study performance and disease resistance. The clones were planted as single-plant plots with one, three and six replications; Northwest was used in each planting as the standard for comparison. The planting survival ranged from 0% to 100%, average 59%. The height growth for seven selections exceeded that for Northwest (109 cm), the greatest being PX7-8 (142 cm).

Disease Inoculation Tests

Tests were initiated in 1966 in cooperation with Dr. H. Zalasky. Inoculations with the black poplar gall [*Diplodia tumefaciens*] were made in the greenhouse on 32 clones, which were planted in the field on May 30. On the basis of this preliminary study six clones appeared to have some resistance. Some 300 rooted cuttings of 32 clones were field planted and inoculated with the black poplar gall and Septoria canker [*Septoria musiva*] for evaluation in 1967 and 1968.

Regional Poplar and Willow Tests

These tests were continued in 1967 with the cooperation of the Plant Industry Branch of the Alberta Department of Agriculture, the Forestry Branch of the Saskatchewan Department of Natural Resources, and of the Department of Forestry and Rural Development in Manitoba. Plantings of 15 poplar and 11 willow clones as five replications of single-plant plots were established at one location in Alberta, three in Saskatchewan, three in Manitoba, duplicate plantings for a check were at the Tree Nursery, Indian Head. Survival of the planting at Indian Head was 83% for the poplar and 87% for the willow; survival of the planting at Brooks, Alta., was 77% and 68%, respectively. Performance data in 1966 for the 1965 check poplar planting at Indian Head showed *P. sargentii* to be the most vigorous clone followed by *P. cardiensis* and *P.* '44-52'. Reports for the 1965 regional planting in Saskatchewan indicated that *P. gelrica*, *P. vernirubens* and *P. cardiensis* were the most promising poplar clones; in Manitoba plantings of *P.* '44-52' was the most vigorous clone and *P. vernirubens* the second. Growth data in 1967 for the 1965 planting at Indian Head indicated that two poplar clones, B.L.#3 and 44-52, were significantly more vigorous than all other clones (19), with *P. sargentii*, *P. cardiensis* and *P. vernirubens* ranking fourth, twelfth, and fourteenth, respectively. Performance data in 1967 for the 1965 regional test planting at Carrot River, Sask., showed the clones *P. petrowskyana*, *P. tristis* and 44-52 ranking first, second and third for vigor. In this test peachleaf willow ranked first and Basford second for vigor; in the 1965 planting at Indian Head Basford willow was the most vigorous. The above results indicate that poplar clones vary greatly for vigor for the first 3 years of growth and in the different climatic regions, and that willow clones are less variable than poplar. An additional test planting of 84 poplar and 33 willow clones was established on the nursery in 1967 as three replications of single-plant plots.

CONIFER PERFORMANCE

Regional Species Tests

Regional species tests were initiated in 1967 in cooperation with the provinces of Saskatchewan and Manitoba. Seedlings of 20 species were supplied for four sites in Saskatchewan and of 14 species for two sites in Manitoba. A duplicate planting of 25 species was made on the Tree Nursery. Due to the small size of the seedlings (2-2) and inadequate site preparations none of the plantings were a complete success.

Seed

Seed of 25 conifer species (70 lots) procured from various sources in Europe, U.S.A., and Canada was sown on 31 May 1966. Seed of 13 lots failed to germinate. Good germination was obtained with Norway spruce [*Picea abies*] - 1 lot, ponderosa pine [*Pinus ponderosa*] - 4, white pine [*P. strobus*] - 2, Scots pine [*P. sylvestris*] - 5, and cedar [*Thuga occidentalis*] - 3. Germination of the 16 lots of spruce seed, stratified for 60 to 90 days, was low. Although damping-off losses were severe, stands in October were estimated to be 29,000 seedlings.

Scots Pine

Two provenance tests for Scots pine are in progress. In 1960, 3-0 seedlings of one Finnish and 10 Russian seed sources were planted in a cooperative study with Mr. M.J. Holst. The height measurements for 1966, as summarized in Table 3, indicate that the progeny of the three Russian sources (Orel, Woronesh, and Kiev) continued to show great vigor; progeny of the Tobolesk, Beloneskig, and Niska sources continued to show least vigor. The ranking for height has remained the same since 1964, when the plants were 8 years (3-5) old. In the 1962 provenance planting of 31 Russian seed sources (a cooperative study with Dr. D. Dawson of the U.S.D.A., Forest Service) the Orel provenance also exhibits the greatest height.

Table 3. Comparative Heights of 10-Year-Old Progenies of 11 Provenances of Scots Pine

Original sources of seed	Height			
	1961	1962	1964	1966
	(cm)	(cm)	(cm)	(cm)
Russia, Prov. of Orel	32	63	138	251
Russia, Prov. of Woronesh	28	59	124	240
Russia, Kiev	29	56	122	237
Russia, Prov. of Chkalov	22	43	107	219
Russia, Prov. of Molotow[a]	26	49	106	207
Russia, Smolensk	23	48	102	204
Russia, Prov. of Kaluga	22	46	97	193
Russia, Smolensk	24	48	94	189
Russia, Beloneskig, Bashkiria	19	40	76	158
Siberia, Tobolsk	19	37	76	157
Finland, Niska[b]	11	22	36	76
Means	23	47	98	194

[a]12% have yellow needles during winter.

[b]75% have yellow needles during winter.

Ponderosa Pine

In the provenance study being conducted in cooperation with the U.S.D.A., Forest Service, the relationship between seed and seedlings sizes were of particular interest in 1965 and 1966. Seed size (weight) and height of the 1-0 seedlings were highly correlated but the relationship disappeared in 1966 for the 2-0 seedlings. The least vigor (5.6 cm) was demonstrated by progeny from a California seed source while greatest vigor (10.4 cm) was for progeny from Wisconsin. Complete snow cover during the winter of 1965-66, minimized the expected losses and the stand contained 7,480 seedlings in the fall of 1966.

OBSERVATIONS ON SINGLE, FREELY-SUSPENDED SINGLE CELLS OF JACK PINE GROWING IN CELL CULTURE

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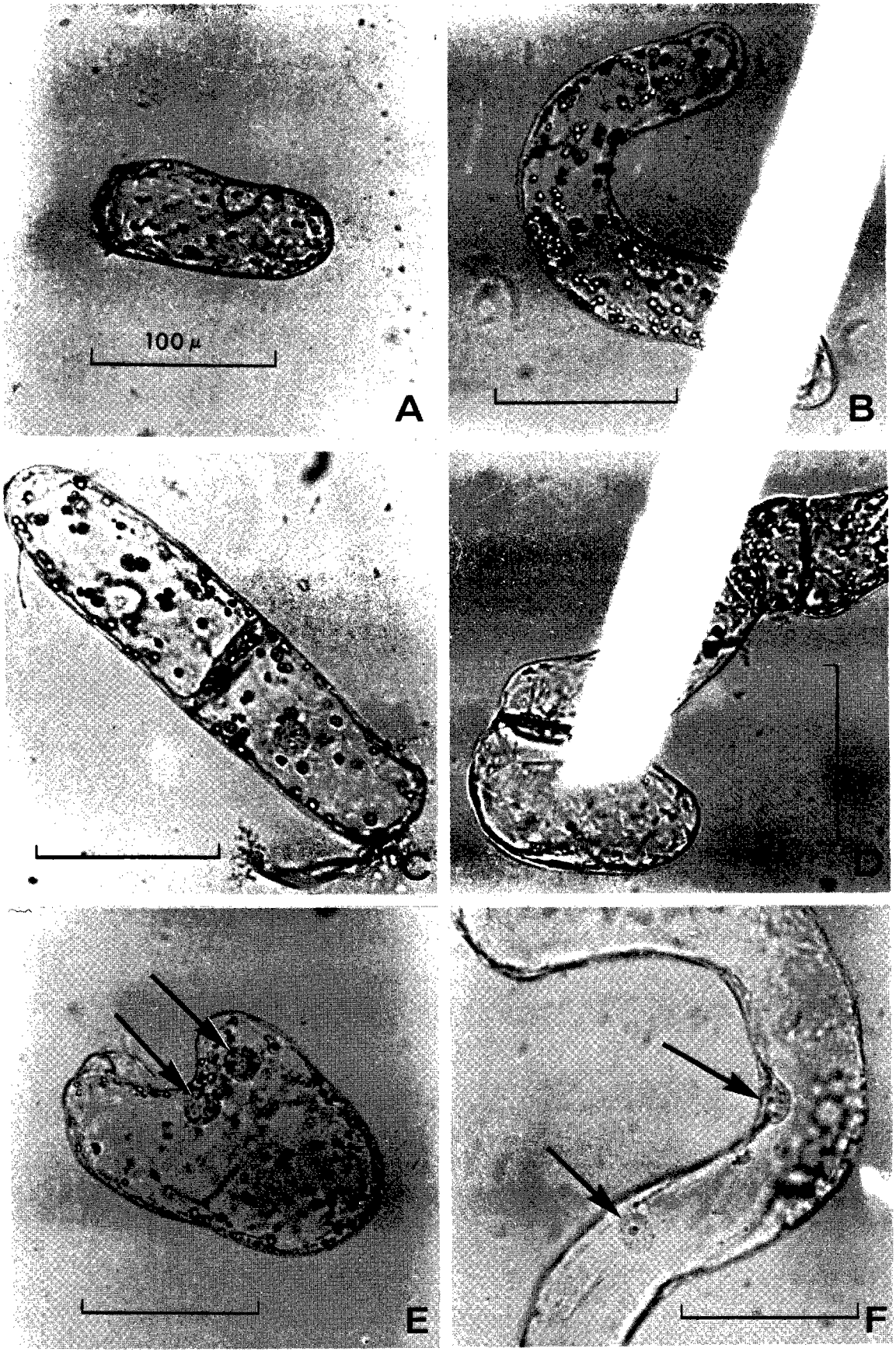
A method has been developed to produce large numbers of single, living cells of jack pine and white spruce in cell and tissue culture (D.J. Durzan and F.C. Steward, unpublished observations). Single cells can be obtained from callus derived from embryos of germinating seeds or shoot apices of mature trees. This report will record our observations that single cells of jack pine in liquid culture media occasionally contain more than one nucleus per cell.

Methods and apparatus used to produce single cells are somewhat similar to those described by Steward *et al.* (1958) for the carrot studies. However, our methods differed from others previously employed. First, culture medium without TiO_2 and formulated after Steinhart *et al.* (1961) was prepared in lieu of Steward's media. Second, 10% coconut milk was replaced by a 1% aqueous extract of germinating jack pine seed. Third, all components of the culture media were filtered rather than autoclaved to maintain aseptic conditions.

A special feature of the Steinhart *et al.* formulation is the presence in the media of kinetin (2.5 ppm), which is an unnatural growth regulator. Kinetin or 6-furfurylaminopurine is a product of aged preparations of nucleic acids and is known to induce cell divisions in the vacuolated cells of tobacco pith (cf. Skoog and Miller 1956). Jack pine cells grown in media containing kinetin occasionally contain two nuclei without the development of a cell wall between what should have been the daughter and mother cell. Other cells divide naturally and produce callus which further leads to the production of more single cells. Steward *et al.* (1958, fig. 33) also observed multinucleated cells in carrot cell culture. Work is currently in progress to study this phenomenon together with the patterns of cellular organization and kinetics that allow single cells to form unorganized or embryo-like structures.

Figure 1 (See next page). Single and multiple freely-suspended living cells of jack pine in liquid medium. A. Single, vacuolated cell showing nucleus, actively streaming protoplasmic strands, starch grains and chloroplasts. B. Elongated cell. C. Two cells with protoplasmic strands protruding through cell wall. D. Multiple, free-floating cells. E. Single cell containing two nuclei. F. Elongated single cell containing two nuclei with clearly-defined nucleoli. Calibration lines are 100 µ long.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REFERENCES

Skoog, F. and C.O. Miller. 1956. Chemical regulation of growth and organ formation in plant tissue cultures *in vitro*, pp 118-131. Symp. Soc. Exp. Biol. 11.

Steinhart, C., L.C. Standifer, Jr., and F. Skoog. 1961. Nutrient requirements for *in vitro* growth of spruce tissue. Am. J. Bot. 48(6):465-472.

Steward, F.C., M.O. Mapes, and J. Smith. 1958. Growth and organized development of cultured cells. I. Growth and division of freely-suspended cells. Am. J. Bot. 45(9): 693-703.

SEED ORCHARDS AND SEED PRODUCTION AREAS IN ONTARIO

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PROVENANCE TESTS

Jack Pine

In the spring of 1967, refill plantings were carried out in five sections of the 1966 all-range jack pine provenance experiment, 255-E and in two sections of the 1966 jack pine provenance hybrid experiment, 268-E. The plantings are located in five districts in northern and northwestern Ontario and are cooperative experiments with Canada Department of Forestry and Rural Development.

SEED ORCHARDS

There were no additional seed orchard sites established in the last 2-year period. Seed orchards previously established were considerably enlarged in 1967 and 1968. Table 1 shows the number of clones and acreage planted in the last 2 years and the total to date.

Red Pine

Grafting of red pine for clonal seed orchards is being continued only to fill failed spots in present seed orchards.

In the red pine seed orchard in Grenfell Township male flowering has been medium to heavy in the last 2 years in the older plantings (1959 to 1962). Cones are being produced each year in small quantities, but have as yet not been sufficient to warrant a collection.

In the red pine seed orchard in Gurd Township male flowering has also been noted in the last 2 years. Scattered cone production has been noted and there are sufficient cones to warrant a small collection in the fall of 1968.

White Pine

A white pine seedling seed orchard was established in the spring of 1967 at Connaught Ranges near Ottawa. The planta-

TABLE 1

Species	Location	PLANTED 1967 No. of clones	1967 acres	1968 No. of clones	1968 acres	To Date No. of clones	To Date acres
White Pine	Lindsay District, Orono Nursery	X	4.4	X	3.8	X	24.5
White Pine	Parry Sound District, Gurd Twp.	Nil	Nil	7	1.5	25	5.5
Red Pine	Parry Sound District, Gurd Twp.	23	3.8	4	1.0	54	12.0
Red Pine	Swastika District, Grenfell Twp.	Nil	Nil	25	refill	59	22.0
White Spruce	L. Simcoe District, Midhurst Nursery	3	refill	9	2.0	21	4.0
White Spruce	Port Arthur District, Camp 503	13	2.0	18	4.0	24	8.0
Black Spruce	L. Simcoe District, Midhurst Nursery	17	4.0	25	5.0	42	11.0
Black Spruce	Port Arthur District, Camp 503	14	2.0	23	4.0	41	8.0

tion itself, of approximately 2 acres, was established in May 1947 with white pine materials growing in the disease garden of the National Research Council Annex on the Montreal Road. Prior to the planting, the materials were culled for poor form, blister-rust infection and slow growth.

At the same time, several lots of white pine were brought from the Petawawa Forest Experiment Station and planted together with the materials from the National Research Council Annex in what is called the "Old Section". During May 1948, all remaining white pine lots from the National Research Council Annex were transplanted to the "New Section". Only plants free from blister rust and of good form were transplanted.

The plantation was thinned in 1957 and 1960. In the latter thinning all the trees that had become infected with blister rust and trees whose grafts showed blister rust infection at Maple were removed. In addition, all weak trees, too small to yield scions for grafting at Maple during the interval between the first and second thinnings, were removed.

A third thinning was carried out prior to June 1967 on the basis of susceptibility to blister rust as determined at Maple. It should be possible to harvest the first seeds, resulting from resistant X resistant trees, in the fall of 1968.

The above information on the history and thinning of this plantation was provided by Dr. Heimburger, Southern Research Station, Maple.

The white pine seed orchard at the Orono Nursery consists of grafter material using scions of trees resistant to rust at Connaught Ranges. Collectable quantities of cones are now being produced in the 1963 and 1964 plantings.

White and Black Spruce

In the early years of grafting white and black spruce, some material from site region 3E was grafted at the Fort William Nursery and some material from site region 3W at the Angus Seed Plant. When moving to the seed orchards at the Midhurst Nursery (3E source) and Camp 503 (3W source) a trucking problem developed due to cost. For the last 2 years the grafted trees have been exchanged by air freight between Fort William and Toronto. The trees are shipped root bare in a plastic bag with moss in large tree-shipping crates. Trees lifted one day can be planted either the next day or the day after and very high survival has been attained. Air transport has provided a fast and comparatively cheap method of shipping grafted material.

SEED PRODUCTION AREAS

Three seed production areas have been established in the last 2-year period, as follows:

Species	Location	Site Region	Acres	Development
Red Pine	Lindsay District, Haldimand Twp.	6E	10.0	Thinned 1967
Red Pine	Sioux Lookout District, McIlraith Twp.	4S	12.0	Marking and thinning 1968
White Spruce	Lindsay District, Orono Nursery	6E	19.4	Thinning 1968

In addition, one white spruce, two black spruce and one red spruce seed-production areas have been located and plans for establishment are being processed.

Red Pine - Lynn Tract - Oro Township

This seed-production area is now showing the benefits of thinning and fertilization. A medium crop of cones is indicated for 1968. Additional thinning is required and the stand will be rogued on the basis of seed production. Each tree (approximately 700) will be numbered and records of cone production will be kept for the next 5 years. Male flowering has been abundant, particularly in 1968, when large clusters of male strobili were observed extending 3 and 4 inches along the branches.

White Spruce - Gurd Township

A collection of 90 bushels from this seed-production area in 1964 yielded over 21 million viable seeds. All the seed sown in the fall of 1967, at four nurseries producing the stock for site region 5E, came from this collection.

White Spruce - Orono Nursery

In the fall of 1967, 115 bushels of cones were collected from this seed-production area.

SEED COLLECTION

In 1966 and 1967, 16,250 and 18,200 bushels of cones and rough seed, respectively, were collected. Seed requirements for the fall of 1968, to maintain the necessary reserve, are for the equivalent of 17,250 bushels of cones and rough seed. The sowing target for the fall of 1968 and the spring of 1969, is for the production of 100 million trees at the 10 provincial nurseries. The seed inventory as of 1 June 1968 at the Ontario Tree Seed Plant at Angus, is 2.9 billion viable seeds of 47 species, weighing 14-3/4 tons. 1967 was a good crop year for most species, particularly white spruce where there was a bumper crop. The shortage in red pine remains. Eight thousand bushels of red pine cones are required this fall.

GENECOLOGY OF YELLOW BIRCH

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During the summer of 1967, 48 populations of yellow birch of five trees each were located in the province of Quebec. In the fall, 30 catkins were collected from each tree. The seed, which was kept separate by trees and stored at 40F, will be sown in the spring of 1969.

Because of the high within-population genetic variability demonstrated by K. Clausen (personal communication) for this species, catkins will be collected from a further five trees in each sampled area in the fall of 1968.

Catkin morphology is now being studied and a preliminary statistical analysis indicates that 15 bracts are necessary to estimate correctly the catkin mean, and that four catkins are necessary to estimate the tree means (Dagnelie 1964).

REFERENCE

Dagnelie, P. 1964. La détermination du nombre de répétitions en vue de l'estimation d'une moyenne. Biométrie-Praximétrie. Vol. 3-4. 117-135.

DEVELOPMENT OF THE OVULATE CONE IN WHITE SPRUCE

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Buds and developing cones were collected from *Picea glauca* Moench. throughout the growing season of 1967. Some ovulate cones were pollinated with pollen of the same species, some with pollen of black spruce [*Picea mariana* (Mill.) BSP.] and some were left unpollinated. Subsequent development was followed on microscopic sections to try to determine the reason why black spruce pollen fails to fertilize white spruce ovules.

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TREE BREEDING IN THE MARITIMES REGION 1966-67

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Two new members were added to the staff of the Maritimes Region to work in the general field of tree breeding or forest genetics in 1966-67. They were D.P. Fowler, formerly employed by the Ontario Department of Lands and Forests, and S.A. Manley, a graduate student at the University of New Brunswick.

The work in this field, which had formerly been under the direction of H.G. MacGillivray, was expanded into four project areas: provenance and progeny testing; genecology of the red - black spruce complex; breeding and breeding systems; and production of haploid and homozygous diploid trees.

Only the progress on the latter two will be presented in this report.

BREEDING AND BREEDING SYSTEMS OF FOREST TREES

The objectives of this project are (a) to better understand the existing and potential genetic variability of native and exotic species of value in the Maritimes Region, and (b) to provide information and breeding material which will make possible the production of genetically improved trees.

Work on this project is a direct continuation and expansion of some of the work previously carried out by H.G. MacGillivray (MacGillivray 1966).

Larix

Because of its rapid juvenile growth, good form, high wood density and ease of handling in forest nurseries, larch is a potentially valuable reforestation species. Our present knowledge of the genetic variation available in the native larch [*Larix laricina* (Du Roi) K. Koch.] is limited. It is the objective of the present work to determine the magnitude and pattern of genetic variations of native larch, determine its relationship to other larch species and to select or develop a superior larch or larch hybrid suitable for reforestation in the Maritimes Region.

In 1967 the hybrid *Larix laricina* x *leptolepis* was crossed with *L. decidua*. This cross, made using three different

female parents, yielded a total of 1282 full seeds which were germinated in petri dishes and planted in the greenhouse in January 1968.

Picea

In the spring of 1966, while the writer was employed by the Ontario Department of Lands and Forests, a number of controlled pollinations were attempted with spruce. In the fall of 1966 the cones from these crosses were collected and sent to Fredericton, N.B., where the seeds were extracted and the resulting plants raised in the greenhouse. The results of this work are summarized in Table 1.

An extremely poor flowering year for spruce in the Maritimes Region occurred in 1967. No controlled pollinations were attempted. Ontario, on the other hand, enjoyed an exceptional flowering year. Control pollinated cones from interspecific hybridization of several spruce species were received from M. Holst, Chalk River, Ont., in the fall of 1967. The seeds were extracted and full and empty seeds separated by floatation in 95% alcohol. The results from these crosses are presented in Table 2.

Of special interest is the apparent success of the cross *Picea glauca* x *P. abies* which yielded approximately 3700 full seeds. This material is of potential value as a means of transferring weevil [*Pissodes strobi* (Peck)] resistance from white to Norway spruce. Also of interest is the apparent difference between red and black spruce in their ability to cross with several of the exotic spruces. This may indicate that the two species are not as closely related as is generally assumed on the basis of natural hybridization.

Red Pine

Studies to determine the magnitude of maternal effects in red pine were continued during 1966-67. This work is a direct continuation of work performed by the writer when he was employed by the Ontario Department of Lands and Forests (Fowler 1966).

HAPLOID AND HOMOZYGOUS DIPLOID TREES

This project is being carried out in cooperation with Dr. J.M. Bonga, tree physiologist, Fredericton, N.B.

The use of near homozygous lines for the production of heterotic hybrids has been used successfully as a breeding

Table 1. Results of controlled spruce pollinations made at Maple, Ontario in 1966

Female \ Parent Male	*abies*	*glauca*	*meyeri*	*omorica*	*pungens*	*schrenkiana*	SELF
abies			3 2 2.0 20			3 0 0 0	3 1 3.0 6
glauca	1 1 .04 0	1 1 35.0 3	1 0 0 0	1 0 0 0	1 1 2.0 11	1 1 .1 0	1 1 1.6 29
meyeri		1 1 .7 2					
omorica		1 1 ?[a] 125			1 0 0 0	1 0 0 0	
pungens		2 1 .3 1		2 1 .2 0		2 0 0 0	
shrenkiana	3 0 0 0		3 0 0 0		4 2 .6 13	3 3 29.3 70	
(*abies* x *sitchensis*)[b]		1 1 39.9 425					

[a] Full and empty seeds would not separate with 95% ETOH.
[b] Identification of female parent questionable.

1	No. trees pollinated
1	No. crosses yielding full seeds
5.0	No. full seeds per cone
10	No. seedlings

Table 2. Results of controlled pollinations made at Petawawa Forest Experiment Station and sent to Fredericton in 1967

Female \ Parent Male	*abies*	*asperata*	*glauca*	*glehnii*	*jezoensis*	*koraiensis*	*koyamae*	*omerica*	*orientalis*	*sinrenkiana*	OPEN
abies	1 1 5.4 138	1 1 3.3 165	1 0 0 0	2 2 .1-2.8 61	2 0 0 0	2 2 8.4-16.0 1073		1 1 1.1 48	2 0 0 0	1 0 0 0	5 5 82-182
asperata	2 1 2.7 47		1 0 0 0		1 0 0 0	1 0 0 0	1 0 0 0		1 1 0.3 1		
glauca	1 1 14.8 3704	2 2 .04-.5 218		3 3 3.7-5.3 3220	3 3 10.1-19.3 9708				3 3 1.4-3.7 3208	2 2 30.2-47.1 10527	10 10 22-58
koraiensis	3 3 2.5-4.3 80	1 1 9.5 38	5 0 0 0	3 1 .2 3	1 0 0 0	2 1 .2 1			3 1 3.0 58		
mariana		3 0 0 0		3 1 .01 1	3 2 .2 53	3 3 .03-3.7 689	3 1 .1 10	3 3 2.0-5.6 1902	3 3 .2-1.1 282	3 1 .05 7	
rubens		3 2 .1 35		4 2 .32 45	5 4 1.0 21	2 0 0 0		4 4 .08-4.4 613	5 3 .09 11		

6	No. trees pollinated
6	No. crosses yielding full seeds
5.4	No. full seeds per cone
1122	Total number full seeds

method for certain agricultural crops. Because of the long period between generations, the development of homozygous (inbred) lines has largely been avoided by tree breeders. If haploid plants could be located or produced, their chromosome complement could be doubled to produce homozygous diploids in a single step and the time required to produce such lines by inbreeding could be shortened.

The gametophyte stage (haploid) in gymnosperms, although greatly reduced in comparison to the sporophyte, undergoes several cell divisions. If the gametophyte could be induced to undergo further divisions and subsequently to differentiate into a functional plant the production of haploids and homozygous diploids would be feasible.

It is the objective of this project to produce haploid and, subsequently, homozygous diploid trees. Initial studies are being carried out with red pine [*Pinus resinosa* Ait.] because of its genetic uniformity and low frequency of deleterious recessive genes. Once techniques have been successfully developed for red pine they will be used for other coniferous species.

During 1967, female gametophytes were collected at 1-2 week intervals throughout the late spring-summer period. Fresh tissue from each collection was cultured *in vitro* on a Whites' medium plus coconut milk and casein hydrolysate. The cultures were examined weekly until deterioration occurred. Subsequent examination of tissues, periodically fixed throughout the experiment, indicated that maximum growth occurred in cultures made from materials collected just prior to or just after fertilization. Future work will be concentrated on tissues at this stage of development.

The effects of varying the concentration of 2,4-D, IAA and NAA in the media were also examined. The results of this work have yet to be evaluated.

PUBLICATIONS 1966-67

Fowler, D.P. 1966. A new spruce hybrid - *Picea schrenkiana* x *P. glauca*. Proc. 2nd Genet. Workshop of Soc. Amer. For. and 7th L.S.F.T.I. Conf. 1965. U.S.F.S. Res. Pap. NC-6: 44-47.

———— 1967. Low grafting and deep planting may prevent mortality due to incompatibility in pines. Forest Sci. 13(3):314-315.

REFERENCES

Fowler, D.P. 1966. Pine and spruce breeding at the Southern Research Station, Maple, Ontario. 10th Meet. Comm. Forest Tree Breed. Can. Progr. Rep: 37-45.

MacGillivray, H.G. 1966. Progress in tree improvement in the Maritimes region. 10th Meet. Comm. Forest Tree Breed. Can. Progr. Rep: 95-98.

PHOTOPERIOD, THERMOPERIOD AND GIBBERELLIC ACID AND THEIR EFFECT ON GROWTH OF SEVERAL CONIFERS

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In the north temperate zone the decreasing photoperiod after the summer solstice is the overall controlling factor for inducing dormancy before the approach of winter. Soil moisture, nutrients and temperature also affect the rate and amount of growth. Interaction between these factors and photoperiod can also occur. Flower initiation (Fraser 1958a; Wareing 1956) metabolic activity (Fraser 1964, 1966) and nitrogen metabolism (Durzan and Steward 1963) are all influenced by photoperiod. Because of the multiple effect and the potential of practical application through its control (Fowler 1961; Fraser 1968) photoperiodic influence on spruce seedlings was studied both in growth chambers and in the field.

It was earlier established that spring temperatures influence the initiation of radial growth in trees (Fraser 1956). Therefore the suggestion that thermoperiod rather than photoperiod should be a deciding factor for growth initiation (both apical and radial) was explored.

Gibberellic acid (GA_3) has promoted apical growth (Fraser 1958b) and early sexual maturity (Pharis and Morf 1967; Kato *et al* 1959; Goo and Yagi 1966) in many tree species. While our earlier work with gibberellic acid application in conifers was not reported on because of negative results (i.e. injury rather than stimulation), the findings of the above authors suggested that our failure resulted from the higher sensitivity of conifers to gibberellic acid. Thus it was decided that another trial with highly reduced concentrations should provide us with a desirable effect.

While photoperiod, thermoperiod and gibberellic acid all exert a definite influence on growth of conifers, their individual effects are not mutually exclusive. It was our aim to establish not only the individual effects of artificial variants of growing conditions, but also a combination of these which would be most favorable to both vegetative and reproductive growth.

EFFECT OF PHOTOPERIOD ON BLACK AND WHITE SPRUCE SEEDLINGS

Seeds of black [*Picea mariana* (Mill.) BSP.] and white [*P. glauca* (Moench) Voss] spruce were planted in October under natural photoperiod in a greenhouse at 21C. Nine months later, when they were about 2 cm high, the seedlings were transplanted into 75 x 40 x 20 cm flats containing silica sand. These flats were transferred into growth chambers at 21C. Three photoperiods were provided by a combination of fluorescent and incandescent lights of 1500 ft-c. The flats were irrigated with a complete nutrient solution.

Seedlings of both species reacted essentially the same, except for additional nitrogen-requirement of the white spruce seedlings for maintenance leader growth and apical dominance after 11 months under long photoperiods. In seedlings grown at the 16-, and 24-hour photoperiods, dormancy will be induced within 2 weeks after transfer into an 8-hour photoperiod. Similarly when seedlings grown in the 8-hour photoperiod are transferred into long photoperiods, their dormancy will be broken and apical growth will resume (Fig. 1). This seedling dormancy in the 8-hour photoperiod can also be broken by a 2 week exposure to 2C. In our experiment growth resumed for 2 weeks after such seedlings were transferred back to 21C at the same (8-hour) photoperiod.

The production of dry matter was greatest in the seedlings grown under the 24-hour photoperiod, both at 14 and 37 weeks. The increase was more prominent in black spruce than in white (Fig. 2), when the dry matter production was compared with that at the 16-, and 8-hour photoperiod. Yet the greatest leader-growth was produced at the 16-hour photoperiod. The distribution of dry matter also changed with age and length of exposure to light. At 14 weeks the 24-hour photoperiod seedlings had a root:shoot ratio of 1:2, whereas at 37 weeks this ratio has changed to 1:1. A similar increase in root:shoot ratio related to the duration of exposure was evident in seedlings grown under the 16-hour photoperiod.

EFFECT OF ARTIFICIAL TEMPERATURE INCREASE ON FIELD-GROWN BLACK AND WHITE SPRUCE SAPLINGS

Apical growth in white spruce at Chalk River, Ontario, Canada (45° 58' N., 77° 31' W.), extends approximately from late May until early July, irrespective of the sites on which they are growing; initiation and cessation of growth in black spruce usually is 2 weeks later. The time of growth-initiation is also subject to about a 2 week variation depending on the average spring temperatures: it will be earlier during a warm, and later

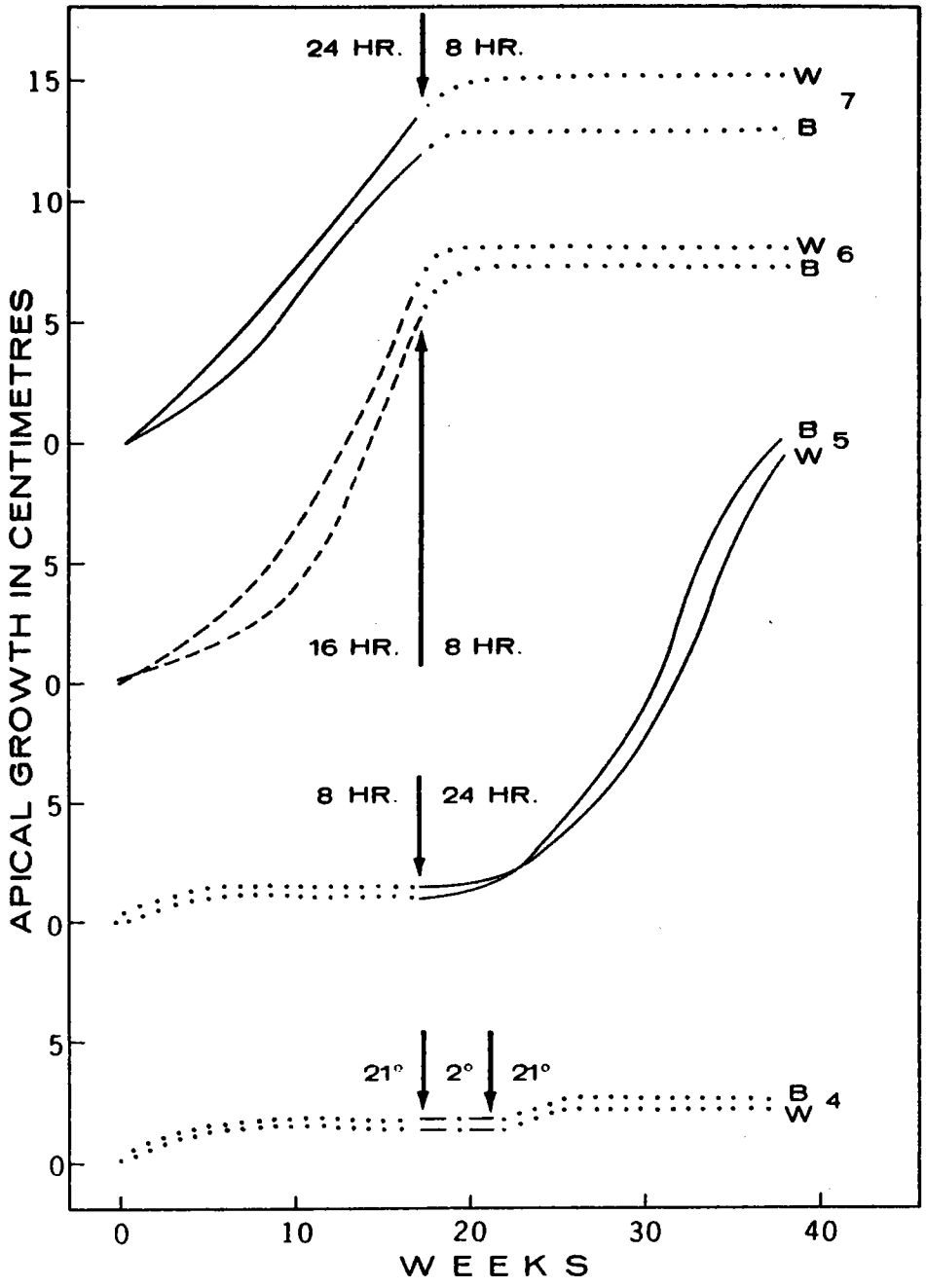

Figure 1. Effect of photoperiod or thermoperiod (number 4 at 8-hour photoperiod, numbers 5, 6, 7 at 21C thermoperiod) on apical growth of black (B) and white (W) spruce.

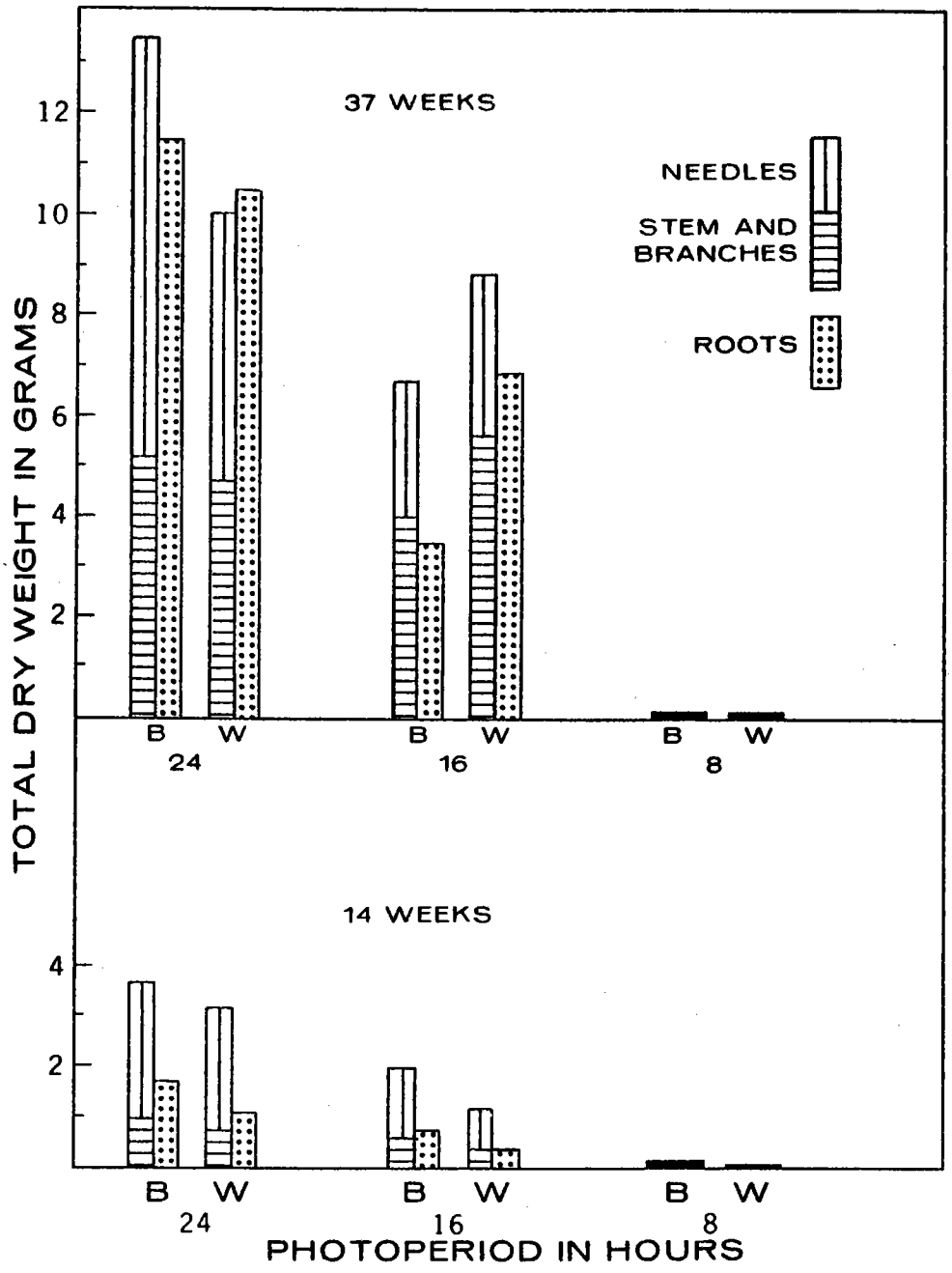

Figure 2. Effect of photoperiod on total dry weight of black (B) and white (W) spruce after 14 and 37 weeks growth at 21 C.

during a cold spring. Other factors, such as the amount of sunshine, moisture and nutrients can vary from year to year. The growth period may also be affected by their influence, combined or individual. When spring temperatures are above average, they favor, besides growth initiation, the formation of staminate and ovulate cones.

In the late winter of 1966-67 (early April at Petawawa) four plastic houses, each 12 feet high, were erected around two groups of nine saplings each of white and black spruce. To moderate the temperature, four thermostatically controlled electric heaters were installed in each house to operate at any temperature below 70F. During the hot summer months a ventilating fan in each house alleviated excessively high temperatures and kept the carbon dioxide content of the air comparable to that of the natural environment. Because of our previous suggestion (Fraser 1962, 1967) that increased photoperiod will accentuate effect of other treatments incandescent lamps were installed to provide illumination of about 200 ft-c during the night in both the plastic houses and in the plantation.

In mid-April, 2 weeks after the introduction of the artificial increase in air temperature, (Fig. 3) apical growth had commenced in white spruce and shortly thereafter in black spruce (Figs. 4a and 5a), while in the control saplings it did not occur until 1 month later in early June (Figs. 4b and 5b). Radial increment in the trunk preceded apical extension in both the plastic-enclosed and control saplings. These observations confirm the supposition that in our latitude, temperature rather than lengthened photoperiod influences the time of spring growth-initiation.

Both raised air temperature and lengthened photoperiod influenced the rate and amount of growth. Continuous growth was evident in both the leader and upper branches, as well as in the cambium in black spruce from May until October. In white spruce the pattern of growth was somewhat different; growth ceased for 1 month in mid-summer, but resumed again and continued until the natural photo- and thermo-periods were re-established in mid-October. Saplings subjected to the aforementioned treatment were not frost hardy, and were winter-killed. However, the re-establishment of the natural photo- and thermo-periods in early September, before the onset of winter frosts, favored natural cessation of growth and the development of winter hardiness.

As we have already confirmed in our earlier studies (Fraser 1962) with photoperiod, the re-establishment of natural day length in early September is essential for the development of winter hardiness. Thus when only the heat in the houses was

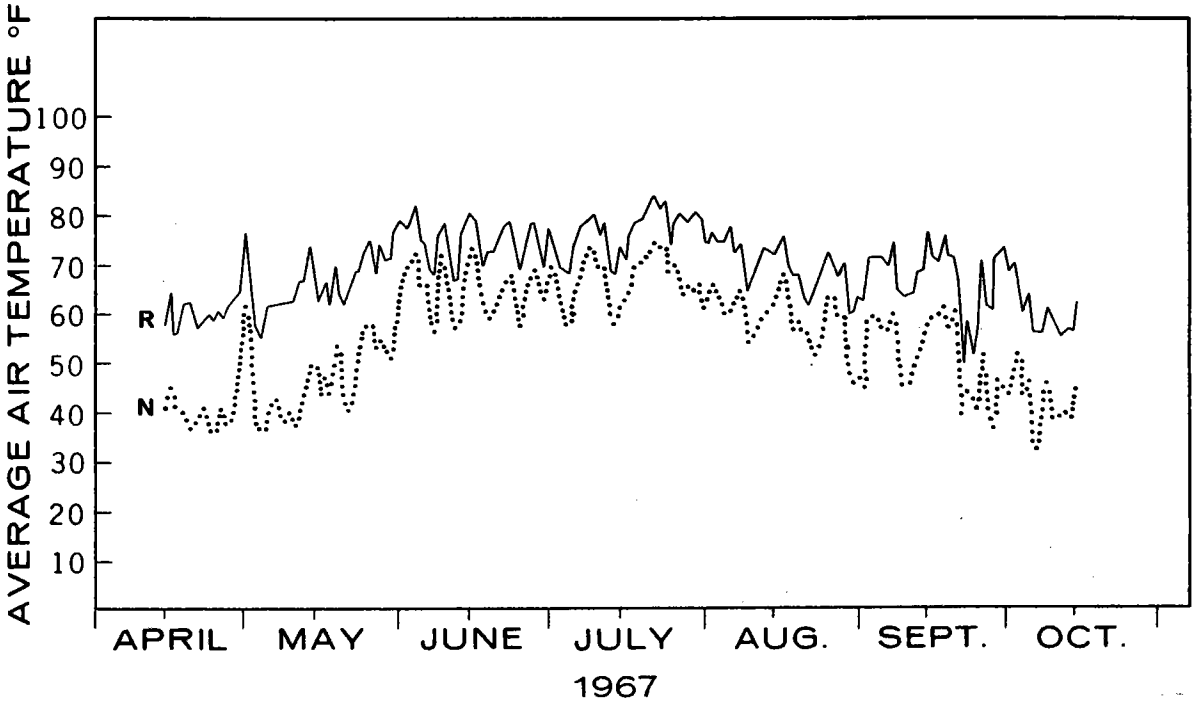

Figure 3. Average daily air temperatures (based on 2-hourly observations from thermographs shielded from the sun) in the open (N) and under the heated plastic houses (R) covering the experimental saplings of black and white spruce.

discontinued while the extra illumination was maintained, the failure of the saplings to develop frost hardiness resulted in winter-kill.

INFLUENCE OF GIBBERELLIC ACID ON VEGETATIVE AND REPRODUCTIVE GROWTH OF BLACK AND WHITE SPRUCE, WHITE CEDAR AND ARIZONA CYPRESS

Because induction of reproductive buds with GA_3 in cypress [*Cupressus* sp.] and cedar [*Thuja* sp.] has been obtained by other workers (Kato *et al* 1959; Pharis and Morf 1967), species from these genera as well as black and white spruce were used in our experiments.

Seedlings of black spruce, white cedar [*Thuja occidentalis* L.] and Arizona cypress [*Cupressus arizonica* Greene] were sprayed three times a week with an aqueous solution of 500 ppm GA_3 and 500 ppm Tween 20, until they were dripping wet. A second group of white cedar seedlings, 25 cm high, was also subjected to this treatment. The seedlings were grown in growth

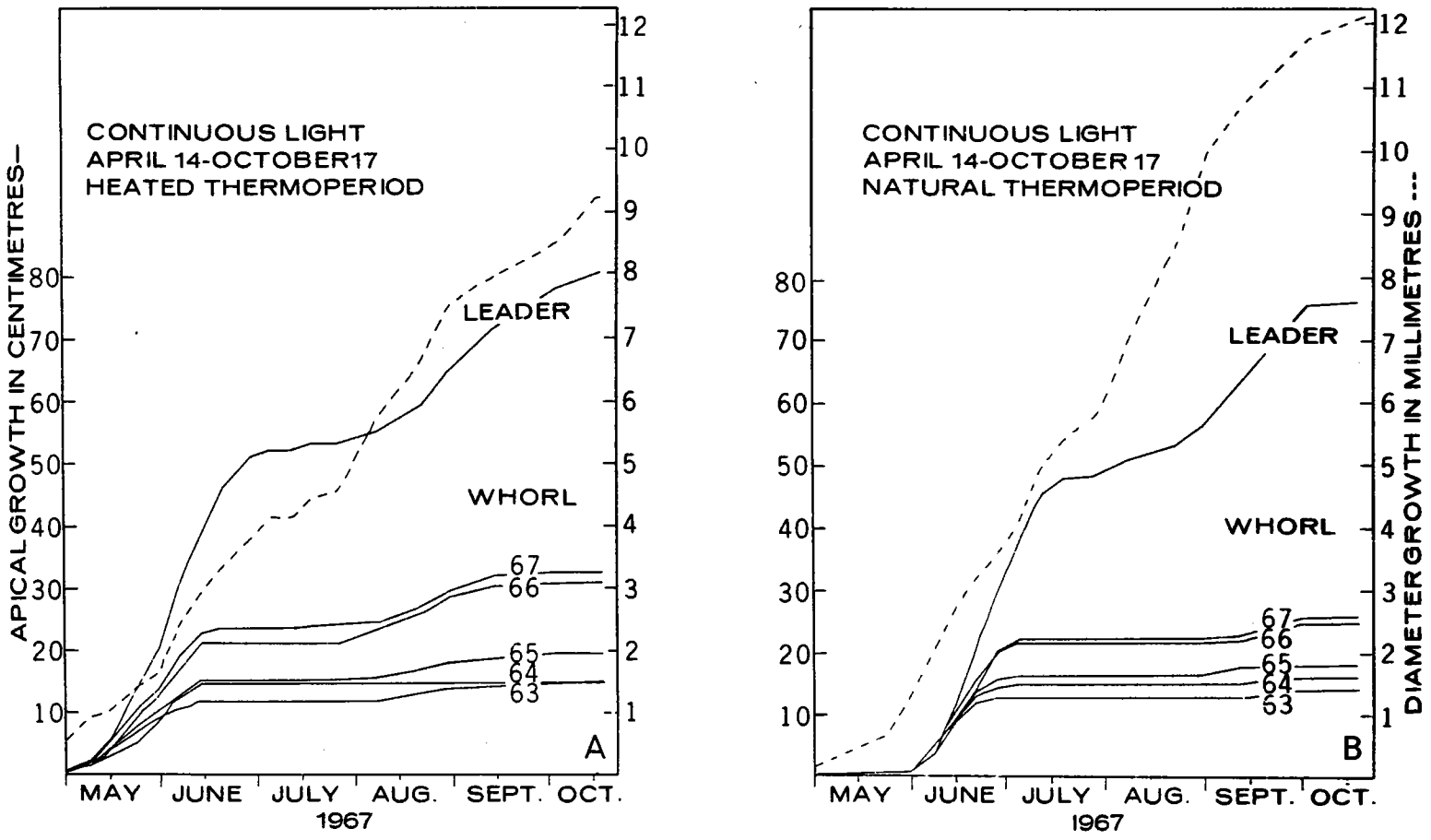

Figure 4. White spruce: cumulative apical and diameter growth of saplings exposed to continuous light and, A - heated thermoperiod, B - natural thermoperiod.

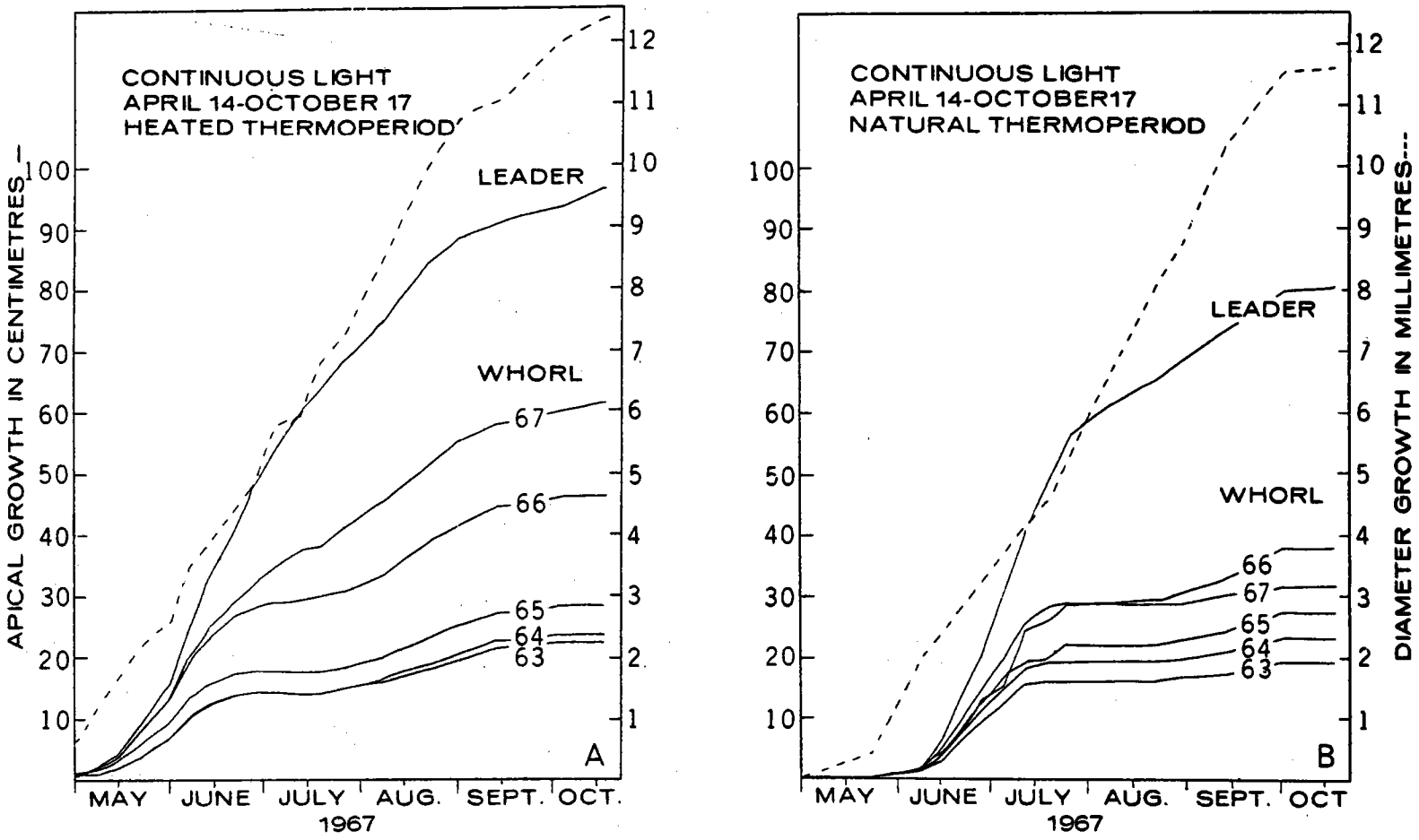

Figure 5. Black spruce: cumulative apical and diameter growth of saplings exposed to continuous light and, A - heated thermoperiod, B - natural thermoperiod.

chambers at 21C with 8-, 16- or 24-hour photoperiods. The light source consisted of a combination of fluorescent lamps and incandescent bulbs of 1500 ft-c. Because browning and some mortality, especially in the Arizona cypress, occurred after the first 3 months, the spray frequency was reduced to twice a week. This modification of treatment reduced damage, although it permitted some development of side branches. One cc per seedling of 500 ppm GA_3 in 500 ppm Tween 20 and water was also applied twice a week to the rhizosphere of black and white spruce seedlings growing in nutrient-supplied sand which was automatically (Bouyoucos control unit) sub-irrigated with water.

Black Spruce

The GA_3 spray stimulated apical growth and inhibited the production of lateral branches.

White Cedar

In young seedlings (shortly after germination) GA_3 inhibited apical growth under all three photoperiods when compared with foliar application of plain water. In the 25-cm high seedlings the results were quite contrary. Here the GA_3 stimulated apical growth, although some browning did occur. Reproductive buds appeared during the seventh month.

Arizona Cypress

The original three-times a week application of GA3 - Tween 20 produced not only lateral branch and root inhibition, but also a deleterious browning and suggestion of potential mortality. When, for this reason, the treatment was reduced to twice a week, the damage was alleviated, although some side branches were developed. Yet these seedlings developed cones at the age of 7 months while no indication of any reproductive tissue was evident in the control specimens which were sprayed with pure water.

Comparing our results with those of Pharis and Morf (1967) at Calgary we find that our seedlings of Arizona cypress required more than twice (3 months for Pharis and Morf) as much time to produce reproductive structures. This can perhaps be explained as a genetical influence, for his seed originated in California, while ours was supplied by Prof. W. Phillips from Tucson, Arizona. This incident suggests that each treatment would have to be tailored to the particular batch of seedlings under investigation.

GA_3 in Tween 20 and water added to the rhizospheres of black and white spruce stimulated apical growth of the shoot. These experiments are still in progress.

To sum up our findings, GA_3 affects both vegetative and reproductive growth of several conifers (as well as hardwoods). It appears that this effect is influenced both by the age of the seedlings treated, the photoperiod under which the seedlings are growing, and the dilution used. The two last conclusions agree with the report on simultaneous work presented by Pharis *et al* (1968). An indication was obtained that the location of the meristematic tissue treated is not critical, i.e. the treatment of the rhizosphere could be compared to aerial spraying.

REFERENCES

Durzan, D.J. and Steward, F.C. 1963. The nitrogen metabolism and seasonal changes in shoots of *Picea glauca* (Moench) Voss. Plant Physiol. 38 (Suppl. vi.).

Fowler, D.P. 1961. The effect of photoperiod on white pine seedling growth. Forest. Chron. 37:133-143.

Fraser, D.A. 1956. Ecological studies of forest trees at Chalk River, Ont., Canada. II. Ecological conditions and radial increment. Ecology 37:777-789.

———— 1958a. The relation of environmental factors to flowering in spruce, pp 629-641. *In* The physiology of forest trees. K.V. Thimann. [Ed.] The Ronald Press Company, New York.

———— 1958b. Growth mechanisms in hardwoods. Pulp Pap. Mag. Can. 59(10): 202-209.

———— 1962. Growth of spruce seedlings under long photoperiods. Can. Dep. Forest., Forest Res. Div., Tech. Note 114.

———— 1964. Seasonal changes in respiration and moisture content of shoot tips of white and black spruce at Chalk River, Ontario. Proc. Can. Soc. Plant Physiol. 5:16.

———— 1966. Oxygen and moisture uptake as indices of metabolic activity in white spruce shoot tips. Can. Dep. Forest. Rural Develop., Forest. Br. Bi-mon. Res. Notes 22 (5):2.

———— 1967. Continuous light accelerates tree growth. Can. Dep. Forest. Rural Develop., Research News 10(1) :11.

———— 1968. Effect of photoperiod on growth of white and black spruce. Proc. Can. Soc. Plant Physiol. 9:35-36.

Goo, M. and Yagi, K. 1966. Use of gibberellin as lanolin paste for flower bud induction of *Cryptomeria japonica*. Tokyo Univ. Forests. Misc. Inf. No. 16: 21-26.

Kato, Y., Fukuara, N., and Kobayshi, R. 1959. Stimulation of flower bud differentiation of conifers by gibberellin. J. Jap. Forest. Soc. 41(8):309-311.

Pharis, R.P. and Morf, W. 1967. Experiments on the precocious flowering of western red cedar and four species of *Cupressus* with gibberellins A3 and A_4/A_7 mixture. Can. J. Bot. 45:1519-1524.

———————— , Ruddat, M.D.E., Glenn, J.L. and Morf, W. 1968. Photoperiodic requirements for induction of flowering in a conifer. Arizona cypress. Proc. Can. Soc. Plant Physiol. 9:55.

Wareing, P.F. 1956. Photoperiodism in woody plants. Ann. Rev. Plant Physiol. 7: 191-214.

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

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SELECTION OF PLUS TREES FOR USE IN THE DOUGLAS-FIR BREEDING PROGRAM

The propagation and preservation phases of this project have continued although no further field selection has been carried out by the B.C. Forest Service since the last report to the Committee. Cooperating members of the Tree Improvement Board have continued some plus tree cruising individually and as part of a joint program. A few additional trees have been registered.

At the beginning of 1968 all but 15 of the 626 registered Douglas-fir trees had been propagated by grafting into the B.C. Forest Service clone bank at Cowichan Lake. Of these registered trees, 423 are selected plus trees, while the remainder are research trees.

A research note (Heaman 1967) has been prepared on the plus tree selection program. This serves as a historical record of the work and describes the methods used, standards applied and the progress made. Emphasis was placed on the B.C. Forest Service involvement but the development of the cooperative effort was included.

The Tree Improvement Board is still active but some divergence of interest into western hemlock and Sitka spruce by the individual companies is taking place. The annual 'Plus Tree Week' cooperative cruise has ceased but in its place other projects in the field of tree improvement have been undertaken on a joint basis. These projects are financed by interested member companies and are directed by Dr. Sziklai, who serves as technical adviser to the Board.

B.C. FOREST SERVICE SEED ORCHARDS

As was noted in the 1966 Report, the decision has been made by the B.C. Forest Service to abandon the clonal seed orchard approach in favor of seedling seed orchards. Initially,

wind-pollinated seed collected from the plus trees in the field will be used. This decision was based largely on the high incidence of graft imcompatibility found in Douglas-fir and the difficulty in rooting the species, but in addition, the early production of cones anticipated on grafted material has been most disappointing in the clone bank at Cowichan. It is also becoming apparent that seedlings provide a more desirable branching habit from the point of view of cone production than do ramets. Although from theoretical considerations this scheme means acceptance of lower genetic gains, it does provide several advantages of a practical nature at this early stage in the program. Such seedling orchards can be expected to produce seed in 10 to 15 years, of suitable provenance and incorporating some genetic advantage. In the interval it will be possible to obtain information and material on which a more intensive approach, yielding greater gains, may be applied.

Advantage was taken of the widespread cone crop in 1966 and, with help from cooperating companies, cones were collected from 90 plus trees at higher elevations on Vancouver Island and the coastal mainland. Seedlings are now being raised for the first two priority orchards. At the high elevation Vancouver Island Seed Orchard site at Campbell River, 10 acres of clonal orchard remain and wind-pollinated seedlings will be used to complete the stocking of the 16-acre field. The mainland seedling orchard will be established at Duncan in 1969.

Seed has also been obtained from plus trees selected in the more northerly coastal area, from Sechelt north to Kingcome Inlet, and stock for a low elevation seed orchard of this provenance is now being grown.

As grafting at the Campbell River orchard dates mainly from 1964 and 1965, with a few 1963 ramets remaining, there has, as yet, not been any appreciable seed production.

GRAFT INCOMPATIBILITY IN THE B.C. FOREST SERVICE CLONE BANKS

The incidence of graft incompatibility is very high in the B.C. Forest Service clone bank but at present no attempts are being made to find a long term solution to the problem as Dr. Copes, U.S. Forest Service Pacific Northwest Station at Corvallis, is carrying out detailed studies on this problem. However, the cutting technique developed by Mr. Karlsson and described in the Forest Research Review (1966) is proving satisfactory as a short term measure. This treatment has been applied in 1966 and 1967 to all ramets in the B.C. Forest Service clone bank showing signs of incompatibility. It appears that

the bridge of callus tissue, developed from the cuts made across the union, prolongs the life of the ramet. It does not appear to provide a permanent solution to the problem and repeated cutting is required to maintain an incompatible combination.

REFERENCE

Heaman, J.C. 1967. A review of the plus tree selection programme for Douglas-fir in coastal British Columbia. B.C. Forest Serv. Res. Note No. 44. 27pp.

SUMMARY REPORT ON FOREST TREE BREEDING
1966 & 1967

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Southern Research Station, Maple, Ontario

In August 1966, Dr. D.P. Fowler resigned as Head of the Tree Breeding Unit and Dr. C. Heimburger was temporarily reinstated in this position. Miss R.M. Rauter also resigned in September 1966 to begin graduate studies. In July 1967 Dr. L. Zufa was appointed Head of the Tree Breeding Unit and Dr. C. Heimburger continued work in a consulting capacity.

WHITE PINE

Resistance to blister rust and weevil, and satisfactory growth form and growth rate are the main objectives in breeding. The work is being carried out in four phases:

1. Clones of *Pinus strobus*, originally selected for resistance to blister rust are being intercrossed to determine their combining ability to transmit resistance to their progenies. Several clones are being regrafted, for additional blister rust resistance tests according to recently improved procedures. Scions of the most promising clones are being supplied to the Timber Branch, Department of Lands and Forests of Ontario and to the U.S. Forest Service, for the establishment of seed orchards.

2. Single-tree progenies of plus trees selected for outstanding growth form and growth rate, and for freedom from attack by weevil, are being mass-inoculated with blister rust to select blister rust resistant clones for further breeding with a superior genetic background in respect to growth form and growth rate, and reaction to weeviling.

3. Introduction of resistance to blister rust into *P. strobus* through interspecific hybridization. One clone of *P. griffithii* has shown to be especially promising in this respect, in transmitting resistance to its hybrids with *P. strobus*.

4. Clones selected for resistance to blister rust are being further tested for weevil resistance by means of field-grafting in plantations under conditions of heavy weevil attack. Some *P. peuce* and *P. monticola* appear promising in this respect.

Acquisitions

The following populations were acquired in the form of seeds:

P. monticola	Wilson Lake, Nakusp, B.C.	(Cones collected
P. monticola	Londonderry Creek, Burton, B.C.	(fall 1966, seeds (extracted at (Angus, Ont.-1/3 (sown fall 1966,1/3 (fall 1967 at St. (Williams
P. aristata	Origin unknown, F.W. Schumacher, Sandwich, Mass.	

The following materials were acquired in the form of scions:

Species	Origin	Clones	Successful Grafts
P. strobus	Finland	4	57
P. monticola	N.Y. State	13	257
P. strobiformis	N.Y. State	2	40
P. strobus	New Westminster, B.C.	5	103
		24	457

Selection

The following clones, found to be resistant to blister rust, were selected and grafted for further testing.

P. strobus	origin unknown, precocious in 1956	3 clones
P. monticola	Nakusp, B.C.	8 clones
P. monticola	Denver, B.C.	2 clones
P. monticola	Salmon Arm, B.C.	3 clones

Regrafting (Phase 1.)

The following clones were regrafted in 1967 for further testing for resistance to blister rust:

P. strobus	70	1008
P. peuce x *strobus*	1	14
P. peuce	1	20
P. strobus x *griffithii* & *recip.*	40	509
P. griffithii	3	35
P. monticola	1	10
P. lambertiana x *koraiensis*	1	7
	117	1603

Mass-inoculation (Phase 2.)

Nineteen populations of *P. strobus*, all half-sib progenies of plus trees containing a total of about 19,650 seedlings were mass-inoculated with blister rust in 1967.

Hybridization

The following crosses, made in 1965, were harvested in 1966:

Parentage	Crosses	Cones	Seeds	Full Seeds	Seedlings
P. strobus x *strobus*	23	229	8724	5313	4380
P. (*griffithii* x *strobus*)x (*griffithii* x *strobus*)	14	148	4371	1178	968
P. (*strobus* x *griffithii*)x (*griffithii* x *strobus*)	1	8	311	133	115
P. griffithii x (*griffithii* x *strobus*)	6	287	11255	2322	1661
P. monticola x (*griffithii* x *strobus*)	1	21	1182	404	291

The following crosses made in 1966, were harvested in 1967:

P. strobus x *strobus*	31	359	10567	5202
P. griffithii x *strobus*	12	97	3951	993
P. griffithii x (*griffithii* x *strobus*)	7	67	2009	403
P. (*griffithii* x *strobus*)x (*griffithii* x *strobus*)	6	37	564	112
P. (*griffithii* x *strobus*)x *strobus*	5	23	1100	386
P. (*monticola* x *peuce*)x (*griffithii* x *strobus*)	5	13	287	50

The following crosses were made in 1967:

P. (*griffithii* x *strobus*)x *strobus*	15	30

Most of the *P. strobus* x *strobus* crosses in 1965 and 1966 were made to evaluate the combining ability in respect to resistance to blister rust of certain clones available for this purpose. The crosses involving *P. griffithii* x *strobus* were made to further test the combining ability of one especially promising resistance transmitter and to compare it with other *P. griffithii* and *P. griffithii* x *strobus* materials.

HARD PINES

The production of a red pine or a red-pine-like hybrid, resistant to the European pine shoot moth and of satisfactory growth form and growth rate continued to be the objective of this project. The efforts to produce interspecific hybrids between red pine [*P. resinosa*] and other species of the Lariciones group, mentioned in the report for 1964 and 1965, resulted a complete failure. None of the resulting seedling populations contained any red pine hybrids. Efforts to produce southern pine hybrids, hardy in southern Ontario, have been continued.

Acquisitions

The following populations were obtained in the form of seeds:

Species	Origin	No.Pops.	No. seedlings 1967
P. (nigra x *resinosa)* x *nigra*	Placerville, Calif.	3	83

The following materials were acquired in the form of scions:

Species	Origin	Clones	Successful grafts
P. resinosa	Orr Lake, Ont.	1	25
P. nigra x *resinosa*	Placerville, Calif.	4	20
		5	45

Selection

The following clones, of above-average growth form, were selected and grafted for further testing:

P. densiflora	Midhurst, unknown origin	1	20
P. densiflora	Japan, Nagano area	9	180
		10	200
P. densiflora x *silvestris*		13 used in crosses and marked accordingly	

Hybridization

The following crosses, made in 1965, were harvested February, 1967:

Parentage	No. crosses	No. cones set	No. cones col'd	No. seeds	No. full seeds	No. seedlings - Jan./68
P. (densiflora x *sil-vestris)* x *silvestris*	26	624	150	2015	352	310
P. (densiflora x *nigra)* x *silvestris*	4	180	47	535	147	143

In 1966, several *P. rigida* were crossed with *P. attenuata* x *radiata* pollen received from Placerville, Calif. in 1965 and stored in a deepfreeze. Although cone set was very good in 1966, all cones aborted subsequently, i.e. the results were the same as in 1965 when fresh pollen was used.

In 1967, grafts of a *P. leucodermis* clone received from Holland, were pollinated with red pine. There was no cone set after this cross in the fall of 1967.

Precocious Scotch pine

In 1963 crosses were made between some precocious Scotch pine with precocious Scotch pine of the same and of another population, and with a "normal" Scotch pine. These crosses yielded seeds and seedlings in 1964 and 1965. The seedlings were subsequently raised in the nursery and set out in a small test plantation at Maple. Several seedlings started to produce female strobili in 1966 and continued in 1967. The growth, growth form, and flowering of these materials were tallied in 1966 and 1967. No male flowers have thus far been observed. The results of these tallies show that precocious female flowering is under strong genetic control and that the flowering seedlings are not inferior in growth rate compared with non-flowering seedlings. Some seedlings with a multi-nodal branching habit resulting from bud prolepsis combined with strong apical dominance, have been observed. The results have been submitted for publication.

SPRUCE

The spruce breeding project was initiated in 1964. The purpose of this work is to select and develop spruces of superior quality for planting in northern Ontario. In addition, efforts are being made to produce spruce materials suitable for growing in southern Ontario, to the south of the natural range of white spruce.

Acquisitions

The following materials were acquired in the form of scions:

Species	Origin	No. clones	No. successful grafts
P. glauca	Geraldton District	4	58
P. glauca	Port Arthur District	4	46
P. mariana	Port Arthur District	2	38
P. omorika x ?	Haney, B.C.	3	58
P. orientalis	Rochester, N.Y.	2	68
P. asperata	Rochester, N.Y.	2	59
		17	327

The following populations were acquired in the form of seeds:

Species	Origin	No. populations	No. seedlings 1967
P. glauca	Emerald Lake, B.C.	1	632
P. glauca	Golden, B.C.	1	305
P. mariana	Petawawa F.E.S.	1	70
P. omorika	Commercial	1	1100
		4	2107

Selection

In 1967 the following spruce materials were selected and some used in hybridization:

Species	Locality	No. trees
P. sitchensis x *glauca* F_1	Maple	9
P. pungens	Maple	1
P. pungens	Midhurst	2
P. glauca	Maple	1
P. glauca	Midhurst	1
P. abies	Maple	1
P. abies	Midhurst	3
		18

Hybridization

The following crosses were made in 1966 and 1967:

Parentage	No. trees	No. successful crosses	No. seeds/ cone	No. seeds sown	No. seeds germ.
1966					
P. schrenkiana x *pungens*	4	2	0.6	13	13
P. schrenkiana x *abies*	3	-	-	-	-
P. schrenkiana x *meyeri*	3	-	-	-	-
P. schrenkiana x *schrenkiana*	3	3	29.3	71	70
P. meyeri x *glauca*	1	1	0.7	2	2
P. (abies x *sitchensis)* x *glauca*	1	1	39.9	437	425
P. glauca x *meyeri*	1	-	-	-	-
P. glauca x *schrenkiana*	1	1	0.1	2	-
P. glauca x *omorika*	1	-	-	-	-
P. glauca x *abies*	1	1	0.04	1	-
P. glauca x *pungens*	1	1	2.0	30	11
P. glauca x *glauca*	1	1	35.0	30	29
P. glauca x *self*	1	1	1.6	30	29
P. pungens x *omorika*	2	1	0.02	1	-
P. pungens x *shrenkiana*	2	-	-	-	-
P. pungens x *glauca*	2	1	0.03	1	1
P. omorika x *glauca*	1	1	?	396	51
P. omorika x *schrenkiana*	1	-	-	-	-
P. omorika x *pungens*	1	-	-	-	-
P. abies x *schrenkiana*	3	-	-	-	-
P. abies x *meyeri*	3	2	1.4	26	20
P. abies x *self*	3	1	0.5	6	6
1967					
P. mariana x *glehnii*	6	2	1.3	84	28
P. mariana x *wind*	1	1	?	253	199
P. koyamai x *abies*	1	1	.36	12	6
P. koyamai x *mariana*	1	-	-	-	-
P. koyamai x *glauca*	1	-	-	-	-
P. koyamai x *orientalis*	1	-	-	-	-
P. koyamai x *omorika*	1	-	-	-	-
P. koyamai x *wind*	4	4	29.2	742	334
P. schrenkiana x *mariana*	1	-	-	-	-
P. schrenkiana x *orientalis*	1	-	-	-	-
P. schrenkiana x *omorika*	1	-	-	-	-
P. schrenkiana x *jezoensis*	1	1	0.05	4	2
P. schrenkiana x *wind*	1	1	0.5	2	2
P. pungens x *mariana*	1	-	-	-	-
P. pungens x *wind*	1	1	1.8	32	31
P. glauca x *wind*	1	1	70	364	14
P. abies x *wind*	1	1	111	220	73

POPLAR

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

Acquisitions

The following poplar materials were acquired in the form of cuttings:

Species	Origin	Clones
P. deltoides	France	2
P. deltoides	Italy	1
P. deltoides	Ontario	5
P. euramericana	France	7
P. euramericana	Germany	10
P. euramericana	Holland	2
P. euramericana	Italy	9
P. euramericana	Spain	3
P. jackii	Ontario	1
P. maximowiczii	Japan	2
P. suaveolens var. *Przewalskii*	Holland	1
P. tristis	U.S.S.R.	1
		44

Hybridization

The following successful crosses were made:

Parentage	No. of crosses
P. (grandidentata x *alba)* x *canescens*	5
P. (alba x *grandidentata)* x *canescens*	2
P. (alba x *grandidentata)* x *(alba* x *tremula)*	2
P. canescens x *(alba* x *davidiana)*	1
P. canescens x *(alba* x *grandidentata)*	2
P. canescens x *petrowskyana*	1
P. tremuloides x *tremula*	1
P. tremuloides x *tremuloides*	1
P. tremuloides x *alba*	1
P. (tremula x *alba)* x *(alba* x *grandidentata)*	1
P. deltoides x *nigra*	4

Most of the crosses follow the experience of past years. Double crosses involving two aspen species and two unrelated strains of *P. alba* were produced on a fairly large scale,

and among the very heterogeneous seedlings a few with good rooting ability and other desirable characteristics were selected for further tests. Some more recent crosses between cottonwood and European black poplar have been made to supply Dr. Zufa with new experimental materials.

Rooting ability tests

The results of these tests in 1966 and 1967 were rather poor, largely because of poor survival of the fall-planted cuttings. The wet spring in 1967 was particularly unfavorable for cutting survival and establishment. This has recently been remedied by covering the rows of planted cuttings with strips of plastic material (polythene) in the fall, covering with soil over the winter and lifting the strips off in the spring. Time will tell if this also will result in better rooting and survival of the cuttings.

VARIATION IN COTYLEDON NUMBER AND SEED WEIGHT IN WHITE SPRUCE IN ALBERTA

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ABSTRACT

The average cotyledon number for 7,909 seedlings of white spruce from 37 samples in Alberta was 5.6/seedling. Averages among samples ranged between 4.8 and 6.6. These 37 samples had a high proportion of seedlings with four cotyledons compared to samples from eastern Canada. Average seed weights per sample ranged between 1.26 and 3.24 mg/seed giving a common average 196,000 seeds/pound. Any two seed samples which differed in their average cotyledon numbers by more than 0.3 of one cotyledon were statistically different. Coefficients of variation in average cotyledon numbers per sample were the same for single trees and groups of trees indicating that the single trees in this study were fertilized by many pollen donors. The higher coefficients of variation in samples with low, rather than high, numbers of cotyledons suggest white spruce gene mixing with black rather than Engelmann spruce in Alberta. Average seed weights per sample in white spruce are useful for describing differences among forest regions while average cotyledon numbers are highly specific for each seed sample regardless of geographic origin. The relationship between seed weight and cotyledon number is offered as an added criterion for the distinction of particular populations of white spruce.

INTRODUCTION

Conifers produce seedlings with more than two cotyledons (Butts and Buchholz 1940). The number per seedling varies within a given species, but it has been used effectively to distinguish hybrids between species (Silen *et al.* 1965). The number of cotyledons per seedling has also been used to describe differences among subpopulations within a species (Klein 1958; Sorensen 1966; Thorbjornsen 1961). In addition, the measure of average seed weight has been used successfully as a criterion for species characterization (Simak 1967; U.S.D.A. 1948).

White spruce [*Picea glauca* (Moench) Voss] differs from *P. mariana* (Mill.) BSP. and *P. engelmannii* Parry in number of cotyledons (Brayshaw 1959; Franklin 1961) and in average seed weight (U.S.D.A. 1948). Where the geographic distribution of

white spruce overlaps that of both other species (Fig. 1), and where there are frequent hybrids between white and Engelmann spruce (Horton 1959) or potential natural hybrids between white and black spruce (Little and Pauley 1958), cotyledon number may have value as a criterion for describing interspecific spruce hybrids.

The main objective of this study was to determine if there are regional differences in average cotyledon number or seed weight in white spruce in Alberta and if such differences are associated with geographic proximity to the other spruces. A complimentary objective was to determine if cotyledon number is correlated with seed weight in the same species.

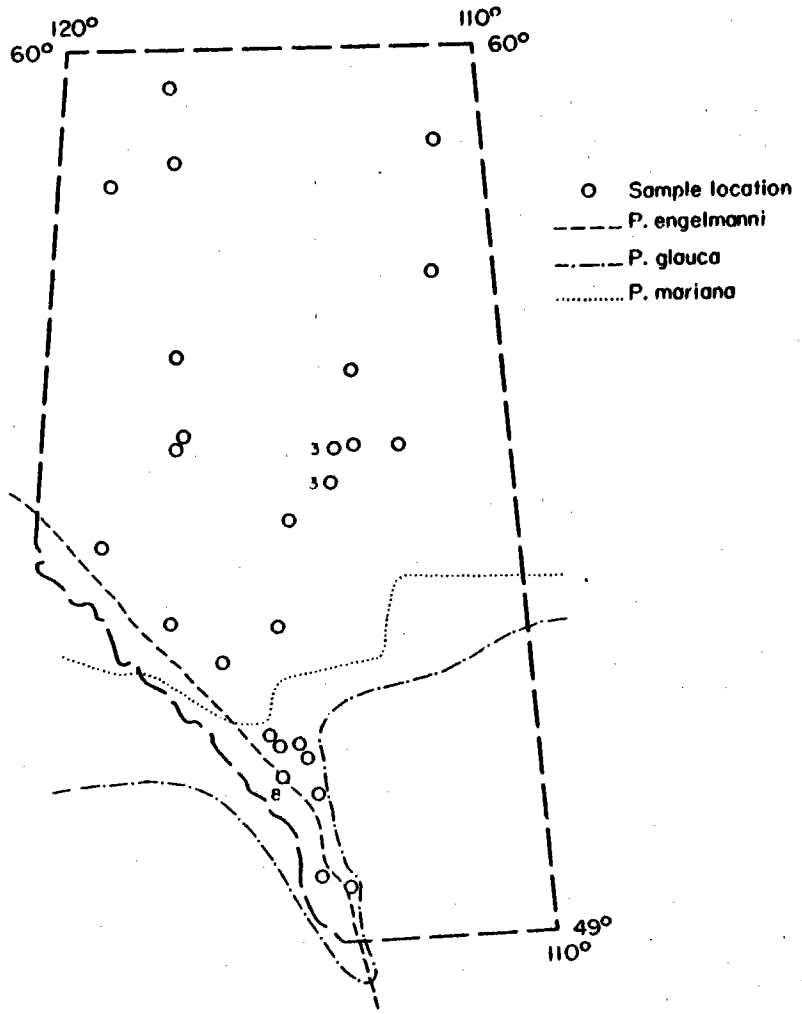


Figure 1. Location of 37 samples of white spruce seed, the eastern limits of P. engelmannii, *and the southern limits of* P. mariana *and* P. glauca.

MATERIALS AND METHODS

Forty different seed lots of white spruce from different geographic areas are described in Table 1. Twenty-three samples were collected between 1959 and 1967 from groups of wind pollinated trees in various parts of Alberta (Fig. 1)[1]. Most of these seeds were collected in late August or throughout September. In addition, 14 collections were made in late August and early September in 1964 and 1966 from single wind pollinated trees located southeast of Lesser Slave Lake and in southwestern Alberta near the Kananaskis Forest Experiment Station. These 37 samples cover the range of white spruce in Alberta. The remaining three samples were collected from single wind pollinated trees near Wasagaming, Man., in the middle of August in 1964.

Average seed weights, measured to the nearest tenth of a milligram, are shown for each seed lot in Table 2. At the time of weighing, moisture contents of air dry seed varied between 3% and 12% (Table 2). All samples contained less than 8% empty seeds (Table 2). Single seeds from individual trees were weighed separately for correlation tests between seed weight and cotyledon number.

The usual germination regime of 30-20C (day-night cycle) which is recommended for white spruce (U.S.D.A. 1948; Heit 1961) was not satisfactory because it facilitated fungal and bacterial growth which decreased total germination and killed many germinants before cotyledons could be counted. Surface sterilization with mercuric chloride (Chen and Jong 1965) was only partially effective in preventing losses from fungi and bacteria. Best results were obtained when unsterilized seeds were placed on moist blotters in petridishes in a germinator which 20-10C day-night temperatures. The seeds were exposed to 500 ft-c of fluorescent light during the 12-hour days.

Cotyledons were counted 10 to 20 days after germination or as soon as they emerged from the seed coats.

RESULTS

Cotyledon Number and Seed Weight Variations in White Spruce in Alberta

Most seedlings of white spruce had between four and seven cotyledons. Seedlings with three, eight, or nine cotyledons

[1]These seeds were kindly donated by the Alberta Forest Service in 1967.

Table 1. Geographic Locations of 40 Seed Samples of White Spruce from Alberta and Manitoba. The First Two Numbers in Each Seedlot Number Indicates the Year of Collection.

Source	Seedlot Number	Latitude °	'	Longitude °	'	Altitude ft asl.
Grande Prairie	64-111B	55	05N	117	10W	2,150
"	64-152	55	13	117	00	2,100
Rocky Mtn. House	59- 89	52	49	115	10	2,800
"	61-142	52	38	116	05	4,500
"	61-149	51	31	114	40	4,500
Crowsnest	60- 4	49	46	113	57	5,000
"	60-277	49	52	114	23	6,000
Whitecourt	59- 10	54	15	114	50	2,300
Edson	59- 60	53	58	118	37	3,000
"	60- 35	53	04	117	15	5,000
Lac La Biche	59- 19	58	45	111	00	800
"	59- 80	57	15	111	21	750
"	59- 82	55	05	112	26	1,900
Peace River	60- 27	58	25	118	45	800
"	59-143	59	37	117	12	800
"	59- 8	56	16	117	05	1,900
"	67- 53	58	45	117	10	1,500
Slave Forest	59- 44	56	00	113	18	1,900
"	64- 45	55	13	113	25	2,025
"	66-169	55	05	113	53	2,100
"	66-171	54	39	113	56	2,200
"	66-172	54	39	113	56	2,200
"	66-175	55	12	113	57	2,050
"	66-176	55	12	113	57	2,050
"	64-100	54	39	113	56	2,200
Bow Forest and Kananaskis	62- 59	51	20	114	45	4,900
"	64-281	51	35	115	12	6,000
"	64-133	51	42	115	18	5,550
"	64-283	50	51	114	33	4,600
"	66-991	51	05	115	02	4,500
"	66-992	51	05	115	02	4,500
"	66-993	51	05	115	02	4,500
"	66-994	51	05	115	02	4,500
"	66-995	51	05	115	02	4,500
"	66-996	51	05	115	02	4,500
"	66-997	51	05	115	02	4,500
"	66- 13	51	05	115	02	4,500
Approximate locations of three Manitoba samples:						
Wasagaming	64- 35	50	50	100	00	2,200
"	64-116BL	50	50	100	00	2,200
"	64-116BR	50	50	100	00	2,200

Table 2. Average Seed Weights and Cotyledon Numbers Per Seedling in 40 Seed Samples of White Spruce from Alberta and Manitoba. The First Two Numbers in Each Seedlot Number Indicates the Year of Collection.

Seedlot Number	Avg Weight mg	No.	Avg No. Cotyledons/ Seedling	Seedlings No.	Empty Seeds/ Sample %	Seed Moisture Content when Weighed %
Alberta in general except Kananaskis, Bow Forest, and Slave Forest						
64-111B	2.1	200	5.5	48	3	5
64-152	2.0	200	5.4	154	2	5
59- 89	2.3	200	5.9	156	2	4
61-142	2.4	200	5.7	172	0	4
61-149	2.4	200	5.4	139	8	6
60- 4	2.6	200	5.8	61	4	4
60-277	1.9	200	5.2	122	7	3
59- 10	2.2	200	5.8	188	0	4
59- 60	1.7	200	4.8	86	6	4
60- 35	2.5	200	5.6	150	6	4
59- 19	2.4	200	5.8	126	6	5
59- 80	2.2	200	5.7	162	4	6
59- 82	2.2	200	6.0	156	6	5
60- 27	2.3	200	5.9	166	3	4
59-143	2.0	200	5.5	182	1	5
59- 8	2.3	200	5.9	185	3	5
67- 53	2.2	200	5.8	129	2	4
Slave Forest						
59- 44	2.2	200	6.0	9	8	12
64- 45	1.8	14000	5.4	531	1	5
66-169	1.8	270	5.4	240	0	5
66-171	2.5	258	6.2	177	0	6
66-172	2.1	383	5.6	323	0	5
66-175	2.0	251	5.4	147	0	6
66-176	2.5	288	6.0	225	0	6
64-100	1.3	2844	4.8	254	0	6
Bow Forest and Kananaskis						
62- 59	2.2	200	5.6	172	4	4
64-281	2.0	200	5.5	117	7	6
64-133	2.2	14000	5.5	604	5	5
64-283	1.9	14000	5.6	400	3	4
66-991	3.1	256	5.8	234	0	5
66-992	3.0	268	5.9	227	0	5
66-993	3.2	250	6.1	245	0	5
66-994	2.9	501	6.1	481	0	4
66-995	2.4	569	5.5	521	0	5
66-996	3.2	248	6.6	194	0	5
66-997	2.5	286	5.3	251	0	5
66- 13	2.9	249	6.6	154	0	4
Manitoba						
64- 35	2.7	2665	6.6	1087	0	5
64-116BL	1.9	3083	6.0	276	0	5
64-116BR	2.1	2559	5.9	326	0	5

(Table 3) comprised only 1.3% of the total population of 7,909 individuals. The average cotyledon number per seedling for the 37 seed sources combined was 5.6. Average cotyledon numbers among the 37 seed samples varied from 4.8 to 6.6.

Table 3. Percentage of 7,909 White Spruce Seedlings in each of Seven Cotyledon Classes. Data Based on 37 Samples from Different Geographic Areas in Alberta.

Number of cotyledons per seedling	Per cent of seedlings
3	.1
4	6.4
5	34.3
6	47.5
7	10.5
8	1.1
9	.1
Average number of cotyledons/seedling	5.6

Seed weights in the 23 samples donated by the Alberta Forest Service averaged between 1.72 and 2.64 mg while average seed weights ranged between 1.26 and 3.24 mg for the 14 single trees. The number of sound seeds per pound could therefore range between 139,000 and 357,000 depending on parentage. The overall average, based on all 37 samples from Alberta, was 196,000 seeds per pound.

No linear correlations could be established within Alberta as a whole between latitude, longitude, or altitude of seed sample and either seed weight or cotyledon number. Three dimensional plots between seed weight or cotyledon number, altitude, and latitude or longitude did not reveal any obvious interaction contributions from these geographic variables.

The data on seed weight and cotyledon number were therefore grouped into seven broad forest regions to determine if seed weights or cotyledon numbers from any one region differed from those of any other. The following areas were compared: Kananaskis and Bow; Crowsnest; Rocky Mountain House, Whitecourt, and Edson; Slave Lake; Grande Prairie; Peace River; Lac La Biche. Analyses of variance showed that there were regional differences in seed weight but not in cotyledon numbers at the 90% level of confidence. The seeds from the Kananaskis and Bow forests were significantly heavier (95% level) than those from the Slave Lake Forest but no other differences were described by this sampling material. The 18 samples collected in close proximity to the natural distribution of Engelmann spruce, from sites averaging 4,160 feet above sea level, were

also heavier (99% level) than those collected from the rest of the province where the elevation averaged 1,815 feet. The 18 samples weighed on the average 2.51 mg per seed while those distant from the mountains averaged 2.13 mg per seed.

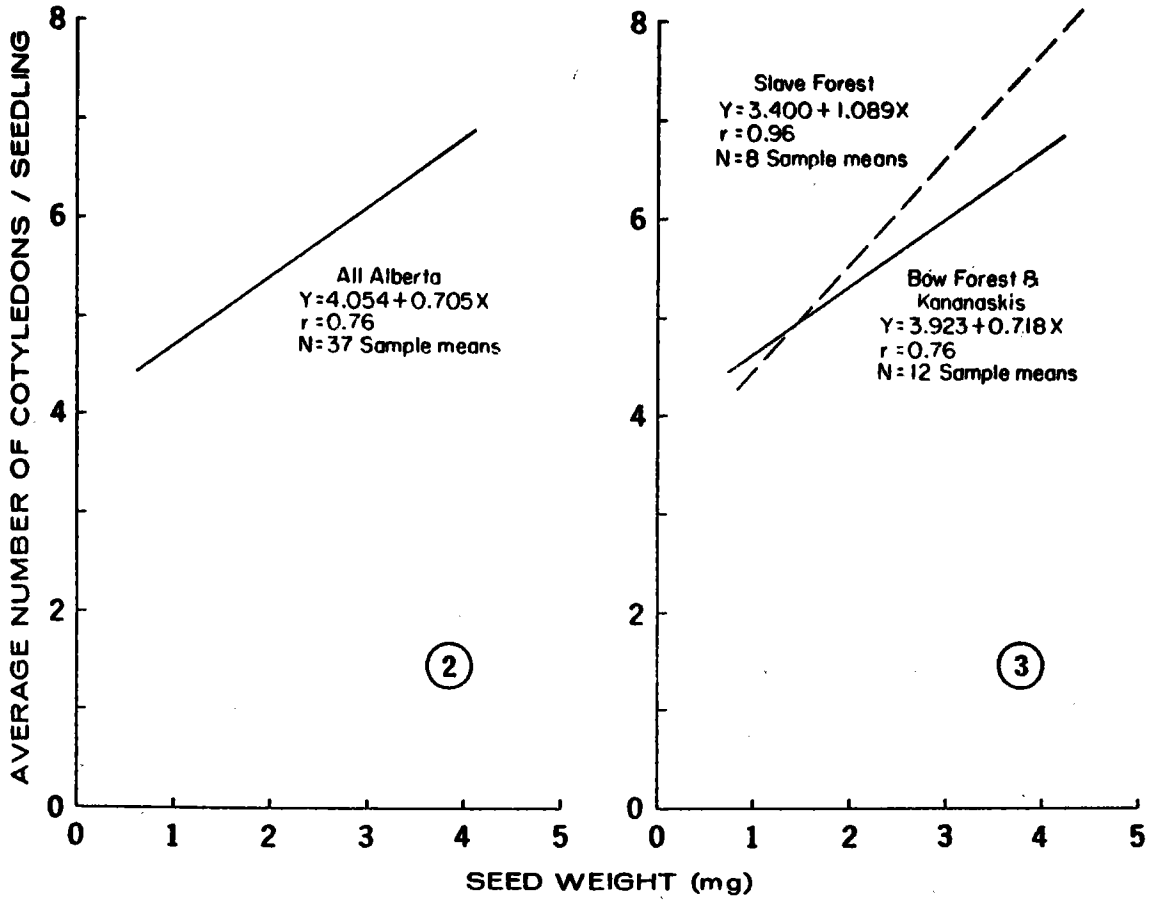
Cotyledon numbers per seedling were compared on a sample to sample basis disregarding geographic origins. The among-sample variation was highly significant (99.5% level) as expected because regional differences did not exist. Any two samples which differed in average number of cotyledons by more than 0.3 of one cotyledon were significantly different from each other at the 99% level of confidence (Duncan's Multiple Range Test). Only one sample was distinctly different from its closest neighbor when ranked by size. Sample 66-13 from the Kananaskis forest produced seedlings with more cotyledons than any other sample. Sample 64-100 from the Slave Lake forest and 59-60 from Edson produced seedlings with significantly fewer cotyledons (99% level) than all other samples.

A negative relationship exists at the 90% level of confidence between mean cotyledon numbers per sample and the coefficients of variation for the same means. As the mean number of cotyledons per sample decreased, the coefficients of variation increased significantly ($Y = 0.258 - 0.0231X$). There was no statistical difference between coefficients of variation in data from single trees (0.121) and groups of trees per sample (0.131) nor were there any differences in standard deviations (both with 0.70).

Correlation Between Cotyledon Number and Seed Weight in White Spruce in Alberta and Manitoba

On a province-wide basis, the 7,909 seedlings from the Alberta seeds demonstrated a positive correlation between seed weight and cotyledon number (Fig. 2). Because regional differences in seed weight did exist, regional differences in the relationship between cotyledon number and seed weight were sought. The total sample data for Alberta were scattered geographically and allowed only one regional comparison, namely that between the Slave Lake forest and the combined data from Kananaskis and Bow forests. Only the northern samples (Slave Lake forest) differed significantly in slope from the province-wide mean (95% level), but the samples from the Bow and Kananaskis forests were statistically different in slope from the ones collected from the Slave Lake forest (99.5% level). The samples from these two regions differed in average seed weights, as already indicated, but they had the same average cotyledon numbers.

The above relationships are based on pooled samples of seeds from several wind pollinated trees per location. In



Figures 2 and 3. Correlation between seed weight and cotyledon number in white spruce seed: 2, from 37 locations in Alberta; 3, from eight locations south east of Lesser Slave Lake and 12 locations in the Bow and Kananaskis forests.

contrast to this, individual seed weights plotted against the corresponding cotyledon number (Fig. 4) for individual wind pollinated trees illustrate different relationships. Samples from the three trees in Alberta and the three trees in Manitoba give very low correlations between seed weight and cotyledon number. The highest coefficient of determination (r^2) for all trees was 0.15. This is less than one third of the r^2 values obtained when pooled samples of seeds from several trees were tested (Figs. 2 and 3).

DISCUSSION AND CONCLUSIONS

The average cotyledon number per seedling in white spruce in Alberta is 5.6 (Table 3) which is similar to values reported for Ontario and the Maritimes (Ahlgren and Ahlgren 1958; Place 1955). However, the seeds from Alberta produced

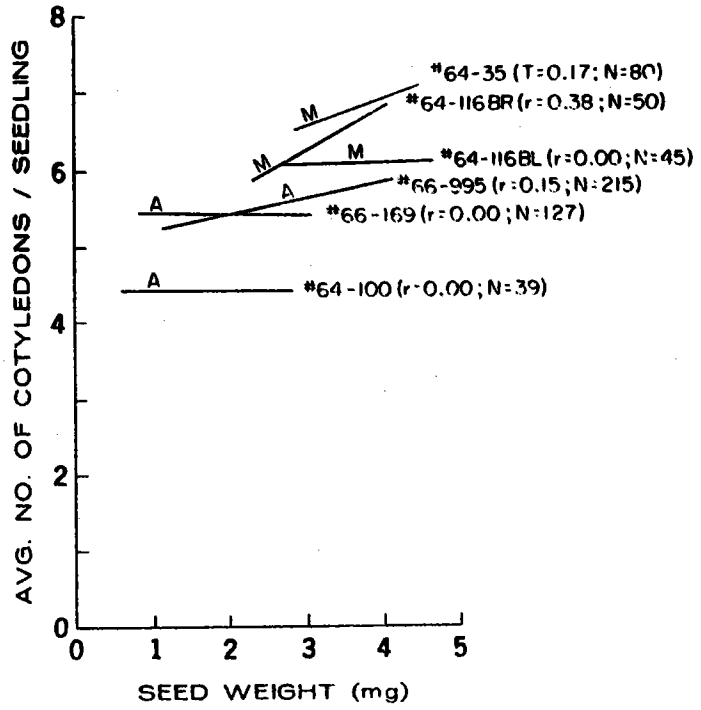


Figure 4. Correlation between seed weight and cotyledon number in white spruce seed from six wind pollinated trees; A - Alberta and M - Manitoba.

more seedlings with four cotyledons than those from eastern Canada. They also illustrated a greater range of cotyledons per seedling than reported hitherto.

The average number of seeds per pound, 196,000, representing samples from single trees and groups of trees in white spruce in Alberta, is intermediate between those quoted in the Woody-Plant Seed Manual (U.S.D.A. 1948) for two populations of white spruce. The range in averages among samples (139,000 to 357,000) is also intermediate between the two given in the Seed Manual.

Linear correlations between seed weight or cotyledon number per seedling in white spruce in Alberta and latitude, longitude, or altitude were not evident. Reasons for this are related to both environmental (Longley 1967; Morgenstern and Farrar 1964) and genetic influences. Three dimensional plots of seed weight or cotyledon number, altitude, and latitude or longitude of sample reveal only that the samples from the foothills in general and from the Kananaskis and Bow forests in particular are heavier than those from other parts of the Province. These heavier seeds may be a result of altitudinal influences on seed weight (Holzer 1966; Simak 1967) or a result of genetic mixing with Engelmann spruce which has a heavier seed than white spruce. They may also be heavier in comparison

to the samples from lower altitudes if the latter are influenced by gene mixing with black spruce which has a lighter seed than white spruce. Factors of site, year of collection, time of collection in fall, and duration of storage also influence seed weight (Baldwin 1942), but none of these are considered important in the comparison between samples from Kananaskis and Bow vs. Slave Lake forests. Most of these samples were collected from single trees in 1966 at the time of peak ripeness and were stored identically prior to testing.

Average cotyledon number per seedling varied among samples and not among forest regions. This parameter is therefore more highly specific of the seed sample than is seed weight. The observation that any two seed samples are significantly different if their average cotyledon numbers vary by more than 0.3 of one cotyledon and the wide range in average values (4.8 to 6.6) indicate how useful this criterion is for describing sample differences.

Cotyledon numbers vary as much in seed samples collected from groups of wind pollinated trees as in samples collected from individual wind pollinated trees. This supports the belief that single trees are fertilized by a large number of different pollen parents (Sarvas 1967).

The negative correlation between average cotyledon number and the coefficients of variation within samples furnish indirect evidence of crossing between white and black spruce. Genetically pure samples of either black or white spruce could be expected to contain less internal variation than genetically impure samples of either species. Because the sample data show greatest variation within samples of white spruce with low average cotyledon numbers, crossing with black rather than Engelmann spruce is suggested. The two samples with the smallest average cotyledon numbers were collected within the area of overlap between white and black spruce. The decreasing internal variation in samples with increasing average cotyledon numbers does not lend support to a species distinction between Engelmann and white spruce.

Most of the weight of a tree seed is composed of maternal tissues (Buchholz 1946) with only about 10% directly influenced by the pollen. On the other hand, the pollen contributes a theoretical 50% to the variation in cotyledon number in any seed. This is the reason why seed weight and cotyledon number are poorly correlated in seeds from individual wind pollinated white spruce trees. The highest coefficient of determination among the six trees studied was 0.15, which is similar to that found by Hadders (1967) for direct male contribution to seed weight. High correlations between seed weight and cotyledon number in single trees can only be obtained, therefore, if

seeds vary little in either seedcoat or endosperm weight within given seed weight classes.

Average seed weight has been shown to be a valid criterion for distinguishing regional populations of white spruce seed. Cotyledon number has been found to be highly specific to individual seed samples. It is suggested that a third criterion, useful in the identification of white spruce seed samples, is the relationship between seed weight and cotyledon number. However, this last criterion is most useful when samples from several trees rather than when single trees are compared.

REFERENCES

Ahlgren, I.F. and C.E. Ahlgren. 1958. A key to the native coniferous tree seedlings of the Quetico-Superior area (N. Minnesota). J. Forest. 56(12):911-912.

Alexander, R.R. 1958. Silvical characteristics of Engelmann spruce. U.S. Dep. Agr., Forest. Serv. Rocky Mtn. Forest Range Exp. Sta. Pap. No. 31. 20 pp.

Baldwin, H.I. 1942. Forest Tree Seed. Chronica Botanica Co. Waltham, Mass. 240 pp.

Buchholz, J.T. 1946. Volumetric studies of seed, endosperm, and embryos in *Pinus ponderosa* during embryonic differentiation. Bot. Gaz. 108:232-244.

Butts, D. and J.T. Buchholz. 1940. Cotyledon numbers in conifers. Trans. Ill. State Acad. Sci. 33:58-62.

Brayshaw, C.T. 1959. Tree seedlings of Eastern Canada. Can. Dep. North. Affairs Nat. Res. Bull. No. 122. 38 pp.

Chen, C-C. and S-C Jong. 1965. Factors affecting the isolation of microorganisms associated with conifers seeds. Bot. Bull. Acad. Sinica 6(2):106-115.

Franklin, J.F. 1961. A guide to seedling identification for 25 conifers of the Pacific Northwest. U.S. Dep. Agr., Forest Serv. Pac. NW. Forest. Range Exp. Sta. 65 pp.

Hadders, G. 1967. Ärflig variation i plantutveckling hos tall (*Pinus silvestris* L.) (Genetic variation in seedling development of scots pine) (Swedish; Eng. sum) PhD thesis, 119 pp. mimeo.

Heit, C.E. 1961. Laboratory germination and recommended testing methods for 16 spruce *Picea* species. Proc. Assoc. Off. Seed Analysts 51:165-171.

Holzer, K. 1966. Die Vererbung von physiologischen und morphologischen Eigenschaften der Fichte. I. Samlingsuntersuchengen. (Inheritance of physiological and morphological characteristics in Norway spruce. I. Seedling tests). (German; Eng. sum) Mitt. der Forstlichen Bundes-Versuchsanstalt. Mariabrunn, Vol. 71. 185 pp.

Horton, K.W. 1959. Characteristics of subalpine spruce in Alberta. Can. Dep. North. Affairs Nat. Res., Forest. Br. Note No. 76. 20 pp.

Klein, W.M. 1958. Cotyledon variation in *Juniperus occidentalis* Hook. Aliso 4(1):129.

Little, E.L. and S.S. Pauley. 1958. A natural hybrid between black and white spruce in Minnesota. Amer. Midland Nat. 60(1):202-211.

Longley, R.W. 1967. The frost-free period in Alberta. Can. J. Plant Sci. 47:239-249.

Morgenstern, E.K. and J.L. Farrar. 1964. Introgressive hybridation in red spruce and black spruce. Can. Dep. Forest., Forest Res. Br., Contrib. No. 608. 46 pp.

Place, I.C.M. 1955. The influence of seed-bed condition on the regeneration of spruce and balsam. Can. Dep. North. Affairs Nat. Res., Forest. Br. Bull. No. 117. 87 pp.

Sarvas, R. 1967. Pollen dispersal within and between subpopulations; role of isolation and migration in microevolution of forest tree species. I.U.F.R.O., Munich, pp 332-345.

Silen, R.R., W.B. Critchfield and J.F. Franklin. 1965. Early verification of a hybrid between Noble and California Red firs. Forest Sci. 11(4):460-462.

Simak, M. 1967. Seed weight of larch from different provenances (*Larix decidua* Mill.). Studia Forestalia Suecica No. 57. 31 pp.

Sorensen, F. 1966. Inheritance of cotyledon number of Douglas-fir. Forest Sci. 12(2):175-176.

Thorbjornsen, E. 1961. Variation patterns in natural stands of loblolly pine. Sixth. South. Conf. Forest Tree Improvement. Proc.:25-44.

U.S.D.A. 1948. Woody-plant Seed Manual. Forest. Serv. Misc-Publ. No. 654. 416 pp.

FOREST TREE BREEDING AND GENETICS AT THE PETAWAWA FOREST EXPERIMENT STATION

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Petawawa Forest Experiment Station, Chalk River, Ont.

This report is an outline of the work done in the last 2 years by the geneticists of the Tree Biology Section at Petawawa Forest Experiment Station (P.F.E.S.). This newly organised section, covering forest genetic and ecological studies, was established in April 1968 with Dr. A. Carlisle as Section Head. Dr. Carlisle was formerly Principal Scientist at the Merlewood Research Station, Nature Conservancy, U.K.

Initially emphasis at Petawawa was on provenance studies using bulk seed from a number of parent trees at each sample location. In recent years data from these studies has allowed the program to progress to single-tree progeny testing. While provenance tests will continue, single-tree progeny tests will receive more attention in the future.

SPRUCE

White Spruce

Provenance Studies

There are two major white spruce provenance studies underway. The first consists of 32 provenances from the central part of the Great Lakes - St. Lawrence Forest Region (Exp no. 93). Of the 20 tests, six are in Ontario, three in Quebec, five in the Canadian Prairies, and six in the U.S. In the western Maryland test, Genys (1965) studied 15 provenances, planted at an elevation of 2,800 ft. Five years after planting the survival was 99.3%. The most rapidly growing provenance originated from Denbigh in southeastern Ontario. Provenances west of this source showed decreasing growth in height with increasing western longitude.

Experiment no. 93-B of the same series of 25 Ontario and Quebec provenances was planted at Petawawa in the spring of 1958. A recent analysis of height at age 9 years indicated significant differences among provenances. The tallest provenances included those from Richmond, Hungerford, Dalhousie and Petawawa, Ont. The provenance from Potter, Ont., was the shortest. Evaluating provenances using average height of the 15 tallest plants,

rather than the average of all plants made little difference in rank. Analysis of plot data in percent of surround rows resulted in a slightly lower F test for differences among provenances and removed enough site variation to make differences among blocks non-significant at $P>0.10$.

The second study includes 75 provenances from the Great Lakes - St. Lawrence Forest Region and contains 29 experiments in North America. In one New Brunswick experiment (194-J) survival was affected by provenance, date of planting, and site affects associated with blocks (Fraser Co. Ltd.). Provenances were planted in the same time sequence through all the replications rather than in random time order in each replication. Those provenances which were planted later in the season had an excess of mortality attributable to the delay in planting rather than to inherent provenance weakness. Of the provenance variation in mortality, 58% could be explained by sequence effect. Provenance mortalities were adjusted by covariance to remove the sequence effect. Blocks varied in mortality as did large areas within blocks. Incomplete blocks of the lattice design were inefficient in removing the "spotty" within-block site effects on mortality.

White Spruce Single-Tree Progeny Studies

Parental crown form *per se* did not appear to influence progeny performance, either in progeny crown form or in height, except that parent trees with slender crowns were about 4% taller and had progeny 4% taller than broad-crowned parents. Branch length was not heritable. Progenies from trees within stands varied almost as much as progenies among stands, justifying individual tree progeny tests when evaluating stands or provenances for breeding value (Exp no. 91-A, 91-B, 92-A, 92-B).

Reciprocal Crossing Among Petawawa White Spruce

Six white spruce of good form were intercrossed to provide material for studies of embryological development, gene action, combining ability, heritability and isolation techniques. Both full-crown isolation tents and small isolation bags were used to control pollination. Individual isolation tents yielded between 1400 and 4700 cones, while small isolation bags yielded from 10 to 125 cones. Unpollinated and self-pollinated cones tended to be smaller and to mature later than cross or open-pollinated cones. The success of these isolation techniques was demonstrated by the absence of filled seed in the unpollinated control bags and tents (Exp no. 331).

Light Intensity and Growth

White spruce transplants were grown in shade (half light intensity) and in full light in a greenhouse and in growth cabinets. In the greenhouse natural day length was supplemented to provide a uniform 16-hour day. The light intensity in the cabinets varied during the photo period, with a maximum of 1,800 ft-c. Full light intensity promoted growth in the greenhouse, but inhibited it in growth cabinets, compared to half light intensity. When the first and last hours of a 16-hour day consisted of incandescent light only, growth was better than with a mixture of incandescent and fluorescent light, or fluorescent light by itself (Exp no. 330).

pH Ecotypes

To investigate whether white spruce exhibit ecotypic variation, seed, foliage and soil were collected from five stands on calcareous soil and five from acid soils. Ten trees were sampled from each of 10 stands. Foliage was analysed for N, P, K, Ca, Mg and soil for pH, organic C, N, K, Ca, Mg, and P by Prof. K.A. Armson, Faculty of Forestry, University of Toronto. These ecotypes will eventually be grown in different nutrient solutions as well as in different soils (Exp no. 340).

Heritability of Wood Density

Crosses of high x high and low x low were made (Exp no. 359). Seed was sown in the autumn of 1967.

Genetic Variation Within the Ottawa Valley

The Pembroke area has been the source of superior seed in earlier provenance experiments. To study genetic variation within this area seed was collected from 80 trees in 14 stands. The seed was sown in the autumn of 1964 and the 2-0 seedlings were transplanted in replicated experiments in the Thomas Nursery and in the Lower Nursery (Exp no. 292-A, 292-B).

Black Spruce

The study of black spruce from Ontario (Exp no. 289) was continued in the nursery experiment at Chalk River in 1966 and 1967. Survival, phenology and growth were measured. The stock was used to establish two field experiments in the spring of 1968, one at Chalk River, and the other at Swastika, Ont., in cooperation with the Ontario Department of Lands and Forests. Extra stock established at Chalk River in an observation planting

on a single-tree-progeny basis will offer good opportunities to collect detailed genetic information from controlled crosses.

Seedlings transferred from earlier experiments at Schmalenbeck, Germany, to Reiersöl, Norway, were studied by Dr. J. Dietrichson of the Norwegian Forest Research Institute in 1966 and 1967. Phenology and hardiness were primary objects of his investigation. Reports dealing with results in Canada, Germany, and Norway will be published.

A range-wide black spruce study, to be carried out cooperatively by the Forest Service of the U.S. Department of Agriculture and the Department of Forestry and Rural Development, was planned. Some seed collections were made in 1967, and details of the plan require further discussion. It is hoped that the plan will receive approval this year.

Red Spruce

In 1967 the two plantings of the red spruce provenance experiment at Chalk River were measured (Exp no. 95-G, -H). A third experiment (Exp no. 95-N), located at the University of Toronto Forest at Dorset, Ont., was measured by Prof. G.M. Wilson of the University. An assessment of winter dessication (parch blight) of Exp no. 95-H showed that the damage was significantly correlated with the hybrid index determined in earlier studies of red spruce-black spruce introgression in the same material. Strongly introgressed provenances were more resistant. Reports dealing with results are in preparation.

The first complete measurement of Exp no. 95 is planned for 1969 when the trees will be 15 years old.

Exotic Spruces

Norway Spruce

New winter-hardy and weevil-free trees have been selected and propagated, particularly fast-growing individuals from Istebna, Poland, (Exp no. 304). Several new families have been produced by controlled pollination of weevil-free trees. These are from second generation plantations in Canada of the Proulx, P.Q., and the Hudson's Place, P.F.E.S. Ont. families, and from Riga and Burtneiki, Latvia, and Valen Bistrei, Roumania (Exp no. 308-B). The 35 mother trees were taken in groups of five and each group was crossed to a different pollen parent.

Two nursery provenance experiments (Exp no. 277 and 310-A) were transplanted. Extreme southern provenances from Yugoslavia and Bulgaria were sown to sample this part of the Norway spruce range (Exp no. 350).

Mr. J.G. Worrall of Yale University recorded leader and cambial growth in Norway spruce clones in the Arboretum (P.A. 101 at P.F.E.S.) as part of a study of within clone variation in comparison with individual tree and provenance variation in phenology (Exp no. 363). An observation tower was built to facilitate measurements of these tall trees.

Norway spruce was crossed with a number of exotic and native spruces (Exp no. 341-D). The seed from these crosses is being studied.

In 1966 seed was sown of Carpathian, German, and Latvian provenances (Exp no. 320-A) and of Czechoslovakian single tree progenies (Exp no. 321-A). Samples from these seedlots were sent to our Maritimes Region, New York, and Maine where even the southeastern types should be both hardy and fast growing.

Other Exotic Spruces

The spring of 1967 was notable for prolific flowering in spruce and the following interspecific crosses were made: *Picea rubens* and *P. mariana* were crossed with *P. asperata, P. glehnii, P. jezoensis, P. koraiensis, P. koyamai, P. omorica, P. orientalis* and *P. schrenkiana. Picea glauca* was crossed with *P. abies, P. asperata, P. glehnii, P. jezoensis, P. orientalis* and *P. schrenkiana. Picea abies* was crossed with *P. asperata, P. glehnii, P. jezoensis, P. koraiensis, P. omorica, P. orientalis,* and *P. schrenkiana. Picea koraiensis* was crossed with *P. abies, P. asperata, P. glauca, P. jezoensis* and *P. orientalis. Picea asperata* was crossed with *P. abies, P. glauca, P. jezoensis, P. koyamai, P. koraiensis* and *P. orientalis.* These crosses are part of a cooperative study of crossability in spruce and the cones were sent to Dr. D.P. Fowler, Maritimes Region for further study.

Seventeen clones of *Picea sitchensis* x *glauca* and *P. sitchensis* x *omorica* obtained from Ekebo, Sweden, were grafted for further study of their hardiness. A number of grafts and seedlots of various exotic spruces and spruce hybrids were field-planted (Exp no. 223-A, 223-B, 223-C and 244).

PINE

Jack Pine Provenances

Entire Range

A revised issue of the provenance description and climatic data for the all-range provenance experiment was compiled (Holst 1967).

Two all-range jack pine provenance experiments containing 98 provenances have had the following characteristics recorded and analysed: height, survival to frost and *Scleroderris lagerbergii* Gremmen, needle fresh and dry weight. Characters which have been recorded but not analysed were lammas and prolepsis growth, double leaders, branch number, length and angle. Twenty-nine of these provenances were studied for phenological characteristics at P.F.E.S. (Exp no. 326) and for wood development by Dr. R.W. Kennedy, Forest Products Laboratory, Vancouver, B.C.

After four growing seasons provenance heights varied from 28 to 99 cm at Petawawa (Exp no. 255 A-2) and 17 to 56 cm at Longlac (Exp no. 255 A-1). Provenances from locations with high daily mean temperatures during May, June and July tended to be tallest in both locations.

Survival to frost at Longlac was more closely related to May, June and July temperature at origin than to all other climatic indices tested (which included indices of growing season length and of winter temperatures). Low summer temperatures at origin was associated with frost tolerance. Because of the absence of frost stress at Petawawa these differences were only evident at Longlac.

In 1966, 99% of the trees at Longlac had to be removed because of infection and death caused by the Ascomycete *Scleroderris lagerbergii* Gremmen. Several provenances had a larger percentage of remaining plants than one would expect if the distribution of disease among provenances was random. The three provenances with the highest survival percentage were from a small area in northeastern Quebec. These provenances exhibited distinctive characteristics in the Petawawa experiment: they tended to have a high dry to fresh leaf weight ratio, which was proportional to their survival percentage, and they tended to begin seasonal growth early in the year, i.e. May 2 or May 3. By June 13, 1968, most of the survivors at Longlac were still growing vigorously and appeared to be healthy although many had branch or stem cankers. These vigorous survivors are being

propagated by grafting and by seed from open-pollination for further study. Inoculations will be attempted either in 1968 or 1969.

At Petawawa, provenances varied in dry-to-fresh needle weight ratios from 0.43 to 0.51. Those with low ratios were generally from the south and 24 at Longlac had low survival to frost and Scleroderris canker.

Phenology of individual trees was studied within each of 29 provenances grown at Petawawa (Exp no. 326). The growth period, defined as the number of days between 1 and 99% of total seasonal growth, was calculated from the data transformed probits.

The mean growth period was from May 6 to July 6 during which the leaders grew a mean of 450 mm. Of the 29 provenances studied intensively, Mistassini Post, northern Quebec, had the earliest date of growth initiation, and Fife Lake, southern Michigan, the latest (May 10). Rigley, N.W.T., had the earliest date of growth cessation (June 28) and Mosinee, Wis., the latest (July 12). Generally, provenances which grew later had longer leaders.

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

Compared with seed of southern origin, seed from the north and northwestern part of the range was smaller, but higher in proportion of female gametophyte, percentage of free sugars and free amino acids, concentrations of soluble proteins in the embryo that were associated with higher proportions of reserve protein and sugars in the female gametophyte. In seed of southern origin the proportion of soluble protein was low in both embryo and gametophyte tissue, but relatively more was found in the embryo: a biochemical state nearer to germination.

Resin samples of 52 jack pine provenances were collected in the Petawawa Forest Experiment Station all-range jack pine test for a study of geographic variation in oleoresins by Prof. G.R. Stairs, Syracuse University, N.Y. (Exp no. 351). Preliminary evaluation indicated little systematic variation among provenances and detailed statistical analysis will follow when supplementary collections of resin have been analysed by gas chromatography.

Cooperators made survival counts and replaced losses in field plantings of the all-range jack pine provenance experiment

(Exp no. 255-E) in nine locations in Ontario and Quebec. All planting sites were visited and arrangements for maintenance and protection were made.

Lake States

Sixteen Lake States jack pine provenances were evaluated for consistency of height growth in plantations in Ontario (Exp no. 125), Michigan, Wisconsin and Minnesota (King 1965). Northern provenances (47-48°N) and southern provenances (44-45°N) contributed much to the interaction and were inconsistent, while central provenances (46°N) were consistent and contributed little to the interaction. An apparent reason for differences in stability is the distance of movement from the area of origin to the planting site, which was least for the central provenances. Increases in height were obtained by growing southern provenances 2-3 degrees north of their origin.

Jack Pine Provenances - Hybrids

A new set of 50 jack pine provenance hybrids and their control provenances were field planted in seven test areas along a transect from southern Ontario to northern Quebec (Exp no. 268-E). A limited number of provenances were planted at Université Laval by Prof. L. Parrot and in New Brunswick by Mr. H.G. MacGillivray.

Jack Pine Progeny Tests

In a natural jack pine stand one tree with good stem form, one of average stem form and one of poor stem form were each crossed to three other trees of the three stem forms at distances of 50, 100, 200, 400 and 800 yards away. A similar transect was made in a second stand. Seed will be collected in 1968. We intend to study heritability of stem form as well as growth and other characteristics (Exp no. 345).

Seventy-five single trees of jack pine representing five types of stem form and some extreme types of branch form were crossed. These crosses will be compared with open pollinated controls collected from the upper and the lower part of the crowns of the same trees (Exp no. 329).

Open-pollinated progenies were collected from five trees in each of two stands in each of five areas along the Ottawa Valley from Petawawa to Deux Rivieres (Exp no. 332). Detailed measurements were made of parental trees and butt logs. Stem discs were removed at 5-ft intervals for growth analysis. Additional small seed collections were made from the crown apex

of each of five trees in each of the 10 stands as a check on sampling position. Seed was extracted and records kept of seed yield, seed size and viability. A progeny test was conducted for 3 months in growth cabinets. Genetic variation in epicotyl (shoot) length relative to error variation was small owing to uncontrolled environmental variation within the cabinets. Future tests of this nature will be designed to minimize the effect of this variation which was related to exposure to air movement and the arrangement of the pots within cabinets. A nursery test was sown in 1968. This material will provide information from the nursery and will later be planted in the field for further study.

Scots Pine

In the fall of 1967, the Russian Scots pine provenance experiment was measured (Exp no. 201-A) and will be compared with other experiments planted in Ontario and the Prairie Provinces.

Cones were collected from controlled crosses of 10 clones for a heritability study of Christmas tree characteristics, weevil resistance and eastern gall rust resistance. A complete reciprocal crossing scheme was used (Exp no. 272-D). Four-year-old plants were scored for their suitability as Christmas trees (Exp no. 272-A).

A number of new Christmas tree selections was made from observation plots planted for this purpose in P.A. 114. Six clones from Scotland, 16 clones from Schwarzwald, Germany, and four clones from southern Ontario were grafted for further evaluation. C.E. Heit's Scots pine Christmas tree provenances were sown for further testing and selection in the more severe climate at Petawawa (Exp no. 342).

Within a number of progenies of controlled crosses, some individuals bore cone-clusters in the autumn of the fourth growing season. The mode of inheritance of the cone-cluster effect was analysed. One particular clone, clone 847, transmitted precocious flowering to a percentage of its progeny in each of the several crosses in which it was involved (Exp no. 272).

A clonal test was established to study eastern gall rust resistance, weevil resistance, and Christmas tree characteristics (Exp no. 80-open and 280-B). Three-year-old seedlings of controlled crosses were rated for their potential as Christmas trees on the basis of needle color, hardiness, and branch form (Exp no. 272-A). As the parents were of mixed

origin these progenies are quite variable. However, a few of the combinations appear to give an acceptable percentage of good plants. In 1966 new crosses were made to explore genetic resistance to eastern gall rust [*Cronartium quercuum*] and weevil [*Pissodes strobi*] resistance. A complete reciprocal crossing scheme was used on 10 clones.

Red Pine

Cones were collected for the study of provenance hybrids between red pines from Trout Lake, Wis., and Angus and Petawawa, Ont. Spraying with insecticide (Lindane) was effective in reducing seed losses from cone boring insects. Seed was sown in 1967 in Wisconsin, New Brunswick, and Ontario (Petawawa), but the Wisconsin sowing failed (Exp no. 305).

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

In the autumn of 1967 eight provenance experiments and two single-tree progeny tests were measured. Exp no. 216-C near Dryden, Ont., was measured by the Sioux Lookout District of the Ontario Department of Lands and Forests.

Other Pines

A number of straight-stemmed mugho pine were selected for further trial of suitability as Christmas trees and for species hybridization.

Various lodgepole pine x jack pine hybrids as well as jack pine provenances were planted by Kimberly-Clark Paper Company at Longlac, Ont., (Exp no. 300-C) and by Université Laval near Quebec, P.Q.

Inducement of Trees to Flower

In mid-June, 1965, 25-year-old red pines in Drury Forest in southern Ontario were fertilized with ammonium nitrate, ammonium sulfate and potassium nitrate for studies of the flower inducing effect of the ammonia and nitrate ions (Exp no. 315). The 1966 flower count gave the following results: ammonium nitrate (17 gm N/m^2) tripled female flowers and reduced male flowers by 16%; the ammonium sulfate (8 gm N/m^2) increased female flowers by 274% and reduced male flowers by only 3%; potassium nitrate (9 gm/m^2) increased female flowers by 246% and

increased male flowering by 3%. Thus ammonia and nitrate appear to have similar effect on stimulation of female flowering but no effect on male flower formation. Only the ammonium nitrate fertilizer reduced male flowering.

A similar experiment was started June 29, 1965, in the Pine Graft Arboretum on the Petawawa Forest Experiment Station where grafts of red pine, jack pine, Scots pine and mugho pine were given ammonium nitrate, ammonium sulfate and potassium nitrate. Here the fertilizer applications were adjusted to equal amounts of nitrogen (20 g N/m^2) (Exp no. 316). Over the winter the Scots pine was severely damaged by pine grosbeaks. Although flowering was abundant this damage ruined the experiment. The red pine did not flower, perhaps because of late application of the fertilizer. The mugho pine flowered abundantly in response to ammonium nitrate. Date of application was too late for jack pine. The general fertilizer effect will be estimated from the 1967 flower count, and the flower stimulating effect of early application in 1967 from the 1968 flower count.

NURSERY AND VEGETATIVE PROPAGATION

During the last few years greater emphasis has been paid to uniformity of the soil in the seed beds. The Dunneman bed was tried for some years, but it was found rather difficult to water and the seedling top/root ratio was too high, especially in the pines.

The seed bed medium used at present is a mixture of three parts nursery soil, three parts hardwood soil, two parts spruce litter, two parts pine litter, and one part compost. The growth of the seedlings in this medium has been good and the health satisfactory.

A grafting experiment demonstrated that it is possible to stimulate growth of scions from very mature white spruce trees by grafting them on the leader directly under the terminal bud and leaving the branches of the rootstocks unpruned (Exp no. 241). Three years after grafting the scions had grown into sturdy, straight grafts, while scions grafted low on the rootstock still grew like side branches after 6 years. At this time the average length of top grafted scions was 207.2 cm compared with 83.5 cm of the low grafts. Cuttings from the stimulated grafts showed that a partial rejuvenation had occurred. Table 1 lists the rooting of 8 top-grafted clones plus control. The control cuttings were taken from 50 trees of one population growing in the nursery.

In the spring of 1967, two slow growing and two fast growing provenances were grafted in all possible combinations (16). The purpose was to see whether the growth rate of the rootstocks would influence the growth of the grafts and if the slow growing rootstocks would have a flower inducing effect.

Tables 2 to 4 summarize operations in the nursery, and vegetative propagation from 1966 to 1967.

Plantations

Thirty-four experiments including 37,419 seedlings covering 30.93 acres were field planted at the Petawawa Forest Experiment Station during 1966-67. An additional 2,338 grafts were planted on 6.41 acres (Tables 5 and 6).

Another 18 experiments were planted by cooperators in Canada. These include 55,921 seedlings which were planted on 50.12 acres (Table 7).

TABLES

Table 1. Rooting of Cuttings Taken from Top-grafted Scions

Vegetative propagation No.	Age of ortet	Number rooted cuttings of 50	Rooting %
Control	14	24	48
V.74	175	0	0
V.76	180	8	16
V.1226	100	5	10
V.1227	100	10	20
V.1265	112	9	18
V.1266	41	13	26
V.1267	70	1	2
V.1268	160	4	8

Table 2. Sowing of Tree Breeding Material

Exp No.	Title	No. of seedlots
	I. Fall 1965 and Spring 1966 in Nursery	
320-A	Comparison of Roumanian, Czechoslovakian, Latvian, German and Polish Norway spruce	15
321-A	Trial of 20 Czechoslovakian single tree progenies of Norway spruce	20
329	Heritability of stem form in jack pine	161
308	Progeny test of winter hardy and weevil-free Norway spruce selections from Latvia, Roumania, Proulx Plantation and Hudson's Place by controlled pollination	26
278	Selection of hardy plants in Douglas fir provenances	34
342	Trial of C.E. Heit's Scots pine Christmas tree provenances	18
	Rootstocks and odd lots	30
	Total number of seedlots	304
	II. Spring 1966 in Greenhouse	
341-A,B	Interspecific spruce hybrids made 1965 at Maple and P.F.E.S.	45
303	Selection of hardy *Thuja plicata* individuals from interior provenances and production of hardy *Thuja plicata* hybrids	3
	Total number of seedlots	48
	III. Fall 1966 and Spring 1967 in Nursery	
348-A	Provenance hybridization in white spruce from Boreal and Great Lakes-St. Lawrence Region crossed with Petawawa	187
350	Trial of four Yugoslavian Norway spruce provenances and 55 Bulgarian Norway spruce single tree progenies from two regions, with three controls	62
328	Trials of exotic *Abies* species	24
305-B	Provenance hybrids between red pine from Trout Lake, Wis., Angus, Ont., and Petawawa	21
	Rootstocks and odd lots	23
	Total number of seedlots	317

Table 3. Transplanting of Tree Breeding Material

Exp No.	Purpose and Material	No. of seedlots	No. of plants
	I. Transplanting, Spring 1966		
272	Progeny testing of Scots pine clones for Christmas tree selections, winter hardiness, weevil resistance and early flowering	63	12,181
267	Addition to Dr. Brittain's birch collections	40	467
255-E	Replacement plants	55	4,343
324	Hybridization of jack pine and Virginia pine	10	1,583
252-A	Replacement plants	9	662
252-B	Replacement plants	10	203
	Rootstocks and odd lots	12	5,848
	Total	199	25,287
	II. Transplanting, Spring 1967		
277	Provenance experiment with eastern and southeastern types of Norway spruce	25	24,421
310-A	Trial of Polish Norway spruce provenances from native stands on both sides of the spruce-free corridor	24	21,722
292	Investigation of population structure in local white spruce	89	31,737
278	Selection of hardy plants in Douglas fir provenances	10	353
341-A	Interspecific spruce hybrids made 1965 and 1967	6	438
341-B	Interspecific spruce hybrids made 1965 and 1967	24	536
	Rootstocks and odd lots	16	17,416
	Total	194	96,523

Table 4. Grafting of Tree Breeding Material

No. of clones	Species and Origin	No. of grafts
	I. Grafting, Winter 1965/66	
26	*Pinus resinosa*, Angus, Ont.	390
11	*Picea glauca*, selected for high density wood	275
10	*Picea glauca*, selected trees from Headquarters stand	250
1	*Picea abies acrocona* (Schmalenbeck, Germany)	10
4	*Picea abies acrocona* x *P. abies* (Schmalenbeck, Germany)	40
1	*Picea abies virgata* (Schmalenbeck, Germany)	10
1	*Thuja standishii* x *plicata* x *occidentalis* (Denmark)	5
14	*Thuja plicata*, (Denmark)	70
12	*Thuja plicata* x *standishii* (Denmark)	60
5	*Thuja standishii* (Denmark)	25
5	*Thuja occidentalis* v. *fastigiata*	25
	Total	770
	II. Grafting, Winter 1966/67	
7	*Picea sitchensis* x *glauca* (Ekebo, Sweden)	80
10	*Picea sitchensis* x *omorica* (Ekebo, Sweden)	29
4	*Pinus mugho rostrata*, Christmas tree selections from P.A. 114	80
16	*Pinus sylvestris*, Schwarzwald, Germany via P.A. 120	240
2	*Pinus sylvestris*, Ross-Shire, Scotland via P.A. 120	30
2	*Pinus sylvestris*, Rannoch, Scotland via P.A. 120	30
2	*Pinus sylvestris*, Achnashellach, Scotland via P.A. 120	30
4	*Picea abies*, Istebna, Poland via P.A. 114	80
	Total	659

Table 5. Field Planting in 1966 and 1967 at Petawawa Forest Experiment Station

Exp No.	Description	No. of plants	Area acres	Plantation area no.
	I. Seed Plants 1966			
86-open	Single tree progeny of Scots pine after controlled and open pollination	132	0.44	115
86-open	"	1,000	0.83	131
207-C	Provenance hybridization in red pine	2,175	1.80	101
217-E	Testing of Japanese birches	130	0.18	114
252-A	*Larix* provenances from Czechoslovakia and via Denmark	1,176	0.97	114
252-B	Botanical collection of *Larix koraiensis, L. gmelini, L. sibirica* and *L. japonica* for observations	400	0.92	114
255-E-2	All-range jack pine provenance experiment	10,778	8.90	131
265-A	Danish, Swedish selected slender Norway spruce plus trees and east German plus stands on trial for winter hardiness and weevil resistance	190	0.31	116
265-B	"	3,381	1.23	114
265-C	"	1,400	0.51	114
266-A	Testing of European Scots pine plus stands	793	0.66	131
267-A	Testing of Dr. W.H. Brittain's Canadian white birches	1,145	1.05	114
268-E-2	Provenance hybridization in jack pine	1,421	1.17	131
268-E-6	"	333	1.10	115
285-A,B	Study of European birch x *Betula papyrifera* hybrids	460	0.53	114
290-B	Progeny testing of needle-blighted and healthy white pine trees from Petawawa F.E.S.	60	0.20	115

Table 5 (continued)

Exp No.	Description	No. of plants	Area acres	Plantation area no.
307-B	Species and provenance hybridization with Appalachian red spruce *P. mariana* x *rubens*. *P. rubens* x *mariana* (Manitoba bs. crosses with Appalachian rs.)	557	0.46	133
307-C	" (*P. mariana* x *rubens*)	210	0.17	133
	Total number of 1966 seedlings	25,741	21.43	
	II. Grafts			
86-open	Selection of Scots pine for seed orchard purposes	114	0.38	129
119-open	Selected clones of Russian Norway spruce via Wisconsin, Thomas Field P.A. 103 and Michigan	299	1.00	116
119-open	"	565	1.29	104
213-C and 244	Trial of *Picea omorica*	60	0.20	116
242-open	Selection of white spruce plus trees	60	0.20	116
244-open	Selection and testing of exotic spruces. (*Picea asperata, P. jezoensis, P. hondoensis* x *glauca*	15	0.03	132
244-open	"	20	0.07	116
275-1A	Selection of weevil resistant Norway spruce plus trees of the Proulx plantation in Grand' Mere, Que.	73	0.24	116
275-1B	Selection of weevil resistant Norway spruce plus trees of the Proulx plantation in Grand' Mere, Que.	244	0.56	104

Table 5 (continued)

Exp No.	Description	No. of plants	Area acres	Plantation area no.
275-1C	Selection of weevil resistant Norway spruce plus trees from the "manure plot" of the Proulx plantation in Grand' Mere, Que.	50	0.17	116
275-2A	Selection of weevil resistant Scots pine plus trees from the Proulx plantation in Grand' Mere, Que.	20	0.07	115
280-B-1	Testing of Scots pine clones for weevil resistance	310	1.00	115
280-B-2	"	465	1.06	131
322-A	Trial of the "Rosendahl" spruce (*Picea glauca* x *mariana*)	28	0.09	116
322-B	"	15	0.05	133
	Total of grafts, 1966	2,338	6.41	

Table 6. Field Plantings of Seedlings in 1967

Exp No.	Description	No. of plants	Area acres	Plantation area no.
6-D	Breeding of weevil resistant and weevil susceptible Norway spruce by means of intraspecific hybridization of the Norway spruces on Hudson's Place	1,515	1.25	114
72-C	One parent progeny test with red spruce, red x black spruce hybrids and black spruce			
Group I	Petawawa bs x rs provenances	458)		113
Group II	Kapuskasing bs x rs prov.	98)	0.75	133
Group III	St. Zenon bs x rs provenances	346)		133
Group IV	*P. rubens* x *rubens*	202	0.33	133
Group V	*P.* [(*mariana* x *rubens*) F_1 x (*mariana* x *rubens*) F_1] F_2	1,065)		
Group VI	*P.* [(*mariana* x *rubens*) F_1 x (*mariana* x *rubens*) F_1] F_2	483)	0.57	133
207-D	Provenance hybridization in red pine	1,052	0.87	101
207-E	"	54	0.16	115
223-A	Engelmann and white spruce types from the Columbia Forest Region on trial in Eastern Canada	342	0.58	114
223-B	" (Ungraded lots)	1,700	1.45	114
223-C	Engelmann and white spruce types from the Columbia Forest Region on trial in Eastern Canada (semi-graded lots)	1,300	1.08	114

Table 6 (continued)

Exp No.	Description	No. of plants	Area acres	Plantation area no.
244-open	Selection and testing of exotic spruces (*P. pungens, P. omorica, P. orientalis* and *P. glehnii*)	200	0.33	116
244-open	" (*P. pungens glauca*)	149	0.12	114
267-A	Testing of Dr. W.H. Brittain's Canadian white birches (1967 addition to 1966 planting)	182	0.21	114
279-A	Selfing of P.F.E.S. white spruces	177	0.15	114
279-B	"	20	0.03	116
284-A	Single tree progeny test of *Abies fraseri* for further selection of winter hardiness	238	0.20	125
328-A	Trials of exotic fir species (*Abies fraseri, A. holophylla, A. sachaliniensis* and *A. veitchii*)	197	0.33	132
328-B	"	395	0.23	125
352-A	Comparison of local white spruce with selected Canadian Norway spruce stands	1,505	0.86	114
	Total number of seedlings, 1967	11,678	9.5	

Table 7. Plantations Established in 1966 and 1967 by Cooperating Agencies

Exp No.	Description	No. of plants	Area acres	Agencies and location
	I. Seed Plants 1966			
255-E-1	All range jack pine experiment	4,866	4.02	Ont. Dept. of Lands and Forests, Southern Research Station, Maple, Ont.
255-E-3	"	4,866	5.00	Ont. Dept. of Lands and Forests, Swastika District.
255-E-4	"	5,194	4.00	Ont. Dept. of Lands and Forests, Cochrane District.
255-E-5	"	2,340	1.60	Ont. Dept. of Lands and Forests, Sudbury District, Espanola Division.
255-E-6	"	2,340	1.93	Marathon Corporation of Canada, Marathon, Ont.
255-E-7	"	4,116	3.11	Ont. Dept. of Lands and Forests, Port Arthur District.
255-E-8	"	2,640	2.18	Ont. Dept. of Lands and Forests, Sioux Lookout District.
255-E-9	"	3,552	5.22	Canadian International Paper Co., Montreal, Que.
255-E-10	"	3,930	5.62	Canadian International Paper Co., Montreal, Que.
255-E-11	"	3,740	3.00	Dept. Forestry & Rural Development, Maritime Region, Fredericton, N.B.

Table 7 (continued)

Exp No.	Description	No. of plants	Area acres	Agencies and location
255-E-12	All-range jack pine experiment	3,740	3.00	Dept. Forestry & Rural Development, Maritime Region, Fredericton, N.B.
268-E-1	Provenance hybridization in jack pine	1,421	1.17	Ont. Dept. of Lands and Forests, Southern Research Station, Maple, Ont.
268-E-3	Provenance hybridization in jack pine	1,421	0.90	Ont. Dept. of Lands and Forests, Sudbury District, Espanola Division.
268-E-4	"	1,421	1.00	Ont. Dept. of Lands and Forests, Swastika District.
268-E-5	"	1,421	1.17	Canadian International Paper Co., Montreal, Que.
268-E-8	"	6,000	5.00	Dept. Forestry & Rural Development, Maritime Region, Fredericton, N.B.
268-E-9	"	1,573	1.00	Université Laval, Quebec, Que.
	Total seed plants, 1966	54,581	48.92	
	II. Seed Plants 1967			
87,268 and 300	Testing of jack pine provenances, provenance hybrids, lodgepole and jack pine hybrids on dry and wet sites	1,340	1.20	Kimberly-Clark Paper Co. Ltd., Longlac, Ont.
	Total seed plants, 1967	1,340	1.20	

REFERENCES

Genys, John B. 1965. Growth potentials of fifteen provenances of white spruce from Canada, tested in Maryland. Chesapeake Sci. 6(2):82-85.

Holst, M.J. 1967. All-range jack pine provenance experiments, Petawawa Forest Experiment Station, Chalk River. Internal Rep. PET-P5-6. 144 pp.

King, James P. 1965. Ten-year height growth variation in Lake States jack pine. U.S. Res. Pap. NC6.

PUBLICATIONS

Holst, M.J. and Teich, A.H. 1966. Potential genetic improvement in white spruce in Ontario. Bi-mon. Res. Notes. 22(5):6.

Holst, M.J. 1967. Summary of Canadian utilization of tree gene resources. FAO Technical Conference on Exploration, Utilization and Conservation of Plant Gene Resources. Rome. 2 p.

Morgenstern, E.K. -- Genetic variation in seedlings of *Picea mariana* (Mill.) BSP. I. Correlation with ecological factors. II. Variation patterns. Silvae Genetica. (In press).

Russell, W.A. and Teich, A.H. 1967. Selection in *Zea mays* L. by inbred line appearance and testcross performance in low and high plant densities. Iowa State Univ. Res. Bull. No. 552.

Teich, A.H. 1967. Resistance of jack pine to *Scleroderris lagerbergii* Gremmen. Bi-mon. Res. Notes. 23:5.

Teich, A.H. 1968. Foliar moisture content as a criterion for resistance to frost and Scleroderris canker in jack pine. Bi-mon. Res. Notes. 24:3.

Von Rudloff, E. and Holst, M.J. 1968. Chemosystematic studies of the genus *Picea* (Pinaceae). III. The leaf oil of a *Picea glauca* x *mariana* hybrid (Rosendahl spruce). Can. J. Bot. 46:1-4.

Yeatman, C.W. 1967. Environmental control in relation to forest genetics research at the Petawawa Forest Experiment Station. Proc. 10th Meet. Comm. For. Tree Breed. in Canada, Vancouver, B.C. 1966. Part II: 155-158.

Yeatman, C.W. 1967. Biogeography of jack pine. Can. J. Bot. 45:2201-2211.

Yeatman, C.W. 1967. Geographic variation of *Pinus banksiana* seedlings. In A Review of Silvicultural Research in Jack Pine. Can. Dep. Forest. Rural Dev. Publ. No. 1173. p 207.

Yeatman, C.W. and Holst, M.J. 1967. Correlations between controlled environment and nursery-grown seedlings of jack pine provenances. Proc. 14th. Northeastern Tree Improvement Conference, Toronto, Ont. (1966). pp 24-30.

WOOD FORMATION IN JACK PINE SEEDLINGS OF VARIOUS PROVENANCES

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The objectives of this study are to determine the degree of variation existing in certain xylem characteristics among 29 widely distributed provenances of jack pine [*Pinus banksiana* Lamb.], and to correlate variations in xylem formation and structure with vegetative growth patterns of the seedlings.

The provenances studied were selected in consultation with M.J. Holst from the larger sample of seedlings included in his all-range jack pine provenance experiment (Holst 1963). These same sources are currently being studied phenologically by A.H. Teich, as reported elsewhere in this volume. The 29 provenances were selected along major transects, to generally give a northern, intermediate and southern source (Table 1). The results reported here are only for the Petawawa-based experiment. The experiment has been replicated at Fredericton, N.B., but a complete set of data is not yet available from this test location.

MATERIALS AND METHODS

Five 4-year old seedlings from each source were randomly selected to study their growth during the 1966 growing season. To mark the progress of annual increment formation, these seedlings were subjected to a minute mechanical injury at the base of the 2-year old (1964) internode three times during the growing season. The technique used was essentially as that described by Wolter (1967); this involves inserting insect pins (0.15 mm diam) through the bark normal to the surface of the stem until a firm resistance is met, at which time mature wood is encountered. The cambium and differentiating zone react to this minute injury by producing traumatic cells which can be detected microscopically after sectioning the stem transversely.

The inner boundary of the wound in effect marked the extent of mature tracheids developed by the tree up to the time of puncturing. That the entire differentiating zone was affected by wounding was shown by an experiment (Neilson 1966) in which potted seedlings were simultaneously punctured and tilted 60 degrees from the vertical in order to form a reaction arc (Kennedy and Farrar 1965). When seedlings were so treated for

a 3-day period, a reaction arc of heavily lignified tracheids was produced coincidentally with the inner side of the wound tissue. Since short tilting periods induce tracheids in the final stages of differentiation (1 to 2 days from maturity) to lignify excessively, the inner boundary of the traumatic marker may be taken to represent the approximate interface between mature tracheids and those in the last stage of differentiation.

If puncturing was delayed for 3 days after returning the seedlings to the upright position, the traumatic marker was located after the reaction arc (Fig. 1), whereas if the puncture was made 3 days prior to tilting, the wound tissue was positioned before the reaction marker (Fig. 2). This bracketing is further evidence that the inner boundary of the traumatic zone delimits mature and differentiating cells.

Captions for Figures 1 to 6 (see opposite page).

Figure 1. Transverse section through a tamarack [Larix laricina *(Du Roi) K. Koch] seedling punctured 3 days after uprighting. Note tangentially-aligned reaction arc (between arrows) formed before wound tissue. Photo by R.W. Neilson.*

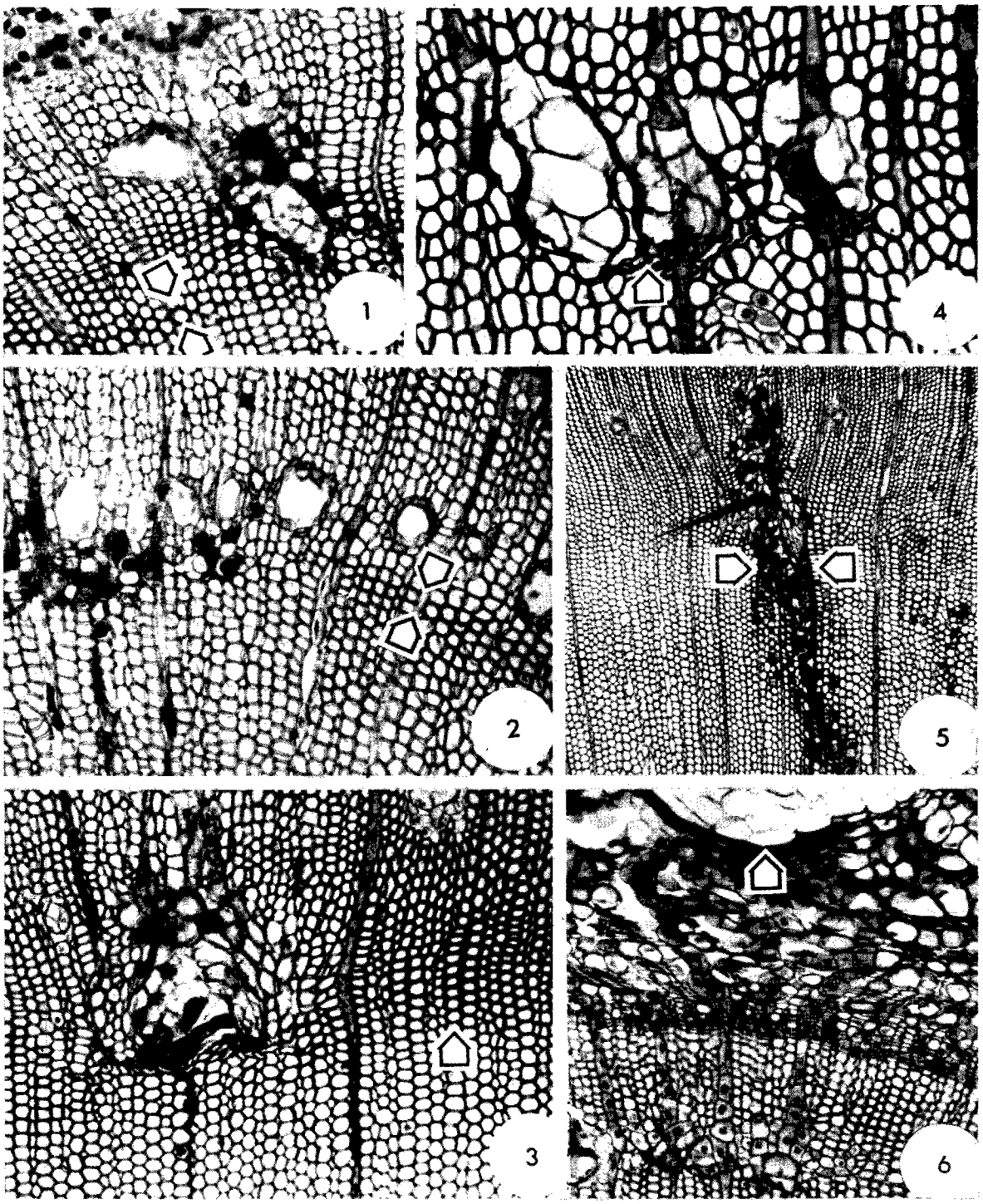
Figure 2. Transverse section through a tamarack seedling punctured 3 days prior to tilting for a 3-day period. Note tangentially-aligned reaction arc (between arrows) formed after wound tissue. Photo by R.W. Neilson.

Figure 3. Traumatic wound in jack pine formed as a result of puncturing on July 15. Wound is almost coincident with beginning of latewood tracheids (arrow).

Figure 4. Traumatic wound in jack pine formed as a result of puncturing on June 10. Note expanded, laterally displaced rays, enlarged traumatic parenchyma, and crushed cells (arrow) behind enlarged parenchyma.

Figure 5. Traumatic wound in jack pine formed as a result of puncturing on June 10. Lower radial limit of traumatic tissue is marked by arrows. Abnormal appearance of xylem below this point is due to mechanical injury of needles and infiltration of extraneous materials.

Figure 6. Traumatic wound in jack pine formed as a result of puncturing on August 20. The periderm has responded by proliferation of phellem (arrow).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On each injury date, 3 pins were inserted approximately 2 mm apart in a longitudinal row into diametrically opposite faces of the stem. The circumference of the stem immediately above and below the longitudinal row was marked with non-leaded paint. The pins were removed after wounding, and used once again if undamaged. On two subsequent occasions, the cambium was similarly marked by diametrically opposite wounds at 60 and 120 degrees around the stem from the original wounds. Wounding was carried out on June 10, July 15 and August 20.

Leader growth of the seedlings was measured at approximately weekly intervals until growth was complete[1]. The seedlings were sacrificed in late October, and a 2-inch long piece of stem containing the punctured zone was stored in 70% ethyl alcohol. The half-length not containing the punctures was used for determination of specific gravity (oven-dry weight/green volume) after dissection of bark, pith and pronounced compression wood, and Soxhlet extraction with alcohol-benzene (2:1).

Transverse sections approximately 20 microns thick were prepared from varying positions within the length of the punctured zone in an effort to detect all wound tissue. Sections were stained with safranin-fast green and mounted in Permount. The percentage of the annual increment formed by June 10, July 15 and August 20 was estimated from traumatic wound tissue. Widths and percentages of earlywood and latewood were also determined. Latewood was distinguished from earlywood by the rather abrupt presence of thick-walled tracheids of small radial diameter (Fig. 3).

The date on which the first latewood tracheid reached maturity was determined graphically for each tree from plots of percentage of ring formed on the three puncturing dates *vs.* day number. By entering the previously calculated earlywood percentage on the ordinate, the date on which the first mature latewood tracheid appeared could be read from the corresponding abscissa value. Similarly, the percentage of total terminal growth by June 10 (date of first puncture wound) was read from curves of cumulative percentage height growth plotted against date. The dates on which 90% and 98% of terminal growth was completed were determined from linear interpolation of the growth data for individual trees.

Although the experimental design called for five replications per provenance, a complete set of phenological and xylem data was sometimes unavailable for certain trees. Missing

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[1]Puncturing and leader growth measurements were carried out at Petawawa under direction of M.J. Holst.

phenological observations were caused by insect and mechanical damage to the leader. Occasional absence of traumatic wound tissue in the xylem may have been the result of failure of the pins to penetrate far enough to reach the susceptible differentiating xylem.

RESULTS AND DISCUSSION

Nature of the Wound Marker

The traumatic tissue formed in reaction to wounding contained obviously widened, laterally displaced rays, and parenchyma cells of abnormally large diameter (Figs. 3 and 4). The inner boundary of the traumatic zone was usually marked by the presence of collapsed tracheids. These cells represented almost mature, but incompletely lignified tracheids which subsequently were crushed by the abnormal enlargement of succeeding parenchyma cells.

Occasionally the traumatic mark was extended some distance in a more or less radial direction, apparently even extending back into the previous annual ring (Fig. 5). Close inspection of these markers, however, indicated the absence of wound parenchyma beyond a certain point taken to be the inner side of the traumatic zone. The apparent extended length was interpreted as a combination of cell rupture caused by physical penetration of the pin beyond the cambial zone, injury to mature ray parenchyma cells, which, because of their continuing vital function, could react physiologically to injury, and production of extraneous materials by traumatic cells, which subsequently could be infiltrated into normal tracheids.

A further response to injury was often noted in the bark in the form of excessive phellem formation (Fig. 6). Formation of this periderm tissue was apparently a protective mechanism to prevent dehydration of the delicate cambial region.

Xylem Variation

The mean values for various xylem characteristics are presented in Table 1. Analyses of variance for each characteristic indicated significant differences in every instance among provenances.

A model representing the growth of the average jack pine stem is presented in Fig. 7, assuming radial diameters of 33 and 16 microns respectively for earlywood and latewood tracheids. These average values were established from random measurements on sections of seven different provenances. The

Table 1. Variation in Xylem Characteristics by Provenance

Provenance No.[1]	Transect Location (E to W)	Provenance Name (S to N)	Mean Values for 1966 Increment								Specific Gravity[3]
			Ring Width (mm)	Earlywood Width (mm)	Latewood Width (mm)	Latewood Per Cent	Per Cent of Ring by June 10	Per Cent of Ring by July 15	Per Cent of Ring by Aug. 20	Day[2] of Appearance of first Latewood	
1	Coastal	Schoodic Head, Me.	1.03	0.67	0.36	33.9	20.5	62.2	77.6	207	0.396
3		Durell Is., N.S.	1.07	0.68	0.38	36.8	28.4	62.0	78.7	203	0.376
11	N.B.-Que.	Cains R., N.B.	2.94	1.60	1.34	42.8	30.8	58.9	76.8	195	0.378
15		Patapedia Depot, Que.	2.68	1.58	1.10	40.8	28.0	61.6	84.5	199	0.382
20		Toulnoustook R., Que.	1.30	0.80	0.50	39.8	27.2	60.1	81.4	197	0.408
28	Que.	Chateau d'Eau, Que.	1.36	0.87	0.51	37.1	33.0	64.2	80.7	194	0.386
31		Taillon Peninsula, Que.	2.58	1.76	0.81	31.2	35.7	66.5	83.4	202	0.378
38		Mistanassini Post, Que.	2.13	1.33	0.80	34.8	31.8	65.2	86.2	192	0.392
23	N.Y.-	Upper Jay, N.Y.	2.51	1.58	0.94	37.3	37.5	60.1	81.1	200	0.386
43	Ont.-	Constance Bay, Ont.	2.14	1.52	0.62	28.8	34.2	67.0	83.2	205	0.364
48	Que.	Baskatong L., Que.	1.76	1.12	0.64	35.6	27.4	59.8	73.9	208	0.378
51		McKinnon L., Que.	2.04	1.27	0.77	37.5	22.8	58.0	83.1	203	0.410
53		Kanaupscow L., Que.	1.70	1.14	0.56	32.1	35.8	69.4	87.8	195	0.410
57	E. Ont.	Miller L., Ont.	3.18	1.70	1.48	45.5	27.8	55.0	77.2	195	0.388
46		Petawawa Plain, Ont.	3.00	2.01	0.99	33.0	40.6	64.7	79.9	202	0.358
64		Smoky Falls, Ont.	2.50	1.37	1.12	44.2	18.6	50.1	74.2	203	0.424
72	Lower Mich.-	Fife L., Mich.	3.03	1.64	1.38	45.5	32.3	56.4	79.0	195	0.366
60	Mid-Ont.	Goulais R., Ont.	2.51	1.58	0.93	36.9	30.3	61.9	79.1	198	0.384
77		Caramat, Ont.	1.91	1.30	0.62	32.3	33.6	67.4	86.0	197	0.394
69	Wis.-Minn.-	Mosinee, Wis.	2.45	1.48	0.97	39.1	25.4	63.5	78.6	194	0.364
78	W. Ont.	Brainerd, Minn.	3.07	2.23	0.84	28.3	29.3	64.4	81.0	212	0.352
84		Vermillion Bay, Ont.	2.76	1.80	0.96	33.6	33.1	64.3	81.8	203	0.406
85		Sandy L., Ont.	2.05	1.49	0.56	27.4	39.5	66.7	82.8	210	0.376
90	Man.-Sask.	Cowan, Man.	2.40	1.48	0.92	38.8	20.4	61.2	86.4	197	0.414
91		Kississing L., Man.	1.36	0.86	0.50	34.1	27.3	63.8	90.6	196	0.394
92		Reindeer L., Sask.	1.94	1.25	0.69	35.7	23.4	63.9	88.4	197	0.398
94	Alta.-N.W.T.	Lac la Biche, Alta.	1.64	1.03	0.61	36.2	21.7	66.7	90.4	196	0.418
96		Fort Smith, N.W.T.	1.17	0.79	0.38	30.1	21.7	65.3	90.0	203	0.400
99		Wrigley, N.W.T.	1.13	0.68	0.45	39.5	24.3	64.4	88.8	193	0.408
Variance Ratio			4.92**	5.24**	4.02**	4.07**	1.85*	5.24**	1.85*	1.99*	4.83*

[1]Numbers refer to original provenances described by Holst (1963).
[2]Numerical day of year.
[3]Extracted, oven-dry weight/green volume.

*Significantly different at 5 per cent level.
**Significantly different at 1 per cent level.

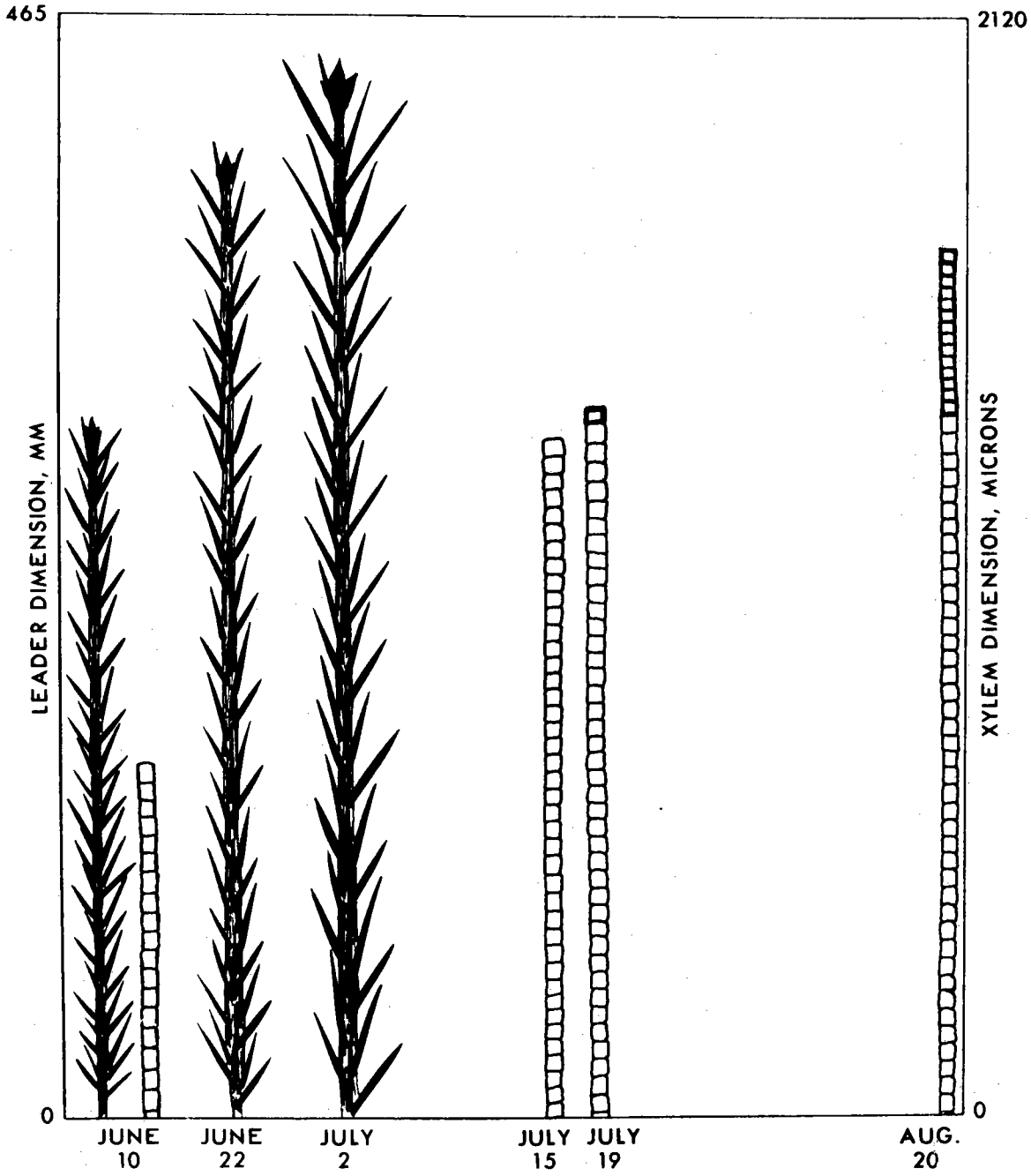

Figure 7. Model of development of the average jack pine seedling during 1966, when height growth totalled 465 mm and radial xylem increment at the base of the 1964 internode totalled 2.12 mm.

model shows that the development of mature xylem lagged markedly behind leader growth. Appearance of the first mature latewood tracheid occurred 17 days after height growth was essentially concluded, since 98% of total leader growth was completed by July 2. In a study of jack pine seedlings growing at approximately the same rate as the trees in this present experiment, Kennedy and Farrar (1965) found that 20 days were required for the complete process of differentiation beginning with division of the cambial initial and ending with complete lignification. It therefore appears that latewood initiation begins almost coincidently with cessation of height growth. This result substantiates the observations of Larson (1964), who concluded that while earlywood production is stimulated during the period of active terminal growth, cessation of terminal activity promotes formation of latewood tracheids. This transition to latewood-type tracheids is apparently mediated by a reduction in indoleacetic acid and possibly other growth hormones as a consequence of reduced vegetative activity (Balatinecz and Kennedy 1967; Larson 1964; Shepherd and Rowan 1967).

The July 2 estimate for date of latewood initiation is exactly the same as the average found by Zahner and Oliver (1962) for red and jack pines at the base of their live crowns. These trees were located in southeastern Michigan in plantations approximately 20 years old, and were not subjected to pruning or thinning regimes which may alter the date of transition to latewood.

Many phenological and xylem attributes showed a significant relationship with provenance, when geographic location was expressed in terms of growing degree-days at point of origin. Greater total height growth was achieved both prior to 1966 ($r = 0.43^{*}$) and during the 1966 season ($r = 0.57^{**}$) in those sources originating from areas with the greatest number of growing degree-days. A later completion of height growth was suggested with increasing growing degree-days, since a smaller percentage of total height was accomplished by June 10 ($r = -0.78^{**}$), and a longer time was required to reach 90% and 98% height growth ($r = 0.78^{**}$, 0.61^{**}). Wider total ring width ($r = 0.51^{**}$), earlywood ($r = 0.49^{**}$) and latewood ($r = 0.47^{**}$) were associated with more growing degree-days. Since a smaller percentage of the 1966 increment was completed by August 20 in those provenances having more growing degree-days ($r = -0.62^{**}$), a delayed cessation of cambial activity is indicated in those provenances originating from milder climates. This is not unexpected, considering the later completion of height growth noted in these provenances.

Specific gravity decreased with increased growing degree-days ($r = -0.69^{**}$). However, the degree of association between specific gravity and other xylem and phenology attri-

butes could not be determined, because specific gravity was estimated for the entire internode section encompassing all three rings, while other attributes were limited to only the final growing season.

Larson (1967) found significant differences in vegetative and wood characteristics among sources in a study of 10 *Pinus resinosa* Ait. provenances, but noted that no consistent relationship with geographic origin or latitude existed. The larger number of provenances in this present study, along with wider geographic bounds and the choice of growing degree-days to express origin, may have resulted in trends becoming apparent.

Simple correlation coefficients between growth characteristics were determined over all trees, regardless of source. Because of the high degrees of freedom involved (29 provenances x 5 replicates - 2), many coefficients were significant, but in general, only those greater than 0.50 are mentioned briefly here. Total ring width, as might be expected, was highly associated with both earlywood (0.94) and latewood (0.90) width. Ring width was correlated positively with total height growth (0.64) and with later dates of completion of height growth. Earlywood and latewood widths were related (0.69), and showed the same general association with height growth as total ring width. Latewood width was associated with latewood percentage (0.62), and was greater in those trees having a small percentage of ring complete by July 15 (-0.51). Latewood width (0.42) was not as strongly associated with total height growth as earlywood width (0.71). Increasing latewood percentages were correlated with those trees having smaller percentages of their rings completed by July 15 (-0.64) and with trees initiating latewood formation at an early date (-0.56).

REFERENCES

Balatinecz, J.J. and R.W. Kennedy. 1967. Mechanism of early-wood-latewood differentiation in *Larix decidua*, pp 36-55. *In* Proc. Fourth TAPPI Forest Biol. Conf.

Holst, Mark. 1963. Exp. No. 255. All-range jack pine provenance experiment. Can. Dep. Forest., Petawawa Forest Exp. Sta. Mimeo. 104p.

Kennedy, R.W. and J.L. Farrar. 1965. Tracheid development in tilted seedlings, pp 419-453. *In* Cellular Ultrastructure of Woody Plants, W.A. Cote, Jr., [Ed.] Syracuse Univ. Press, Syracuse, N.Y.

Larson, P.R. 1964. Some indirect effects of environment on wood formation, pp 345-365. *In* The Formation of Wood in Forest Trees, M.H. Zimmermann, [Ed.]. Academic Press, N.Y.

Larson, P.R. 1967. Effects of temperature on the growth and wood formation of ten *Pinus resinosa* sources. Silvae Gen. 16(2):41-48.

Neilson, R.W. 1966. A method of producing internal markers in xylem using pins. Unpubl. Rep., Fac. Forest., Univ. Toronto. 39 p.

Shepherd, K.R. and K.S. Rowan. 1967. Indoleacetic acid in cambial tissue of radiata pine. Aust. J. Biol. Sci. 20:637-646.

Wolter, Karl E. 1967. A new method for marking xylem growth. U.S. Dep. Agr., Forest Prod. Lab. Mimeo. 5 p.

Zahner, R. and W.W. Oliver. 1962. The influence of thinning and pruning on the date of summerwood initiation in red and jack pines. Forest Sci. 8:51-63.

BREEDING JACK PINE FOR THE MANITOBA-SASKATCHEWAN REGION

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A jack pine [*Pinus banksiana* Lamb.] breeding program has been under development since the summer of 1966 at the Forest Research Laboratory in Winnipeg. During this period, successive written proposals have been prepared, and working techniques tried. Preparation of a detailed proposal for the first selection cycle is almost completed. Implementation of the program is underway.

A brief description of the breeding plan, especially the first selection cycle, and an account of progress, follow.

BREEDING PLAN

Initial emphasis will be on assembling a collection of open-pollinated progenies and clones from phenotypically selected trees found across the region. Introduced populations will be planted at the same time or shortly after establishment of the native progenies and clones. These will provide useful information on geographic variation, and additional genetic material for the breeding population.

The progeny plantings will be designed and assessed for scoring of economically important traits, in the categories of hardiness, productivity, tree quality, and wood quality. Following progeny scoring, at an age of perhaps 10 years, grafted seed orchards will be established using scion material from the maternal clones, or from phenotypically superior progeny individuals, or some of both. Further improvement may be based on synthetic populations, derived from the above materials, enriched by gametes from adapted, productive, introduced trees.

The first selection cycle, including the establishment of operational seed orchards, will be conducted in separate, independent breeding districts. In this way there is reduced risk of failure, late in the rotation, of genotypes with superior earlier performance. Information from the various kinds of experimental plantings established in the early years of the program will provide a rational basis for modifying the original organization. The three districts presently defined include virtually all of the accessible commercial jack pine land in the region. Breeding district boundaries are shown in Fig. 1.

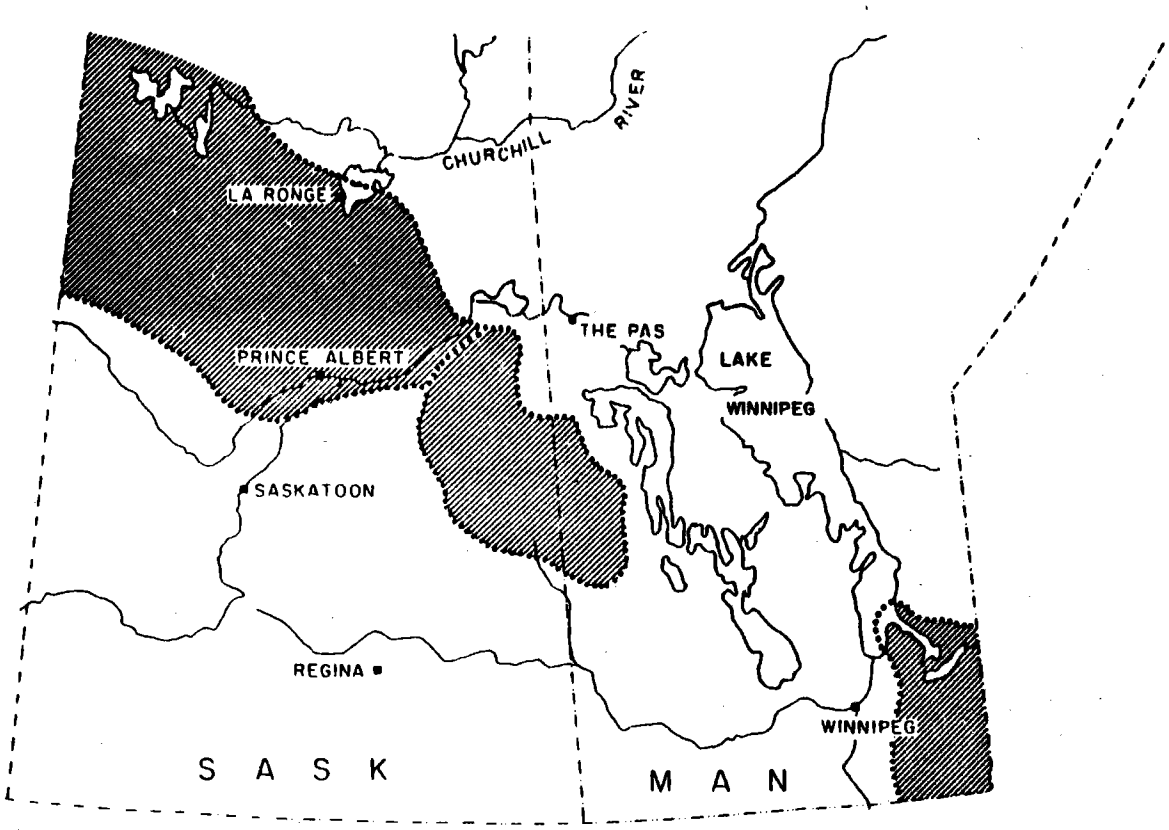

Figure 1. Boundaries of the breeding districts.

The eastern district is separated from the others by an area lacking in accessible land suitable for pine plantation management. The central district differs from the western district in being at a higher elevation, with greater relief.

PROGRESS

Over 200 open-pollinated progenies were collected across the region during the summer and autumn of 1966. Not all of these will be used in the program because the system of obtaining collections has been modified since then. Cones and scions were collected from 204 selected trees in 68 stands in eastern Manitoba from October 1967 through March 1968. These more recent collections, together with about 40 progenies from the 1966 collections, and nursery seed for controls, will assure the availability of planting stock for a 6 x 6 x 6 lattice design progeny test for the eastern breeding district. The plan used for the recent collections will probably be followed, with only minor modifications, in the central and western breeding districts.

Choice of stands for selection was strongly influenced by the objective of obtaining a highly representative sample of the native gene pool. The rationale for this approach is the assumption that useful genotypes may be present in stands established under both unfavorable and favorable conditions. There was a conscious effort to distribute selection uniformly over the district in relation to the presence of pine stands. Within this restriction, fully stocked stands were favored. In a number of instances, however, selection was done in partially stocked stands, or stands of generally poor form, to avoid leaving a large gap in the sampling pattern. In such stands, it was still possible to find trees above the stand average in vigor and stem quality. Concentration of selection effort in a smaller number of the best stands would produce a starting population with a narrower base of genetic variation, although it might have a higher average breeding value. The distribution of selection locations for the eastern breeding district is shown in Fig. 2.

For each stand worked in the 1967-1968 collections, roughly 10 to 30 minutes were spent selecting each of three parent trees. A preliminary trial of formal selection for height growth rate superiority had indicated that differences among trees within a stand were too small to justify the time required for their detection. Selection was limited to vigorous dominants and codominants. These were carefully scrutinized for stem straightness, freedom from forks, and persistence of central leader dominance.

Selected trees were felled, then cones and scions were collected. Detrimental effects of cone aging and self-pollination were taken into account in the cone collection procedure. However, the amount of vitality loss of the seeds in a particular cone or the self-pollination probability associated with its crown position can be estimated only in a very approximate way.

Grafting was done as soon as possible after collection. The number of selections for which at least one successful graft was obtained is not yet established, but it will probably be between 80 and 95% of the 204 selections made this year.

Seed extraction and cleaning were done at times when grafting could not be done owing to space restrictions. As we presently have only a small oven available for cone drying, most of the cone lots were opened at room temperature, following immersion in hot water to break the resin seal. Following opening and extraction, cones were again immersed in hot water and allowed to open a second time for the extraction of additional seed. Viability and germination speed of filled seeds

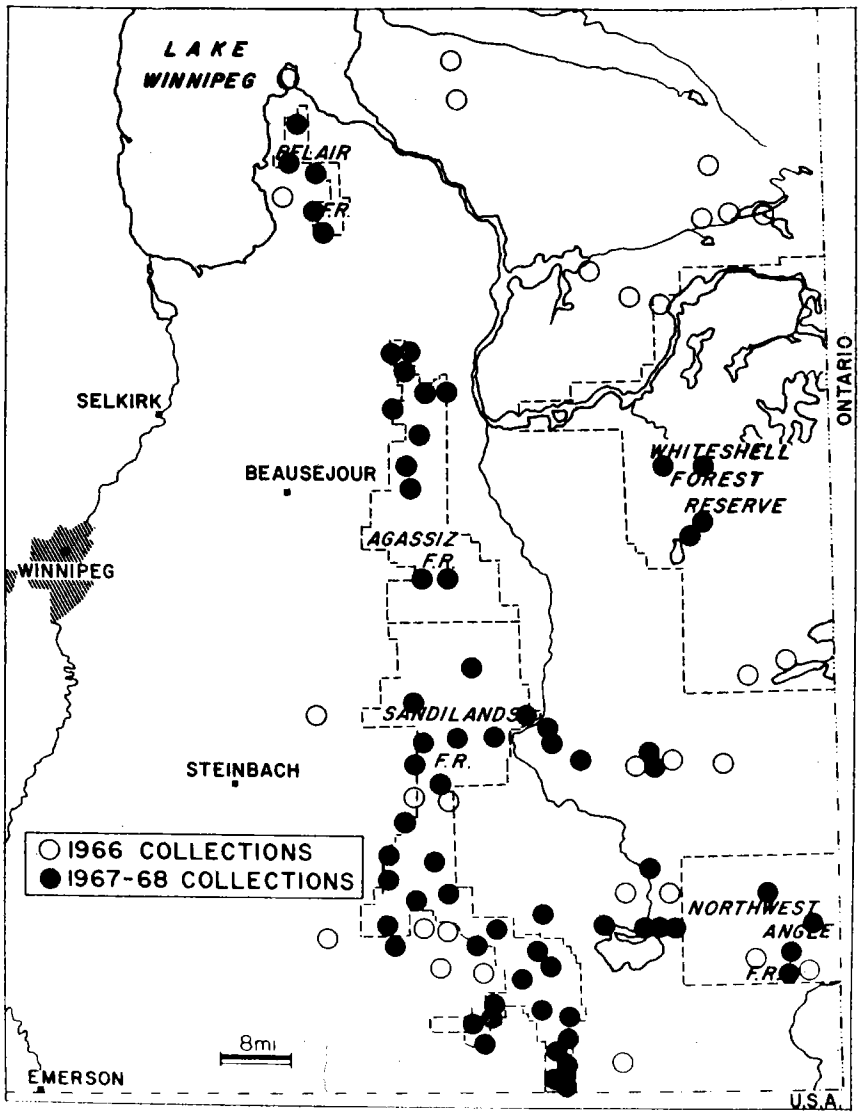

Figure 2. Selection locations for the eastern breeding district. Ten selections not shown are from the interlake area (to the left of Lake Winnipeg on this map), from stands 75 to 100 miles north of Winnipeg.

were as good for the second extraction as for the first. All preparations for sowing have been completed.

Sowing will be done this year according to a five-replicate randomized block design. A row of evenly-spaced seeds extending from one edge to the middle of the seedbed will constitute a plot. Three replications will have 28 seeds per plot, and two will have 42 seeds per plot. It is anticipated that development of a research nursery for the laboratory will allow more generous sowing next year and thereafter.

SELECTION AND REPRODUCTION OF HARDWOOD SPECIES FOR REFORESTATION OF SWAMPS IN SOUTHERN ONTARIO

H.C. Larsson
Southern Research Station, Maple, Ontario

The elimination over the past 15 years of American elm growing in the swamps of southern Ontario by the Dutch elm disease has lead to a program for the reforestation of these decimated swamps with high quality lumber-types of silver maple [*Acer saccharinum* L.], eastern cottonwood [*Populus deltoides* Marsh.], European willow [*Salix alba* L.], American willow [*Salix amygdaloides* Anderss.], and European alder [*Alnus glutinosa* L.].

SILVER MAPLE

Since 1957, 23 high quality silver maple phenotypes have been located in four swamps in southwestern Ontario. Great effort has been made over the past 2 years to reproduce these trees both asexually and sexually. Asexual reproduction has been largely confined to the planting of greenwood cuttings in early July of 1966 and 1967. The cutting material was procured wherever possible from current juvenile growth of epicormic and coppice shoots. These were subsequently cut to about 6 inches long. The leaves were reduced by one half of their original area. The cuttings were then soaked in a solution containing 200 ppm of indole butyric acid for 1 hour and planted in a 1 to 1 V/V mixture of sharp sand and vermiculite in an outside cold frame covered with plastic shading. The humidity was about 90% and the temperature was kept below 80F.

The rooting success has varied from tree to tree. Generally speaking, cuttings from juvenile growth rooted best and those from branches rooted poorly. However there were two exceptions, one tree which was reproduced from branches gave 20% rooting success whereas another tree from succulent shoots arising from a layered clone did not root at all.

Sexual reproduction by controlled crossing was attempted for the first time in the spring of 1967 following a discussion with Dr. J.L. Farrar, Faculty of Forestry, University of Toronto. The technique consisted of shooting off branches with a .225 'Savage' rifle from six high quality phenotypes growing in the Burford and Beverly swamps. The branches were placed in water in a greenhouse at a temperature of 70F and 60% relative humidity. All branches came into flower within 48 hours after being brought indoors and were immediately pollinated. There was a total of

eight successful crosses producing approximately 800 seeds within 3 weeks of pollination. Seeds were sown in tubes in early April and were planted in late May 1967 under shades in the nursery in a randomized and replicated design to determine progeny differences.

Controlled crossing was again repeated in the spring of 1968 using the branches from seven trees occurring in the Burford, Beverly and Greenock swamps. The progeny from the 2 years of crossing will be tested for vigor and quality in a prepared research swamp in the Hespeler District.

EASTERN COTTONWOOD

Considerable effort over the past 2 years in cooperation with Dr. L. Zufa, Research Branch, Department of Lands and Forests, has been devoted to locating and reproducing, asexually, high quality eastern cottonwood growing under extremely wet conditions. In 1967, three high quality swamp-type cottonwood were located and successfully reproduced by cuttings that year.

In 1968, six additional high quality swamp-type cottonwood and two "jackii" were located and are now being reproduced asexually. The clones will be tested in some of the main swamps of southwestern Ontario when sufficient planting stock is available.

EUROPEAN AND AMERICAN WILLOW

Sixteen clones of high quality lumber phenotypes of *Salix alba* and two clones of *Salix amygdaloides* were selected in cooperation with Dr. Zufa for clonal testing in the main swamps of southern Ontario. In 1967 the cuttings were established in the hardwood nursery at Maple. In the spring of 1968, 3,000 cuttings from the 18 clones were planted at the Orono Forest Nursery. Cuttings from these will be outplanted in several swamps in 1969.

EUROPEAN ALDER

In 1962, seed from five lumber strains of European alder from Germany were procured through Dr. F.U. Klaehn of Syracuse University. They were sown in the Orono Nursery in the spring of 1962 and were outplanted in three swamps in the spring of 1965 under natural conditions. They are now from 4 to 12 feet tall. Dormant cuttings were taken in the early spring

of 1968 from the fastest growing trees of good form and were planted in the greenhouse at Maple in an effort to root them. If this is successful, clonal tests with this material will be carried out in the main swamps of southern Ontario.

PROGRESS IN PROVENANCE, PROGENY, AND SPECIES TESTS, AND LARCH BREEDING IN THE MARITIME PROVINCES, APRIL 1966 AND MARCH 1968

H.G. MacGillivray
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PROVENANCE TESTS

Red Pine

Highly significant differences were found among the mean heights of young red pine [*Pinus resinosa* Ait.] from 16 seed sources growing at Iris, Prince Edward Island (Table 1). The heights may have been influenced by damage caused by the European pine shoot moth [*Rhyacionia buoliana* (Schiff.)] which is common in this area. The data dealing with insect damage in this plantation have not been analysed. If juvenile growth in red pine is a reliable indication of yield at maturity then some gain on Prince Edward Island may be expected from intelligent choice of seed source. The local controls, Grand Lake, N.B., and Stanley, N.S., rank 12th and 16th respectively. Data collected from another part of this study, a second red pine provenance test located on the Eden Barrens, Pictou County, N.S. were not analysed. This test consists of the 24 provenances, including the 16 planted at Iris. The four provenances that rank first at Iris are also of high rank at Eden. The local control from Grand Lake, ranks 6th and the two sets of red pine from Stanley, rank 14th and 24th on the Eden Barrens. The trees at Iris are more vigorous and appear healthier than those on the Eden Barrens.

Jack Pine

In 1966 data were collected in a study of phenology, cambial activity, and lignification using selected provenances of jack pine [*P. banksiana* Lamb.] growing in a nursery provenance test at the Acadia Forest Experiment Station. This was conducted in cooperation with Dr. R.W. Kennedy, Forest Products Laboratory, Vancouver, B.C., and Mr. M. Holst, Petawawa Forest Experiment Station, Chalk River, Ont. Leader measurements were taken weekly throughout the growing season. On specified dates needle lengths were measured and the cambium was wounded using small insect pins. The wounds show as scars when viewed on slides under a microscope. Wood samples from all trees were collected, preserved, and forwarded with the raw data to Dr. Kennedy.

Spruce and Fir

Tree heights, number of branches in the top whorl, branch length, number of forks in the stem, and foliage color were recorded in 1966, for an all-range seed-source test in white spruce [*Picea glauca* (Moench) Voss] at Acadia. These data were collected in cooperation with Dr. H. Nienstaedt, North Central Forest Experiment Station, Rhinelander, Wisconsin, and submitted to him for processing. Considerable variation in foliage color was observed in balsam fir [*Abies balsamea* (L.) Mill.] growing in provenance tests and in unreplicated plots of known seed source. It appears that seed from some parts of Newfoundland produces trees with darker green foliage than that produced by New Brunswick balsam fir. Further study is necessary before definite conclusions are reached. Seed was collected from some promising Newfoundland sources in 1966 and sown at Acadia in 1967. Scions and cuttings from trees selected for superior foliage color are being propagated.

SELECTION IN FIR

Resistance to Balsam Gall Midge

Initial steps were taken in 1966 to select strains of balsam fir that would resist attack by the balsam gall midge [*Dasineura balsamicola* (Lint.)]. This insect is difficult to control with contact poisons as it is protected within a gall on the needle. Galled needles drop from the twigs about the time Christmas trees are harvested reducing the value of the tree. In late November 1966, members of the Forest Insect and Disease Survey selected apparently resistant trees in Christmas-tree plots located in areas where this insect heavily infested the balsam fir. Scions and cuttings were collected from the top and bottom thirds of the crowns of these apparently resistant trees and also from neighboring trees that were severely attacked. This was done to compare the growth habits of ramets from different levels in the crown. True fir scions and cuttings from side branches produce plants with a strong tendency to retain their plagiotropic growth habit. It is expected that those from the tops of the crowns will produce plants with erect stems or plants that can be influenced to adopt an orthotropic growth habit.

Vegetative Propagation

Scions were grafted for tree breeding material. Cuttings were placed under intermittent mist in a greenhouse rooting chamber to obtain clonal material on its own roots for controlled study of resistance to the gall midge. A second purpose

is to see if the rooting of cuttings is a practical method of propagating desirable clones for use as planting stock in Christmas tree production. No significant difference was found between the rooting ability of cuttings from apparently resistant trees and those from susceptible trees. As expected, cuttings from the bottom third of crowns rooted better than those from the top third, and those treated with a hormone powder, Seradix B 3, rooted better than untreated cuttings. Hormone-treated cuttings from the bottom third of the crown rooted best (65% with roots) and those from the top third rooted moderately well (40% with roots). All rooted cuttings that were transferred from the greenhouse to the nursery in June 1967 appeared to be healthy in the spring of 1968.

PLANTING, 1966-67

Pine

Several new provenance, progeny, hybrid, and species tests were established in the Maritime Provinces during 1966 and 1967. Interprovenance hybrids of jack pine with provenance controls and complex hybrids of jack pine and lodgepole pine [*P. contorta* Dougl. var. *latifolia* Engelm.] (Table 2: No. 1), and two all-range provenance tests in jack pine were planted (Table 2: No. 2 and No. 4). Three plantations to demonstrate the relationship of the latitude of the seed source to the growth habit, especially height growth, were planted, one at Acadia and two in Nova Scotia, using material from the all-range provenance test in the nursery. The provenances were grouped by bands of longitude according to the longitude of their seed sources and then arranged for planting within these groups according to the latitude of their seed sources (Table 2: No. 5). A species test in pine (Table 2: No. 3) was established on the Shelburne Barrens in Nova Scotia. As this area has one of the mildest climates in the Maritimes several species normally not considered winter-hardy in the Maritimes were included.

Christmas Trees

A combination test of provenances and species as Christmas trees involving the inland variety of Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco var. *glauca* (Beissn.) Franco]; Veitch fir [*A. veitchii* Lindl.]; and balsam fir was planted (Table 2: No. 6).

Spruce

Different replications of a provenance-progeny test in Norway spruce [*P. abies* (L.) Karst.] with local white spruce

and black spruce [*P. mariana* (Mill.) BSP.] as controls were located on four different sites (Table 2: No. 7). These sites included three moisture regimes and three nutrient regimes. The object is to study the influence of these site factors on growth of the three species as well as their influence on susceptibility of the Norway spruce to damage by frost and by the white pine weevil [*Pissodes strobi* (Peck)]. The second provenance test of Norway spruce with local white, red [*P. rubens* Sarg.], and black spruce as controls was established on a relatively uniform site as an experiment in spacing (Table 2: No. 8-1).

LARCH BREEDING

Although 1965 was a poor flowering year a few female flowers were isolated on tamarack [*Larix laricina* (Du Roi) K. Koch] at Acadia. Japanese larch [*L. leptolepis* (Sieb. & Zucc.) Gord.] and European larch [*L. decidua* Mill.] were used as pollen parents. Some self-pollinations were made. No viable seeds were obtained from isolated female flowers that were left unpollinated as a control. The surviving seedlings in the spring of 1968 were: 14 tamarack x European larch, three tamarack x Japanese larch, and three from self-pollinated tamarack.

Reciprocal crosses were made in the spring of 1966 with Japanese larch, European larch and tamarack. Intraspecific and self-pollinations were made for each species. Backcrosses were attempted (1) using the S_1, Japanese larch x self, and the original Japanese larch parent and (2) using trees of the hybrid, tamarack x Japanese larch, and the two parent trees. A cross between this hybrid and European larch was also made. In the early spring a break-down of the cooling system for the cold room, where the seeds were stratified, caused the temperature there to rise to about 70F. Many seeds were in early stages of germination when this was discovered. This probably prejudiced the successful germination of the seeds when they were sown in nursery seedbeds later that spring (Table 3).

Table 1. Mean Height Growth of 10-year-old Red Pine from Different Seed Sources

Seed Source	Iris, P.E.I.		Eden Barrens, N.S.	
	Rank	Mean Height (adjusted)* cm	Rank	Mean Height (unadjusted) cm
Grand Bend, Ont.	1	164.6	4	102.5
Presque Co., Mich.	2	164.3	1	105.1
Sturgeon Falls, Ont.	3	161.1	7	100.0
Chippewa National Forest, Minn.	4	152.5	2	104.1
Rawdon, Que.	5	148.0	21	89.3
Douglas, Ont.	6	145.6	12	98.5
Schoolcraft Co., Mich.	7	143.5	3	103.0
Superior National Forest, Minn.	8	139.5	15	94.7
Grand Traverse Co., Mich.	9	136.5	10-11	98.6
Itasca Park, Minn.	10	136.1	20	89.7
Dryden, Ont.	11	132.4	22	82.6
Grand Lake, N.B.**	12	132.0	6	100.9
Trout Lake, Wisc.	13	131.0	10-11	98.6
Thistledew Lake, Minn.	14	128.8	23	82.5
Fort Frances, Ont.	15	126.4	17	93.3
Stanley, N.S.**	16	120.6	-(14 & (24	96.2 & 82.3
Six Mile Lake, Minn.	-	-	5	101.9
Lake Thirteen, Minn.	-	-	8	99.4
Boulder Junction, Wisc.	-	-	9	99.2
Onelda Co., Wisc.	-	-	13	98.3
Lake States, U.S.A.	-	-	16	93.4
Cass Lake, Minn.	-	-	18	93.2
Clubhouse Lake, Minn.	-	-	19	90.5
Zone 3, Pembroke, Ont.	-	-	25	74.2***

*Confidence limits for mean height using t.01, = mean height (adjusted) ± 10.9 cm. Differences between mean heights, at Iris, P.E.I., of more than 10.9 cm. are highly significant.

**Local control.

***This low mean height is largely attributed to nursery factors rather than to inheritance. These seedlings came from a different nursery and, when planted, were much smaller than those from the Petawawa nursery.

Table 2. New Experiments Established During 1966 and 1967

No.	Type	No. of provenances species, or hybrids	No. of trees/ plot	No. of replica-tions	Spacing (ft)	Time of planting or sowing	Age planting stock	Remarks
1	Test of hybrids	Jack pine 11 provenance hybrids 10 " controls 4 complex lodgepole and jack pine hybrids	40	3 x 2:6	6 x 6	spring 1966	3 year	Located east of Blackville Fire Tower in east-central N.B. Design: 5 x 5 balanced lattice square with two rows surround trees.
2	Provenance test	56 provenances of jack pine	5	3 x 3:9	10 x 6	spring	2 + 0	Located near No. 1 above. Originally 72 provenances were included. Shortages made substitution of 16 necessary. Design: 8 x 9 rectangular lattice with two rows of surround trees.
3	Trial of native and non-native pines	53 species, varieties and provenances of pines	10 (seed spots)	4	6 x 6	Nov.'66		Established on Shelburne Barrens, N.S., by direct sowing. Two randomized blocks on each of two sites; one good, one poor. One block of each pair fertilized. Hardpan along one side of each block shattered with dynamite.
4	Provenance test	56 provenances of jack pine	5	3 x 3:9	10 x 6	spring 1967	2 + 1	Located near Little Bald Mt., in north-central New Brunswick. Severe continental climate with short growing season.
5	Demonstrations of relationship of growth to latitude of seed source	96 provenances in jack pine	10		6 x 6	spring 1966	4 - 0	Three plantations, one in New Brunswick and two in Nova Scotia.

Table 2 (continued)

No.	Type	No. of provenances species, or hybrids	No. of trees/ plot	No. of replications	Spacing (ft)	Time of planting or sowing	Age planting stock	Remarks
6	Provenance-species test for Christmas trees	5 provenances Douglas fir 2 " balsam fir 1 provenance Veitch fir	25	4	6 x 6	spring 1966	2 + 2	Located on the Acadia Forest Experiment Station, N.B. Observation plots of this material were planted by cooperators in 12 locations in the Maritime Provinces.
7	Provenance - progeny test	12 Norway spruce provenances from Germany, Manitoba (Finland), Denmark and Poland. 4 progenies of Norway spruce from Denmark. Local white spruce and black spruce controls	30	8	6 x 6	spring 1967	2 + 3	Located at the Acadia Forest Experiment Station. Surplus material planted in northwestern and southern New Brunswick by cooperators.
8-1	Provenance test	6 provenance of Norway spruce from Denmark, Germany and Poland with 2, 2, and 1 local provenances of white, red, and black spruce respectively	49	1 1 1 1 4	4 x 4 6 x 6 8 x 8 10 x 10	autumn 1967	2 + 3	Located at the Acadia Forest Experiment Station. Cooperators planted about 16,000 trees in observation plots in 5 locations in New Brunswick and one in Nova Scotia.
8-2	Provenance test	5 provenances of Norway spruce with white, red and black spruce as in 8-1 above	25	6	6 x 6	spring 1967	2 + 2	Located near Hampton, N.B.

Table 3. Results of Larch Crosses Made in 1966

Parent Male / Female	Japanese	European	Tamarack	Tamarack x Japanese	Self	Wind	Control (No artificial pollination)
Japanese	3620 28% 159	1293 20% 83	1992 4.9% 8	954 5.8% 3	1164 8.4% 30	5528 19% 148	1137 0.7% 0
European	27 26% 1	229 50% 38	49 8.2% 0	*	95 19% 2	2162 39% 131	119 5.1% 0
Tamarack	949 0% 0	1217 0% 0	1267 3.5% 39	433 4.1% 7	824 2.4% 3	8173 2.7% 146	1005 0% 0
Tamarack x Japanese	407 16% 21	301 20% 33	678 12% 1	81 0% 0	554 5.6% 1	? ? 25	*
Japanese x Self	491 3.5% 1	*	*	*	211 2.3% 0	*	*

*No pollination attempted, or in the case of the controls, no female flower isolated.

1000	- Number of seeds
10%	- Percentage of full seeds (Separated by flotation in 95% ethyl alcohol).
30	- Number of seedlings

GENECOLOGY OF RED AND BLACK SPRUCE

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This investigation into the spruce complex in central New Brunswick was undertaken to facilitate mapping of forest cover types that are particularly susceptible to spruce budworm infestation. A forest cover with a high proportion of red spruce is believed to harbor persistent populations of the spruce budworm. Hybridization and taxonomic confusion complicate identification within the red spruce-black spruce component, especially in the Maritimes region where introgression is common (Morgenstern and Farrar 1964).

Phenological and morphological observations formed the basis of the investigation. The relative phenology of the tree species was observed and measured at the Acadia Forest Experiment Station and in the Miramichi watershed. Black spruce in bogs were the last to develop but both black and red spruce on upland sites showed intergradation. Red spruce retained bud scales on the developing shoot up to 5 days longer than black spruce, but much individual tree variation was encountered. During 1967 black spruce on upland sites was generally several days earlier than red spruce, but again individual tree variation and microclimate were responsible for considerable overlap.

The morphology of the two species was studied in detail to find satisfactory methods of distinguishing the two pure species, and to develop a hybrid index sufficiently sensitive to determine the extent of introgression.

During 1968, field work will be organized to determine the extent of introgression. Sample plots will traverse budworm-persistent areas and long slopes between black spruce bogs and lowlands to red spruce upland. From 12 to 24 samples will be selected at random from each plot depending on the variation encountered (Critchfield 1957; Morgenstern and Farrar 1964). Branch samples will be collected from the upper five whorls of each tree.

A hybrid index will be developed that will include those qualitative and quantitative attributes that exhibit physiological independence. Such an index could be used whenever the taxonomic status of the black-red spruce complex must be evaluated. Qualitative categories can be defined by photographs and descriptions. Quantitative measurements will contribute toward the development of a discriminant function which can separate the pure species from hybrids.

The habitats in which hybrids are found will be examined, with emphasis on transects where the comparative ecology of intergrading sites can be described. Drainage and vegetation, both of which appear to be important, will be examined. Depth of organic layer and mottling will be used to describe the drainage condition; vegetation will be analyzed using percentage cover and occurrence, and soil differences will be recorded in terms of pH, texture and rooting depth.

REFERENCES

Critchfield, W.S. 1957. Geographic variation in *Pinus contorta*. Maria Moors Cabot Foundation. Pub. No. 3. 118 pp.

Morgenstern, C.K., and J.L. Farrar. 1964. Introgressive hybridization in red and black spruce. Univ. Toronto, Fac. Forest. Tech. Rep. 4. 46 pp.

AN INDUSTRIAL TREE IMPROVEMENT PROGRAM IN NORTHERN ONTARIO

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The 1964-66 report outlined the objectives of the Kimberly-Clark program. The present report is concerned primarily with work done in the last 2 years. The principal areas of activity are outlined below.

CLONE ORCHARD

Additional plus trees are being added as they are encountered. At present the clone orchard contains 621 grafts representing 82 parent trees. Both black and white spruce produced cones in limited quantities in 1967. These were collected, the seed extracted and sown in the nursery.

SEEDLING ORCHARD

Superior black and white spruce trees from the nursery are being added at the rate of about 100 trees annually.

SEED FOREST

Work has been confined to the Lydia Lake seed forest. Thinning was carried out on part of the area in 1967. Experimental spraying of the cone bearing areas of sample trees to control insects was carried out in cooperation with the Department of Forestry and Rural Development.

TREE IMPROVEMENT IN NEWFOUNDLAND

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The tree improvement program in Newfoundland is mainly concerned with a study of the variation patterns in the local black spruce [*Picea mariana* (Mill.) BSP.] and trials of exotic species and races.

BLACK SPRUCE

Black spruce was chosen as the first local species to study because it is one of the two important pulpwood species, is adaptable to a wide range of site conditions, has no serious insect or disease problems and is relatively easily managed in the nursery. In addition, it seems to offer fairly simple seed production possibilities if one assumes that the best procedure might be the use of moderately liberal selection standards for plus trees and combination progeny tests and seedling seed orchards.

The project was initiated in 1967 to determine the extent of variation between regions, within regions, and between individuals in a stand. From early performance in nurseries and growth chambers it is hoped that tentative seed transfer rules can be established and indications obtained about the practicality of plus tree selection.

In the summer and fall of 1967, cones of seven dominant or codominant trees per stand were collected from stands distributed over most of the range in Newfoundland. Collections along elevational and coast-to-inland transects as well as from two locations in Labrador were also made. A few seed lots from the Maritime Provinces, Quebec, and Ontario were contributed by Department of Forestry and Rural Development personnel in those regions. Cone lengths and widths and 1000-seed weights have been recorded. Two nursery experiments were sown in the spring of 1968. One experiment was established in the main black spruce region, near Gander, using individual seedlots from seven trees from each of 19 provenances and the other was sown in three ecological regions; one near Corner Brook, one near Gander and one near St. John's, using seed from 39 provenances for which the single-tree seedlots had been bulked. The experimental design in both cases is a five-replicated randomized block with plots sown in lines at right angles to the direction of the seedbeds. Phenological observations and growth measurements will be made next year.

EXOTIC SPECIES AND RACES

Of the six softwood species indigenous to Newfoundland only balsam fir [*Abies balsamea* (L.) Mill.] and black spruce are presently of major commercial importance. As the former has severe insect problems and the latter is not especially fast-growing, it is desirable to establish trials with exotics, emphasizing those that have proven successful in regions such as Scotland and Norway which have climatic similarities to Newfoundland. Sitka spruce has shown promise in small trials and therefore a larger scale provenance experiment was deemed worthwhile. Seed from 12 provenances along the Pacific coast from Oregon to Alaska was sown in the Acadia Forest Experiment Station nursery in 1965 and 1966. When the seedlings were 2-0 in the springs of 1967 and 1968 they were transported to Newfoundland for transplanting. The seedlings will be planted out on a wide variety of sites in all regions of the Island beginning in 1969.

A second project is the establishment of arboreta near Corner Brook, Gander, and St. John's with emphasis on acquiring species of *Abies*, *Larix*, *Picea*, *Pinus* and *Betula* from areas of the world with climatic similarities to Newfoundland. Each plot is to contain 100 trees planted at 10 x 10 foot spacing. In 1967 plots were planted of *Betula ermanii*, *B. maximowiczziana*, *B. platyphylla*, *B. verrucosa*, *Larix laricina* (Nova Scotia), *L. leptolepis*, *L. occidentalis*, *Pinus nigra* var. *austriaca*, *P. nigra* var. *corsica* and *Robinia pseudoacacia*.

A number of provenance experiments have been established in the past under the supervision of investigators in other regions. Under the direction of H.G. MacGillivray of the Acadia Forest Experiment Station, a provenance experiment with four provenances of Newfoundland and Maritime balsam fir was established in 1961 and an experiment containing 30 provenances of red spruce [*Picea rubens* Sarg.] was planted in 1964. Under the direction of Mark Holst of the Petawawa Forest Experiment Station a provenance experiment with Lake States - St. Lawrence region white spruce [*Picea glauca* (Moench) Voss] from 31 provenances was planted near Gander in 1963, and one with 28 provenances was planted near Corner Brook in 1965. The former is due for the 10-year from seed measurement in the fall of 1968.

BREEDING PSEUDOTSUGA IN COASTAL BRITISH COLUMBIA

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INBREEDING STUDIES WITH DOUGLAS-FIR

Owing to both pressure of other work and to the erratic and sparse production of male and female strobili, the inbreeding studies made from 1952 to 1968 have been somewhat disjointed. Some interesting information, however, has been obtained and is summarized below.

There is now ample evidence that a wide range in self-incompatibility exists in the Douglas-fir. Twenty-five trees have been self-pollinated to date and the number of germinants per cone have varied from 0 to 11. Some trees however, which appeared to be self-incompatible when first self-pollinated, have produced some viable seed when selfed another year. At the present time, therefore, no tree is considered self-incompatible until it has been selfed at least two different years.

The time factor in inbreeding to more than one generation is not such an obstacle as in commonly thought. Some of the first selfed families planted at Lake Cowichan in 1956 and 1958 produced both male and female strobili in 1962 and again in 1966 and 1968. At the present time, four S_2 selfed families have been been planted and another nine are in the nursery. The first female strobilus on an S_2 inbred was observed in 1968. There is again a wide range in self-incompatibility within the S_1 selfed families, the number of germinants per cone varying from zero to nine.

It is evident that the Douglas-fir is a most heterozygous species as there is much variation within both S_1 and S_2 families. There are consequently ample opportunities for further selection.

Records have been kept of the production of male and female strobili in all the selfed families that have been planted. The results show wide variation within and between selfed families. Consistent producers of male and/or female strobili appear at any early age whilst other trees in the same selfed family appear to be non-productive. There is little doubt that the production of strobili is strongly inherited and as such is little influenced by any of the fertilizer treatments that have been recommended to date. It has been found that at Lake Cowichan such treatments will increase production on the

productive trees within a selfed family but have no effect on those that are unproductive.

In view of the wide variation in both form, vigor and reproductive ability in selfed families, at least 50 seedlings are established per selfed-family, wherever possible.

INTRASPECIFIC CROSSES WITH DOUGLAS-FIR

Seventeen test sites have been established to date on Vancouver Island and the Lower Mainland. These are located in different environments and at elevations varying from 100 to 2800 feet. In general, survival has been satisfactory in spite of severe browsing on some sites. The first crosses which were planted on four test sites in 1966 had an overall survival of from 92 to 98% on completion of their second growing season. Eight test sites were established in 1967 and in spite of a very dry summer and mortality from a potentially dangerous fungus *Rhizinia undulata* Fr. ex Fr., which was first identified on one of the sites, overall survival ranged from 72 to 98%. Another five test sites were established in 1968.

Only limited pollinations could be made in 1967 but in 1968 extensive pollinations were possible on the Cowichan Lake clone bank. It is already noticeable, however, that not only are certain clones much more productive than others but that there is also wide variation between ramets of the same clone. In addition, graft failure from overgrowth of the scion continues to be a major problem and no permenent solution has yet been found.

An increasing amount of information will be obtained from the growing number of test sites with every year after establishment but some tentative conclusions can already be made.

There appears to be no incompatibility barrier to prevent successful crosses being made between very widely separated Douglas-fir growing in completely different environments. Seedlings, for example, have been raised from a cross between a tree growing at 49°18'N, 125°13'W, elevation 200 feet in British Columbia, and another at 33°54'N, 109°07'W, elevation 9,500 feet in Arizona. The species undoubtedly has considerable genetic stability.

Crosses with southern pollen parents when grown on the coast would seem to offer more promise than those that have been made to date with pollen parents from the interior of the province. The latter crosses might be of value when grown in the interior but when grown on the coast they not only go into

dormancy early in the summer but flush early in the spring and are more susceptible to spring frosts.

The main problem in the intraspecific crossing program to date has been that of obtaining sufficient supplies of fresh pollen from outside of the province at the right time of year for crossing. Cooperation from other tree breeders, and research workers has continued to be excellent but it is necessarily restricted to regions where other breeding programs are active. There is the added disadvantage that there is little chance of ever seeing the pollen parent in person and again it may be impossible to repeat a promising cross. The choice of pollen parent is particularly important in regards to its phenology. The only permanent solution is a breeding arboretum containing specimens from widely different locations throughout the whole range of Douglas-fir. Such an arboretum was started at Lake Cowichan in 1959 and has expanded considerably since that date. The present seed collections which are either from single or several trees range from 19°40'N (southern Mexico) to 54°30'N (northern British Columbia). In addition, this arboretum already contains the clones of another 79 plus trees from Washington, Oregon and California. In future years, this arboretum will be used exclusively for crossing so that both seed and pollen parent can be selected and reciprocal crosses made if necessary. The advantages from such an arboretum were clearly illustrated in 1968. It has not been found possible to date to obtain *Pseudotsuga* pollen from Mexico although many inquiries have been made. In 1961, however, some seed was collected in Mexico by Forestal, Forestry & Engineering Limited, from Vancouver. This seed was sown in 1962 and planted at Cowichan in 1964. Several of these young trees produced sufficient male and female strobili in 1968 for pollinations to be made.

RESEARCH PROJECTS ON FOREST GENETICS AND TREE IMPROVEMENT AT THE FACULTY OF FORESTRY, LAVAL UNIVERSITY, QUEBEC

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PROVENANCE STUDIES

Hardwoods

Continuing the projects initiated previously, a provenance study of *Juglans nigra* and *J. cinerea* has been established during the three last years grouping some 30 different origins. Among these (*J. nigra*) a certain number were discarded since they showed heavy frost damage after the first winter in the nursery. Provenances whose origin was below 40°N lat normally showed frost damage. A selection was also made for nut maturity and winter hardiness in a local stand imported some 95 years ago and which shows very great differences among individuals.

A collection of various poplar clones was planted in 1966 with some *Larix*. One of these clones [Roxbury Poplar: *Populus nigra* x *trichocarpa*] shows superior growth in this local climate. Some of this clonal collection came from Dr. Shreiner, Durham, Mass.; some from Dr. Heimburger, Maple, Ontario; and one was locally selected (25 years old).

The seedlings for the provenance study of sugar maple [*Acer saccharum*] being conducted in cooperation with B. Gabriel from Vermont will be 3+0 at the end of this summer and is still in the nursery where various measurements were recorded. It will be planted in 1969.

A provenance study of *Prunus serotina* was started with Professor Cech, West Virginia University, and seeds were collected locally. Seedlings are to be sent in 1968. (Project WVU:MS-1)

Conifers

In 1967, a plantation of pine hybrids [*Pinus banksiana* x *P. contorta*] was established in a replicated experiment in cooperation with the Petawawa Forest Experiment Station, Ont.

In 1967, good larch material [Dunkeld hybrid (*Larix eurolepis*), Japanese (*L. leptolepis*) and European (*L. europea*)] was planted in observation plots near Quebec and in the Matane

County 30 miles east of Rimouski. This was made possible through Mr. D. Cook, Albany, N.Y.

In 1968, the white spruce [*Picea glauca*] provenance experiment 194-M was planted with a statistical design.

GENETIC STUDY

Acer saccharum

For the last 4 years, three sugar bushes were visited daily during sap flow. A refractometer was used to collect data from 50 individual trees recorded in each of these maple stands. Differences between maple stands and among trees within a stand are obvious and a tree with high sugar content in the sap seems to keep this percentage from year to year. Selection criteria will be used in the future to propagate individuals yielding sap of high sugar content.

Vegetative propagation of *Juglans*

Over the last 2 years grafting of *Juglans nigra* was initiated to propagate some good local winter hardy specimens. The methods employed included grafting in the field and in the greenhouse using budding and terminal grafting methods but the results were very unsatisfactory.

Larch vegetative propagation

During the last 2 years a grafting project of various larch provenances and hybrids was also initiated and will be continued in the future.

TREE IMPROVEMENT

In cooperation with the Department of Lands & Forests tree improvement program, the practice of selecting permanent forest seed stands was initiated in 1967. The new program will be increased in the future for hardwoods as well as conifer species. (See "Le Naturaliste Canadien, 94:589-597, 1967). Other projects indirectly related to the improvement are also under investigation, e.g. use of various herbicides in young plantations.

ACADEMIC PROGRAM

The undergraduate course is given during the second term with 2 hours lecture per week. Problems are discussed and seminars held during this second term. Forty and 55 students attended these lectures during the 1966-67 and 1967-68 school years respectively. In the undergraduate program two students are working on this field for their B.S.F. theses.

FOREST GENETICS AND TREE IMPROVEMENT IN QUEBEC

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INTRODUCTION

In the fall of 1966 a forest geneticist was appointed to the Quebec Laboratory of the Department of Forestry and Rural Development. Since that time a second research officer has been appointed to carry out genecological studies on hardwood species, and three technicians have been assigned to work in the general field of tree improvement and forest genetics.

As the 1966 appointment was the first in forest genetics in the Quebec Laboratory, it was necessary to spend some time in establishing priorities and organizing research facilities. The initial phase of this work is now almost completed, and research in forest genetics and tree improvement has been initiated.

Facilities now available for research in forest genetics and tree improvement include growth chambers, greenhouse space with automatic control of heat, light, and watering, and an x-ray unit for seed testing. A research nursery has been established at the Valcartier forest experiment station, and a seed extracting and processing laboratory will be ready by the fall of 1968.

BLACK SPRUCE [*Picea mariana* (Mill.) BSP.]

In the fall of 1967, 22 subpopulations were sampled throughout the range of the species in Quebec. The seed was kept separate by parent trees. Further collections will be made in the fall of 1968. When the required number of subpopulations have been sampled, a study of geographic variation of black spruce in Quebec will be initiated. This investigation is part of a larger, cooperative, range-wide study of black spruce.

A demonstration seed orchard for this species is being established at the Valcartier forest experiment station. In recent years, it has been shown that differences in embryo development can have a striking effect on germination behavior, and thus on the subsequent growth of juvenile populations. Therefore, if two provenances are being assessed for genetic

differences in a controlled environment, it is necessary to determine the degree to which the provenances differ in embryo development.

As a preliminary step in the study of geographic variation in black spruce in Quebec, four black spruce seed lots, collected on four different dates (Aug. 12, 19, 25 and Sept. 2) in the same year, and in the same area, were x-rayed to determine embryo development. The same seed was subsequently incubated for 14 days, and germinated at 25C. Five replications of 100 seeds of each seed lot were used in this study.

Figure 1 gives the results of the x-ray assessment and the germination test. The index of seed maturity, assessed from radiographs, is the per cent of fully developed embryos (embryo completely fills embryo cavity) in each seed lot. The peak value, obtained by germinating the seed, is a general index of the rate of germination and is calculated in the manner proposed by Czabator (1962). It will be seen that there is a close relationship between embryo development and germination behavior in black spruce seed (Roche 1968).

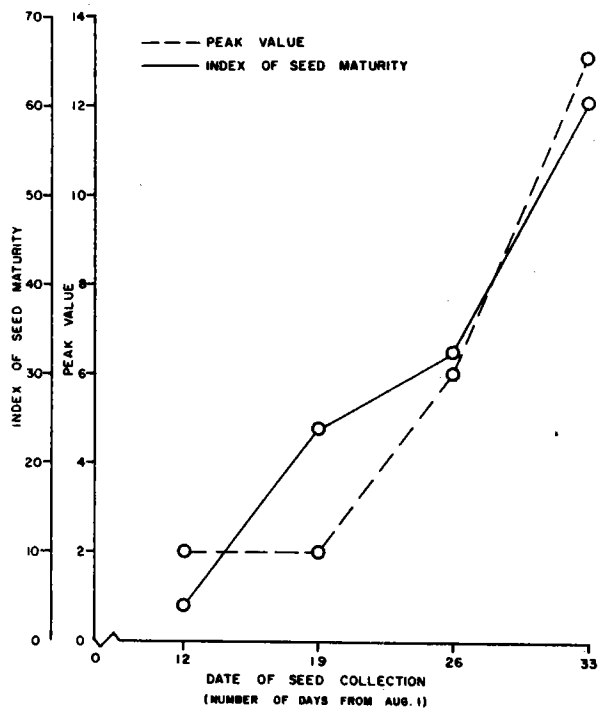

Figure 1. Relationship between germination behavior and embryo development.

RED SPRUCE [*Picea rubens* Sarg.]

During the 1967 field season, two red spruce provenances situated in three locations in Quebec were assessed[1] (Fig. 2, 3). Flushing of these provenances was typical of all but one of the 15 provenances in our red spruce trials. Flushing occurred first at Drummondville and last at Lake Megantic in 14 of the 15 provenances; height growth was greatest at Valcartier, with one exception. In general northern provenances showed superior height growth.

WHITE SPRUCE [*Picea glauca* (Moench) Voss]

Twenty-eight provenances from throughout the species distribution in British Columbia were sown in the spring of 1968 at the Valcartier forest experiment station. The provenances were sown on a prepared soil mix (University of California B2 soil mix, Baker 1957) in four randomized blocks. On completion of the nursery phase, these provenances will be outplanted in selected localities in Quebec.

BALSAM FIR [*Abies balsamea* (L.) Mill.]

In the fall of 1967, 26 subpopulations were sampled throughout the distribution of the species in Quebec. The seed was kept separate by parent trees. Further collections will be made in the fall of 1968.

In the spring of 1968, nine subpopulations were sown in two randomized blocks at the Valcartier forest experiment station, the soil mix being the same as that used for white spruce.

To determine the distribution of *Abies balsamea* var. *balsamea* and *A. balsamea* var. *phanerolepis* Fern. in Quebec, a biometrical assessment has been made of the cones collected in the fall of 1967. The cone scale morphology of these two forms in Quebec is shown in Fig. 4.

Intra- and inter-population variation in seed quality in this species in Quebec is shown in Table 1.

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[1]This provenance trial was established in 1959 by J.D. MacArthur of the Quebec Laboratory, and is part of an experiment initiated by M. Holst of the Petawawa Forest Experiment Station, Chalk River, Ontario.

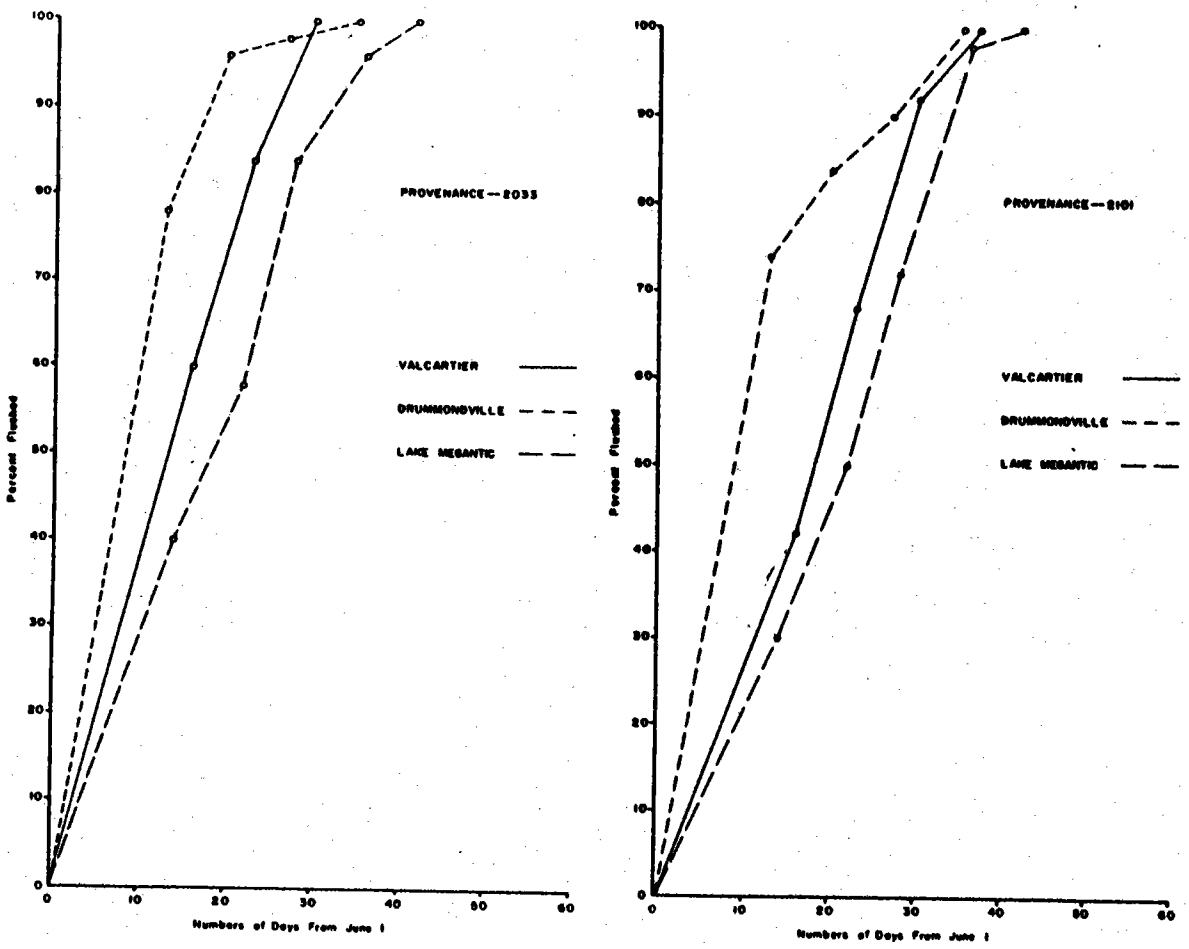

Figure 2. Times of flushing of two red spruce provenances at three locations in Quebec.

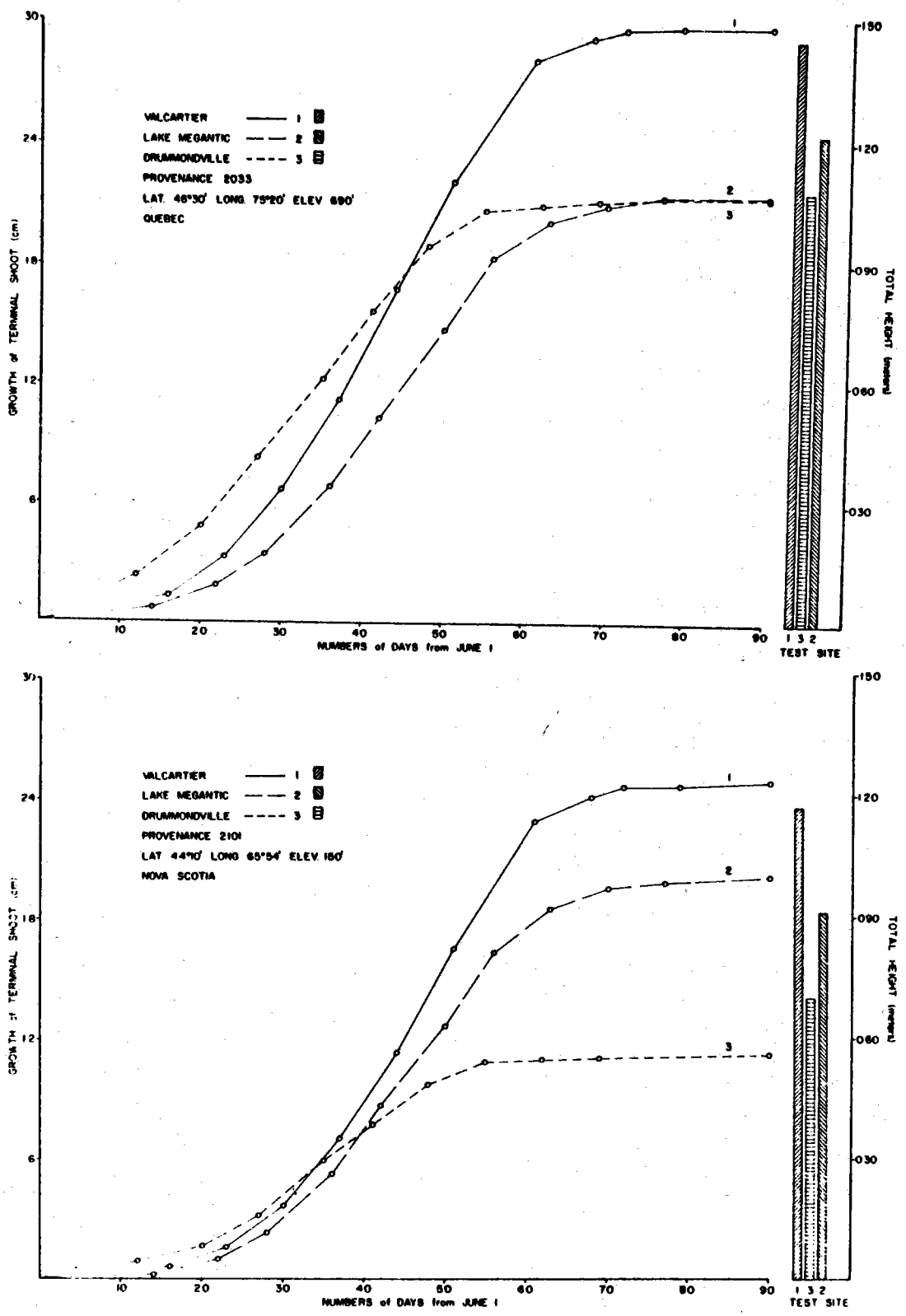

Figure 3. Mean height of two red spruce provenances at three sites in Quebec.

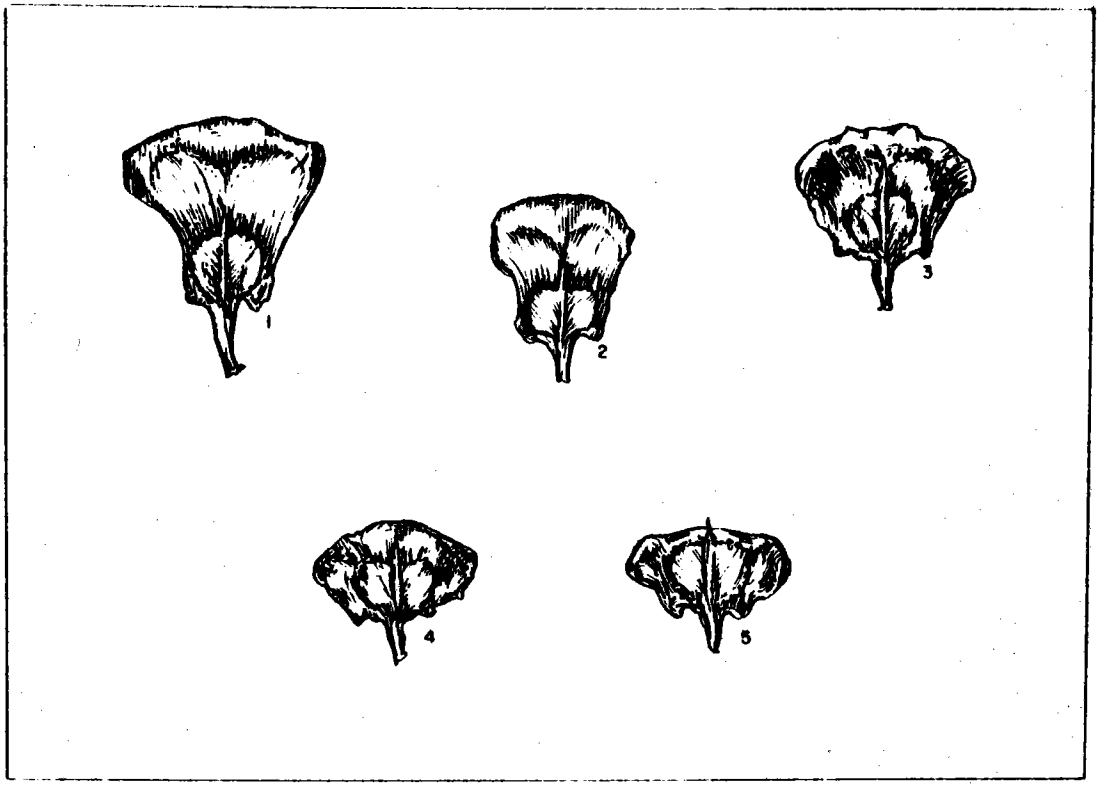

Figure 4. Variation in cone scale morphology in Abies balsamea *in Quebec. Typical form of* A. balsamea *var.* balsamea, *1; intermediate forms, 2, 3, 4; typical form of* A. balsamea *var.* phanerolepis. *Each scale is representative of a single tree from one locality, 45°55' lat, 72°29' long, elev. 200 ft.*

DOUGLAS FIR [*Pseudotsuga Menziesii* (Mirb.) Franco]

Ten provenances of Douglas-fir from the interior of British Columbia were sown in the spring of 1968 at the Valcartier forest experiment station. The soil mix and the experimental design were the same as that used for white spruce. On completion of the nursery phase, these provenances will be outplanted in selected localities in Quebec.

Table 1. Inter- and Intra-population Variation in Seed Quality in Balsam Fir Determined by X-ray Photography

P	Tree No.	A	B	C	D
1	1	14	74	1	11
	2	35	58	2	5
	3	13	58	9	20
	4	55	32	5	8
	5	51	38	3	8
2	1	24	53	13	10
	2	22	51	10	17
	3	10	55	10	25
	4	21	32	23	24
	5	14	35	26	25
3	1	28	36	12	24
	2	28	41	23	8
	3	15	52	24	9
	4	0	50	42	8
	5	39	33	12	16
4	1	54	1	37	8
	2	48	0	44	8
	3	68	3	28	1
	4	60	1	26	13
	5	78	3	18	1
6	1	68	1	22	9
	2	65	13	11	11
	3	62	10	18	10
	4	54	2	36	8
	5	66	6	24	4
8	1	52	4	41	3
	2	43	0	49	8
	3	23	11	28	38
	4	51	3	37	9
	5	41	4	50	5
9	1	38	11	50	1
	2	57	2	35	6
	3	36	10	35	19
	4	71	0	22	7
	5	64	2	31	3
11	1	17	24	27	32
	2	2	16	28	54
	3	1	2	22	75
	4	1	1	11	87
	5	9	11	4	76
14	1	12	42	21	25
	2	14	32	11	43
	3	20	16	22	42
	4	9	9	19	63
	5	10	17	15	58
15	1	6	56	17	21
	2	1	32	20	47
	3	1	14	20	65
	4	5	35	10	50
	5	0	26	11	63
17	1	15	8	48	29
	2	19	8	36	37
	3	23	1	58	18
	4	25	3	48	24
	5	20	14	63	3
18	1	0	0	97	3
	2	32	1	16	51
	3	34	3	23	40
	4	0	0	95	5
19	1	8	22	60	10
	2	4	31	42	23
	3	0	8	37	55
	4	0	3	53	44
20	1	22	4	14	60
21	1	6	30	32	32
	2	22	1	25	52
25	1	50	14	8	28
26	1	2	16	28	54
	2	9	46	15	30

Quality classes A, B, C and D are estimated on the basis of 500 seeds and expressed in per cent. A - Endosperm plus embryo; B - Endosperm but no embryo; C - empty seed; D - insect infested seed; P - population. Note that insect infestation varies from 1% in population 4 to 87% in population 11.

REFERENCES

Baker, K.F. 1957. University of California system of producing healthy container plants. Manual 23, Calif. Agr. Exp. Sta., Berkeley, California. 331 pp.

Czabator, F.J. 1962. Germination value: an index combining speed and completeness of pine seed germination. Forest Sci. 8:386-396.

Roche, L. 1968. Relationship between embryo development and germination behaviour in black spruce. Dep. Forest. Rural Develop., Forest. Br. Bi-mon. Res. Notes (In press).

BIBLIOGRAPHY

Roche, L. 1965. The use of x-ray photography in assessing the maturity of Engelmann spruce seed. B.C. Forest Serv. Res., Rev. for year ended March 1965, 42-44.

————1966. A problem analysis and general proposals for the initiation of a program of forest genetics and tree improvement in Quebec. (Unpublished data).

————1967. Variation, Selection et Amélioration des essences forestières résineuses. Bulletin technique d'information Q-X-1, 74 pp., 18 illus. Forest Res. Lab., Dep. Forest. Rural Develop., Quebec (French translation by E.R. Falkenhagen).

————1968. The value of short term studies in provenance research. The Commonwealth Forestry Review 47: 14-26.

STUDY OF VARIATION IN CANADIAN TRUE FIRS

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A study was initiated in 1959 to determine the extent of geographic variation in the true firs, genus *Abies*, in Western Canada.

First, alpine fir [*Abies lasiocarpa* (Hook.) Nutt.] was studied with respect to needle and cone characteristics in 65 populations located in British Columbia. Needle length and width, distance between stomata in a row on the abaxial surface of needle, difference between cone scale and bract length and seed wing area, were assessed and analysed. In addition, histological characteristics of the needle, cone scale and bract were investigated. The results of the above study were presented in an internal report (Roller 1966a); they suggested existence of geographic varieties in alpine fir.

In 1963 the project was extended to balsam fir [*Abies balsamea* (L.) Mill.] in northern Alberta and greater variability was found in the needle and cone characteristics of this species than had been expected. It was concluded that vegetative features might be of limited value as taxonomic criteria because of the extent to which they are modified by environmental conditions. Qualitative differences in vegetative characteristics such as needle color, crown density, position of branches and cones, bark structure and, as indicated by a number of authorities, monoterpene characteristics can aid the determination of species or their variants.

Differences in the above qualitative characteristics, especially in bark structure, cone position, and needle color in true firs growing in the Lesser Slave Lake area in northern Alberta were observed in 1965. In addition, needle, cone and resin samples of five trees were collected for preliminary investigation. The analysis of monoterpene components of the resin samples indicated wide variation (Roller 1964, 1967).

On the basis of the above investigation, the projected study of alpine and balsam fir was modified to cover additional qualitative traits and to sample more widely over the ranges of these species. The field work was carried out in August 1967.

The following techniques to estimate the extent of variation in the two species were decided upon: monoterpene analysis by gas-liquid-chromatograph, analysis of organic and

mineral content of needles, assessment of stomatal density on the abaxial surface of the needle, determination of resin canal size and position in the needle cross-section (Roller 1966b), counts of tissue elements in the vascular bundles of needles, measurement of the lengths of cone scales and bracts, examination of the shapes of cone scales and bracts and expression of the ratio of lenticels and resin blisters occurring on the bark. In order to obtain data that might be correlated with the foregoing characteristics it was considered desirable to assess available mineral content and physical properties of the soils associated with the tree population samples. In addition, branch angle, needle color, cone position and crown density were to be observed and recorded in the field.

The sampling scheme comprised an east-west transect extending from within the distribution range of balsam fir in central Manitoba to that of alpine fir in British Columbia and covering the zone in which they overlap in northern Alberta. The sampling was more intensive in the latter zone than it was towards the extremities of the transect. Five trees about 100 yd apart were sampled at 85 separate locations.

Three-year old needles were taken from branches on the south side of the tree at a height of 150 cm. Slightly ripened cones were collected from the trees and dry scale and bract particles from the ground beneath them. A 50 cm^2 segment of bark was cut from the south side of the trunk of each tree at a height of 150 cm. Resin was tapped from bark blisters on the trunk and stored using the methods of Zavarin and Snajberk (1965). In addition a soil sample was taken from the rooting zone of each tree. The investigation of the material collected is progressing. This report deals only with the monoterpene analyses carried out by the author in the Department of Chemistry, University of Manitoba. The analyses have been arranged so that the biochemical procedures involved might be practised and organized to best advantage as the earliest samples are treated, and so that early results might indicate the relative worth of chemotaxonomy in this variation study. Thus resin samples from a group of populations located in the area of the Lesser Slave Lake, Alberta, that possibly includes forms intermediate between alpine and balsam fir, were among the first to be analysed. The early analyses otherwise comprised samples collected from alpine fir at Liard Hot Spring, B.C., and three from balsam fir at the Riding Mountain, Man.; these would serve as reference samples for comparative purposes.

A Varion Aerograph gas-liquid-chromatograph was used with 9 foot by 1/8-inch coiled copper column. The resin was diluted in ether and O-xylene. The solution was injected directly into the column.

A sample fractogram is shown in Fig. 1 to demonstrate the general location, retention time and height of peaks which represent the different volatile constituents. The method of measurement of peaks was adapted from Dal Nogare and Juvet (1962). The percentage compositions were calculated from measured planimeter units with respect to the total monoterpene content. One planimeter unit is equal to 0.07 cm^2. The peaks were identified by comparing retention time of the unknowns with those of standard compositions.

In the present study the main monoterpene products are alpha-pinene, beta-pinene, limonene and beta-phellandrene for both alpine and balsam fir (Table 1). There is a fair quantity of unidentified components with high retention time (Fig. 1, no. 8) as well as some minor components such as 3-carene and myrcene.

According to Zavarin and Snajberk (1965) and Zavarin (personal communication) monoterpene components that distinguish alpine fir are a low quantity of myrcene, fair quantities of 3-carene, a low quantity of beta-phellandrene and a high quantity of limonene.

The monoterpene composition data presented in Table 1 follow the above mentioned patterns for both alpine and balsam fir except for the 3-carene content in the monoterpene of some trees located in the Morten Mountain and Lesser Slave Lake areas of northern Alberta. The 3-carene content of these trees indicates their close relationship to alpine fir and may suggest the existence of forms intermediate between alpine and balsam fir.

The data derived from the 85 sample stands should indicate the extent of variation for the traits concerned within and between balsam and alpine fir; they will also indicate whether any basis exists for varietal differentiation. Morphological and histological characteristics will be given due emphasis but more advanced techniques of chemotaxonomy, if they can reasonably be applied, may be needed to elucidate the relationships of forms intermediate between the two species.

ACKNOWLEDGEMENTS

The author is indebted to Dr. Eugene Zavarin, Associate Forest Products Chemist, University of California, Richmond, Calif., for his valuable communication; to G.A. Wollner, Chemist, University of Manitoba, for the use of his facilities; to Dr. Brian M. Lawrance, Research Director, Seasoning Ltd., Toronto, for aid in programming the column for GLC test. Samples of known monoterpenes were kindly provided by Peter P. Roller, Chemist, University of Stanford, Stanford, Calif.

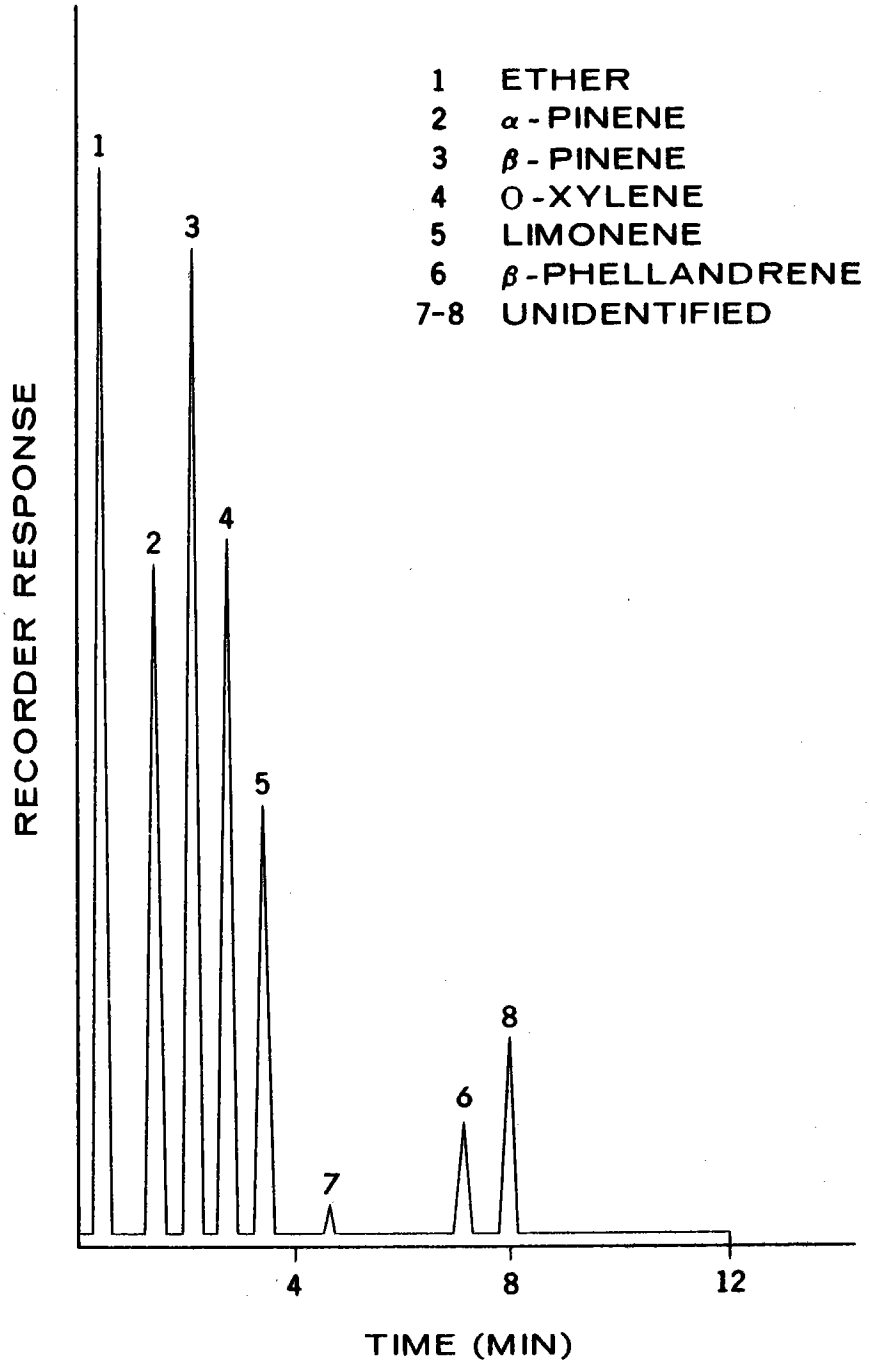

Figure 1. Fractogram of Abies balsamea *(L.) Mill. terpene in ether and O-xylene -- Swan Hills, Alta.*

Table 1. Monoterpene hydrocarbon composition of alpine and balsam fir oleoresin

Location		α-pinene RRT .550 %	β-pinene RRT .748 %	3-carene RRT .820 %	Myrcene RRT .852 %	Limonene RRT 1.000 %	β-phellandrene RRT 2.032 %	Unidentified and trace components %	Total terpene Planimeter units
Morten Mt.	1	7.3	65.1	-	-	21.6	3.6	2.4	25.5
Alberta	2	10.8	54.0	10.8	-	13.5	5.4	5.5	29.5
	3	10.9	54.9	-	-	21.9	6.6	5.7	31.0
	4	7.1	49.5	0.7	-	28.4	7.1	7.2	27.0
	5	7.1	52.5	-	-	26.2	9.5	4.7	34.0
Lesser	1	15.1	30.4	18.2	-	24.2	3.0	9.1	26.5
Slave Lake	2	6.0	36.0	-	-	42.0	6.0	10.0	26.5
Alberta	3	13.7	45.6	-	-	31.7	4.5	4.5	31.0
	4	10.4	36.1	2.5	-	41.0	5.0	5.0	29.5
	5	5.6	44.4	5.6	-	27.7	2.8	13.9	28.0
Swan Hills	1	11.6	35.5	-	-	46.8	5.8	0.3	27.0
Alberta	2	20.0	25.0	-	-	50.0	2.5	2.5	27.0
	3	13.1	28.9	-	-	47.3	5.2	5.5	27.0
	4	24.2	42.5	-	-	24.2	3.0	6.1	21.0
	5	10.0	50.0	-	-	35.0	-	5.0	21.5
	6	8.8	23.4	-	-	58.8	5.9	2.1	20.0
Riding Mt.	1	7.7	26.8	-	2.0	54.7	1.3	7.5	31.0
Manitoba	2	9.6	41.5	-	2.7	26.9	13.1	6.2	29.5
	3	15.5	57.6	-	2.6	14.2	6.7	3.5	26.7
Liard Hot Spring B.C.	1	15.6	22.1	-	0.7	18.7	35.6	7.2	34.8

RRT = Relative retention time with respect to limonene.

REFERENCES

Nogare, S.D. and R.S. Juvet, Jr. 1962. Gas-liquid chromatography theory and practice. Interscience Publishers, John Wiley & Sons, N.Y.

Roller, K.J. 1964. Studies in *Abies* species and *Pinus resinosa*. 9th Meet. Comm. Forest Tree Breeding Can. Proc. 143-145.

———— 1966a. A study of the needle and cone tissue of alpine fir. Int. Rep. MS-36, Can. Dep. Forest. Rural Develop.

———— 1966b. Resin canal position in the needles of balsam, alpine and Fraser firs, Forest Sci. 12:348-355.

———— 1967. Possible occurrence of hybrid firs in Alberta. Can. Dep. Forest. Rural Develop. Bi-mon. Res. Notes. 23:10.

Zavarin, E. and K. Snajberk. 1965. Chemotaxonomy of genus *Abies* - I. Phytochem. 4:141-148.

A PROVENANCE STUDY OF COASTAL DOUGLAS-FIR

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The objectives of this study (Experimental Project 599) are concerned with developing seed transfer rules for application in reforestation projects.

Details concerning cone collections have been published twice (Anon. 1967; Schmidt 1967). A map showing the location of each collection was also reproduced in each of these publications.

Seedlings of 88 Douglas-fir provenances are being grown at the Cowichan Lake Experiment Station nursery. These will be planted at three test sites representing different climates on southern Vancouver Island; at a low elevation in a high rainfall area, a low elevation in a low rainfall area, and at an elevation of 3500 feet.

During the seedling stage assessments were made of rate of germination, formation of apical buds, and total height at the end of the first growing season. Analyses of these data are not completed.

REFERENCES

Anon. 1967. E.P. 599 - A provenance study of Coastal Douglas-fir, pp 42-43. B.C. Forest Serv. Res. Rev.

Schmidt, R.L. 1967. B.C. Forest Service initiates Douglas-fir provenance study, pp 72-74. B.C. Lumberman, March.

FOREST GENETICS AND TREE BREEDING AT THE FACULTY OF FORESTRY, UNIVERSITY OF BRITISH COLUMBIA

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ACADEMIC PROGRAM

The undergraduate forest genetics course was taken by 21 students in 1966/67 and by 36 students in 1967/68.

The postgraduate program also increased substantially. During 1967/68 four Ph.D., (Roche, El-Lakany, Kiss and Meagher), one M.Sc. (Ho), and two M.F. (Addison and Griffin) candidates are working in the field of forest genetics.

Accommodation in the new MacMillan Building provided approximately eight times more space than we had previously.

RESEARCH PROGRAM

Provenance Studies

Work on provenance studies is gradually progressing into the progeny-provenance stage. Sample collections from individual trees within populations kept separately to provide much-needed information on the intra-population variation.

Mr. L. Roche completed his Ph.D. dissertation on "Geographic variation in *Picea glauca* in British Columbia" (pp.206) and received his degree in May 1968.

Mr. H. El-Lakany is studying γ-irradiation effects on seed germination.

Mr. R.H. Ho's research is directed to pollen germination of Douglas-fir *in vitro*.

Progeny Studies

Cones of Douglas-fir from 1335 trees and 91 different locations (Map; Table 1) were collected in 1966. Study on cone and seed morphology progressing successfully. For seed measure-

ments the recently purchased Swedish tree ring measuring equipment with a minimum alteration proved to be a valuable instrument. From the first analysis of the data it appears that the seed size shows more clinal than ecotypical variation as it was thought earlier. The characteristics on seed morphology between Coast and Interior sources is now more apparent than was known known previously.

Mr. G. Kiss, Ph.D. candidate, who is now working for the B.C. Forest Service Research Division in Victoria, analysed juvenile seedling characteristics on 150 open pollinated progenies of Douglas-fir. Seedlings from this experiment were planted out in three different locations - Port Renfrew (Vancouver Island), U.B.C. Research Forest (Haney) and U.B.C. Campus, Vancouver.

Mr. E.Th. Bjorkland completed his B.S.F. thesis on samples collected from the coast on "The influence of elevation on seed and cone characteristics of Douglas-fir" (pp. 30 plus appendix) and substantiated Seigo's (B.S.F.-1966) findings observed on Interior sample. Mr. H. Griffin, M.F. candidate, is working on variation of Sitka spruce cone and seed characteristics and his thesis is expected to be completed during 1968.

As a useful aid on evaluation of viability of seed by use of x-ray, the work progressed satisfactorily during last year. Mrs. A. Hamori-Torok completed a B.S.F. thesis on "Determination of germinability of *Pseudotsuga menziesii* (Mirb.) Franco and *Pinus contorta* Dougl. by x-ray contrast method" (pp.85).

Dr. S. Reck, post doctorate fellow from the Institute of Forest Genetics, Schmalenbeck, West Germany, completed his assignment on variation on wood densities of Douglas-fir. With the help of our forest companies a financial contribution of approximately $8,000 was provided during 1966 and 1967 summers, to support collection and evaluation of increment cores from more than 1200 trees. Besides covering intensively the Coast region of British Columbia, Dr. Reck himself collected cores from close to 400 trees from the southern Coastal range of Douglas-fir. His report is under preparation.

Intra-specific Hybridization

While the year of 1967 was a sterile year as far as seed production is concerned, 1968 kept us busy carrying out control pollinations on Douglas-fir. During the spring of 1968, beside repeating polyallel crosses on U.B.C. Campus, intra-specific crosses were attempted on U.B.C. Research Forest, Haney, and on Hernando Island, where an isolated population was found. It was also possible to field test Mr. Ho's findings on germina-

tion of Douglas-fir pollen and apply irradiated pollen on one of our Douglas-fir trees on the U.B.C. campus.

Mr. J.N. Cosco in his B.S.F. thesis, "Analysis of the reciprocally crossed progeny of Douglas-fir parents A, B, E and 11", analysed the 5-year-old progenies from polyallel cross. Seedlings from tree 11 consistently surpassed in height growth the seedlings from trees A, B and E. The 132 day "long day" treatment in growth chamber in 1964 gave similar results indicating the importance of controlled environments in genetical studies as a useful aid in early testing of Douglas-fir.

TREE IMPROVEMENT

The close cooperation with coastal forest companies provided research projects for graduate and undergraduate students. Establishing cooperative projects, such as Douglas-fir and western hemlock plus tree selection, anatomical study on Douglas-fir graft unions, clonal study of Douglas-fir, also provided summer employment for three students.

A $5,000 annual scholarship offered by B.C. Forest Products Limited allows us to further deepen our knowledge in the field of forest genetics.

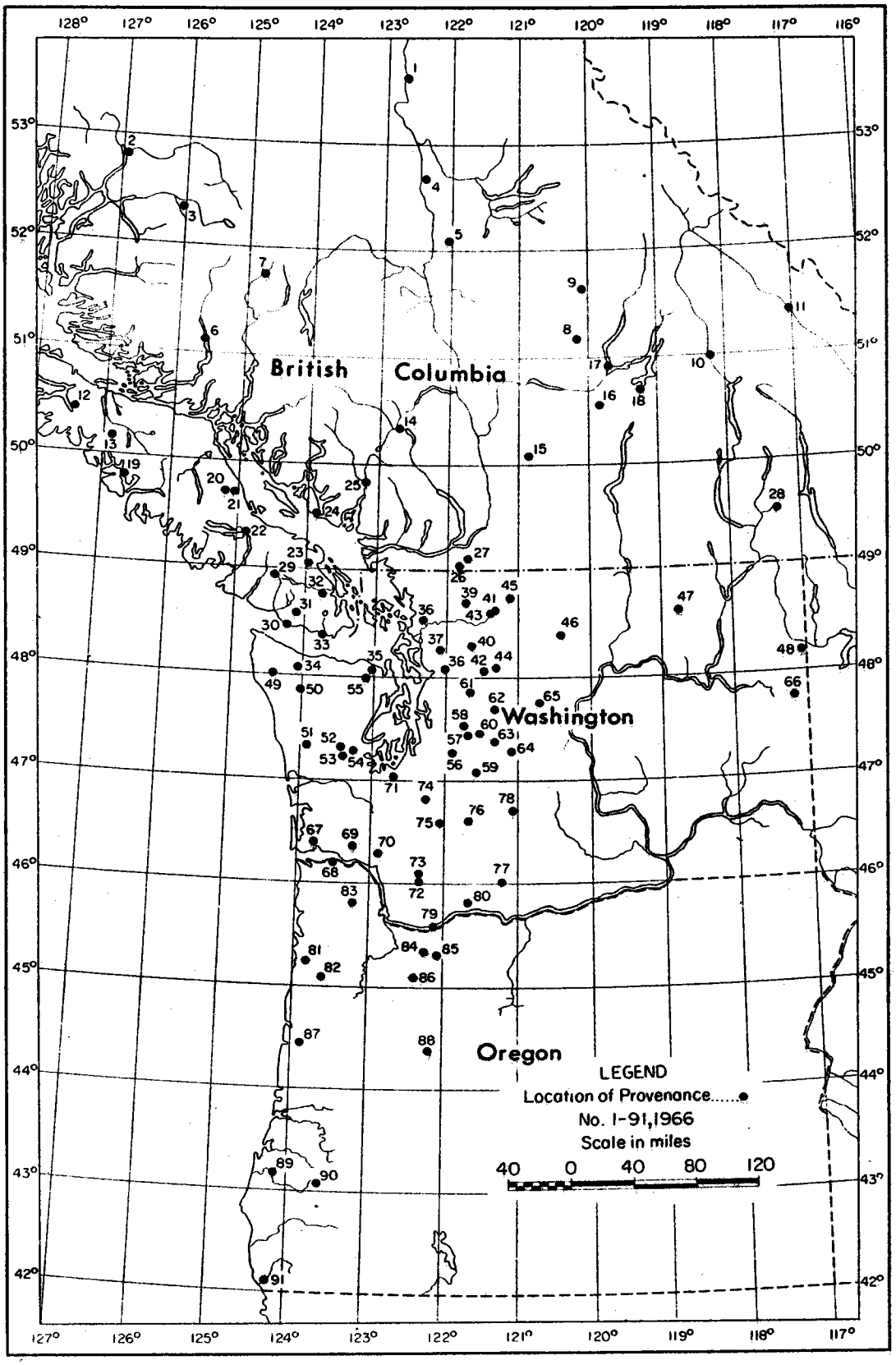
British Columbia
Washington
Oregon
LEGEND
Location of Provenance.....
No. 1-91,1966
Scale in miles
40 0 40 80 120

Table 1. *Pseudotsuga menziesii* (Mirb.) Franco Provenances 1966 I.U.F.R.O.

British Columbia

	Elevation feet	Latitude ° '	Longitude ° '	No. of trees
1. Stoner	1800 - 2000	53 37	122 40	15
2. Dean	20	52 48	126 57	14
3. Stuie	750	52 22	126 00	6
4. Alexandria	1800 - 2400	52 41	122 26	16
5. Williams Lake	2000	52 06	122 00	16
6. Klinaklini	10	51 07	125 36	10
7. Tatla	2900	51 44	124 44	16
8. Barriere	1400	51 12	120 09	15
9. Clearwater	1500	51 39	120 00	16
10. Revelstoke	2000	51 00	118 12	15
11. Golden	2400 - 3000	51 23	117 00	15
12. Jeune Landing	550	50 27	127 27	15
13. Nimpkish	300	50 19	126 53	13
14. Owl Creek	700	50 20	122 43	15
15. Merritt	2400 - 3000	50 04	120 51	16
16. Chase	1650	50 33	119 47	16
17. Monte Creek	2000 - 2200	50 37	119 54	15
18. Salmon Arm	1400 - 1700	50 44	119 13	16
19. Tahsis Inlet	50	49 47	126 38	11
20. Forbidden Plateau	2000	49 40	125 09	15
21. Courtenay	220	49 41	125 03	15
22. Alberni	450	49 19	124 51	15
23. Cassidy	650	49 03	123 57	13
24. Sechelt	600	49 31	123 53	15
25. Squamish	50	49 47	123 09	15
26. Chilliwack Low	550	49 04	121 48	15
27. Chilliwack High	3000	49 06	121 42	13
28. Nelson	2500 - 2900	49 30	117 16	14
29. Caycuse	700	48 55	124 26	16
30. Jordan River	800	48 28	124 14	13
31. San Juan River	700	48 35	124 05	15
32. Duncan	200	48 45	123 45	14
33. Sooke	150	48 24	123 44	15

Washington

	Elevation feet	Latitude ° '	Longitude ° '	No. of trees
34. Lake Crescent	1000	48 04	124 00	14
35. Sequim Bay	100 - 300	48 02	123 02	16
36. Sedro Woolley	200	48 32	122 19	16
37. Arlington	300	48 13	122 04	15
38. Granite Falls	300	48 05	122 02	16
39. Concrete	1300 - 1800	48 39	121 43	16
40. Darrington	500	48 16	121 38	15
41. Bacon Point	1500 - 1800	48 36	121 23	15
42. Perry Creek	1900 - 2100	48 03	121 28	16
43. Marblemount	400	48 35	121 24	15
44. Sloan Creek	2000 - 2300	48 05	121 18	16
45. Diablo Dam	1300 - 1500	48 43	121 07	15
46. Twisp	2400 - 2800	48 23	120 24	15
47. Republic	2400	48 36	118 44	15
48. Newport	2400	48 12	117 03	16
49. Forks	300	47 59	124 24	14
50. Hoh River	800	47 48	123 58	14
51. Humptulips	450	47 19	123 54	14
52. Matlock	1500 - 1800	47 18	123 26	14
53. Matlock	400	47 15	123 25	14
54. Shelton	300	47 15	123 12	16
55. Gard Station	1500	48 00	123 05	14
56. Enumclaw	800	47 16	121 56	15
57. North Bend	500	47 28	121 45	16
58. Chester Morse Lake	1800 - 2200	47 22	121 40	16
59. Parkway	2400	47 02	121 34	15
60. Denny Creek	1600 - 2000	47 24	121 32	14
61. Gold Bar	400	47 51	121 39	15
62. Skykomish	1000	47 42	121 20	15
63. Keechelus Lake	2600	47 23	121 22	15
64. Cle Elum	2100	47 13	121 07	15
65. Chiwachum	1800	47 41	120 44	16
66. Spokane	1800 - 2200	47 47	117 12	15
67. Naselle	100 - 200	46 22	123 44	15
68. Skamokawa	600 - 800	46 21	123 30	16
69. Cathlamet	500 - 800	46 18	123 16	15
70. Castle Rock	500	46 19	122 52	14
71. Yelm	200	47 01	122 44	15
72. Yale	400	46 00	122 22	15
73. Cougar	1500 - 1800	46 05	122 18	15
74. Alder Lake	1400	46 48	122 17	16
75. Randle	1100	46 33	122 03	16
76. Packwood	1900 - 2400	46 34	121 40	14
77. Glenwood	1600	46 00	121 10	16
78. Rimrock	2500	46 40	121 02	15
79. Prindle	1500	45 37	122 08	15
80. Willard	1500 - 1800	45 48	121 41	15

Oregon

	Elevation feet	Latitude ° '	Longitude ° '	No. of trees
81. Hebo	400 - 600	45 13	123 51	15
82. Grand Rond	500 - 700	45 06	123 36	16
83. Vernonia	700	45 46	123 13	15
84. Sandy	900	45 23	122 18	15
85. Cherryville	2000 - 2400	45 19	122 08	15
86. Pine Grove	2400	45 06	121 23	15
87. Waldport	100 - 300	44 24	123 52	15
88. Upper Soda	3000 - 3500	44 23	122 12	15
89. Coquille	100 - 400	43 12	124 10	14
90. Olalla	1100	43 05	123 34	8
91. Brookings	800 - 1200	42 07	124 12	16

Province or State	Number of	
	Provenance	Trees
British Columbia	33	474
Washington	47	710
Oregon	11	151
Totals	91	1,335

THE FOREST TREE SEED BUREAU

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In 1966 the Department of Forestry and Rural Development appointed an officer to establish the Forest Tree Seed Bureau at the Petawawa Forest Experiment Station with a view to meeting the frequent demands for tree seed of known origin and quality for research in silviculture and tree breeding and genetics. The purposes of the Bureau are: (1) to provide information on tree seed procurement in Canada and abroad, (2) to maintain a seed bank of Canadian and of important exotic tree species to supply and exchange tree seed, (3) to investigate and improve standard methods of collection, processing and storage of tree seed and for testing of seed quality, (4) to examine national and international standards for tree seed certification and (5) to study the morphology and taxonomy of seed and germinants of Canadian tree species.

Information on seed procurement, including names of persons and institutions willing to supply tree seed, is being gathered and it is mainly through this source that seed is procured for the seed bank. All seedlots are registered as to species, geographic origin, physiographic and climatic data, date and manner of collection, conditions of seed extraction and seed quality.

The Bureau is equipped with facilities that include a small seed extraction plant, cold (2C) and frozen (-18C) storage space, and a laboratory for germination tests and other seed analyses.

SEED PROCUREMENT AND SEED SUPPLY

Native tree seed of 88 seedlots was procured by the Seed Bureau through local collections, assistance and cooperation of provincial forest services and regional offices of the Department of Forestry and Rural Development and through the seed trade. A total of 31,700 grams of seed was collected from 15 softwood and hardwood species. Some of the seeds represent general collections; others are single tree collections.

In reply to 22 requests from Canada and other countries, seed of 20 species was dispatched to 11 different countries.

SEED YIELD OF 1967 LOCAL COLLECTIONS

1967 was a good seed year for most of the important native tree species in Ontario, especially for *Thuga occidentalis*, *Picea glauca*, *Picea mariana*, *Larix laricina* and *Betula alleghaniensis*. Table 1 illustrates seed yield of eight species collected from the Petawawa Forest Experiment Station area, from Kiosk near North Bay, Ontario, and from northern Ontario in 1967.

The difference in seed yield between the Bureau and the Ontario records might have been due to either the size of sample or frequency of sampling.

It was noted that seed of *Acer saccharum* has only 43 - 57% filled seed based on 1967 collections from Lake Dore, Kiosk, Grand Bend and Harriston, Ontario. The high percentage of empty seeds seems to be a common characteristic in this species as only one of the seed in the paired samara is viable (Fowells 1965).

Table 1. Seed yield in Ontario in 1967

Species	Clean seed yield per bushel of fruit or cones	Average weight of clean seed per bushel of fruit or cones	Average weight of clean seed per bushel of cones. Ontario*
	grams	*pounds*	*pounds*
Acer saccharum	3299	4.52	
Betula alleghaniensis	1795	3.97	
Fagus grandifolia	2042	4.52	-
Larix laricina	813	1.79	.55
Picea glauca	259	.57	.73
Picea mariana	147	.33	.40
Pinus banksiana	240	.53	.41
Pinus strobus	250	.55	.81

*Anon. 1963. Manual of seed collecting. Ontario Department of Lands and Forests, TM-513.

SEED PROCESSING

Excellent seed yield of *Populus* species has resulted from using the compressed air technique (Roe and McCain 1962).

Picea mariana seed has been extracted by soaking the cones prior to each of the three kiln dryings. This procedure seems to produce twice the number of seed per cone as conventional extraction with only one kiln drying. Further work will be done on extraction and de-winging of this species.

SEED TESTING

Laboratory germination tests of tree seed are made according to the rules prescribed by the International Seed Testing Association (1966) and the Association of Official Seed Analysts (1965). With modern germination cabinets equipped with light, automatic day-to-night alternating temperatures and over 95% relative humidity, 100% germination of many tree seeds has been obtained. Complete germination of seeds of unchilled *P. glauca* and *P. mariana* has been achieved after three weeks under 20 - 30C alternating temperatures, 8-hour light and over 95% relative humidity. The results are in agreement with Heit's earlier work (1961).

SEED MORPHOLOGY

During seed tests, polyembryony was found in *Fraxinus*, *Tilia* and *Quercus* species. The polyembryony found in these species appears to have originated from two or more embryo sacs in an ovule, each of which developed to an embryo (Maheshwari 1950 p 353).

X-RADIOGRAPHY

Analysis of seed quality by non-destructive X-radiography was tested with the G.E. LC-90 Industrial X-ray machine which has a range of 0-40 kvp and 1-5 ma. Standard procedures for testing *P. strobus* seed were established while procedures for other species are being worked out.

REFERENCES

A.O.S.A. 1965. Rules for testing seeds. Proc. Assoc. Official Seed Analysts, Vol. 54, No. 2. 112 p.

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S. Dep. Agr. Forest Serv., Agr. Handbook 271. 762 p.

Heit, C.E. 1961. Laboratory germination and recommended testing methods for 16 spruce (*Picea*) species. Proc. Assoc. Official Seed Analysts, Vol. 51: 165-171.

I.S.T.A. 1966. International rules for seed testing. Proc. Internat. Seed Testing Assoc., Vol. 31, No. 1, 152 p.

Maheshwari, P. 1950. An introduction to embryology of angiosperms, p 353. McGraw-Hill Book Company, Inc., New York.

Roe, E.I. and D.P. McCain. 1962. A quick method of collecting and cleaning aspen seed. Tree Planters' Notes 51: 17-18.

POLYPLOIDY INDUCTION IN POPLARS

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In a series of experiments, induction of polyploidy was attempted in poplars by using chemicals with known or supposed C-mitotic effects to treat the vegetative tissues and the generative organs of the plants.

METHODS OF TREATMENT

The following treatments were tested: (1) soaking germinating seed in the chemicals, (2) absorbing the chemicals through the root system of 2-4 day old seedlings, (3) absorbing the chemicals through young green aspen sprouts and then rooting them, (4) absorbing the chemicals through the root system of rooted young aspen sprouts, (5) submerging fast growing young shoots in the chemical solution, (6) submerging pollinated female catkins in the chemical solution, and (7) submerging male inflorescences in the chemical solution or absorbing the solution through branches with inflorescences.

CHEMICALS USED

Polyploidy induction was attempted using the following chemicals and concentrations:

Acenaphthene - oversaturated aqueous solution
Auramine - 0.01-0.5% aqueous solution
Aurantia - 0.001-0.01% aqueous solution
Chloral hydrate - 0.1% aqueous solution
Colchicine - 0.01-0.2% aqueous solution
Dihydroquercetine - oversaturated aqueous solution
Diphenylamine - oversaturated aqueous solution
Hexachlorocyclohexane - oversaturated aqueous solution
Hydroxyquinoline - 0.01-0.02 mol/l aqueous solution
Indoleacetic acid - 0.001-0.5% aqueous solution
Kinetin - oversaturated aqueous solution
Paradichlorobenzene - saturated aqueous solution
Podophyllin - oversaturated aqueous solution
Sodium cacodylate - 0.05-1% aqueous solution

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[1]Present address: Ontario Department of Lands and Forests, Southern Research Station, Maple, Ont.

Tribromoanaline - oversaturated aqueous solution
Urethane - 1% aqueous solution

The germinating seed and the young seedlings were treated with all the chemicals. Only colchicine and acenaphthene were used in Treatments 4-7. The aspen sprouts (Treatment 3) were treated with acenaphthene only.

MATERIALS

The following sources are the sources of seed treated: (1) *P. tremuloides* Michx. open pollinated seed from a single tree, Maple, Ont., (2) *P. grandidentata* Michx. open pollinated seed from a single tree, Petawawa, Ont., (3) *P. tacamahaca* Mill. open pollinated seed from a single tree, Toronto, Ont., (4) *P. deltoides* Marsh. open pollinated seed from several trees, Turkey Point, Ont., (5) *P. canescens* (Ait.) Sm cl. "C-18", open pollinated seed from a single tree, Maple, Ont.

The treatment of young sprouts and shoots were performed on the following: (1) One-year-old seedlings, open pollinated progeny of *P. canescens* (Ait.) Sm "cl C-18", (2) One-year-old seedlings, open pollinated single tree progeny of *P. tremuloides* Michx., Thunder Beach, Georgian Bay, Ont.

Polyploidy induction in the pollen grain was attempted with male inflorescences of *P. tremuloides* Michx., Maple, Ont. The newly formed embryos of *P. tremuloides* (Maple, Ont.) x (*P. alba* x *tremula*, hybrid no. AE 28) were treated.

The materials were made available for experimenting by Dr. C. Heimburger, Southern Research Station, Maple.

METHODS OF CHROMOSOME COUNTING

The ploidy level of treated plants was checked by chromosome counts in mitotic cells. Samples were taken from the stem and sometimes from both the root and stem of 6-7 month-old plants, or 1-2 months after treatment of the shoots.

The following microtechnique for chromosome counting was developed: expanding top-leaf buds or root tips were taken between 10-12 AM. The expending leaf buds were pretreated in a saturated aqueous solution of p-dichlorobenzene for 4-5 hours in a refrigerator. The root tips were pretreated in 0.01% colchicine solution for a ½ hour or in saturated aqueous acenaphthene solution for 2 hours. The samples were fixed in 3:1 acetic-alcohol, hydrolysed at 60C for 10-12 minutes in 1N HCl and stained in Feulgen reagent.

This method assured a relatively good number of well-spread chromosome plates. However, an exact count was very difficult because of the high number (2n=38) and small size (0.5-2μ) of the chromosomes. For this reason, the establishment of the presence of aneuploids was impossible. On the other hand, the distinction of polyploids from diploids was not difficult.

The results of pollen treatments were determined on the basis of pollen-diameter measurements.

RESULTS

Treatment

The most effective treatment was that of young seedlings or absorbing the chemical solution through the root system for 2-4 days. Treating the germinating seed for 1-4 days had a similar effect. However, it resulted in a higher mortality rate when chemicals with toxic effects were used. Somewhat less effective, but still satisfactory, was the treatment of rooted aspen sprouts by absorbing the acenaphthene solution through the root system for 20 days.

Soaking freshly picked aspen sprouts in acenaphthene and treating young aspen shoots after etiolation by submerging them in colchicine and acenaphthene resulted only in the production of a low percentage of mixoploids.

Treatment of pollinated female catkins by submerging them in colchicine and acenaphthene solution gave no result.

Better results were obtained with expanding male flower buds by absorbing the colchicine solution through whole branches for several days than by submerging the catkins in the solution.

Chemicals

Almost all the experimental chemicals were effective to a greater or lesser degree. Some of them were tested in only one or two concentrations, which does not allow the drawing of final conclusions as to their value.

The highest proportion of polyploids (75-100%) was induced with hexachlorocyclohexane, but the test concentration (oversaturated aqueous solution) was toxic and only a very low percentage (3-6%) of the treated plants survived.

Good results were obtained with colchicine treatments (30% induced polyploids). The toxicity of this chemical was lower and the plant survival rate higher (30-50%) than with the hexachlorocyclohexane.

Experiments were performed with auxins, the objective being the regeneration of the young seedlings treated with colchicine or hexachlorocyclohexane. Two methods were tried, adding the auxins together with C-mitotic agents or adding them after the polyploidy induction treatment. One to 10 ppm concentrations of indoleacetic acid, indolebutyric acid, naphthaleneacetic acid, kinetin and 50 ppm of gibberellic acid were tried. The indoleacetic acid treatments were effective, but particularly so when combined with colchicine. The gibberellic acid treatment had a negative effect on root regeneration.

Relatively good results (10-25%) induced polyploids) were obtained with acenaphthene and paradichlorobenzene; these chemicals were of low toxicity and the treated plants regenerated easily.

Treatments with sodium cacodylate, of very high toxicity, urethane, of high toxicity, aurantia, indoleacetic acid and podophyllin, of low toxicity, also resulted in polyploidy induction (5-10%).

The induction of mixoploids, only, resulted from treatments with auramine, tribromoanaline, diphenylamine, chloral hydrate, dihydroquercetine and kinetin. All these chemicals were of medium toxicity except dihydroquercetine, which was very toxic.

In one variant, gibberellic acid (50 ppm) was given to the young seedlings through the root system, together with the C-mitotic agent. This treatment was supposed to increase shoot elongation, penetration of the drug and rate of cell division. It resulted in a more expressed variability among treated plants. However, the increase in the rate of induced polyploidy was not significant.

In a variant of the treatment of generative organs by submersion, dimethyl sulfoxide in 2, 5 and 10% concentrations was used together with colchicine and acenaphthene or to promote penetration of the drug. These concentrations were apparently too strong and in most cases killed or poisoned the treated tissue.

DISCUSSION

The poplar species in experiments showed a well expressed difference in sensitivity toward C-mitotic chemicals. Almost always, *P. tacamahaca* was the least sensitive to poisoning and the first in regeneration; *P. tremuloides* produced the greatest number of induced polyploids and *P. deltoides* the least. This behavior was similar in almost all experiments. An exception to the rule was found in the P-dichlorobenzene treatment, which was more effective with *P. deltoides* than with other species.

A relatively high number of mixoploids were produced, even with the less effective chemicals. These plants maintained their chimaeral character during the first 6-8 months of development without showing more expressed disturbances or difficulties in development.

In some cases polyploidy on the higher than tetraploid level was found; the existence of mixoploids on polyploid level was also probable. Irregularities were observed in growth of such plants.

Many of the polyploids and mixoploids at the tetraploid level developed almost normally, sometimes even showing very vigorous growth. They were characterised by larger, coarser dentate leaves.

In many cases, the large abnormalities in growth could be due to the toxic action of the chemicals, rather than to the polyploidy or mixoploidy at the tetraploid or lower levels. Observations and comparisons of the appearance of plants analyzed for chromosome number support this thinking.

The poplar species in these experiments expressed a very characteristic behavior in respect to these abnormalities. In almost all experiments, *P. deltoides* was the species with the most abnormal appearing plants, and *P. tremuloides* the species with the least abnormalities.

Additional experiments are necessary with those chemicals which were effective, particularly those which have been previously less extensively used for polyploidy induction. More information is needed on their mode of action and their effect on dividing cells.

SUMMARY

Polyploidy induction was attempted in five poplar species with 16 different chemicals using various treatments on vegetative tissues and generative organs. The most significant conclusions of this work are as follows:

(1) Absorbing the C-mitotic agent through the root system of young seedlings or rooted young sprouts was found to be an effective means of inducing polyploidy.

(2) Chemicals other than colchicine were experimented with and found to be effective for polyploidy induction. These are, in order of effectiveness, hexachlorocyclohexane, acenaphthene, paradichlorobenzene, sodium cacodylate, urethane, aurantia, indoleacetic acid and podophyllin.

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CURRENT WORK OF THE TREE BREEDING UNIT

L. Zufa
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In July 1967, D.P. Fowler's position in the Tree Breeding Unit was filled by L. Zufa. C.C. Heimburger retired from the Unit on 1 February 1968. Miss R.M. Rauter is returning in the summer of 1968 after completing her thesis work.

Work with spruce, poplar, white pine and hard pine continues on an active basis, while work with cedar continues on a maintenance basis.

SPRUCE

Objectives

The improvement of white and black spruce by selection and intraspecific breeding and the development of hybrid spruces of superior growth, form and wood quality, resistant to diseases.

Methods

1. Selection and intraspecific breeding in white and black spruce. Breeding of geographically distant provenances. Progeny testing and variation studies.

2. Development of breeding arboreta. Acquisition of exotics and representatives of native species.

3. Interspecific breeding in combinations known for crossability to induce hybrid vigor, desired ecological tolerance and other characteristics of silvicultural importance.

4. Interspecific breeding on an exploratory level or to establish crossability patterns and to obtain preliminary information on the characteristics of the hybrids.

5. Study of floral morphogenesis, of fertilization and embryogenesis to support interspecific breeding.

Discussion

The spruce project of the Tree Breeding Unit is a recent one dating from 1964. Interspecific breeding on an exploratory level has been the main effort and will be continued. Studies of floral morphogenesis, fertilization and embryogenesis will be initiated to facilitate the breeding work.

Emphasis will be put on interspecific breeding in combinations which may give hope for significant improvements in silvicultural characteristics, as well as an extension in the ecological range of native spruce. Crosses such as *P. glauca* x *abies*, *P. glauca* x *jezoensis*, *P. glauca* x *pungens*, *P. mariana* x *glehnii*, *P. obovata* x *mariana*, *P. abies* x *mariana*, *P. mariana* x *omorica*, *P. mariana* x *koraiensis*, *P. mariana* x *rubens*, will be attempted, using appropriate selections of parent trees. When direct crosses are not feasible, multiple crosses will be attempted.

More attention will be paid to the selection of white and black spruce in order to acquire the appropriate parent material for interspecific and intraspecific breeding. Comparative field tests will be started to evaluate the silvicultural value of the hybrids.

Current work

1. Cultivation, in the greenhouse, of seedlings from the 1967 seed crop.

2. In the spring of 1968 the following material was acquired and grafted:

P. mariana, Alberta provenance - 10 trees
P. smithiana, Yale University - 2 trees
P. mariana x *rubens*, New Brunswick - 10 trees

3. Sparse flowering limited work in 1968 but pollination was accomplished in the following combinations:

P. abies x *P. mariana*
P. abies x *P. glauca*
P. abies x *P. rubens*
P. (*sitchensis* x *glauca*) x *P. abies*
P. asperata x *P. glauca*
P. asperata x *P. mariana*
P. jezoensis x *P. glauca*
P. jezoensis x *P. mariana*

POPLARS

Objectives

The improvement of native poplar species and the development of hybrid poplars of superior growth, good form and desired wood quality, resistant to diseases and suitable for the future needs of poplar timber production under varying conditions in Ontario.

Methods

Methods will depend on the requirements of the main poplar areas in Ontario.

1. Southern Ontario conditions, aspen sites.
   a) Selection in previously produced interspecific hybrids to produce aspen clones that propagate easily by vegetative means and possess other desired characteristics.
   b) Production of F_2 hybrid generations of interspecific hybrid parents to develop hybrid poplar clones.

2. Southern Ontario conditions, cottonwood sites.
   a) Cottonwood selection and study of its variations.
   b) Interspecific crosses of *P. deltoides* with *P. nigra*, *P. jackii* and *P. balsamifera* to develop clones with desired characteristics for different ecological requirements.

3. Central and Northern Ontario conditions, aspen sites.
   a) Aspen selection and study of its variation.
   b) Interspecific crosses of *P. tremuloides* and *P. grandidentata* with European and Asiatic aspens to produce uniform hybrid populations with desired characteristics.
   c) Interspecific crosses between aspen and cottonwood hybrids to induce rooting ability and develop clones with desired characteristics. Polyploidy induction in hybrids to facilitate breeding work and assure a higher rate of improvement.

4. Central and Northern Ontario conditions, cottonwood and balsam poplar sites.
   a) Selection of cottonwoods, "jackii" poplars and balsam poplars and study of their variation.
   b) Crosses of *P. deltoides* with *P. jackii* and *P. balsamifera* to develop cottonwood hybrid clones and to extend the range of cottonwood.

5. Field production tests of the newly produced hybrids in cooperation with silviculturists.

6. Acquisition of a gene pool of poplar exotics for the realization of the aims of interspecific breeding.

Discussion

Breeding of poplars under Dr. Heimburger's guidance started in 1946, the objectives being the development of aspens for Southern Ontario conditions. This work has now reached the stage where a selection of trees in existing hybrid populations can be made and the development of new clones that can be easily

propagated vegetatively can be attempted. Selected F_1 interspecific hybrids can now be used for the breeding of F_2 hybrid generations of unrelated hybrid parents. Production of entirely new types of poplar hybrids and the induction of genes for rooting ability may be expected from these crosses.

In the past, no attention was paid to the improvement of aspens for Central and Northern Ontario conditions and to the improvement of cottonwoods and balsam poplars. The growing capacity of these poplar species, the possible industrial value of poplar timber and the suitable ecological conditions for their growth predict the necessity of beginning such a project for future needs. The results obtained in poplar improvement here and elsewhere in the world gives hope for relatively rapid success.

Current work

1. Forty-one trees were selected in the existing hybrid aspen populations and regrafted.

2. Two hundred and four hybrid aspen clones (ortets) with a total of 4,310 cuttings (ramets) were submitted to a rooting trial.

3. The following new selections were made and scions for vegetative reproduction and branches with flower buds were procured: cottonwood and "jackii" poplar in Southern and Central Ontario - 7 trees; aspen from Northern and Central Ontario - 14 trees; and "jackii" and balsam poplar, from the Boreal forest region - 11 trees.

4. In the spring of 1968, hybrid seed was produced and seedlings originating from the following crosses were developed: (general listing)

For Southern Ontario conditions

P. canescens x (*P. alba* x *sieboldii*)
P. canescens x (*P. alba* x *grandidentata*)
P. canescens x (*P. alba* x *davidiana*)
P. canescens x (*P. alba* x *adenopoda*)
P. alba x (*P. canescens* x *gradidentata*)
P. alba x *sieboldii*
P. (*grandidentata* x *davidiana*) x (*alba* x *grandidentata*)
P. (*grandidentata* x *davidiana*) x (*alba* x *sieboldii*)
P. (*grandidentata* x *davidiana*) x (*alba* x *tremula*)
P. (*alba* x *grandidentata*) x *glandulosa*
P. (*alba* x *grandidentata*) x (*alba* x *tremula*)
P. (*alba* x *grandidentata*) x (*alba* x *sieboldii*)
P. (*alba* x *grandidentata*) x (*alba* x *davidiana*)
P. (*alba* x *grandidentata*) x *sieboldii*
P. sieboldii x (*alba* x *grandidentata*)

P. sieboldii x (*alba* x *davidiana*)
P. sieboldii x (*alba* x *tremula*)
P. canescens x (*P. canescens* irradiated[1] + *deltoides*)
P. canescens x (*P. canescens* irradiated[1] + *jackii*)
P. alba x (*P. canescens* irradiated[1] + *deltoides*)
P. alba x (*P. canescens* irradiated[1] + *trichocarpa*)
P. deltoides x *nigra*

For Central and Northern Ontario conditions

P. tremuloides x *sieboldii*
P. tremuloides x *tremula*
P. tremula x *tremuloides*
P. tremuloides x (*tremuloides* irradiated[1] + *jackii*)
P. tremuloides x (*tremuloides* irradiated[1] + *balsamifera*)
P. tremuloides x (*tremuloides* irradiated[1] + *deltoides*)
P. tremula x (*tremuloides* irradiated[1] + *deltoides*)
P. tremula x (*tremuloides* irradiated[1] + *jackii*)
P. deltoides x *jackii*
P. deltoides x *balsamifera*
P. deltoides x *trichocarpa*

5. Maintenance work and observations of the previously established objects are underway.

WHITE PINE

Objectives

The improvement of eastern white pine by selection and breeding and the development of hybrid white pines of superior growth, good form and wood quality resistant to blister rust and weevil.

Methods

1. Selection and intraspecific breeding in eastern white pine. Progeny testing.

2. Provenance and variation studies in eastern white pine.

3. Interspecific breeding in promising combinations such as *P. griffithii* x *strobus* - for blister rust resistance and for hybrid vigor, *P. peuce* x *strobus* for weevil resistance or *P. monticola* x *strobus* for shade tolerance and weevil resistance. Progeny testing.

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[1]Pollen irradiated at 10,000 r per minute, total 200,000 r was used. The expected effect of irradiation was in killed nucleus and viable cytoplasm.

4. Development of clones, by means of rooting stem cuttings and needle bundles with induced buds.

Discussion

Emphasis will be on improvement of growth rate, stem form and branchiness, in addition to blister rust resistance.

Seemingly blister rust resistant trees were found to produce progenies with different degrees of resistance. Therefore, more attention will be paid in testing the ability of these trees to transmit resistance to their progeny.

The newly produced populations will be tested for blister rust resistance. The seedlings will be cultivated and infected in tublings and kept under artificial conditions of temperature and light. This will allow for the handling of a larger amount of material and for the shortening of the time necessary for testing.

Resistant individuals will be selected for rooting ability. It is hoped that starting with young seedlings, and taking cuttings only from the newly rooted cuttings, the young physiological age of the reproductive material and its good rooting ability can be maintained.

Comparative field tests will be established. Accurate testing of blister rust resistance will be attempted by means of replicated clonal tests. It is hoped that the development of white pine clones will allow for a rapid solution to the blister rust problem.

Current work

1. Cultivation of the seedlings obtained from 1966/67 seed crop, in tublings.

2. Grafting work: new selections - 9 trees regrafting for blister rust testing - 36 trees.

3. Rooting tests with stem cuttings and needle bundles; bud induction in needle bundles.

4. Interspecific breeding work. Combinations: *P. griffithi* x *strobus*, *P.* (*griffithii* x *strobus*) x *strobus*. The breeding work is limited by the lack of pollen collections.

5. Maintenance work and observations of the previously initiated objects.

HARD PINES

Objectives

The improvement of the red pine by selection and breeding and the development of hybrid hard pines of superior growth, form and wood quality, resistant to disease and suitable to Ontario conditions.

Methods

1. Selection and intraspecific breeding in red pines, emphasizing the crosses of geographically distant provenances and of evidently distinct genotypes.

2. Interspecific crosses of red pine with related pines using irradiated red pine pollen (with killed nucleus, but viable cytoplasm) as an intermediate.

3. Species crosses within the series Sylvestris, to develop new hybrid pines with superior characteristics.

Discussion

The breeding of 2-needle pines started in 1946, the objective being the induction of resistance to the European pine shoot moth. This can no longer be considered of particular importance in most parts of Ontario.

The study of variation and inbreeding in red pine, completed by D.D. Fowler, shows that there can be little hope for red pine improvement using conventional methods of selection. The search will be continued for differences among geographically distant provenances. It appears that red pine cannot be crossed with other pine species by using ordinary breeding techniques. New techniques must be developed and the reasons for incompatibility studied.

The development of entirely new hybrid types of hard pines is being attempted. It is hoped that the new types will be adaptable to a wide range of ecological conditions and that they can substitute for red pine if a pest threatens to destroy this genetically uniform species in the future.

Current work

1. Cultivation of the hybrid seedlings obtained from 1966/67 seed crop.

2. Attempts at interspecific breeding in red pine in the following combinations: *P. resinosa* x (*P. resinosa* irradiated[1] + *P. nigra*), *P. resinosa* x (*P. resinosa* irradiated[1] + *P. leucodermis*). The breeding work is limited by the lack of pollen collections.

3. Observations and maintenance of the established objects.

SPRUCE SYMPOSIUM

WHITE SPRUCE SEED SOURCE VARIATION AND ADAPTATION TO 14 PLANTING SITES IN NORTHEASTERN UNITED STATES AND CANADA

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Research on provenance and genetic variation in white spruce (*Picea glauca* (Moench) Voss) has been in progress in Canada and the United States only since about 1950. Genetic information on the species, therefore, has been limited to a few publications by Holst (1958, 1960), Genys (1965) and to some recent work by Roche (1967). Taxonomic studies by Taylor (1959) and Garman (1957) have considered the relation between *P. glauca* and *Picea engelmannii* Parry.

Holst's work suggested the existence of two clines in white spruce - one located west of, and the other east of Petawawa, Ont. The annual growth of seedlings from both clines planted at Petawawa decreased with increasing latitude of the seed source, but at a faster rate in the eastern cline. Holst's work also suggested the existence of edaphic ecotypes adapted to limy sites. Genys (1965) described two clines in eastern Ontario and southern Quebec. Seedlings from the Denbigh, Ont., and St. Maurice River, Quebec, sources were high yielding, and seedlings from both clines showed east to west declines in growth. The boundary between the two clines fell between 76° and 77°E longitude.

The western workers (Roche 1967, Taylor 1959, Garman 1957) demonstrated gene interchange between *P. glauca* and *P. engelmannii* at intermediate altitudes in British Columbia where the two species overlap.

Our provenance studies consisted of white spruce seedlings from 29 sources grown in a Wisconsin nursery and field-planted in 14 locations across the northern United States and southern Canada. The test region extends from 42° to 48°N in latitude, and from North Dakota to New Brunswick. Seed-source performance was evaluated by height growth of seedlings during 5 years of field testing. The analysis and discussion will consider the adaptation of the plants to the highly variable sites of the test region.

MATERIAL AND METHODS

Seed Collecting and Nursery Handling

Seed was collected in 1955, 1956, and 1957; the Canadian seed source collections were generally stand collections from many parent trees, while the United States collections were from about 10 parent trees per seed source (Table 1).

Table 1. White spruce seed source locations.

Seed source number	State or province	Latitude °N	Longitude °W	Number trees in sample*
1628	S. Dakota	44-10	103-55	13
1630	Montana	46-48	109-31	5
1631	Manitoba	49-51	99-30	S
1644	New York	44-23	74-6	10
1645	Wisconsin	45-41	89-7	10
1646	Minnesota	47-33	94-9	2
1647	Minnesota	47-33	94-10	2
1649	New Hampshire	44-51	71-26	10
1652	Alaska	65-21	144-30	6
1653	Alaska	63-45	144-53	S
1654	Alaska	66-35	145-11	1
1655	Maine	44-50	68-38	15
1657	Labrador	52-36	56-26	S
1658	Labrador	53-46	60-05	S
1659	New Brunswick	47-50	68-21	S
1660	Quebec	46-32	76-30	S
1661**	Quebec	48-18	71-22	S
		48-13	71-38	
1662	Ontario	48	81	S
1663	Ontario	45-44	76-51	S
1664	Manitoba	54-39	101-36	S
1665	Saskatchewan	59-19	105-59	S
1667	Yukon	60-49	135-35	S
1669	Minnesota	47-33	94-8	6
1676	Michigan	44-30	83-45	17
1677	British Columbia	54	123	S
1678	Manitoba	56-56	92-51	S
1686	Ontario	52-15	81-40	25
1687	Ontario	48-30	89-30	S
1697	Saskatchewan	49-40	109-40	S

*S indicates stand collection.

**This seed source includes samples from two areas.

Cold-soaked seed was sown in the Hugo-Sauer Nursery near Rhinelander, Wis. (approximately 45° 40'N), in row plots across the seedbed with four replications. After 2 years in the nursery, the seedlings were transplanted and then grown for another 2 years until field planting in 1962. The distribution of plants to cooperators varied; those in Minnesota received 2-0 stock in 1960 and transplanted the material in local nurseries; the others received 2-2 stock in the spring of 1962 immediately prior to field planting.[1]

Field Testing

All test sites were planted with 2-2 stock except those in Lower Michigan, which were planted with 2-3 stock. Plantation establishment and maintenance varied widely among the 14 locations; trees were planted on intensively cultivated soil at some sites, and directly on the existing sod at others (Table 2). Repeated chemical treatment and fertilization were used in some plantings, while others received little or no maintenance. As a result, mean tree growth varied greatly among plantations, reflecting both the degree of site preparation and maintenance and the actual differences in climate and site.

A randomized block design was used for all tests, but the number of blocks and plot sizes varied. Most commonly used were four-tree plots with 10 blocks. The number of seed sources tested in the plantations also varied, but the basic number was 28 (one Minnesota seed source was excluded). The Denbigh, N.D., planting included only 15 seed sources, but all others had at least 22 (Table 2). Total heights after 5 years of field testing are reported here.

RESULTS

Survival exceeded 80% in all plantings except Denbigh, N.D.; Bergland, Mich.; and Cadillac, Mich. There were significant differences in seedling survival among seed sources in eight of the plantings, due largely to poor survival of seedlings from three Alaskan sources and one Yukon source. The other sources showed only minor differences in seedling survival.

Seed-source differences in seedling height growth after 5 years were highly significant (Table 3). The interaction between the seed sources and plantation environment was also significant, although interaction trends were difficult to determine. A rank correlation analysis between height growth in the nursery and height growth in 11 of the field tests failed to shed much light on the interaction. In all cases, r was positive and relatively high ($r > 0.73$), indicating that the ranking of the seed sources on the basis of height growth was

[1]Thanks are due the following cooperators for their assistance with seed collection and plantation establishment: Mark Holst, Petawawa Forest Experiment Station; Professor S.S. Pauley, University of Minnesota; Professor Jonathan W. Wright, Michigan State University; the Northeastern Forest Experiment Station, USDA Forest Service; and Dr. H.G. MacGillivray, Fredericton, New Brunswick.

Table 2. Location and design of white spruce seed source field tests.

Plantation Number	Plantation location (closest town)	Latitude °N	Longitude °W	No. of replications	No. of seedlings per plot	No. of seed sources	Site preparation	Plantation maintenance
1	Denbigh, N.D.	48.3	100.6	10	4	15	Plowed, disked	Mechanical and chemical release
2	Cass Lake, Minn.	47.3	94.5	10	4	28	Cleared, stumped	Manual and chemical release
3	Grand Rapids, Minn.	47.2	93.5	10	4	26	None	None
4	North Branch, Minn.	45.5	93.0	5	4	22	None	None
5	Cloquet, Minn.	46.6	92.5	5	4	24	None	None
6	Isabella, Minn.	47.5	91.4	10	4	28	Repeatedly disked	Chemical release fertilization
7	Hiles, Wis.	45.7	88.9	4	49	28	Repeatedly disked harrowed	Chemical release and fertilization
8	Bergland, Mich.	46.8	89.2	3	49	28	Roto-tilled	Chemical release and fertilization
9	Cadillac, Mich.	44.3	85.4	4	49	28	Repeatedly disked	Manual and chemical release
10	Hickory Corners, Mich.	42.4	85.4	10	4	24	Disked, harrowed	Unknown
11	Dowagiac, Mich.	42.0	86.0	10	4	24	Herbicided	Unknown
12	Bradley, Maine	44.5	68.4	10	4	24	None	Unknown
13 & 14	Acadia Forestry Station, N.B.	46.0	66.3	10	4	26	Unknown	Unknown

Table 3. Average total height of 28 white spruce seed sources grown in 14 field tests. (In inches)

Seed source number	State or province	Plantation number*														Seed source mean
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1628	S. Dak.	19.7	17.8	32.1	19.0	34.5	26.8	12.0	10.2	13.3	19.9	19.7	18.2	31.4	28.0	21.6
1630	Mont.	12.2	10.5	15.7	--	--	18.5	6.7	7.6	8.2	13.2	14.0	15.6	18.6	23.7	14.5†
1631	Man.	20.4	21.6	40.8	32.0	35.8	32.9	13.3	14.8	13.5	27.6	24.2	21.3	31.4	28.9	25.6
1644	N.Y.	26.0	22.2	46.5	32.4	39.9	35.2	15.5	14.2	18.4	28.3	27.2	22.7	37.2	28.2	28.1
1645	Wis.	20.8	24.7	46.4	31.6	40.1	32.9	16.1	14.4	17.2	34.0	26.3	26.5	37.5	29.1	28.4
1647	Minn.	--	28.6	49.9	30.7	36.0	36.8	17.9	15.3	16.8	33.0	29.0	27.1	42.6	35.5	30.7
1649	N.H.	--	22.4	43.3	28.7	40.5	29.9	13.3	13.5	18.1	28.3	24.3	25.4	41.0	34.0	27.9
1652	Alaska	--	8.3	--	--	--	9.2	5.5	6.3	7.7	--	--	--	--	--	--
1653	Alaska	8.5	13.0	16.2	--	17.9	14.8	7.3	8.3	8.3	17.3	--	13.2	17.3	15.0	13.3†
1654	Alaska	--	10.8	16.2	--	--	11.3	6.6	9.9	8.7	13.5	14.4	12.1	14.0	21.0	13.5†
1655	Me.	--	22.0	43.1	33.3	37.1	31.3	13.4	13.3	17.5	35.3	31.9	23.4	37.9	34.5	28.8
1657	Lab.	--	17.0	22.6	12.7	20.7	21.1	10.7	9.7	11.4	19.1	18.6	16.5	21.6	21.0	17.1
1658	Lab.	--	18.2	27.7	20.4	30.2	25.2	12.5	9.6	12.2	23.1	19.0	19.8	23.3	20.7	20.1
1659	N.B.	22.5	22.3	42.2	23.6	43.7	34.2	14.2	13.6	15.9	30.3	28.8	25.3	41.1	28.5	27.6
1660	Que.	--	25.5	43.5	29.6	38.7	34.4	17.0	15.0	18.3	31.8	28.6	28.3	42.7	34.1	29.8
1661	Que.	--	21.5	40.9	26.4	38.6	33.5	14.6	13.4	15.1	30.5	25.7	22.0	35.9	35.6	27.2
1662	Ont.	--	25.3	45.7	24.6	43.9	35.0	18.8	14.0	17.8	29.3	29.8	25.4	43.0	32.9	29.7
1663	Ont.	29.6	27.1	55.2	34.2	46.3	40.4	16.0	15.0	16.8	33.8	33.2	26.9	47.3	35.1	32.6
1664	Man.	17.2	18.8	33.0	24.6	27.7	25.6	11.6	11.2	12.0	24.7	24.5	20.1	27.9	24.7	21.7
1665	Sask.	13.3	16.7	25.6	15.9	27.9	20.4	8.9	11.1	9.5	17.5	14.4	18.1	22.2	15.8	16.9
1667	Yukon	--	12.3	--	--	--	12.3	6.5	8.8	8.1	--	--	--	--	--	--
1669	Minn.	23.4	26.5	46.5	--	36.6	35.2	15.9	14.9	15.3	31.1	28.6	25.8	37.8	27.0	28.3†
1676	Mich.	21.6	21.0	43.5	36.3	37.7	32.2	13.3	11.9	17.8	34.4	27.3	27.3	34.1	35.5	28.1
1677	B.C.	16.1	13.2	24.0	16.9	33.8	25.9	9.6	10.0	10.7	22.7	18.9	19.2	20.5	26.8	19.2
1678	Man.	--	13.8	--	--	--	17.1	8.5	9.2	10.0	--	--	--	--	--	--
1686	Ont.	--	20.5	32.4	18.6	33.9	28.0	12.5	11.2	13.7	24.2	20.5	23.5	35.3	31.1	23.5
1687	Ont.	23.1	23.3	39.5	29.5	40.0	29.3	15.4	14.2	15.0	25.4	25.7	23.8	36.1	30.3	26.5
1697	Sask.	12.1	12.5	--	--	--	21.1	8.1	8.1	9.7	--	--	--	--	--	--
Plantation Mean		19.1	19.2	36.3	26.1	35.5	26.8	12.2	11.7	13.5	26.2	23.2	22.0	32.4	28.2	24.2
Standard Error of Seed Source Means		1.7	1.6	1.8	3.0	2.5	1.5	.7	.7	.8	1.3	1.3	1.3	2.7	2.4	

*For key to plantation numbers, see Table 2.

†Based on interpolated values at plantings 2 through 14 when the source was not included in those plantings.

relatively uniform from one field test to the next. The significant interaction must, therefore, result largely from the relative magnitude of the response of the seedlings from the seed sources to the changing environment.

To further interpret the data on height growth, we used the technique developed by Finlay and Wilkinson (1963) and applied to tree genetics by Morgenstern and Teich (1968). Finlay and Wilkinson used the method "...to describe the adaptation response of individual varieties to the range of environments in which they were grown and to assess a population of varieties for adaptation and yield performance." Using the mean height growth of seedlings from each seed source and the mean height growth of seedlings from all seed sources at each of the planting sites as items in the analysis, we computed the linear regressions of seed-source means on plantation means for each seed source (Table 4). All but four of the coefficients are based on 11 to 14 plantations. Seed sources 1652, 1667, 1678, and 1697 were included in only five or six plantings, thus their coefficients are less reliable. Because the mean heights of these four seed sources are not comparable to the others, they have been left out of Table 4.

If the correlation coefficients are high, the regression coefficients are measures of the "adaptive stability" of seedlings from the seed sources to the best environments. Clearly, if the scatter of the seed-source means around the regression line is great, the seedlings from the seed sources are low in adaptive stability. A regression coefficient of about 1 indicates average stability; if it is associated with a high mean height growth, the seed source has seedlings with general adaptability to all 14 environments. In other words, the seedlings from this seed source have better than average height growth on all sites and their response to a change in sites closely follows the average response of seedlings from all seed sources in the test. Seed sources 1660, 1662 and 1647 are examples of seed sources having seedlings with general adaptability to the test site conditions (Fig. 1).

On the other hand, if a regression coefficient of 1 is associated with a low mean height growth, it describes a seed source with seedlings poorly adapted to all the environments.

Regression coefficients above 1 describe seed sources with seedlings of below average stability, but with above average response to site improvements. Depending on their mean height, seedlings from such seed sources may grow poorly on low quality test sites, yet outperform seedlings from most other seed sources on the best sites. Or, they may be better than average on all sites and particularly outstanding on the best sites. The one outstanding seed source in this study was 1663, from Beachburg, Ont. Without exception, seedlings from this seed source were above average on all sites and superior on the very best sites. At Grand Rapids, Minn. - the best of the planting sites - their growth exceeded the plantation average by 52% and the average of seedlings from two local sources by 14%.

Regression coefficients below 1 indicate greater resistance to environmental change, that is, above average stability, and therefore

Table 4. Linear regression and correlation coefficients of seed source mean heights at each of the test sites on the mean heights of all the seed sources at the test site.

Seed source number	Number of plantations in test	Linear regression coefficient b	Correlation coefficient r	Seed source mean height inches
1628	14	.893	.95	21.6
1630	12	.505	.79	14.5*
1631	14	1.009	.97	25.6
1644	14	1.098	.96	28.1
1645	14	1.122	.98	28.4
1647	13	1.127	.94	30.7
1649	13	1.154	.98	27.9
1652	5	.206	.87	--
1653	12	.416	.92	13.3*
1654	11	.359	.75	13.5*
1655	13	1.115	.96	28.8
1657	13	.471	.87	17.1
1658	13	.686	.96	20.1
1659	14	1.167	.96	27.6
1660	13	1.064	.98	29.8
1661	13	1.091	.98	27.2
1662	13	1.154	.96	29.7
1663	14	1.429	.97	32.6
1664	14	.793	.97	21.7
1665	14	.636	.93	16.9
1667	5	.349	.86	--
1669	13	1.073	.95	28.3*
1676	14	1.131	.96	28.1
1677	14	.756	.88	19.2
1678	5	.569	.99	--
1686	13	.907	.93	23.5
1687	14	1.005	.99	26.5
1697	6	.815	.97	--

*Based on interpolated values at the plantings where the source was not included.

better adaptation to the low-yielding environments (relative to the seed sources tested). Depending on the mean height, they may actually describe seed sources with seedlings that are better than average on the poor sites, but inferior on the best sites. Or, the seed sources may have seedlings poor on all sites and particularly inferior on the best sites. Sources 1630, 1657, 1658 and 1665 are examples of the latter.

Clinal variation with a latitudinal as well as a longitudinal trend undoubtedly exists within the species. Considering the mean provenance height for all 14 field tests, seedlings from the southeastern Ontario (Beachburg) collection reached the best overall development. In all cases, the farther the provenance was from this area, the poorer the performance of its seedlings (Fig. 2). The regression coefficients follow the same pattern, indicating that the response of seedlings from

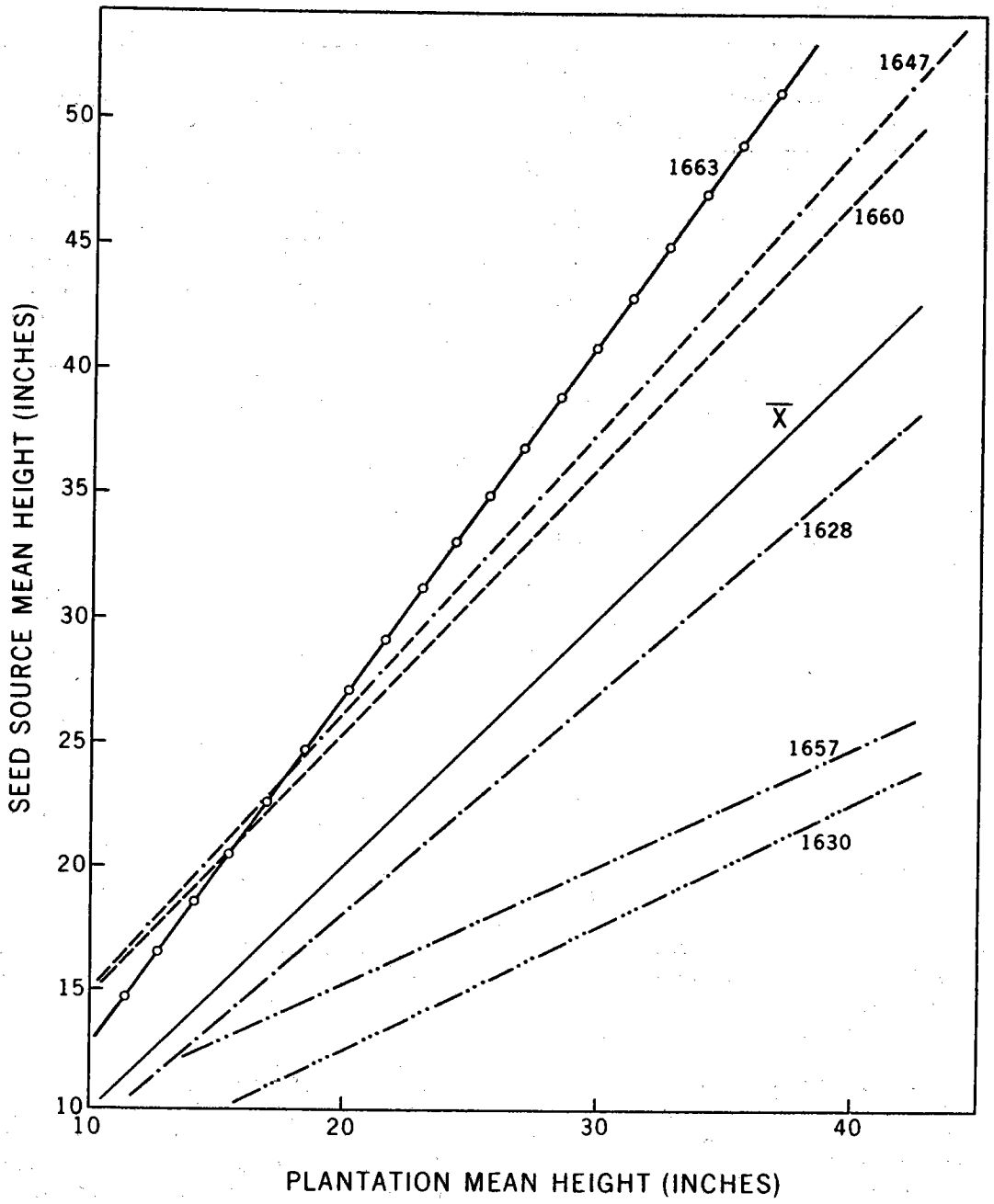

Figure 1. Growth and adaptation of selected white spruce seed sources tested on 14 sites in northeastern United States and southeastern Canada. Seedlings from seed sources 1647, 1660, 1662, and 1663 show good growth and average or below average stability, while those from 1930 and 1957 show poor growth and above average stability.

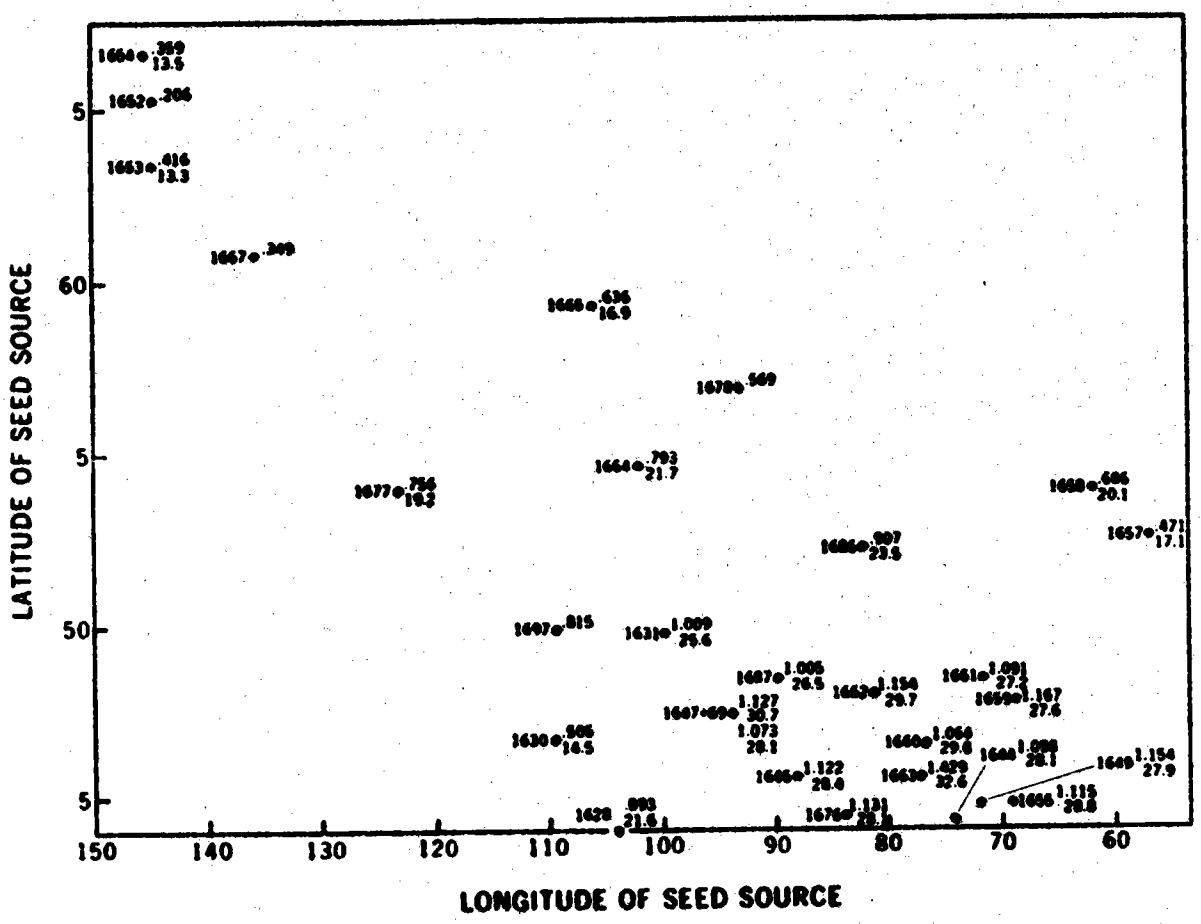

Figure 2. Variation patterns of white spruce seed sources. The number to the left is the seed source number; the upper right number is the regression coefficient (see text) and the lower right number is the average seedling height for seed source for all 14 plantations. Comparable means could not be computed for sources 1652, 1667, 1678, and 1697 (see text).

a seed source to changes in the test site environments decreased in proportion to the distance of the seed source from southeastern Ontario.

The number of seed sources in this study was not large enough to describe the variation in a transcontinental species adequately. However, more complete sampling would probably emphasize clinal variation. Perhaps the southeastern distribution of the species forms one end of a two-pronged cline that extends into northwestern Canada on the west side of Hudson Bay and into Labrador on the east side. The seedlings from southeastern seed sources are characterized by considerable taxonomic variation. In the area where they have been field-tested (from the Lake States to the Atlantic Ocean along the southern edge of the species distribution) seedlings from these southeastern sources show average or below average adaptive stability, but above average growth potential (compared to other seed sources in the test).

The stability indices, that is, the regression coefficients and the mean seed-source heights in this study do not follow the patterns found for barley by Finlay and Wilkinson (1963). They observed varieties of this cultivated plant that were superior on poor sites yet inferior on good sites. They also found the other extreme - varieties inferior on the poor sites yet highly productive on the best sites. We did not find these combinations in white spruce. They tested 277 varieties of barley, and we tested only 28 white spruce seed sources - a fact that may in part explain the difference. Two other explanations are plausible: (1) While the adaptive range for each variety of an ancient cultivated species like barley has been narrowed, the adaptive range for the species as a whole undoubtedly has been extended as a result of selection and breeding for high yield on both good and poor sites. Wild species like white spruce, on the other hand, when competing with other species have simply failed to become established on extreme sites, and types adapted to these sites have not been able to evolve. (2) Seedlings from 11 of 28 seed sources were moved 4° or more south to the most northerly planting site and were, therefore, growing under shorter day length. On the two most southerly sites in Lower Michigan seedlings from all sources were moved south. This would tend to cause early cessation of height growth. Therefore, regardless of the other site qualities, the short day length may not have allowed seedlings from northern seed sources to benefit from high soil fertility or favorable temperature and moisture regimes.

Interpreting the results in terms of the adaptation of the seedlings from these seed sources must be limited to the region of the field tests. The photoperiodic effects in themselves set limits, as do the other environmental factors. Yet, the environments tested probably represent a spectrum wide enough to permit extrapolation to the general region of the test plantations. It should also be pointed out that 5 years of field testing is insufficient to completely evaluate the adaptation of seedlings from these seed sources to highly variable environments. Nevertheless, it might be worthwhile to consider the data from the standpoint of tree breeding. The most important observation is that seedlings from several of the seed sources in the test grew well on all outplanting sites. Seed sources 1647 from the Chippewa National Forest, 1660 from Quebec, and 1662 and 1663 from

Ontario are among the 10 best seed sources in every one of the 14 outplantings. In this connection, it should be mentioned that after 29 years of field testing seedlings from seven white spruce seed sources in northern Wisconsin, seedlings from a Douglas, Ont., source maintain a height growth advantage of 22% over the plantation average and 16% over seedlings from the local white spruce seed source.[2] This indicates that the 5-year data may be reliable.

This study suggests that white spruce from the entire southeastern part of its range might yield excellent material for further tree improvement in the region described by the test plantings. One approach would be to select the best trees of the best seed sources in the 14 outplantings. Another would be to start additional testing of new selections. The entire region should be included, but work should be concentrated in the area between 85° and 72°W longitude and south of 48°N latitude. Considering that the variation among individual white spruce trees is pronounced (Holst and Teich 1966, Jeffers 1968), such tests should be done on an individual tree basis. This procedure promises to lead to new superior strains generally adapted to the entire test region. It is possible that some selections, like seedlings from the Beachburg seed source, would be below average in adaptive stability. Therefore, progeny tests should be widely distributed from the Lake States to New Brunswick, particularly on the best sites.

[2]Data on file at the North Central Forest Experiment Station, Rhinelander, Wisconsin.

REFERENCES

Finlay, K.W. and G.N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Austral. J. Agr. Res. 14:742-754.

Garman, E.H. 1957. The occurrence of spruce in the interior of British Columbia. B.C. Forest Serv., Dep. Lands Forests, Tech. Publ. T-49. 31 p.

Genys, John B. 1965. Growth potentials of fifteen provenances of white spruce from Canada, tested in Maryland. Chesapeake Sci. 6(2):82-85.

Holst, M.J. 1958. Our cooperative white spruce provenance experiment. Can. Dep. North. Affairs Natur. Resources, Forest. Br., Forest Res. Div. 13 p.

Holst, M.J. 1960. Genetics as a factor in quality control. Pulp Pap. Mag. Can. 61:140-144.

Holst, M.J. and A.H. Teich. 1966. Potential genetic improvement in white spruce in Ontario. Can. Dep. Forest. Rural Develop., Forest. Br. Bi-mon. Res. Note 22(5):6.

Jeffers, Richard M. 1968. Parent-progeny growth correlation in white spruce. Can. Comm. Forest Tree Breeding, 11th Ann. Meeting Proc. (In press).

Morgenstern, K.K. and A.H. Teich. 1968. Phenotypic stability of height growth of jack pine. (In press).

Roche, Laurence. 1967. Variation, sélection et amélioration des essences forestières résineuses. Can. Dep. Forest. Rural Develop. Tech. Bull Q-X-1:75 p.

Taylor, T.M.C. 1959. The taxonomic relationship between *Picea glauca* (Moench) Voss and *P. engelmannii* Parry. Madrono 15: 111-115.

INTRASPECIFIC VARIATION AMONG 200 STRAINS OF TWO-YEAR-OLD NORWAY SPRUCE[1]

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INTRODUCTION

Norway spruce (*Picea abies* (L.) Karst.) is an important timber tree of Europe. It provides lumber and is the most significant resource of the pulp and paper industry. In many European countries, Norway is also a preferred Christmas tree, an appreciated ornamental, and a valuable windbreak.

In eastern United States, Norway spruce has long been planted as an ornamental. Some of these early plantings may be traced back to 1876 when seedlings were sold at the Centennial Exposition in Philadelphia (Wright 1956). In some regions, pairs of Norway spruce were planted by newlyweds to symbolize good luck and long life. Many of these trees grew into large and beautiful specimens.

The first large-scale plantations were established in the Adirondack Mountains, New York, in the early 1900's. In these and other early plantings, Norway spruce was a productive tree. Consequently, its use in American forestry rapidly increased. By 1965, the annual planting of Norway spruce totaled nearly ten million trees (Abbott and Eliason 1968). About one-quarter million seedlings of this spruce are planted annually in Maryland alone. Consequently, Norway spruce deserves appropriate attention. Particularly important is the selection of desirable seed sources.

In Europe, Norway spruce grows under diverse conditions from the Arctic Circle to southern France and from lowlands (near sea level) to elevations of 1850 meters. The largest portion of its range is in the Baltic Sea region which includes large areas of Norway, Sweden, and Finland; all of Estonia, Latvia and Lithuania; western parts of Russia; and northern Poland. In the east, Norway spruce of this region introgresses with Siberian spruce (*P. obovata* Ledeb.). To the south, the North Carpathian range of Norway spruce extends from southern Poland through northern and western Czechoslovakia to the Bavarian Forest in Germany. The southeastern range, known as South Carpathian, includes portions of western Ukraine, central Rumania and some outliers in southwestern Bulgaria. The fourth large range of Norway spruce is the Alpine

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which extends from sub-Alpine areas in southern Germany, through Switzerland, Austria and northern Italy, to the southeast - Yugoslavia and Albania - and to the southwest - eastern France. Some isolated outliers of Norway spruce also are found in the North German region - the Harz Mountains and the Lüneburger Heide.

Variation in Norway spruce has been observed for as long as 200 years, particularly the differences in cone color (Rühl 1928). Nurserymen have selected a large number of variants in form and growth rate (Bailey 1933; Rehder 1947). Today many of these are being propagated by grafts or cuttings. There are, however, no described geographic varieties. Despite this, racial variation in Norway spruce has long been proven by European investigators (Dietrichson 1967; Kalela 1937; Langlet 1953, 1961; Rohmeder 1959; Rubner 1957; Schönbach 1957; Stern 1957).

In North America, the first experiments were established with seedlots as part of the International Provenance Trials with Spruce of 1938/39, sponsored by the International Union of Forest Research Organizations (Veen 1952). At an early age, some of these experiments provided valuable information (Heimburger 1944). Later, attacks by white pine weevil (*Pissodes strobi*) and other destructive agents decreased their value for critical studies of growth rates (Holst 1955, 1963; Slabaugh and Rudolf 1957). The summary of the results of these experiments in two locations in Canada and five locations in the United States indicated that provenances from the southeast corner of the Baltic Sea, from Poland, and from White Russia have grown best in the western half of the Great Lakes--St. Lawrence Forest Region (Holst 1964). However, some fast-growing provenances from Rumania (Crucea and Valdu Rau), White Russia (Stolpce), Czechoslovakia (Suinosice), Ukraine (Dolina), and Poland (Istebna) have grown well in a more humid and milder climate along the Atlantic Ocean, including the New England states.

Past experiments in Europe and in North America were designed to offer basic information. A detailed population structure of Norway spruce remained undetermined because these studies were based on only small numbers of sources. A new experiment was needed, and it was started by Prof. O. Langlet, Royal College of Forestry, Stockholm, Sweden, in 1959. This study, known as an Inventory Trial with Spruce, was first established near Stockholm with 1050 seedlots. In 1964, 1322 seedlots were sown near Hamburg, Germany. By now, research plantations, as a part of this trial, are established in 18 different locations, including Canada. Unfortunately, this planting stock was not acceptable to the plant quarantine authorities in the United States. The only shares of this experiment in the United States are 180 seedlots in Maryland (subject of this report) and a smaller number of seedlots which were supplied to Dr. J.W. Wright in Michigan.

The major objective of the study in Maryland was to determine the growth rates of over 200 strains of Norway spruce in the nursery and to learn which geographic regions are most promising in selection of desirable seed sources. Further studies will be continued in the field.

METHODS

The study was made of Norway spruce seedlings grown from 203 different seed sources. Most seedlots (180) were identical with sources used in the Inventory Trial with Spruce by Prof. O. Langlet. The remaining 23 seedlots were acquired independently from individual cooperators.

Before sowing, each seedlot was subdivided into four subsamples and stratified for about 2 weeks in cold (40 F) water. On 5 May 1966, the experiment was started in the State Forest Tree Nursery at Harmans, Maryland. A 4x replicated, completely randomized block design was used with 2-foot rows as plots. The rows were 6 inches apart, and each plot included about 16 trees. In the first winter, seedlings were mulched with straw.

Two characters were studied: date of bud setting and 2-year height. During the fall of 1966 when at least 50% of the seedlings in a plot had set their terminal buds, this was recorded as the bud-setting date. Two-year heights were determined by measuring the largest seedling in each portion of a 6-inch row (four seedlings per plot). Plot means for heights and days of the year for the bud setting were used as items in the analysis of variance. Degrees of freedom totaled 811 (202 for varieties, 3 for blocks, and 606 for interaction). The multiple range test was used to determine the least significant difference among the strains, and a regular correlation analysis was applied to learn the relationship between the dates of bud setting and the heights. The data on seed weights of 180 sources were received from P. Krutzsch (Sweden).

RESULTS

The growth rate of Norway spruce originating from different parts of its range was distinctly variable (Table 1). Two-year heights of strains from different geographic sections ranged from 6.6 cm (Finland) to 18.0 cm (Lüneburger Heide, Germany). This variation was even larger among individual strains, extending from 5.3 cm (a progeny from Finland) to 19.3 cm (a source from Beerfelden, near Heidelberg, Germany). Strains classified by their growth rate in Table 1 also showed a considerable diversity among the sources originating from similar geographic areas. This variation was particularly evident among the progenies from regions with varying altitudes.

Table 1 also shows that all sources of Norway spruce from its northern range (Finland, Sweden, Lithuania, and White Russia) grew slowly. Only four strains from the Baltic range - those from northern Poland - grew at an average rate. Norway spruce from the North Carpathian region had variable heights. Two sources from southern Poland and one source from the Fichtel Mountains grew at an average rate, while strains from the Bavarian Forest and Czechoslovakia included four rapidly growing progenies, eight sources with average heights, and eleven progenies with inferior heights. This strong within-region variation was apparently due to differences in altitude. In contrast to the Baltic sources which included no strains with superior heights,

Table 1. Two-year performances of different strains of Norway

Origin of seedlots Region (sub-range) Country or geographic section of Germany (G)	Strains studied	Mean height	Strains with superior heights*				
			Strains	Mean height	Elevation	1000 seed weight	Bud set after August 8 (1966)
	no	cm	no	cm	100 m	gr	day
Baltic							
Finland	3	6.6	0	-	-	-	-
Lithuania	2	10.4	0	-	-	-	-
Sweden, Southern	1	11.5	0	-	-	-	-
White Russia	1	12.8	0	-	-	-	-
Poland, Northern	4	14.4	0	-	-	-	-
North Carpathian							
Poland, Southern	2	14.9	0	-	-	-	-
(G) Fichtel Mountains	1	16.8	0	-	-	-	-
Czechoslovakia	2	12.9	0	-	-	-	-
(G) Bavarian Forest	21	13.3	4	18.1	-11	8.5	34
North German							
(G) Lüneburger Heide	1	18.0	1	18.0	-1	9.1	22
(G) Harz Mountains	10	16.9	5	18.0	1-6	8.4	35
(G) Western Hills	6	15.9	1	19.3	3-6	7.5	37
Sub-Alpine and Alpine							
(G) Upper Neckar	3	16.1	1	17.5	7	8.4	36
(G) Jura	31	16.1	6	17.8	3-7	8.0	31
(G) Bavaria (Sub-Alpine)	29	16.2	5	17.9	1-7	7.9	36
(G) Schwarzwald	17	15.8	2	17.9	7-10	8.1	36
(G) Bavarian Moraines	22	15.7	3	17.4	3-9	8.0	34
(G) Bodensee and Oberschwaben	20	15.9	3	17.5	-7	7.9	31
(G) German Alps	13	14.1	0	-	-	-	-
Austria	2	14.6	0	-	-	-	-
France	2	14.4	1	17.5	8-9	-	34
South Carpathian							
Rumania	5	15.5	1	17.5	-9	7.6	32
Origin Uncertain							
Plantations	3		1	17.5	(Md.)	-	39
(?) "Alps"	2		1	17.5	-	-	39

*Strains that grew at least 17 centimeters and were significantly (at the 5 per cent level) larger than "strains with inferior heights" (listed in the third column).

spruce in Maryland (at the State Forest Tree Nursery in Harmans).

Strains with average heights					Strains with inferior heights				
Strains	Mean height	Elevation	1000 seed weight	Bud set after August 8 (1966)	Strains	Mean height	Elevation	1000 seed weight	Bud set after August 8 (1966)
no	cm	100 m	gr	day	no	cm	100 m	gr	day
0	-	-	-	-	3	6.6	Low	-	1
0	-	-	-	-	2	10.4	1-2	-	7
0	-	-	-	-	1	11.5	Low	-	23
0	-	-	-	-	1	12.8	2-3	-	10
4	14.4	1-2	7.3	16	0	-	-	-	-
2	14.9	5-6	8.3	29	0	-	-	-	-
1	16.8	8-9	8.3	32	0	-	-	-	-
1	14.3	-	-	23	1	11.5	-	-	7
7	15.4	-11	8.1	27	10	9.9	11+	7.5	8
0	-	-	-	-	0	-	-	-	-
5	15.7	3-6	8.3	32	0	-	-	-	-
5	15.3	3-6	8.1	26	0	-	-	-	-
2	15.4	3-7	8.2	33	0	-	-	-	-
25	15.7	1-7	7.7	31	0	-	-	-	-
24	15.9	3-7	7.6	34	0	-	-	-	-
14	15.6	3-10	7.6	30	1	12.3	7-8	7.5	27
18	15.7	6-9	7.3	30	1	11.3	9	6.8	29
16	15.7	5-10	7.4	30	1	13.3	5-6	7.2	30
11	14.6	9-11	7.7	26	2	11.8	8-13	7.4	18
1	16.3	5-7	-	36	1	12.8	High	-	7
0	-	-	-	-	1	11.3	12	-	19
3	15.6	9	7.5	33	1	13.3	11	7.2	34
1	15.5	(Sweden)	7.4	27	1	12.5	(Rügen Is.)	8.3	22
1	16.3	-	-	27	-	-	-	-	-

the 17 sources from the North German region, 3 sources from Upper Neckar, 31 sources from German Jura, and 29 sources from Bavaria (in the sub-Alpine region) included no strains with inferior heights. A particularly high ratio of outstanding strains (five out of ten) came from the Harz Mountains in the North German range. A single source studied from the Lüneburger Heide also grew rapidly. Most sub-Alpine sources grew at an average rate. For instance, Schwarzwald (Black Forest), long considered a prime source of Norway spruce, was represented by 14 strains with average heights, two strains with outstanding heights, and one strain with inferior height. Similar variations were evident among the sources from Bavarian Moraines, the Bodensee region, and Oberschwaben. The sources from the German Alps and from Austria included no strains with superior heights. Among the sources from this region and from France, the high-elevation strains grew slower than those from lower altitudes. A similar altitudinal variation was evident among the five sources from Rumania which included one rapidly growing progeny, three progenies with average heights, and one progeny with inferior height.

Seedlings from a planted Norway spruce in Maryland equaled in height and other characters some sources from Bavaria. Another progeny from planted trees in Germany (Rügen Island) was more similar to the true Swedish source than a progeny from a plantation in Sweden (Hjuleberg). At this stage of our study, it is difficult to determine if some other sources grouped by geographic regions were, in fact, of non-native origin. This is, however, quite possible among the sources from Germany where Norway spruce has been planted for centuries.

Two-year heights of different strains were strongly correlated ($r = .825$) to the date of bud setting (day of the year when 50% of the terminal buds were set in the first year). This correlation suggests that about 68% ($r^2 = .68$) of the sources with large heights were those that formed their terminal buds late or vice versa -- about 69% of the slow-growing sources were those that set their terminal buds early. In fact, the bud-set date varied by 6 weeks. Sources from Finland formed their buds as early as August 8 (in 1966), while some Bavarian sources (particularly those from the Franken Jura) grew 6 weeks longer, until September 20. The time of bud setting among other sources was also significantly different, depending on geographic origin. Table 1 shows an interesting delay of bud setting by progenies from north to south and from high to lower elevations. For instance, there was a 2-week difference in bud-set date between sources from Finland and those from northern Poland and another 2-week difference between the northern and southern strains from Poland. One of the sharpest contrasts in bud-setting date (3 to 4 weeks) was between the high-elevation and the low-elevation strains from Austria and among some sources from different elevations in the Bavarian Forest.

Elevation, or climatic conditions related to different elevations, must have been a strong factor which influenced the evolution of different geographic strains. Most within-region variations in height growth and in time of bud set were associated with differences in altitudes. This is particularly evident among the sources from the mountainous regions (the Alps and the Carpathians). In general, the progenies from higher elevations formed terminal buds earlier and grew slower than the sources in the same region from lower elevations.

The change of characters with increasing elevations may be clinal, but this cannot be proven on the basis of present data (elevations for many seedlots were expressed by broad ranges, permitting no precise correlation analysis).

Seed weights of different sources ranged from 6.5 to 9.1 g per 1000 seeds. Table 1 indicates that seeds from northern Poland (northern range) and from Rumania (southern range) were relatively light. In contrast, all seedlots from Harz and Lüneburger Heide were heavy. Apparently, this variation in seed weight was associated with geography. Seedlots from high elevations in the Bavarian Forest were also somewhat lighter than those from lower elevations. However, more data are needed to learn if such altitudinal differences hold true.

DISCUSSION

From the genecological point of view, Norway spruce again proved itself as a very variable species. In general, its northern sources formed terminal buds early and grew slowly; the southern sources set terminal buds later and grew more rapidly. This general trend, however, was modified by altitudinal differences and other factors. The sources from high elevations were somewhat similar to sources from northern latitudes. They formed terminal buds earlier and were smaller than sources in the same region from lower altitudes. It is apparent that climatic variation is one of the strongest factors associated with the evolution of different geographic strains. For instance, the date of terminal bud setting was well adjusted for resistance to early frosts (early in northern regions and in the mountains, later in the south and in the southern lowlands).

On the basis of rapid growth, the results of this study suggest that the strains from the Harz Mountains may well be recommended for practical use. The ten sources from this region included no progenies with inferior heights and the highest ratio of strains with superior heights (five out of the ten). Further studies may disclose that some individual strains from other regions may prove to be as desirable or even more desirable. Such progenies in the nursery were German strains from Beerfelden (near Heidelberg) and from Walsrode (in Lüneburger Heide).

Norway spruce from the Baltic range (Sweden, Finland, Lithuania, White Russia and northern Poland) grew either slowly or were average but included no strains with outstanding heights. Also, no rapidly growing strains came from southern Poland and Czechoslovakia. Apparently, Norway spruce from eastern Europe was less outstanding in Maryland than in some IUFRO plantings in more northern regions. High-elevation sources of Norway spruce also were not promising for rapid growth.

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LITERATURE CITED

Abbott, H.G. and E.J. Eliason. 1968. Forestry tree nursery practices in the United States. J. Forest. 66(9):704-711.

Bailey, L.H. 1933. The cultivated conifers in North America. The MacMillan Co., New York. 404 pp.

Dietrichson, J. 1967. Broad sense heritability estimates of growth rhythm and height growth of Norway spruce (*Picea abies* L. Karst.) seedlings of south Norwegian origin. Reports of the Norwegian Forest Res. Inst. 23(85):207-221.

Heimburger, C.C. 1944. Strain tests of Scotch pine and Norway spruce. Dominion Forest Serv., Can. Report No. 49351, mimeo. 9 pp.

Holst, M.J. 1955. Breeding for weevil resistance in Norway spruce. Zeits. Forstgenetik u. Forstpflanz. 4(2):33-37.

Holst, M.J. 1963. Growth of Norway spruce (*Picea abies* L. Karst.) provenances in eastern North America. Can. Dep. Forest. Publ. 1022. 15 pp.

Holst, M.J. 1964. Forest tree breeding and genetics at the Petawawa Forest Experiment Station. Proc. 9th Meeting of the Comm. on Forest Tree Breed. in Canada: 63-107.

Kalela, A. 1937. Zur Synthese der experimentellen Untersuchungen über Klima-Rassen der Holzarten. Comm. Inst. For. Fenniae, 26, Helsinki. 434 pp.

Langlet, O. 1953. Några data från det internationella granproveniensförsök et av 1938 i Sverige. Skogen 40:238-239; 244-245.

Langlet, O. 1961. Central European spruce provenances in Swedish forestry. K. Skogs-o Lantbr. Akad. Tidskr., Stockh. 99:259-327.

Rehder, F. 1947. Manual of cultivated trees and shrubs, hardy in North America. The MacMillan Co., New York. 996 pp.

Rohmeder, E. 1959. Beispiele für die Überlegenheit fremder Provenienzen über die einheimische Standortsrasse bei den Baumarten *Pinus silvestris* und *Picea abies*. Allg. Forstzeitschr. 14:756-760.

Rubner, K. 1957. Ergebnisse eines heute 20 jährigen Fichtenherkunftsversuches, I. Teil. Die Fläche in Bayern. Silvae Genet. 6:65-74.

Rühl, A. 1928. Vorläufige Mitteilung über das Auftreten rot-und grünzapfiger Fichten in Estand. Tartu Ülikooli Metsaosakonna toimetused nr. 12:43-56.

Schonbach, H. 1957. Ergebnisse eines heute 20 jährigen Fichtenprovenunzversuches, II. Teil. Die Flächen in Thüringen und Sachsen. Silvae Genet. 6:74-91.

Slabaugh, P.E. and P.O. Rudolf. 1957. The influence of seed source on the development of Scotch pine and Norway spruce planted in Lower Michigan (fifteen-year results). Pap. Mich. Acad. of Sci., Arts, and Letters XLII:41-51.

Stern, K. 1957. Über die Regression des Samengewichtes zur Keimpflanzengrösse bei der Fichte. Silvae Genet. 6:155-156.

Veen, B. 1952. Report of a tour of inspection along the test areas of the International Provenance Trials with larch, pine and spruce of 1938/39 and 1944/45, and suggestions for future treatment and assessments. I.U.F.R.O. (Section 22) leaflet. 44 pp.

Wright, J.W. 1956. Cultivated spruces in the Philadelphia area. Morris Arbor. Bull. 7(4):52-57.

SURVIVAL AND HEIGHT GROWTH OF RED SPRUCE PROVENANCES IN THREE EXPERIMENTS IN ONTARIO

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INTRODUCTION

Red spruce, *Picea rubens* Sarg., has received little attention from forest geneticists until recently. Although its range and genetic relationship to other spruce species are now much better known than 30 years ago (Heimburger 1939, Wright 1955, Gordon 1957, Holst 1957, Morgenstern and Farrar 1964), there is still not a single report on silvicultural characters from provenance studies. In 1951 Mr. Mark Holst of the Petawawa Forest Experiment Station initiated a provenance study which was then probably the first for this species anywhere. Seed and plant material from this investigation has been widely distributed to establish provenance trials in eastern North America, and has also been sent to Europe. Foresters who have supported it, either by assisting with seed collections, or by planting experiments, will be interested in the first results reported in this paper.

OBJECTIVES

The general objective of provenance studies with red spruce is to locate populations of wide ecological amplitude which are superior to native populations with regard to silvicultural characters. Of special interest is the growth and hardiness of populations from the southern Appalachian Mountains (Heimburger and Holst 1955).

MATERIALS AND METHODS

Between 1951 and 1953, seed from 20 stands was collected throughout the species range. Seed was bulked on a stand basis, each stand being represented by an average of 20 trees. The origin of the 12 provenances common to the three experiments in Ontario is given in Table 1. Nursery sowings were made at the Petawawa and Acadia Forest Experiment Stations in 1954 and 1955, and some Acadia seedlings were shipped for transplanting to Petawawa in 1957. In 1959 the 14 provenances at Petawawa were examined together with other material to test hypotheses regarding introgressive hybridization between red spruce and black spruce, *Picea mariana* (Mill.) BSP. Using needle color, bud

Table 1. Origin of the 12 provenances common to the three experiments.

Seedlot No.	Place of Origin	Latitude °N	Longitude °W	Elevation 100 ft
2019	Indian Gap, N.C.	35.6	83.5	53
2020	Glade Run, W. Va.	38.6	79.8	38
2021	Bear Meadows, Pa.	40.7	77.7	18
2022	October Mtn. State Forest, Mass.	42.4	73.2	18
2024	Upper Jay, N.Y.	44.4	73.7	20
2031	Andorra Forest, N.H.	43.1	72.1	17
2032	Valcartier For. Exp. Sta., Que.	46.9	71.5	9
2033	St. Charles de Mandeville, Que.	46.5	75.3	7
2100	Sheet Harbour Waters, N.S.	45.2	62.7	2
2101	Corberrie, N.S.	44.2	65.9	2
2102	Great Salmon River, N.B.	45.4	65.4	2
2103	Acadia For. Exp. Sta., N.B.	46.0	66.3	2

color, twig color, twig surface shape, and hair type a hybrid index (Anderson 1949) was constructed and introgressive hybridization could be demonstrated (Morgenstern and Farrar 1964).

Three experiments were then established as follows: two were planted at the Petawawa Forest Experiment Station, one in 1958 and the other in 1960; and the third in the University of Toronto Forest near Dorset in 1960. The three experimental areas differed with respect to experimental design, soil texture, soil moisture and regional climate (Table 2).

Following the 1967 growing season, when the trees were 13 years old from seed, total height and survival were recorded. Height at Arbour's Field, Petawawa, was measured to the top of the 1966 leader because the trees in that experiment were one year older. Measurements were made in 5-cm classes and plot means were calculated.

The measurements in each experiment were subjected to analysis of variance. Survival percentages were transformed by arcsin (Snedecor 1956, p. 316) before analysis. A combined analysis of variance was made for all three experiments to calculate variance components for the provenance-location interaction. Correlations were computed with latitude, elevation, length of the frost-free season, June-August precipitation, and the hybrid index (Morgenstern and Farrar 1964).

RESULTS AND DISCUSSION

The general condition of the two Petawawa experiments was characterized by slow initial growth, winter drying of the needles, and considerable mortality and spring frost damage in some provenances, particularly on the grassy site at Arbour's Field. The experiment at Dorset suffered less from desiccation and frost, but was attacked more severely by the white pine weevil, *Pissodes strobi* Peck., than the Petawawa experiments. Survival at the three sites did not differ greatly. The mean height of the experimental plantations had the following sequence: Arbour's Field < Fuelwood Area < Dorset. Height therefore increased with the moister soil in the Fuelwood Area and the more humid regional climate at Dorset (Table 3).

The analysis of variance showed that differences among provenances in survival percentages were not statistically significant at the 5% level at two locations, but were significant at even the 1% at the third, Arbour's Field. For this location, the multiple-range test (Duncan 1955) indicated that the two southern provenances from North Carolina and West Virginia with a survival of 39-40% differed from the Pennsylvania, Quebec and some New Brunswick and Nova Scotia provenances with a survival of 64-72% (Table 4). This very pronounced provenance reaction to a seasonally dry, grassy site with spring frost is also seen in the combined analysis of variance of all three experiments. In this analysis, the variance component for provenance-location interaction accounted for 79% of total variance, locations for 21%, leaving 0 for provenances.

Variation in total height was more pronounced than that of survival. The analysis of variance indicated differences, significant at the 1% or the 0.1% level, at each of the three locations. The provenance-location interaction contributed 7%, provenances 36%, and locations 57% of the total variance. The low variance component for interaction expressed the fact, seen in Table 4, that there was a very limited change in rank of the provenances at the three locations: as a group, northern provenances from continental climates in Quebec and New Brunswick were tallest; central provenances from New York and New England and some northern Maritime provenances from New Brunswick and Nova Scotia intermediate; and southern provenances, from North Carolina and West Virginia, usually shortest. The multiple-range test indicated that the differences among these groups were significant at the 1% level in the two Petawawa locations; at Dorset the first and the second group were not as clearly separated (Table 4). The Dorset experiment, although growing best, was least efficient from the statistical viewpoint as shown by its large standard error of a provenance mean (Table 3).

The correlation analysis provided some indications of geographic and genetic relationships. Correlations with climatic variables (length of the frost-free season and June-August precipitation) at the place of seed origin were not significant and will not be presented here. The best correlation of height in all three experiments was with the hybrid index established in the same provenances at an earlier stage (Morgenstern and Farrar 1964). Height was also correlated with latitude and elevation but to a lesser degree. Survival correlations were significant only in the experiment at

Table 2. Description of the three experimental areas.

Exp. No.	Location	Latitude °N	Longitude °W	Moisture Region*	Soil	Number of Replications**	Trees per Plot	Year of Planting
95-G	Petawawa F.E.S., Arbour's Field	46.0	77.5	B_2 Moist humid	Sand dry-fresh	3	40-100	1958
95-H	Petawawa F.E.S., Fuelwood Area	46.0	77.5	B_2 Moist humid	Glacial till fresh	6	49	1960
95-N	Univ.Toronto Forest, Dorset	45.1	78.9	B_3 Wet humid	Glacial till fresh	3	49	1960

*Sanderson, M. 1948. Climates of Canada according to the new Thornthwaite classification. Sci. Agr. 28:501-517.

**The randomized block design was used in each experiment.

Table 3. Summary of survival and height data for the three experiments, giving range of provenance means, general mean, and standard error of a provenance mean.*

Experiment No.	Range		General Mean		Standard Error	
	Survival %	Total Height cm	Survival %	Total Height cm	Survival % Transformed	Total Height cm
95-G Arbour's Field, P.F.E.S.	41-91	54-153	74.1	88	5.44	6.48
95-H Fuelwood Area, P.F.E.S.	75-86	98-153	79.5	118	3.09	5.80
95-N Univ.Forest, Dorset	56-85	99-169	66.5	139	4.55	9.68

* $s_m = \sqrt{\frac{\text{Error mean square}}{\text{Number of replications}}}$ (Duncan 1955)

Table 4. Results of Duncan's multiple-range test. Provenance means not connected by vertical lines are significantly different at the 1-percent level. Survival percentages differed significantly only in Exp. 95-G, and only these are shown.

	Exp. 95-G Arbour's Field, Petawawa F.E.S.			Exp. 95-H Fuelwood Area, Petawawa F.E.S.		Exp. 95-N University Forest, Dorset	
Provenance	Survival % Transf.	Provenance	Height cm	Provenance	Height cm	Provenance	Height cm
Acadia	72.2	St. Charles	153	St. Charles	153	St. Charles	169
Bear Meadows	69.3	Acadia	116	Acadia	140	Bear Meadows	159
Corberrie	66.6	Bear Meadows	109	Bear Meadows	137	Corberrie	157
St. Charles	65.9	Valcartier	101	Valcartier	134	Acadia	155
Valcartier	64.9	Sheet Harbour	86	Corberrie	127	Valcartier	144
October Mtn.	63.7	Corberrie	83	Upper Jay	110	Sheet Harbour	142
Salmon River	61.7	Salmon River	79	Sheet Harbour	107	Salmon River	134
Sheet Harbour	60.1	October Mtn.	74	October Mtn.	106	Andorra For.	131
Andorra For.	59.4	Andorra For.	71	Indian Gap	106	October Mtn.	128
Upper Jay	47.6	Upper Jay	67	Andorra For.	102	Upper Jay	125
Indian Gap	41.5	Indian Gap	59	Salmon River	101	Indian Gap	124
Glade Run	39.7	Glade Run	54	Glade Run	98	Glade Run	99

Table 5. Correlation coefficients† in Exp. No. 95-G at Arbour's Field, Petawawa Forest Experiment Station.

	X_1	X_2	X_3	X_4	X_5
X_1 Height	1.00	+0.72**	-0.82**	+0.59*	-0.56
X_2 Survival		1.00	-0.57	+0.68*	-0.82**
X_3 Hybrid index			1.00	-0.62*	+0.65*
X_4 Latitude				1.00	-0.92***
X_5 Elevation					1.00

†Significance levels: *, 5%; **, 1%; ***, 0.1%.

Arbour's Field, and here the correlations with elevation and latitude were higher than with hybrid index. Table 5 shows the correlations obtained in this experiment.

The first results from these red spruce experiments, demonstrating the important role of introgressive hybridization between red spruce and black spruce, are unusual and perhaps different from what was expected at the time of planning and establishment. Most provenance studies indicate the effects of natural selection by photoperiod and temperature (Wareing 1956, Stern 1964) while effects of introgressive hybridization have rarely been recorded or emphasized. Introgressed populations in the overlapping distribution area of red spruce and black spruce have been known for some time (Heimburger 1939, Holst 1957, Morgenstern and Farrar 1964), and it is therefore not surprising that the gene exchange of the two physiologically very different species has some silvicultural consequences. Black spruce requires more light than red spruce but probably is more tolerant of variation in soils and nutrients. It grows more rapidly at an early age and therefore suffers less from frost in habitats with poor air drainage. The limited flow of black spruce genes to red spruce, which is the basis of introgression, nevertheless does not lead to the loss of identity of red spruce. Populations still exist which develop successfully in mixtures with hardwoods. Yet the greater range of variation introduced by black spruce may be beneficial particularly where clearcutting and artificial regeneration are practiced.

It is recognized that these results come from a limited area. A more complete evaluation of red spruce provenances will be possible after additional experiments in Quebec, the Maritimes, and New England have been measured and assessments have been repeated over a longer time period. Furthermore, different responses could be expected with experiments planted into the shelter of hardwoods.

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LITERATURE CITED

Anderson, E. 1949. Introgressive hybridization. Wiley and Sons, New York. 109 p.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Gordon, A.G. 1957. Red spruce in Ontario. Sylva (Toronto, Ontario) 13(1):4-10.

Heimburger, C.C. 1939. Notes on red spruce. Forest. Chron. 15: 226-227.

Heimburger, C.C., and M. Holst. 1955. Notes from a trip to the southern United States January, 1953. Forest. Chron. 31:60-73.

Holst, M.J. 1957. Annual report 1956-57. Forest tree breeding and genetics at Petawawa Forest Experiment Station. Proc. 5th Meetg. Comm. Forest Tree Breedg. in Can., Chalk River, Ont., 1957. Part II. 14 p.

Morgenstern, E.K., and J.L. Farrar. 1964. Introgressive hybridization in red spruce and black spruce. Univ. Toronto, Fac. Forest., Tech. Rep. 4. 46 p.

Snedecor, G.W. 1956. Statistical methods. Iowa State College Press, Ames, Iowa. 534 p.

Stern, K. 1964. Herkunftsversuche für Zwecke der Forstpflanzenzüchtung, erläutert am Beispiel zweier Modellversuche. Züchter 34: 181-219.

Wareing, P.F. 1956. Photoperiodism in woody plants. Ann. Rev. Plant Physiol. 7:191-214.

Wright, J.W. 1955. Species crossability in spruce in relation to distribution and taxonomy. Forest Sci. 1:319-349.

PARENT-PROGENY GROWTH CORRELATIONS IN WHITE SPRUCE

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White spruce attains commercial size from the Yukon across Canada to Newfoundland and Nova Scotia and the northeastern United States -- an area of uniformly severe winters. It is one of the most economically important timber species in the boreal forest. Currently, spruce (mostly white spruce) ranks fourth in pulpwood production in the Lake States and the average annual production of spruce from 1961 through 1965 was 341 thousand cords. In 1967 the Wisconsin stand nurseries alone contained nearly 11 million white spruce seedlings and transplants. More than 4 million white spruce were planted in 1967 on six national forests in the Lake States.

Since white spruce is easily planted and grows on a variety of soils, interest in the genetics of this species has been steadily increasing. There is much phenotypic variability in this species in terms of vigor, height growth, form, and branchiness, not only between widely separated stands but also within and between stands within the same region. White spruce may be readily hybridized with several other spruce species. This species is therefore a logical object of an intensive tree improvement program.

While seed source studies of white spruce have been underway for many years in the Lake States, northeastern United States, and Canada, heritability studies, on the other hand, have received little attention until recently. Consequently, there is little published information on inheritance in North American spruce species. Holst and Teich (1966), working with 11-year-old white spruce progenies from nine pairs of dominant trees from the Carnarvon - Algonquin Park - Sundridge area, found that significant differences occur in height and leader number both among progenies from different stands and among progenies from individuals within the same stand. Within stands, slender-crowned plus-tree types produced progenies 4% taller than those from broad-crowned trees. They also reported narrow sense heritabilities of: 85% for number of leaders, 75% for height, 57% for branch length relative to leader length, and 0% for branch length. Holst and Teich also determined heritability estimates for height and leader number at age eight for progenies from 26 open-pollinated plus-trees selected at random at the Petawawa Forest Experiment Station and found these to be 87% and 68%, respectively.

Cram and Lindquist (1961) reported that the height of 13-year-old open-pollinated progenies of 24 Colorado blue spruce selections was closely related to the height of the same progenies at age eight, with a correlation coefficient of 0.88.

King, Nienstaedt, and Macon (1965) demonstrated that white spruce seedlings selected on the basis of superior nursery performance maintained their height growth advantage over average 2-2 nursery stock after seven growing seasons in the field.

In order to more intensively test the heritability of important traits in white spruce, a comprehensive study was begun at the Institute of Forest Genetics at Rhinelander, Wisconsin, in 1965. This report deals with parent-progeny growth correlations.

MATERIAL AND METHODS

Thirty-two white spruce parents growing at various locations in the Upper Peninsula of Michigan, northeastern Wisconsin, and northern Minnesota were selected on the basis of vigor, height growth, form, needle length, branchiness, or branch angle. While one individual might have been selected for outstanding form, another might have been selected for its short needles. Average yearly growth of the female parents, determined by dividing the total height (cm) by the estimated total age of the parent at time of measurement, ranged from 20.6 to 40.1 centimeters. Open-pollinated seed collected from these trees was sown in a randomized block design with four replications in the Hugo Sauer State Nursery at Rhinelander, Wisconsin, in the fall of 1963. As many as 120 seedlings per half-sib family were transplanted in each of four replications in a randomized block design in the fall of 1965. In 1967, after the 4th growing season, the total height and 1967 growth were measured on 10 seedlings per family in each replication or a total of 40 seedlings per half-sib family (Table 1). At time of measurement four families had insufficient number of seedlings for measurement, so the number of half-sib families was reduced to 28 (Fig. 1).

STATISTICAL ANALYSES AND RESULTS

An analysis of variance performed on the 1967 progeny growth data for the 28 half-sib families showed that significant differences occurred between families.

Analysis of variance - 1967 growth (cm) for 28 white spruce half-sib families at age four

Source of variation	D.F.	M.S.	F.	Level of Significance
Total	111			
Replications	3	12.13	2.62	N.S.
Families	27	32.04	6.94	0.5%
Error	81	4.62		

Table 1. Parent descriptions and progeny current annual growth and total height at age four.

Parent Descriptions										Progeny Average 1967 Growth and Total Height at Age Four	
L.S.No.	Year Seed Collected	State	County	Lat. °N	Long. °W	DBH (inches)	Ht. (feet)	Age (years)	Yearly Growth (cm)	1967 Growth (cm)	Total Height (cm)
683-1	1956	Mich.	Alger	46.5	87.0	10.3	54	51	32.3	9.5	19.7
5	"					7.2	39	51	23.3	8.6	17.8
686-1	1956	Mich.	Marquette	46.2	87.5	17.4	44	47	28.6	10.4	19.6
2	"					11.9	36	38	28.9	10.3	19.5
5	"					11.2	33	39	25.8	7.4	16.5
10	"					9.3	39	42	28.3	12.6	23.4
687-2	1956	Mich.	Marquette	46.2	87.6	17.3	65	72	27.5	10.2	20.4
5	"					15.0	66	74	27.2	11.8	22.1
688-8	1956	Mich.	Marquette	46.5	87.7	8.0	30	36	25.4	9.5	18.7
691-2	1956	Mich.	Marquette	46.5	88.1	13.6	50	54	28.2	7.4	15.6
8	"					11.8	57	68	25.6	10.5	19.5
10	"					12.2	61	76	24.5	9.7	19.2
692-6	1956	Mich.	Marquette	46.8	87.6	16.7	62	60	31.5	7.5	15.3
8	"					10.5	48	71	20.6	7.2	14.4
10	"					9.2	47	41	35.0	12.9	25.2
1885	1959	Wis.	Menominee	44.9	88.7	9.3	49	38	39.3	18.4	30.5
1886	"					7.9	39	38	31.3	11.7	22.4
1887	"					9.5	50	38	40.1	18.4	30.3
1888	"					8.3	45	38	36.1	14.0	24.6
1889	"					7.3	46	38	36.9	15.2	26.2
1890	"					8.7	46	38	36.9	12.4	22.1
1892	1960	Wis.	Ashland	46.1	90.7	18.6	68	73	28.4	12.3	22.3
1893	"					21.4	72	76	28.9	10.9	20.9
1894	"					15.3	64	64	30.5	11.3	21.6
1895	"					18.8	75	68	33.6	12.4	23.9
2511	1962	Minn.	Koochiching	48	94	28.7	123	130	28.9	10.0	18.5
2523*	"	Wis.	Forest	45.8	88.8	20.8	103	95	33.1	12.2	22.9
2526	"	Mich.	Ontonagon	46.4	89.2	20	100	90	33.9	11.5	22.6
								Mean	30.4	11.3	21.3

*Seed from parent 2523 were collected from grafts of this parent.

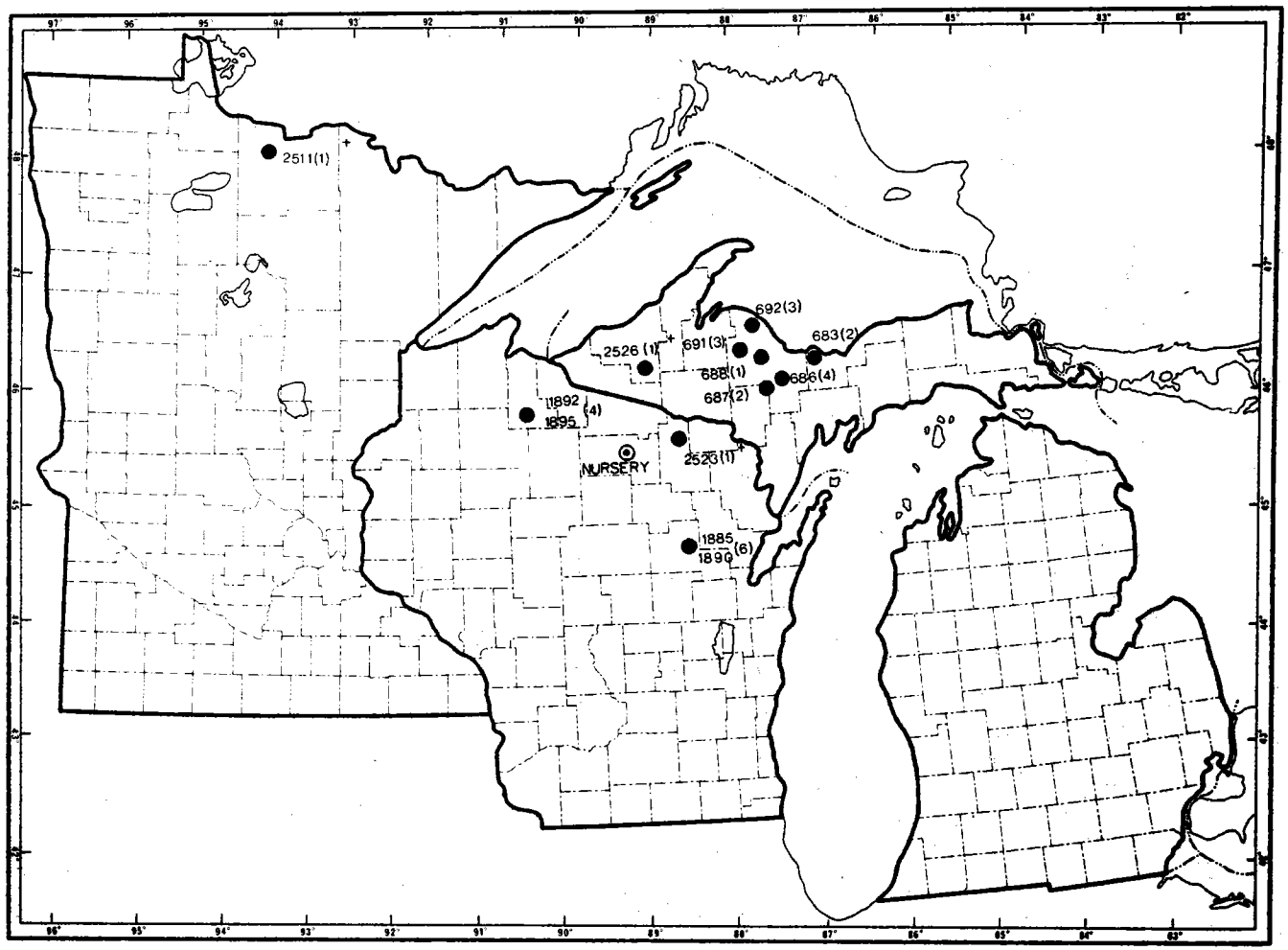

Figure 1. Location of selected open-pollinated white spruce female parents.

Both mean progeny height at 4 years of age and mean 1967 progeny growth were significantly, positively correlated with parent average yearly growth (r = .81 and .80, respectively) (Figs. 2 and 3).

Mean 1967 growth and mean height of the progenies, as might be expected, were highly positively correlated with a correlation coefficient of 0.98.

The average total height of progenies from all trees within a stand or from a single parent, when related to latitude of the stand or individual parent, resulted in a significant, negative, linear regression (Fig. 4). In other words, the progenies of trees from the southernmost latitudes were taller than the progenies of trees from the northernmost latitudes.

The slowest growing parent (692-8) from Marquette County, Michigan, produced progeny growing at a yearly rate (1967) 36% less than the average of all progenies. The two fastest growing parents (1885 and 1887) from Menominee County, Wisconsin, on the other hand, produced progenies exhibiting 63% faster growth in 1967 than the average of all progenies and 256% faster yearly growth when compared to the progeny of the slowest growing parent.

CONCLUSIONS AND RECOMMENDATIONS

The data, in conjunction with data presented by other researchers, indicate the general feasibility of phenotypic selection in white spruce.

When the progenies from the 11 parents of similar age (36 to 42 years) are compared, those from the five fastest growing parents are growing at a yearly rate (1967) of 21% better-than-average for their age group. Because volume is a function of both height and diameter and because height and diameter are closely correlated, a 20% increase in total height would represent much more than a 20% increase in merchantable volume if the yearly growth of the progenies from the five fastest growing parents is maintained to rotation age.

Measurement of progeny growth rate at age four favors trees exhibiting early rapid growth. Later measurement of growth rate will be necessary in order to determine changes in growth rates associated with age. However, the data reported by King, Nienstaedt, and Macon (1965) indicate that superior growth rates in white spruce are maintained at least for 7 years in the field. Therefore, considerable cost in the selection of parent trees can be justified if only a fraction of this increase is achieved.

In addition to following seed zone recommendations, the nurseryman is well advised to choose trees exhibiting rapid growth rate as well as other desirable characteristics.

Similarly, the fastest growing, not necessarily the tallest trees, should be left in stands being selectively logged.

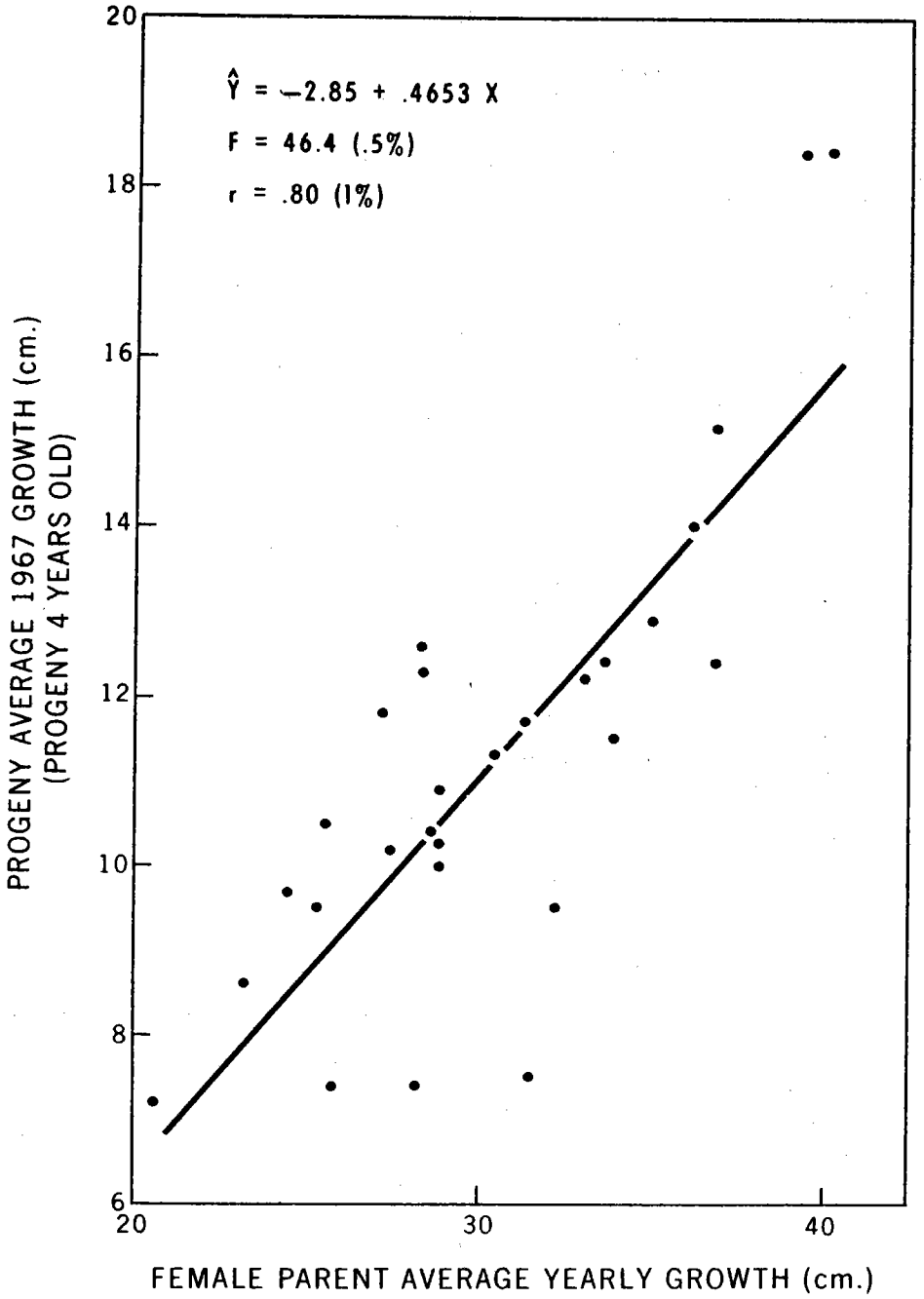

Figure 2. Female parent-progeny growth relationship in white spruce; 28 selected open-pollinated parents.

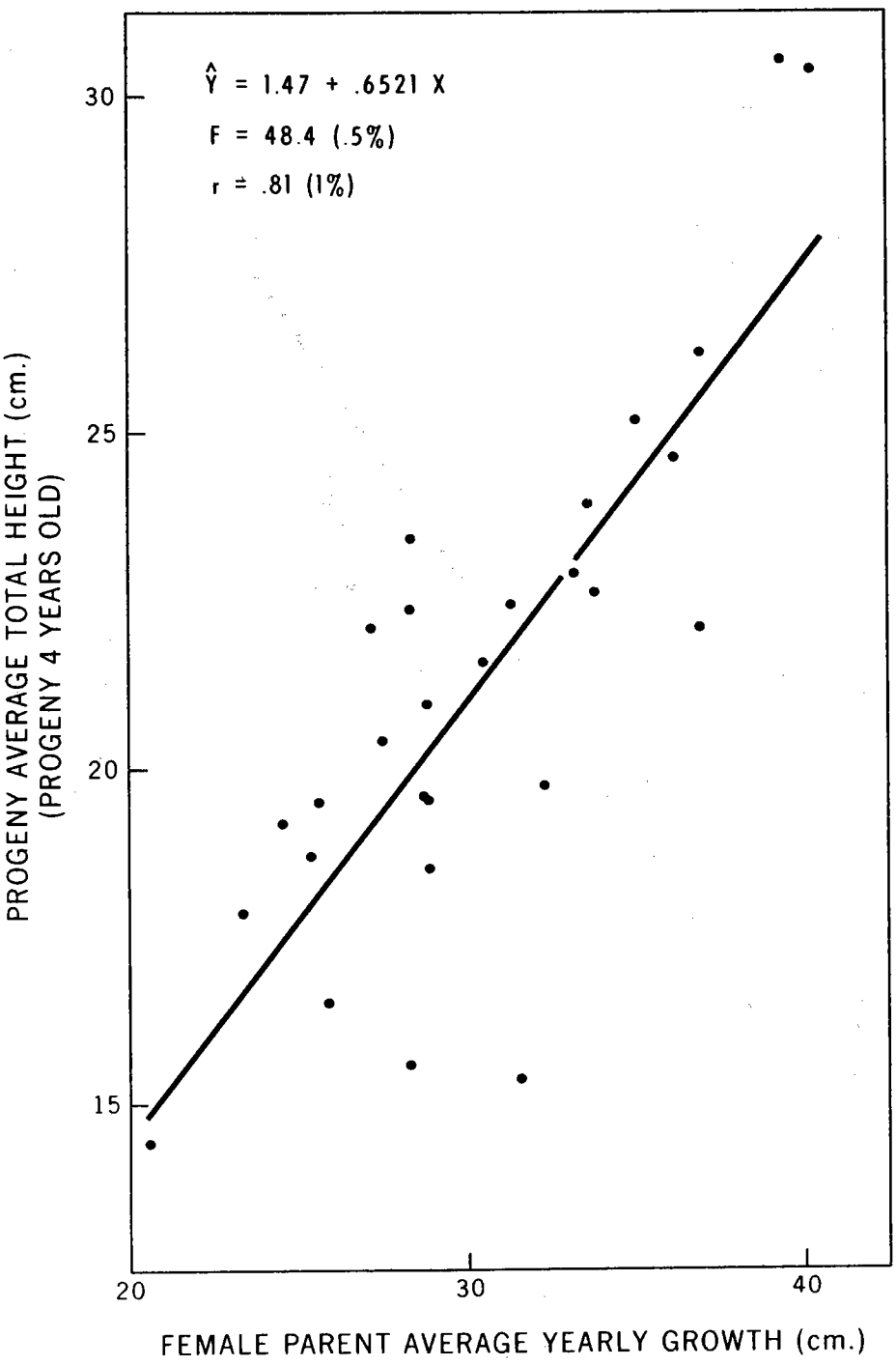

Figure 3. Growth of female parent-progeny total height regression; 28 selected open-pollinated parents.

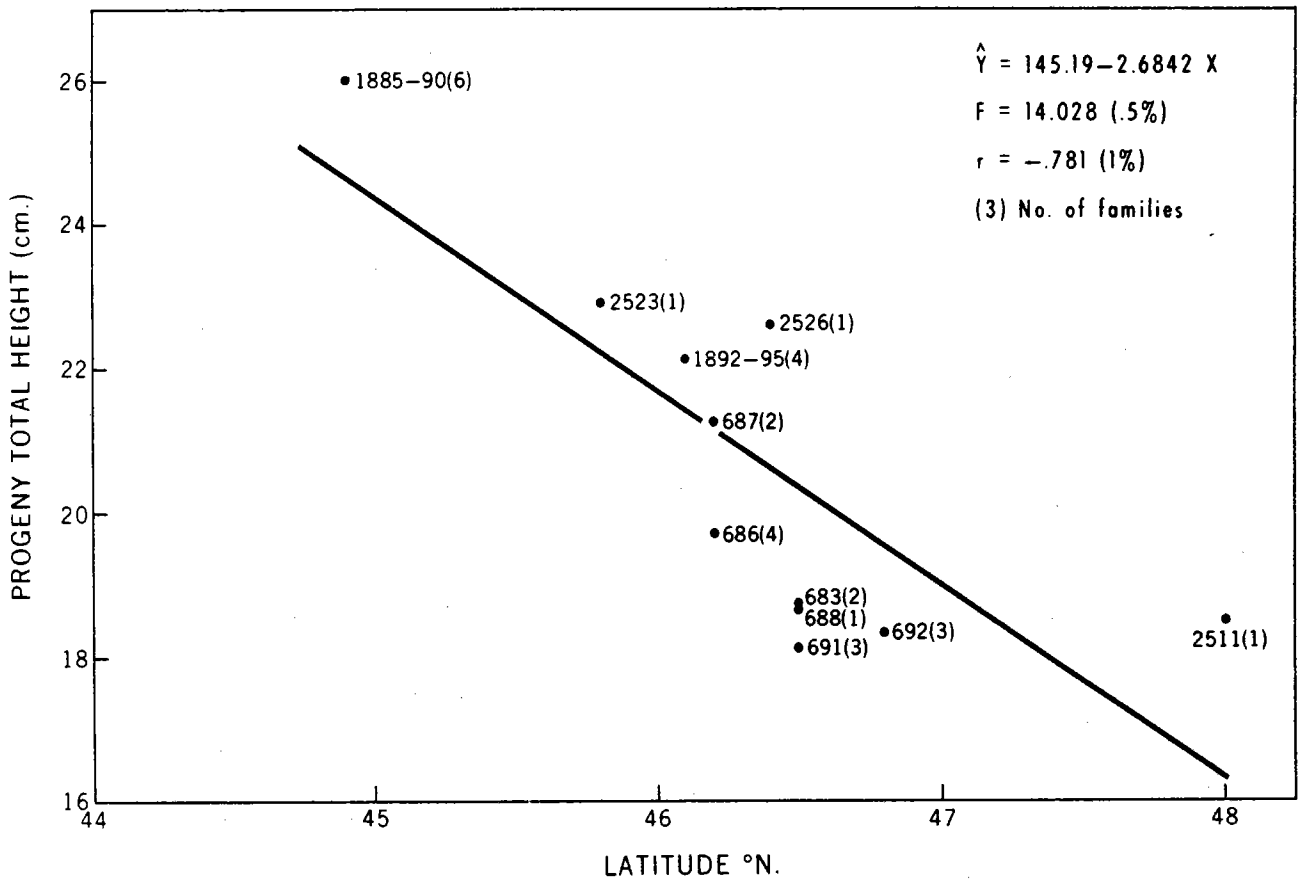

Figure 4. Correlation of progeny by total height at 4 years and latitude.

REFERENCES

Cram, W.H. and C.H. Lindquist. 1961. Summary report for the Forest Nursery Station Research Branch. Can. Dep. Agr., Indian Head, Sask. p. 16.

Holst, M.J. and A.H. Teich. 1966. Potential genetic improvement in white spruce in Ontario. Bi-Mon. Res. Notes. Can. Dep. Forest. Rural Develop. 22(5):6.

King, J.P., H. Nienstaedt and J. Macon. 1965. Super-spruce seedlings show continued superiority. U.S.D.A. Forest Serv. Res. Note LS-66, 2 p. Lake States Forest Exp. Sta., St. Paul, Minn.

BLACK SPRUCE WOOD QUALITY
1. THE PREDICTION OF SPECIFIC GRAVITY

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The prediction of specific gravity of the tree stem from core samples has been reported by a number of authors (Einspahr, van Buijtenen and Thode 1962; Fielding and Brown 1960; Wahlgren, Hart and Maeglin 1966). There is general agreement that two radial increment cores, taken at right angles from breast height, will relate adequately to mean tree specific gravity.

In this study, discs were obtained from 120 trees, representing the six merchantable site classes in northern Ontario. One disc was cut from the base of each percentile bolt in the stem. Disc specific gravity was weighted by the volume of the bolt and specific gravity of the tree was calculated as the weighted average of the bolt gravities. Diameter strips of 20 mm square cross section were removed from three discs taken at the 15% height level. The diameter strip was divided at the pith into two radial strips, each of which was subdivided into four equal segments. The specific gravity of each pair of segments working from the pith outward, was averaged and weighted by the disc area represented, to provide the weighted mean specific gravity of the strip.

Calculation of the number of strips required to estimate mean tree specific gravity was made using the equation, No. Strips = $\overline{Sx^2}t^2.05/(.05\bar{y})^2$, where $\overline{Sx^2}$ was the mean variance of specific gravities over all core samples and $\bar{y}$ was the weighted mean tree specific gravity for all trees on one site.

Calculation of the number of trees required for an estimate of the site average of mean tree specific gravity was made, using the equation, No. Trees = $\overline{Sy^2}t^2.05/(.05\bar{y})^2$, where $\overline{Sy^2}$ was the mean variance of specific gravity over all trees on one site.

The mean and the variance of diameter strip and whole tree specific gravity is presented in Table 1. The number of diameter strips required to predict tree mean specific gravity within 10%, and the number of trees which must be sampled to obtain the site average of mean tree specific gravity is listed in Table 2. Both of the latter estimates were calculated at the .05 level of accuracy.

Table 1. Weighted Mean Specific Gravity of Diameter Strips and the Whole Bole of Black Spruce on Six Sites*†.

Sample	S.I. 55		S.I. 50		S.C. 0		S.C. 1		S.C. 2		S.C. 3	
	Strip	Tree	Strip	Tree	Strip	Tree	Strip	Tree	Strip	Tree	Strip	Tree
1	.399	.398	.412	.411	.402	.408	.393	.399	.409	.408	.492	.489
2	.424	.434	.403	.421	.455	.448	.453	.459	.448	.436	.478	.487
3	.402	.405	.425	.423	.462	.465	.397	.403	.451	.457	.477	.495
4	.412	.410	.394	.395	.431	.442	.421	.416	.419	.427	.491	.514
5	.390	.401	.428	.413	.427	.436	.401	.392	.409	.410	.501	.500
6	.415	.418	.434	.425	.413	.405	.418	.419	.446	.431	.505	.513
7	.366	.373	.395	.390	.453	.446	.457	.465	.439	.441	.502	.494
8	.382	.391	.408	.410	.446	.444	.438	.437	.419	.417	.508	.507
9	.385	.410	.413	.418	.438	.437	.445	.435	.457	.457	.479	.493
10	.368	.364	.419	.412	.402	.405	.398	.406	.433	.427	.481	.489
11	.397	.398	.394	.400	.460	.459	.428	.409	.413	.438	.468	.478
12	.422	.430	.409	.411	.396	.403	.400	.400	.444	.448	.472	.472
13	.374	.387	.448	.433	.397	.394	.396	.391	.401	.406	.482	.495
14	.419	.425	.398	.397	.389	.388	.419	.414	.426	.423	.474	.487
15	.387	.387	.420	.430	.417	.427	.438	.436	.437	.438	.492	.499
16	.404	.428	.427	.426	.419	.425	.436	.449	.455	.462	.468	.485
17	.360	.363	.399	.415	.421	.419	.426	.417	.430	.423	.485	.504
18	.394	.396	.434	.428	.434	.434	.422	.411	.430	.431	.472	.478
19	.394	.398	.418	.416	.418	.416	.424	.434	.401	.410	.500	.503
20	.364	.369			.395	.401					.482	.498
Mean	.393	.399	.415	.414	.424	.425	.421	.420	.430	.431	.485	.494
Variance	.00039	.00046	.00436	.00270	.00054	.00049	.00038	.00045	.00031	.00029	.00016	.00013

*Site Index (S.I.) ratings were used for well-drained upland sites (Lake States Tech. Note 473, Jan. 1957).

†Site Class (S.C.) ratings were used for lowland sites (Normal Yield Tables, W.L. Plonski, 1956).

Table 2. Sample size for estimates of mean tree specific gravity.

Site	No. Diam Strips ($\hat{\bar{y}} \pm 5\%, t.05$)	No. Trees ($\hat{\bar{y}} \pm 2.5\%, t.05$)
S.I. 55	6	20
S.I. 50	4	8
S.C. 0	7	19
S.C. 1	6	20
S.C. 2	5	13
S.C. 3	3	6

A preliminary analysis of these data indicated that it would be necessary to take at least three diameter strips from the 15% height level to estimate within 10% of the tree mean specific gravity. There was no consistent relationship between the number of diameter strips required and the site from which samples were taken. On the average, five diameter strips would be needed to predict mean tree specific gravity, and the use of one or two radial strips would not be adequate.

Further sampling of the main sites is necessary, using seven diameter strips per tree, and 20 trees per site, to verify these relations and to provide regression equations for converting diameter strip specific gravity to weighted tree specific gravity.

REFERENCES

Einspahr, D.W., J.P. van Buijtenen and E.F. Thode. 1962. Wood and pulp properties as determined from slash pine increment core and whole tree measurements. Silvae Genet. 11:68-77.

Fielding, J.M. and A.G. Brown. 1960. Variations in the density of the wood of Monterey pine from tree to tree. Comm. of Australia, Forest. Timber Bur. Leafl. 77, 28 p.

Wahlgren, H.E., A.C. Hart and R.R. Maeglin. 1966. Estimating tree specific gravity of Maine conifers. Forest Prod. Lab. Madison. Res. Pap. FPL61. 22 p.

BLACK SPRUCE WOOD QUALITY
2. STRUCTURE OF WOOD AND PAPER STRENGTH

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The primary object of the research now in progress at the Ontario Research Foundation (ORF) is to assist in the establishment of criteria for the selection of superior black spruce trees, while at the same time obtaining much needed basic information on the morphological, physical, and chemical properties of this important pulpwood species.

The major current investigation concerns 20 mature trees from a good site in Parnell Township, Kapuskasing District, Ontario. The first phase of the study, which is nearing completion, has centered on samples taken from the 25% height level in four trees. Material from each tree was divided into four age groups, to give a total of 16 fractions for pulp tests.

A wide range of features, both structural and chemical, were examined using both whole discs and samples taken from the 16 fractions after they had been chipped for pulping. Besides the commonly measured gross fiber dimensions and estimates of latewood, these included the size, frequency, and relative volume of resin ducts and rays, both medullary and fusiform. Precise cross-sectional dimensions of cell wall and lumen were made, with separate measurements for earlywood and latewood and in both radial and tangential directions. Analyses were made for lignin, pentosan, and extractive content. In the case of several features, measurements were made or expressed in more than one way. For example, specific gravity was obtained for both extracted and unextracted wood; fiber length was obtained from macerations and, using the cell-tip method, from the exact boundary of earlywood and latewood. Two latewood percent values were obtained - the conventional expression calculated on the basis of observed width of latewood, with a second based on the relative number of latewood cells observed. In all, values were obtained for 67 structural, physical and chemical variables.

Following morphological and chemical assessments, samples were pulped using the bisulfite process. Handsheets were prepared and tests were made of their tensile (breaking length), burst, and tear strength.

The analysis of the data, which is still in progress, falls into three separate though not unrelated parts. Firstly, patterns of variation in the wood of a number of features are being examined with a view to adding to our rather scanty knowledge of the basic structure

of black spruce wood. Secondly, the degree of correlation between different cell dimensions and features is being studied with the object both of providing further background information to the geneticist and of assisting in the interpretation of the wood-paper relationships, the study of which constitutes the third part of the overall analysis.

The morphological investigations have shown among other things that at about the 15th ring from the pith, fibers had already obtained 80-90% of their mature cross-sectional dimensions and 60-70% of their mature length. Both tangential and radial wall thickness in earlywood cells were found to remain almost constant from pith to bark, while in latewood cells only the radial walls showed any marked increase outward. Percentage latewood (Mork's definition) declined from about 40% in the ring nearest the pith to less than 20% by the 15th ring and thereafter remained almost constant. Specific gravity was found to be highest in the rings nearest the pith. Specific gravity then declined to a low point in the region of the 15th ring and increased with ring age thereafter.

It would appear from these observations that the 'corewood' in black spruce -- if the region of rapid change near the pith can be so designated -- is confined to the first 10 or 15 rings. Probably less than 20% of the volume of a mature tree is classifiable as 'corewood', an amount unlikely to be of practical significance. Certainly the general impression gained -- and this is of great importance from the point of view of pulpwood quality -- is that black spruce is a species with unusually uniform cell structure.

The tensile, burst, and tear strength of the paper handsheets, corrected for pulp freeness and final lignin content, were entered into regression analyses with all 67 wood variables taken singly, in pairs, and in groups of three in all possible combinations. Linear relationships were assumed. The numbers of combinations possible amounted to several hundred thousands. To reduce the (computer) printout to a manageable size, a program was devised that screened the results so that only those equations in which the dependent variables involved were each individually significant were on the printout. Even so, many hundreds of equations were obtained, reflecting the fact that among other things, a high degree of correlation between many of the variables existed.

The regression equations are still being examined and it would be premature to reach firm conclusions at this stage, particularly as there are indications that some of the relationships are not linear. Of the three strength criteria used only tensile strength has been examined in any detail. Tensile strength, which is the most useful general indicator of the three modes of paper strength assessed, tended to be negatively correlated with specific gravity, growth rate, and fiber length. When variables were taken singly, tensile strength was found to be correlated with only two variables: radial wall thickness of latewood fibers and lignin content of the wood. Both these variables accounted for about half the variation in tensile strength, with a negative relation in both cases. In the two-factor regressions, radial wall thickness of the latewood fibers consistently appeared to be strongly (and negatively) correlated with tensile strength with a

range of other factors also appearing as a significant second variable. These features included among others the number of bordered pits per fiber (positive relation) -- indicating a possible connection with ease of penetration of cooking liquor -- and the radial cell and lumen diameter of earlywood cells (positive correlations). The negative correlation with latewood radial wall thickness presumably reflects the uncompressibility of the latewood fibers when incorporated into the paper sheet. This same variable also appeared fairly consistently in the three-factor equations. Other variables which emerged in these regressions as being significantly correlated with tensile strength were various expressions of average fiber diameter (positive relation) and frequency of medullary rays (negative relation) and specific gravity (negative relation). The three-factor regressions accounted for up to 86% of the variation in tensile strength, with some variables significant at beyond the 0.1% level.

These results, together with those for burst and tear strength, will require careful scrutiny in order to establish which of the many inter-correlated variables are those most directly responsible for the paper strength properties investigated. With this done, the question will arise as to whether these features should themselves be the object of attention in tree typification or breeding studies or whether other features correlated with these should be used because they are more easily measurable.

SEED SOURCE AND GROWTH RATE EFFECTS ON WOOD QUALITY IN NORWAY SPRUCE

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INTRODUCTION

Mass selection for optimal wood producing ability within a tree species usually begins with the broad question of geographic variation. Determination of the proper provenance then allows additional, within-population selection to maximize growth rate potential. Concurrent with this approach is the question of wood quality as it relates to volume growth and the answer must eventually be resolved from both biological and economic considerations.

In the spruce breeding and seed orchard programs at the New York College of Forestry we have selected plus trees principally on the basis of phenotype and have only recently begun to turn our attention toward wood quality as a selection criterion. In so doing, we have asked the obvious questions of how growth rate affects wood quality between and within populations. A previous study (Stairs *et al.* 1966) investigated variation between fast-grown and slow-grown Norway spruce (*Picea abies*, L. Karst.) trees from a single plantation of unknown seed source. The results obtained suggested that a 2X (merchantable volume) growth rate increase had little or no effect upon pulp yield or quality per cubic volume of wood. In addition, the specific gravity of juvenile wood appeared to be equal to or greater than that of mature wood developed at age 20. Thus these results were encouraging in relation to selecting fast-growing Norway spruce trees for short-rotation management.

Mergen, Burley and Yeatman (1964), suggested that up to 25% of the variation in wood quality of Norway spruce could be accounted for by flushing time. Previous studies with this species contain conflicting evidence of significant differences among seed sources with respect to wood quality. Significant provenance variation has been reported by Burger (1941), Klem (1933, 1951, 1956, 1957), Parrot

(1960), and Mergen and Simpson (personal communication). In contrast, Knudsen (1958) and Göhre (1955) found no significant differences associated with provenance. The relationship between annual ring width and specific gravity is also somewhat ambiguous, but the published evidence generally supports a negative correlation. Approximately 70% of the articles reviewed by the authors reported a decrease in specific gravity with increasing ring width, while the remainder suggested little or no differences.

Studies of fiber length in Norway spruce have upheld the rule of increasing length as the distance from the pith becomes greater. The relation between annual ring width and fiber length is less clear, but some reports have indicated an increased length with faster growth rates. (For general reviews see Bisset 1949; Spurr and Hyvarinen 1954; and Dinwoodie 1961).

The investigation herein reported evaluated specific gravity and fiber length between fast- and slow-growing trees among selected Norway spruce provenances.

MATERIAL AND METHODS

The study trees were sampled in a 25-year-old Norway spruce plantation established in New York State as a part of an International Union of Forest Research Organization (IUFRO) investigation. Six sources were chosen to provide a wide latitudinal separation; within each source five fast-growing and five slow-growing trees were selected (Table 1). Wood samples obtained from each tree at dbh with a 10 mm increment borer were placed in plastic tubes for storage at 0 C. For evaluation, each sample was divided into two 5-year segments based on rings 1-5 and rings 15-20 from the pith.

Specific gravity determinations were conducted by the maximum moisture method (Smith 1954), after removal of alcohol-benzene soluble extractives in accordance with Tappi Standards of 1959.

Individual fibers were prepared by macerating wood samples (1:1 glacial acetic acid and 20% hydrogen peroxide) for about 24 hours at 60 C. The fibers were stained in basic fuschin and mounted in sodium silicate, using Echols' (1961) liquid dispersion method. Measurements of 50 fibers on two slides were made for each sample at 30X to the nearest 0.1 mm.

The significance of provenance age segment, growth rate, and the interactions of these three variables were tested by an analysis of variance; various simple correlations were calculated.

RESULTS AND DISCUSSION

A summary of the provenance data is presented in Table 1; results of the statistical analyses are shown in Table 2. The specific gravity variation was non-significant between seed sources and the variance analysis indicated no significant differences due to age level.

Table 1. Summary of provenance data.

IUFRO No.	Country of Origin	Seed Source				Mean Values			
		latitude N	longitude E	altitude	relative growth rate	height	dbh	specific gravity	Tracheid length
		° '	° '	m		ft	inch		mm
24	Norway	60 32	12 11	180	Slow	15.4	1.92	0.3462	2.43
					Fast	24.2	4.82	0.3426	2.66
7	USSR	57 03	23 10	165	Slow	19.2	2.20	0.3533	2.67
					Fast	34.8	5.56	0.3343	2.66
9	USSR	53 28	26 43	170	Slow	18.2	2.04	0.3530	2.52
					Fast	30.6	5.48	0.3475	2.69
34	Poland	52 52	23 47	180	Slow	20.2	1.98	0.3728	2.63
					Fast	31.4	5.06	0.3515	2.72
29	Rumania	46 21	25 50	1100	Slow	21.6	2.06	0.3619	2.30
					Fast	36.6	6.36	0.3400	3.17
21	Rumania	45 10	22 20	1050	Slow	16.4	1.90	0.3691	2.53
					Fast	28.4	5.00	0.3374	2.50

Table 2. Analysis of variance for wood properties.

Source of Variation	df	Tracheid Length F	Tracheid Length P	Specific Gravity F	Specific Gravity P
Provenance (A)	5	0.772	N.S.	0.543	N.S.
Growth rate (B)	1	5.594	N.S.	56.915	0.005
Age level (C)	1	85.571	0.005	2.223	N.S.
Interaction					
A x B	5	0.713	N.S.	0.426	N.S.
A x C	5	0.027	N.S.	———	N.S.
B x C	1	8.615	0.05	3.479	N.S.
Error	5				

df - degrees of freedom; F - variance ratio; P - probability.

The effect of growth rate was highly significant, a negative correlation of 0.867 was obtained between diameter and mean specific gravity. Thus our data supported the generality of lower specific gravity with faster growth-rates that seems predominant in observations made between widely divergent growth-rate-groups in this species. The lack of significance in relation to age has been reported in other spruce studies (Stairs *et al.* 1965; Hildebrandt 1954) and differs from the generality found with many other conifers (Zobel 1961). Thus, this study adds to a body of literature suggesting that juvenile wood in spruce will not necessarily provide lowered pulp yields. The significant effect of growth rate indicates that within-population selection should include consideration for the negative correlation with specific gravity. However, the difference in growth rates between the groups was exaggerated in this study and is not a true representation of the selection differential as normally defined. It must be noted that growth rate is a relative factor and varying the magnitude of difference between fast- and slow-growth may account for conflicting reports of growth rate effects in the literature. Where slight differences in growth rate are observed it is possible that genetic effects could offset the growth rate effect while in more variable comparisons the reverse could be true.

The consistently lowered specific gravity within a source as growth rate increased does not negate the argument that certain sources may have an inherent higher specific gravity. Although variance attributable to seed source was judged nonsignificant among all sources, the range of variation among sources was probably great enough to be of practical significance in large-scale forest plantings. The lack of statistical significance may be related to the small size of the sample and also to the sampling technique. Selecting fast- and slow-

growth trees yield a random sample of total variance for the seed sources. Interestingly, the variance of fast-grown trees was less than that of the slow-grown ones. The practical significance of the latter observation will require additional study, but the present evidence strongly suggests that selection should be made for growth rate in all instances, with the assumption that volume gains will offset the lowered specific gravity that may be obtained. These data indicate that comparisons between provenances must be made with careful regard to homogeneity of variance and sampling techniques. Hartig (1884) warned that differences in spruce wood quality claimed between sites or silvicultural treatments might really reflect only ring width variation or sampling position.

In the present study, the specific gravity of juvenile wood was strongly correlated with mature wood ($r = .95$). Thus early evaluation could have provided a reliable indicator of specific gravity at a later age in the sample trees.

The analysis of variance for means of fiber-length indicated nonsignificance for provenance and growth rate variables, but highly significant values for age effects. However, single tree values showed a significant positive correlation between growth rate and fiber length ($r = 0.665$ for both dbh and height; $df = 58$). Therefore, it appeared that increased growth rate in Norway spruce caused a slight but positive increase in fiber length. The gain in length due to increasing growth rate is probably less than that obtainable in the strict genetic sense, and is assumed to be additive over the entire range of genetic variance. Statistically significant interaction for fiber lengths was observed between growth rate and age. However, the variance was greater by several orders of magnitude for age effects and the biological validity of cambial age effect on fiber length should not be disallowed due to this interaction.

REFERENCES

Bisset, I.J.W. 1949. I. Bibliography of references on the variation of tracheid and fiber lengths and their distribution in Angiosperms and Gymnosperms. II. Summarized data on the variation of fiber and tracheid lengths and their distribution in Angiosperms and Gymnosperms. Commonwealth Sci. Ind. Res. Organ., Div. Forest Prods., Australia. Bibliographic Serv. No. 37, 5 pp.

Burger, H. Holz. 1941. Blattmenge und Zuwachs. V. Fichten und Föhren verschiedener Herkunft auf verschiedenen Kulturorten. Mitt. Schweiz. Centralanstalt forstl. Versuchsw. 22:10-62.

Dinwoodie, J.M. 1961. Tracheid and fiber length in timber, a review of literature. Forest. 34:125-144.

Echols, R.M. 1961. Liquid dispersion method for mounting wood fibers on slides. Forest Sci. 7:369-370.

Göhre, K. 1955. Einfluss von Wuchsgebiet, Standort, Rasse und Berwirtschaftung auf die Rohwichte des Holzes. Arch. Forstw. 4:414-433.

Hartig, R. 1884. Der Einfluss des Baumalters und der Jahrring breite auf die Beschaffenheit des Holzes. Allgem. Forst-u. Jagdztg. 60:128-137.

Hildebrandt, G. 1954. Untersuchungen an Fichtenbestanden über Zuwachs und Ertrag reiner Holzsubstänz. Deut. Verlag Wissenschaften, Berlin. 133 pp.

Klem, G.G. 1933. Untersuchungen über die Qualität des Fichtenholzes. Medd. Norske Skogforsksv. 5:197-348.

Klem, G.G. 1951. Spruce as raw material for the pulp industry. Svenska Skogavforer Tidskr. 49:329-341. (Original not seen, abstracted Forest. Abstr. 13:3461, 1952).

Klem, G.G. 1956. Cultivation value of Norway spruce of Norwegian and Central European provenance. Norsk Skogbr. 2:181. (Original not seen, abstracted Forest. Abstr. 17:3834, 1956).

Klem, G.G. 1957. The quality of Norway spruce of Norwegian and German origin. Medd. Norski Skogforskv 14:285-314.

Knudsen, M.V. 1958. A comparative study of some technological properties of Norway spruce in a provenance test. Intern. Union Forest Research Organizations, 12 Congr., Oxford 41/2:219-228.

Mergen, F., J. Burley and C.W. Yeatman. 1964. Variation in growth characteristics and wood properties of Norway spruce. Tappi 47:499-504.

Parrot, L. 1960. De la variabilité Génétique de la densité du bois chez l'Epicea. Ann. ecole natl. eaux forets, Nancy 17:267-334.

Smith, Diana M. 1954. Maximum moisture content method of determining specific gravity of small wood samples. U.S. Forest Prod. Lab. Rep. No. 2014.

Spurr, S.H. and M.J. Hyvarinen. 1954. Wood fiber length as related to position in tree and growth. Bot. Rev. 20:561-575.

Stairs, G.R., R. Marton, A. L. Brown, M. Rizzio and A. Petrik. 1966. Anatomical and pulping properties of fast and slow grown Norway spruce. Tappi 49:296-300.

Zobel, B. 1961. Juvenility in wood production. Recent Advances in Bot. 1663-1665.

PRELIMINARY OBSERVATIONS ON HYBRIDIZATION OF ROCKY MOUNTAIN SPRUCES

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INTRODUCTION

Approximately one-half of the commercial sawtimber in Colorado is Engelmann spruce (*Picea engelmannii* Parry)[1] (Anon. 1958). It occurs in extensive subalpine stands that contribute to watershed protection and to the production of construction lumber. Blue spruce (*Picea pungens* Engelmann), or Colorado spruce, according to Kelsey and Dayton (1942), is rarely harvested for its wood, but this species withstands temperature extremes and drought, and several cultivated varieties are valued for windbreaks and as ornamentals (Cram 1964; Harlow and Harrar 1958; Wyman 1961).

The biological relationship between Engelmann spruce and blue spruce is not well understood. Some reports in the literature allude to natural hybridization between these two species (Wright 1955), but this phenomenon is not convincingly documented. Generally, blue spruce occurs in a lower altitudinal zone than Engelmann spruce, but in northern Colorado they overlap on native sites by about 500 feet of altitude, and field identification is not always certain.

The relative ease or difficulty with which interspecies hybrids may be obtained contributes to the understanding of species development, especially when this information is augmented by that obtained from studies of comparative morphology and phenology. Furthermore, the achievement of artificial hybrids provides a basis for considering the value of further controlled pollinations in order to combine characters of the species involved.

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[1]The names of native and exotic tree species used in this paper are according to Little (1953b) and Rehder (1940), respectively.

METHODS

During the spring of 1964, one blue spruce tree located on the campus of Colorado State University (altitude approximately 5000 feet), and one Engelmann spruce tree located about 30 miles west of Fort Collins, Colorado (altitude approximately 8500 feet), were selected as female parents. Female strobili were isolated with kraft paper bags on May 15 (blue spruce) and June 2 (Engelmann spruce), and intraspecific-, interspecies-, and self-pollinations[2] were made on 20 May 1964 and 16 June 1964, respectively. The interspecies pollinations on the Engelmann spruce mother tree included both blue spruce and white spruce (*Picea glauca* (Moench) Voss) pollens. The pollen had been collected in the spring of 1964 and stored in cotton-stoppered vials at 0 to 4 C.

About 5 weeks after pollination, the kraft bags were replaced with plastic net bags, and several developing cones were also bagged as wind-pollinated examples at that time. Cones were collected from the Engelmann spruce on 29 September 1964 and from the blue spruce on 8 October 1964. All of the seeds obtained from the one or more cones within a single isolation bag formed a unit and were stored together at 0 to 4 C.

Germination tests on two 50-seed samples, from each of 56 isolation bags, were conducted in 4.5-inch square plastic germination chambers on standard germination blotters. Each germination chamber was randomly positioned on a benchtop where the temperature was maintained at 70 to 75 F (21 to 24 C). Water was supplied as needed to keep the blotters moist, and two 100-watt incandescent lamps provided constant light throughout the test period. Germinations were recorded daily, and observations were made of the developing seedlings. Following the 26-day test period (18 June 1966 to 13 July 1966), which was terminated following a 5-day period of no germination, each ungerminated seed was cut and tallied as full or empty.

For some of the pollination treatments, 70-day nursery tests were begun 13 June 1966 in order to compare germination results there to those in the laboratory and to observe continued seedling development.

RESULTS AND DISCUSSION

Compatibility

The results of this preliminary study suggest that interspecies compatibility between *Picea engelmannii* and *P. pungens* is low. As determined by blotter tests, a seed set of 2.2 sound seeds per cone

[2] On the Engelmann spruce, selfing was accomplished by enclosing nearby male and female strobili in the same isolation bag; thus, the exact date of pollination is unknown. For cross-pollinations, the nearby male strobili were removed from the branchlets prior to bagging.

(1-2%) was obtained when Engelmann spruce was the female parent, but the reciprocal cross failed to set sound seeds. Intraspecific pollinations on the Engelmann spruce mother tree, on the other hand, produced a seed set of 87.3 seeds per cone (49.6%), significantly higher (1% level of probability) than the seed sets of the interspecies- and self-pollinations, as determined by Scheffé's (1959) S-method (Table 1).

The absence of seed set (or low seed set) may be due to unreceptiveness of the female strobili at the time of pollination, non-viable pollen, incompatibility between the pollen and the ovular tissue (or other incompatibilities), or some combination of these. Not only did the blue spruce female parent fail to produce sound seed from Engelmann spruce pollen, it also failed to produce selfed progeny, and the intraspecific pollinations yielded poor results. Only wind pollination produced a significantly higher (1% level) seed set than any of the other pollen treatments, but this was still low (Table 1). On the other hand, the Engelmann spruce pollen yielded high seed set when applied on the Engelmann spruce mother tree. In his extensive Canadian studies of blue spruce compatibility, Cram (1960, 1962) reported different degrees of self- and intra-specific compatibility, ranging from apparently incompatible (no seed set) to highly compatible (85 seeds per cone), in single years. He also found (1962, 1964) that seed set varied from year-to-year on the same trees, although some selections have shown self-incompatibility in several successive seasons (Anon. 1966). Possibly some individual trees are both self- and interspecies-incompatible, and the blue spruce mother tree used in this study may be such an individual.

Though inconclusive due to tree-to-tree variation, the cross-incompatibility found in this study on a blue spruce female and the low cross-compatibility of the Engelmann spruce female agrees with Richens (1945), who listed the cross *P. engelmannii* x *P. pungens* but not the reciprocal. Furthermore, on sites in northern Colorado where both species are sympatric, Engelmann spruce has preceded blue spruce in phenological development by approximately 1 week during 3 years of observation. Thus, if natural hybrids occur between these taxons, as has been suggested to Wright (1955) by Johnson, Engelmann spruce may be the more probable female parent.

The interspecies cross *P. engelmannii* x *P. glauca* produced an average seed set of 95.3 sound seeds per cone, significantly higher than the results of the crosses with blue spruce pollen (1% level) and the results of the selfings (5% level), as determined by Scheffé's (1959) S-method. This relatively high compatibility agrees with the findings of other investigators.[3] Richens (1945) and Johnson (1939) listed this interspecies cross, and Eklundh (1943) found that it was easily accomplished, although no details were given. Wright (1955) obtained an average seed set of 10 seeds per cone when Engelmann spruce was the female parent and an average of 1.3 seeds per cone from the reciprocal cross with white spruce.

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[3]Some hybrid inviability may be expected under rigorous conditions, such as the seedbed, where actual germination percent of seeds from Engelmann spruce x white spruce crosses declined considerably below that of the seeds from Engelmann spruce intraspecific crosses.

Table 1. Seed yields and seed set from blue spruce and Engelmann spruce crossings, 1964.

Parental Combinations* female x male	Basis		Developed** Seeds per Cone		Seed Set† per 100 Seeds	
	bags	cones	mean	S.D.††	mean	S.D.††
	number					
Pi pun - 18 x						
Pi pun-40	6	31	173	32.2	2.0	2.1
Pi pun-11	4	9	213	16.9	1.5	2.4
Self	4	15	153	75.9	0.0	-
Wind	4	27	211	50.1	10.5	4.6
Pi eng-9	9	23	229	35.4	0.0	-
Pi eng - 4 x						
Pi eng-9	5	36	176	62.2	49.6	20.5
Self	5	15	148	18.5	11.2	25.4
Wind	4	29	157	20.9	29.2	5.9
Pi gla-3	3	19	181	13.4	52.7	7.4
Pi pun-18	5	69	121	44.4	1.0	0.7
Pi pun-Kirlin	7	67	163	21.7	2.0	2.6

*Pi pun, Pi eng, and Pi gla designations refer to blue spruce, Engelmann spruce, and white spruce, respectively.

**Visually judged to be of normal size.

†Filled seeds as determined in blotter tests, 1966.

††Standard deviation computed between isolation bag units within pollen treatment.

The wood of white spruce and Engelmann spruce cannot be separated anatomically (Panshin and de Zeeuw 1964), and consistent differences between chemical extracts from the heartwood of these two taxons have not been found (Barton and Gardner 1957). For Engelmann spruce in Colorado, geographic isolation prevents cross-pollination and consequent introgression with white spruce. However, where the ranges of these two taxons overlap, especially in southern British Columbia (Little 1953a), they apparently hybridize freely. Taylor (1959), based on his analysis of cone morphology, considered the two to be subspecies of *P. glauca* and the population *Picea glauca* var. *albertiana* (S. Brown) Sargent (western white spruce) to be a hybrid swarm of the two subspecies. Thus, because of the apparent compatibility and morphological similarity of Engelmann spruce and white spruce, it is not surprising that early taxonomists had difficulty in distinguishing these taxons (Engelmann 1862; Parry 1862, 1863). In general, the encouraging results of this interspecies cross suggest that further investigations should be undertaken to clarify species relationships and to elucidate the possibilities of improvement.

Seed development

Cone development and seed development are apparently not indications of seed set in the species studied. Although seed set was found to vary significantly (1% level) among the several pollen sources on both mother trees, the average number of developed seeds per cone (i.e., those visually judged to be of normal size) did not differ significantly among these pollen sources on either mother tree, as determined by Scheffé's (1959) S-method. This may have been due to variation between isolation bags within a pollen treatment, and the standard deviation (Table 1) ranged from 7% of the treatment average (Engelmann spruce x white spruce) to 50% (blue spruce selfing). The number of developed seeds represented 94% or more of the total seeds extracted (i.e., very few seeds were classified as aborted), except for one interspecies combination on the Engelmann spruce mother tree (Pi eng-4 x Pi pun-18) in which 84% of the total seeds developed. Wright (1955), too, has reported high sets of cones and empty seeds from all of his pollinations on white spruce. Orr-Ewing (1954) found that after selfing Douglas-fir (*Pseudotsuga taxifolia* (Poir.) Britton) = (*Pseudotsuga menziesii* (Mirbel) Franco), developmental processes proceeded normally until after fertilization, when embryo collapse occurred, resulting in empty or nearly empty seeds. The mechanism which brings about development of cones with empty seeds in the spruces is not known.

Initiation of germination

For a given germination chamber, the date following seeding on which the first seed within that chamber showed an emerging radicle was recorded. These data showed similarities in the time when germination began, among the following groups:

1. Intraspecific half sibs of the Engelmann spruce mother tree, including pollinations by Pi eng-9, selfing, and wind.
2. Intraspecific half sibs of the blue spruce mother tree, including pollinations by Pi pun-40, Pi pun-11, and wind.
3. Interspecies half sibs of the Engelmann spruce mother tree, including pollinations by Pi pun-18 and Pi pun-Kirlin.

Figure 1 shows extensive overlap among all three groups in the date of germination initiation of seeds in different chambers. However, when the mean day of initial germination was computed, it was found to be 9.17 days for the Engelmann spruce half sibs and 12.94 days for the blue spruce half sibs. The mean day of initial germination for the putative hybrid half sibs was 11.09 days, or very nearly the simple arithmetic mean between the dates of the two parental half sib groups (11.06 days). The 95% confidence limits indicated no significant difference in the mean day of germination initiation between the putative hybrid progenies and either of the parental progenies, but the parental progenies differed from each other in this respect. Thus, this germination characteristic behaved as a quantitative trait in a first-generation hybrid.

Germination trend

The germination trends displayed by the distribution patterns of total germination in Figure 2 suggest no outstanding differences among the three progeny groups named above. The measure of germination trend used for statistical analysis was computed as the weighted mean day of germination for each progeny group from blotter test data.[4] These means and their 95% confidence intervals were 10.47 ± 0.18 days, 11.40 ± 0.99 days, and 13.00 ± 0.53 days, respectively for the Engelmann spruce, putative hybrid, and blue spruce progenies. The mean day of germination of the putative hybrid did not differ significantly from that of the Engelmann spruce female parent, but that of the blue spruce was significantly larger than the other two. These results suggest that maternal influence may be operative in controlling germination trend. However, the failure of overlap of only 0.08 days in the confidence limits of the putative hybrid and the blue spruce progenies suggests that further data could indicate intermediacy for this germination characteristic.

Cotyledon number

The mean cotyledon number of the putative hybrid seedlings (5.4 ± 0.34) did not differ significantly from that of the female parental Engelmann spruce seedlings (5.8 ± 0.14). However, the blue spruce intraspecific progeny had significantly more cotyledons (7.2 ± 0.30) than either of the other two progeny groups. A similar suggestion of maternal influence on cotyledon number was observed by Fowler (1966). He noted that the cotyledon number of hybrid progeny from a cross between *Picea schrenkiana* Fisch and Meyer and *P. glauca* did not differ significantly from that of female parental progeny of open- and self-pollinations. The differences in distribution of cotyledon number in Figure 3 show that the range among the putative hybrid seedlings is the narrowest, while that of the blue spruce seedlings is the widest. The data for Engelmann spruce agree with Bates' (1925) early observations that the range in cotyledon number is four to seven, mostly six for that species.

Hypocotyl color

The intraspecific progeny of the blue spruce mother tree had red-pigmented hypocotyls. On the other hand, all of the Engelmann spruce, as well as the Engelmann spruce x blue spruce putative hybrid progenies, had green hypocotyls. Bates (1925) long ago considered the green hypocotyl color as a key characteristic for identification of Engelmann spruce seedlings, and from the results of this study, one is tempted to infer that hypocotyl color is influenced by the maternal parent. However, Fowler (1966) observed that the red hypocotyl color of hybrid seedlings between *P. schrenkiana* and *P. glauca* resembled that of the male parental progeny at 6 weeks. After 8-10 weeks, the color had become yellowish-red. The blue spruce seedlings observed in the nursery in the Colorado study lost their red coloration gradually, becoming green by the end of the first growing season. Thus, the nature of genetic control of hypocotyl color is not clear.

[4] No Engelmann spruce x blue spruce hybrid seedlings were obtained in the nursery seedbed, suggesting some hybrid inviability.

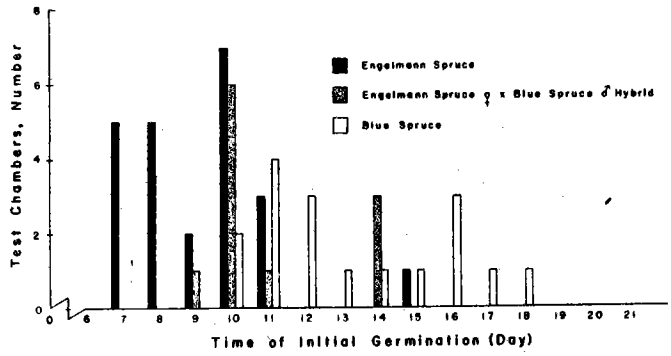

Figure 1. Distribution of time (day) of initial germination of seed samples in blotter test chambers, 1966, from intra- and inter-specific crosses between Engelmann spruce and blue spruce, 1964.

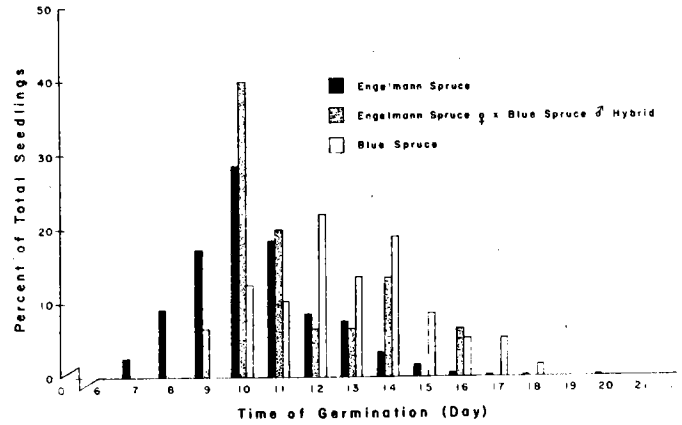

Figure 2. Distribution of total germination in blotter tests, 1966, of intra- and inter-specific crosses between Engelmann spruce and blue spruce, 1964.

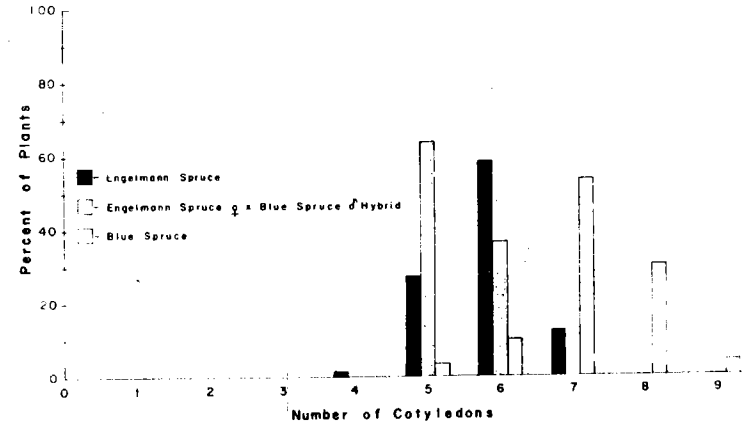

Figure 3. Distribution of cotyledon number of progenies of intra- and inter-specific crosses between Engelmann spruce and blue spruce, 1964, from blotter tests, 1966.

Hybrid abnormalities

Of a total of 19 putative hybrid seedlings obtained from the interspecies crosses between Engelmann spruce and blue spruce, four germinated normally but ceased development shortly after emergence of the radicle. Four others displayed abnormal germinations in which the cotyledons of the seedlings protruded from the seed before the radicle emerged. Development of these seedlings usually ceased after the cotyledons appeared, and the radicle did not break through the seed-coat, a characteristic that has also been observed by Illies (1952) among wind-pollinated progenies of Norway spruce (*Picea abies* (Linnaeus) Karsten). In those few seedlings which continued to grow, a branched hypocotyl developed with a rudimentary set of cotyledons terminating both branches. Growth in these instances proceeded with the radicle tip remaining inside the split seed coat. These abnormalities occurred in interspecies crosses only when blue spruce was the pollen parent (all seedlings obtained from the white spruce pollinations on Engelmann spruce were normal), and they suggest some degree of hybrid inviability.

SUMMARY

Caution needs to be exercised in the interpretation of the results of this study. Due to the low number of putative hybrid progeny obtained, random deviations tending to display a particular character could occur. Furthermore, the absence of hybrid progeny from the blue spruce mother tree prevents clear detection of maternal-paternal influences that may affect seedling characteristics. With these qualifications, the following seem to be suggested from the results of this preliminary study of crosses within *Picea* A. Dietrich, based on germination chamber and seedbed observations:

1. Interspecies compatibility between Engelmann spruce and blue spruce is low. And if natural crosses between these two taxons occur, Engelmann spruce may be the more probable female parent.
2. Interspecies compatibility between Engelmann spruce and white spruce is high, and further investigations to elucidate the species relationship and the possibilities for improvement should be undertaken.
3. Seed development is no indication of seed set in the species studied, and morphogenetic studies will be necessary to explain this phenomenon.
4. Initiation of germination within Engelmann spruce and blue spruce may be under control of multiple genes, as indicated by intermediacy of the mean day of initial germination of the putative hybrid between those of the parental species progenies.
5. Germination trend may be controlled by maternal influence; the putative hybrid did not differ significantly from the Engelmann spruce maternal parent in mean day of germination. Further data could indicate, however, that the putative hybrid is intermediate in this characteristic also.

6. Cotyledon number of the interspecies putative hybrid seedlings did not differ significantly from that of the female parental Engelmann spruce seedlings, suggesting maternal influence.

7. The nature of genetic control of hypocotyl color in spruce is not clear. Hypocotyl color of the interspecies putative hybrid resembled that of the maternal parental progeny. But other investigators have found such color to resemble that of the paternal parental progeny.

8. Some hybrid inviability may exist in certain spruce interspecies hybrids. Seedbed germination of Engelmann spruce x white spruce hybrid seeds was considerably less than that of Engelmann spruce; no seedbed germination was achieved from the seeds obtained from the Engelmann spruce x blue spruce cross. Furthermore, approximately one-half of the Engelmann spruce x blue spruce hybrid seeds in laboratory tests germinated abnormally. Coupled with the low interspecies compatibility, few natural hybrids between the southern Rocky Mountain spruce species would be expected.

REFERENCES

Anon. 1958. Timber resources for America's future. U.S. Dep. Agr. Forest Serv., Forest Resource Report No. 14. Washington, D.C. 713 pp., illus.

Anon. 1966. Summary report for the tree nursery. Can. Dep. Agr., Indian Head, Sask. 35 pp.

Barton, George M. and J.A.F. Gardner. 1957. A comparison of the heartwood extractives of *Picea glauca* and *Picea engelmanni*. Forest. Chron. 33(2):136-138.

Bates, Carlos G. 1925. A key to the identification of some coniferous seedlings. J. Forest. 23(3):278-281.

Cram, W.H. 1960. Shelterbelt tree breeding. 1958-59 biennial progress report. Forest Nursery Station, Indian Head, Sask. 5 pp.

Cram, W.H. 1962. Shelterbelt tree breeding. 1960-61 biennial progress report. Forest Nursery Station, Indian Head, Sask. 11 pp.

Cram, W.H. 1964. Shelterbelt tree breeding. 1962-63 biennial progress report. Proc., Comm. Forest Tree Breeding Can. 9:9-21.

Eklundh, C. 1943. Artkorsningar inom sl. *Abies, Pseudotsuga, Picea, Larix, Pinus,* och *Chamaecyparis,* tillhörande fam. Pinaceae. (Species crosses within the genera *Abies, Pseudotsuga, Picea, Larix, Pinus,* and *Chamaecyparis,* belonging to the family Pinaceae). Svensk Papp Tidn. 46:55-61, 101-105, 130-133. In Forest. Abstr. 5(1):95-96.

Engelmann, G. 1862. Supplements to the enumeration of plants of Dr. Parry's collection in the Rocky Mountains. Amer. J. Sci. Arts Second Ser. 34:330-341.

Fowler, D.P. 1966. A new spruce hybrid - *Picea schrenkiana* x *P. glauca*. Proceedings, Lake States Forest Tree Improvement Conference 7:44-47. (North Central Forest Exper. Sta. Res. Pap. NC-6).

Harlow, William M. and Ellwood S. Harrar. 1958. Textbook of Dendrology. McGraw-Hill Book Company, Inc., New York. 561 pp.

Illies, Z.M. 1952. Keimlingsabnornitäten bei *Picea abies* (L.) Karst. Zeitschrift für Forstgenetik und Forstpflanzenzüchtung 2(2): 28-32.

Johnson, L.P.V. 1939. A descriptive list of natural and artificial hybrids in North American forest-tree genera. Can. J. Res. 17C (12):411-444.

Kelsey, Harlan P. and William A. Dayton. 1942. Standardized plant names. J. Horace McFarland Company. Harrisburg, Pennsylvania. 675 pp.

Langner, W. 1959. Selbstfertilität und Inzucht bei *Picea Omorika* (Pancic) Purkyne. Silvae Genet. 8:84-93.

Little, Elbert L., Jr. 1953a. A natural hybrid spruce in Alaska. J. Forest. 51(10):745-747.

Little, Elbert L., Jr. 1953b. Checklist of native and naturalized trees of the United States (including Alaska). U.S. Dep. Agr. Agri. Handbook No. 41. Washington, D.C. 472 pp.

Orr-Ewing, A.L. 1954. Inbreeding experiments with the Douglas-fir. Forest. Chron. 30(1):7-16.

Panshin, A.J. and Carl de Zeeuw. 1964. Textbook of wood technology. Vol. I. McGraw-Hill Book Company, Inc. New York. 643 pp., illus.

Parry, C.C. 1862. Physiographical sketch of that portion of the Rocky Mountain range, at the head waters of South Clear Creek, east of Middle Park: with an enumeration of the plants collected in this district, in the summer months of 1861. Amer. J. Sci. Arts Second Ser. 33:231-237.

Parry, C.C. 1863. Ascent of Pike's Peak, July 1st, 1862. Acad. Sci. St. Louis, Transactions 2:120-125.

Rehder, Alfred. 1940. Manual of cultivated trees and shrubs hardy in North America. The MacMillan Company. New York. 996 pp.

Richens, R.H. 1945. Forest tree breeding and genetics. Imperial Agricultural Bureaux. Joint Publication No. 8. Imperial Bureau of Plant Breeding and Genetics, Cambridge, England. 79 pp.

Scheffé, Henry. 1959. The analysis of variance. John Wiley and Sons, Inc., New York. 477 pp.

Taylor, T.M.C. 1959. The taxonomic relationship between *Picea glauca* (Moench) Voss and *P. engelmannii* Parry. Madroño 16:111-115.

Wright, Jonathan W. 1955. Species crossability in spruce in relation to distribution and taxonomy. Forest Sci. 1(4):319-349.

Wyman, Donald. 1961. Spruces popular despite limitations. Amer. Nurseryman 114(9):12-13, 106-111.

INTROGRESSIVE HYBRIDIZATION IN THE SPRUCE SPECIES OF BRITISH COLUMBIA

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INTRODUCTION

There are four spruces in British Columbia which form a complex of sympatric and allopatric populations with a province wide distribution. These are Sitka spruce (*Picea sitchensis* (Bong.) Carr.), black spruce (*P. mariana* (Mill.) BSP.), white spruce (*P. glauca* (Moench) Voss ssp. *glauca*), and Engelmann spruce (*P. glauca* (Moench) Voss ssp. *engelmannii* (Parry) Taylor). The taxonomic literature also recognizes the occurrence of two other varieties of white spruce in British Columbia, e.g. Porsild spruce (*P. glauca* (Moench) Voss var. *porsildii* Raup), and western white spruce (*P. glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.).

The distribution of the components of this great spruce complex is known only in very general terms, and there are no detailed distributional maps available for British Columbia other than those published by Whitford and Craig in 1918.

The present study is divided into two parts, one of which refers to physiological variation in immature spruce populations, and the other to morphological variation in mature populations. The genecological and silvicultural implications of the results will be reported elsewhere. This paper, therefore, is concerned principally with the results of the study which relate to natural hybridization of spruce in British Columbia.

MATERIALS AND METHODS

Physiological Variation in Juvenile Populations

One hundred and fifty spruce provenances were sown in a specially prepared soil mix (Baker 1957) at the Cowichan Lake nursery on Vancouver Island, British Columbia, in the spring of 1964. The provenances were randomized in six replications and sown at right angles to the long axis of the beds. Each provenance represents the bulked seed of a varying number of trees collected and registered under the supervision of professional personnel of the British Columbia Forest Service. Fig. 1 and Table 1 give details of the geographic

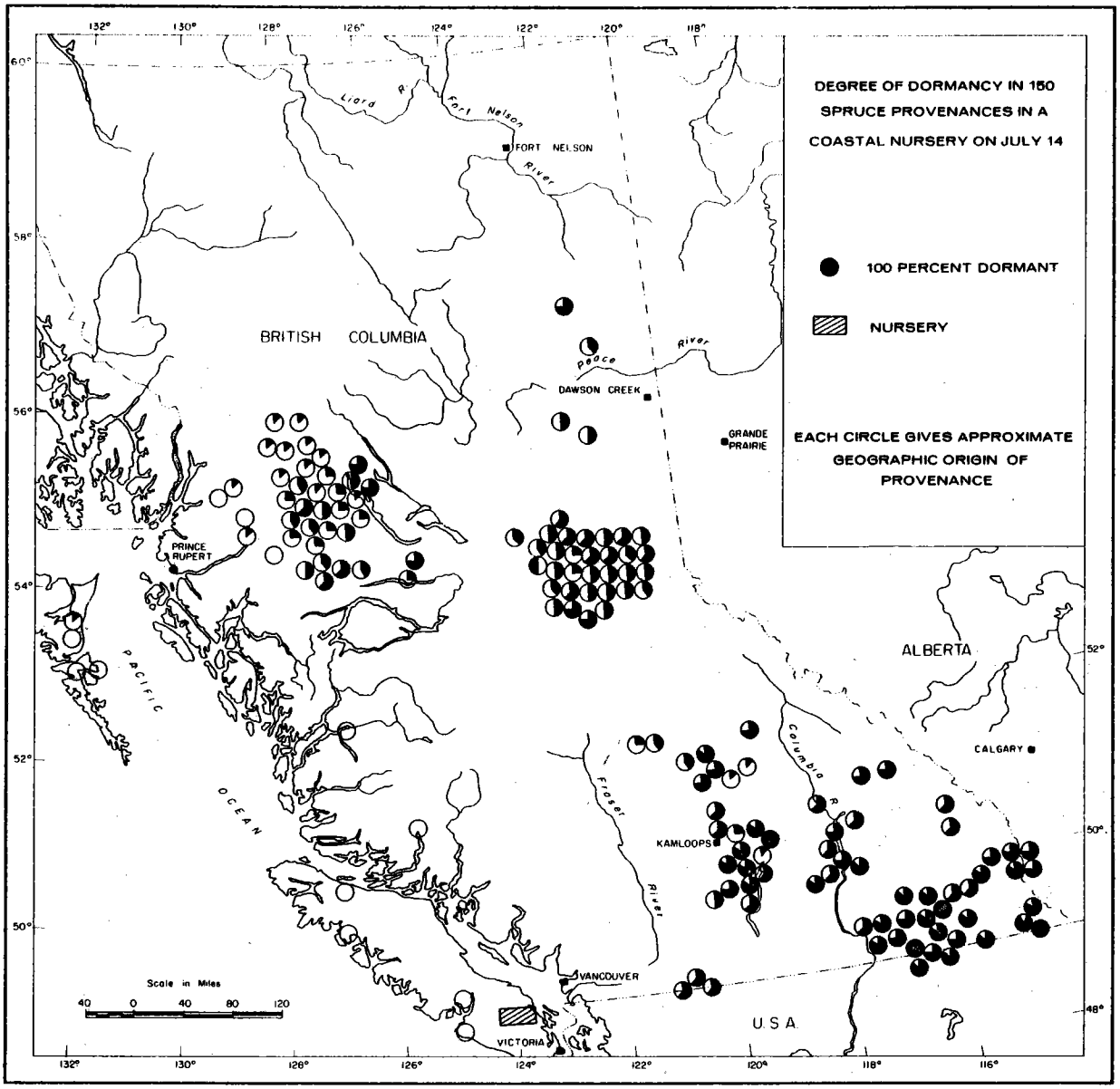

Figure 1. Relationship between the degree of dormancy at the Cowichan nursery on July 14 and altitude at place of origin of each provenance. High elevation provenances go dormant first, then provenances at lower elevation followed by those from areas of coastal influence, that is, the Nass and Skeena river basins. The correlation coefficient between degree or dormancy and altitude is 0.86.

Table 1. Geographic origin of 150 spruce provenances (seed collections) arranged in order of increasing elevation.

Prov No.	Lat	Long	Elev in 1000 ft	Prov No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
1	53 40	132 20	0.1	33	54 06	122 03	2.0
2	52 22	126 45	0.1	34	54 06	127 25	2.0
3	50 03	127 03	0.1	35	55 40	122 12	2.0
4	55 05	129 25	0.1	36	54 56	127 25	2.0
5	54 03	128 39	0.1	37	54 56	127 25	2.0
6	49 08	125 25	0.2	38	54 56	127 25	2.0
7	48 50	124 45	0.3	39	54 56	127 25	2.0
8	53 05	132 05	0.3	40	54 56	127 25	2.0
9	53 30	132 15	0.4	41	54 00	122 00	2.0
10	53 06	132 03	0.4	42	54 11	122 07	2.0
11	50 32	127 15	0.6	43	54 11	122 07	2.0
12	55 05	129 20	0.7	44	54 05	121 53	2.0
13	54 40	128 45	0.7	45	54 06	122 03	2.0
14	54 45	128 45	0.8	46	54 56	127 25	2.0
15	51 11	125 34	0.9	47	54 05	122 03	2.1
16	55 08	127 24	1.0	48	54 15	122 20	2.2
17	55 18	127 42	1.1	49	54 15	122 20	2.2
18	55 28	127 42	1.2	50	54 10	122 15	2.2
19	55 17	127 24	1.2	51	55 18	127 19	2.2
20	51 37	119 50	1.4	52	54 05	122 03	2.2
21	51 35	119 51	1.4	53	54 10	122 10	2.2
22	54 54	127 15	1.5	54	54 00	122 00	2.2
23	55 36	127 50	1.5	55	54 00	122 00	2.2
24	55 36	127 50	1.5	56	54 30	124 00	2.2
25	53 25	122 40	1.7	57	54 30	122 40	2.2
26	55 28	127 50	1.7	58	52 20	121 40	2.2
27	54 48	127 00	1.9	59	52 25	121 25	2.2
28	54 45	127 00	1.9	60	54 07	122 50	2.2
29	54 10	122 15	1.9	61	56 30	121 06	2.3
30	54 10	122 10	1.9	62	54 20	122 40	2.3
31	54 14	127 22	2.0	63	55 20	126 38	2.3
32	55 30	121 35	2.0	64	54 17	122 37	2.3

Table 1 (continued)

Prov No.	Lat	Long	Elev in 1000 ft	Prov No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
65	54 05	122 05	2.3	98	49 07	120 53	4.0
66	54 05	122 05	2.3	99	50 38	118 00	4.0
67	55 02	126 30	2.3	100	51 14	120 15	4.0
68	54 40	127 15	2.4	101	49 55	118 35	4.0
69	54 15	122 15	2.5	102	49 10	120 35	4.0
70	54 10	123 10	2.5	103	49 55	120 35	4.0
71	54 38	127 12	2.5	104	49 55	119 46	4.1
72	54 22	122 30	2.6	105	50 15	117 50	4.2
73	54 05	127 15	2.6	106	49 00	116 40	4.2
74	54 53	126 44	2.7	107	50 40	119 35	4.2
75	54 07	125 25	2.7	108	51 44	120 05	4.2
76	57 10	121 50	2.7	109	50 39	117 32	4.2
77	55 36	127 50	2.7	110	49 20	117 15	4.2
78	54 27	126 54	2.7	111	50 42	119 30	4.2
79	54 00	121 30	2.7	112	50 52	119 50	4.2
80	54 15	121 55	2.7	113	49 03	116 58	4.3
81	54 04	121 27	2.8	114	51 08	117 05	4.3
82	54 21	125 26	2.9	115	51 07	118 15	4.3
83	55 05	127 20	2.9	116	49 29	117 14	4.4
84	53 40	122 25	3.0	117	49 05	115 47	4.5
85	54 08	127 09	3.0	118	49 55	114 46	4.5
86			3.0	119	50 32	115 55	4.5
87	50 10	118 00	3.1	120	50 25	118 02	4.5
88	55 00	127 00	3.2	121	49 49	116 16	4.5
89	54 06	127 25	3.3	122	49 55	114 45	4.6
90	53 20	122 10	3.4	123	50 51	119 52	4.6
91	51 42	120 10	3.5	124	51 40	120 10	4.6
92	49 04	120 45	3.5	125	49 05	116 45	4.6
93	52 12	119 15	3.5	126	50 08	115 26	4.6
94	51 10	120 15	3.8	127	49 22	114 35	4.6
95	49 00	116 45	3.8	128	51 46	120 10	4.6
96	49 35	115 59	3.8	129	51 00	119 52	4.7
97	50 00	118 00	3.8	130	50 07	119 42	4.7

Table 1 (continued)

Prov No.	Lat	Long	Elev in 1000 ft	Prov No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
131	50 04	119 41	4.7	141	50 15	115 45	5.0
132	51 07	117 15	4.7	142	50 29	119 45	5.1
133	49 10	116 08	4.7	143	49 26	116 08	5.1
134	49 15	116 14	4.8	144	49 55	114 44	5.1
135	50 34	119 29	4.9	145	49 20	116 08	5.3
136	49 55	114 55	4.9	146	49 15	117 45	5.5
137	49 45	117 00	4.9	147	49 18	116 00	5.5
138	49 46	115 24	5.0	148	50 01	119 42	5.5
139	50 05	117 45	5.0	149	49 06	114 40	5.6
140	49 03	114 40	5.0	150	49 35	117 48	5.7

origin of each provenance. The location of the Cowichan nursery is also indicated in Fig. 1. Table 3 summarizes the measurements made during the first and second nursery year.

Morphological Variation in Mature Populations

The study of variation in mature populations refers to an assessment of variation in spruce cone scale morphology. One hundred and fifty seven areas were sampled throughout the range of spruce in British Columbia (Table 2, Fig. 2). Twenty cones were taken from the base of each of five trees to give 100 cones per sampled area. The cones were kept separate by trees. In the laboratory a cone scale was taken from the midpoint of each cone and measured (Fig. 3).

All data were subjected to statistical analysis, and, to clarify the complex pattern of variation in cone scale morphology in sympatric zones, recourse was made to extensive graphing of cone scale data. A modified form of the "line of shape" method developed by Jentys-Szaferowa (1959) was used, and is explained below.

From the total number of trees sampled, five trees of white, Engelmann and Sitka spruce were selected from allopatric zones of each of these species. Since no allopatric zone of black spruce was sampled it was necessary to select individuals known to be pure black spruce trees from different sympatric zones of white and black spruce. These trees, representing the pure form of each of the four spruces occurring in British Columbia, are henceforth referred to as standard samples. The cone scale samples of these trees were measured in the manner described, and mean measurements obtained for each of the four species in its pure form (Table 4).

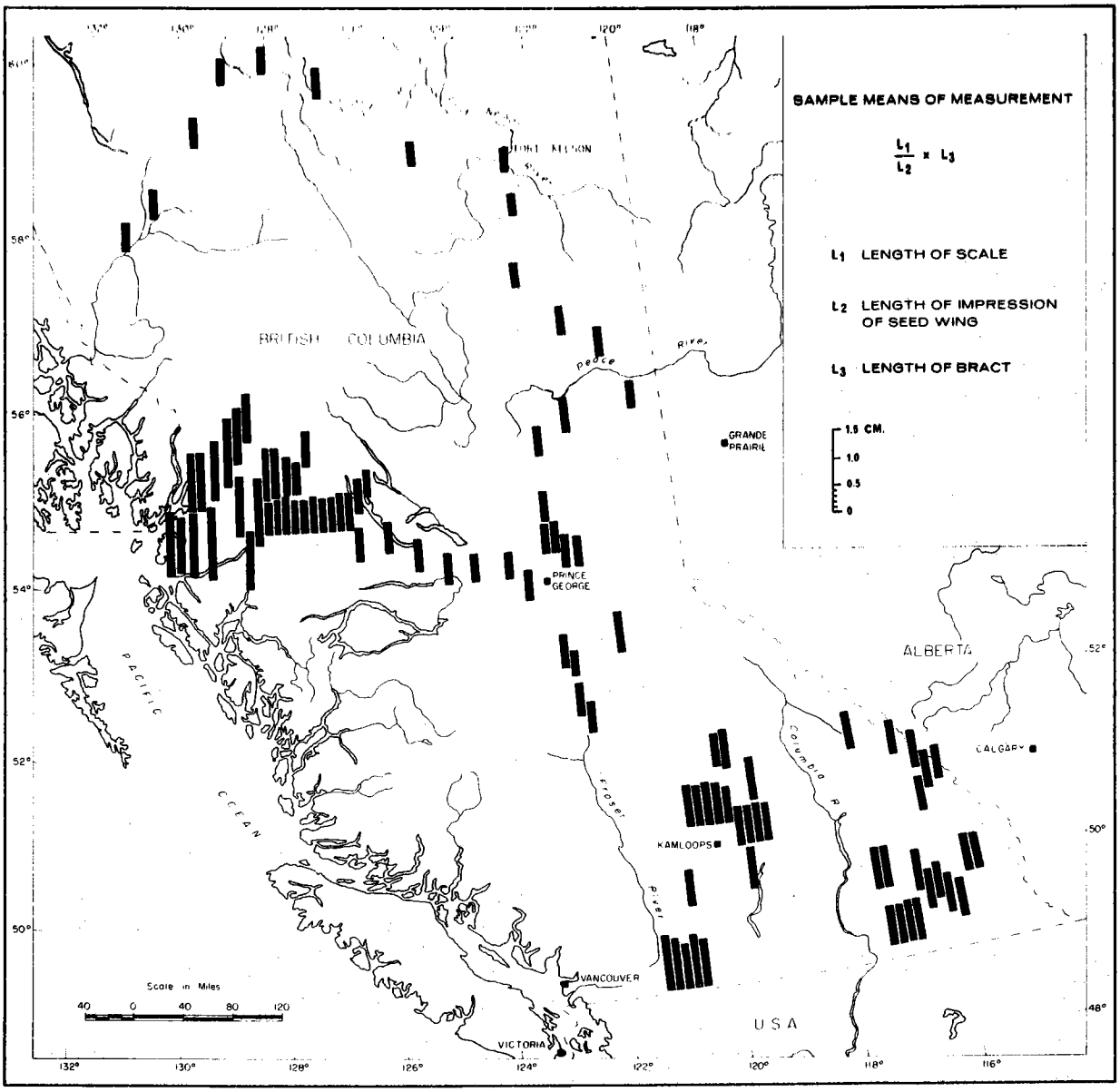

Figure 2. Pattern of variation in a single measurement of spruce cone scale morphology. Each bar represents the mean of 100 cones. 1964 collection.

Table 2. Geographic origin of 157 spruce cone samples arranged in order of increasing elevation.

Sample No.	Lat	Long	Elev in 1000 ft	Sample No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
1	54 14	128 32	0.3	33	54 06	122 23	2.0
2	54 15	129 27	0.3	34	59 58	128 9	2.1
3	54 15	129 48	0.4	35	53 40	120 25	2.1
4	54 13	130 16	0.4	36	55 37	122 00	2.1
5	54 15	130 8	0.5	37	51 10	120 05	2.1
6	55 10	129 15	0.5	38	52 21	122 20	2.2
7	55 2	129 33	0.5	39	53 00	122 30	2.2
8	54 35	128 23	0.5	40	54 50	127 15	2.2
9	55 3	129 30	0.5	41	54 32	125 45	2.2
10	54 37	128 42	0.6	42	54 39	122 43	2.2
11	54 57	128 23	0.7	43	54 6	122 4	2.2
12	55 16	129 02	0.7	44	54 1	124 6	2.3
13	55 2	128 16	0.8	45	54 18	122 37	2.3
14	55 7	127 46	1.1	46	54 00	122 30	2.3
15	55 23	128 53	1.2	47	53 49	122 47	2.3
16	55 12	127 41	1.2	48	53 67	122 42	2.3
17	55 23	127 36	1.2	49	54 18	122 36	2.3
18	51 50	120 03	1.3	50	58 14	130 38	2.3
19	57 55	131 11	1.3	51	49 17	117 13	2.4
20	55 28	128 47	1.4	52	54 20	122 37	2.4
21	51 35	119 53	1.4	53	54 26	124 21	2.4
22	58 37	122 41	1.6	54	55 3	126 30	2.4
23	58 12	122 44	1.7	55	53 45	122 52	2.4
24	59 39	126 53	1.7	56	55 21	122 36	2.4
25	51 08	120 02	1.8	57	54 13	125 39	2.5
26	52 46	122 26	1.8	58	54 44	127 11	2.5
27	54 50	127 14	1.9	59	53 40	122 25	2.5
28	54 45	127 08	2.0	60	53 45	122 30	2.5
29	52 55	122 27	2.0	61	53 41	122 55	2.5
30	51 50	120 03	2.0	62	49 02	117 10	2.5
31	54 06	122 04	2.0	63	49 14	121 06	2.5
32	54 02	121 40	2.0	64	54 03	124 42	2.5

Table 2 (continued)

Sample No.	Lat	Long	Elev in 1000 ft	Sample No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
65	51 50	120 03	2.6	98	50 42	120 23	3.6
66	52 12	122 06	2.7	99	53 18	122 08	3.7
67	53 54	123 26	2.7	100	50 55	120 25	3.7
68	53 40	122 25	2.7	101	49 04	120 50	3.8
69	53 45	122 15	2.7	102	51 03	119 53	3.8
70	55 45	120 38	2.8	103	51 21	116 34	3.8
71	51 05	120 00	2.8	104	57 17	122 45	3.9
72	49 07	118 35	2.8	105	50 55	120 25	3.9
73	54 44	127 12	2.8	106	53 40	122 25	3.9
74	54 29	126 15	2.8	107	49 33	116 27	3.9
75	59 48	129 08	2.9	108	50 52	119 50	3.9
76	54 45	127 02	2.9	109	49 06	120 50	4.0
77	51 50	120 03	2.9	110	54 47	127 17	4.0
78	53 40	122 25	2.9	111	51 50	120 03	4.0
79	54 07	121 44	3.0	112	50 44	119 27	4.0
80	51 04	119 56	3.0	113	49 03	120 51	4.0
81	56 25	121 09	3.0	114	50 42	120 23	4.0
82	54 44	127 16	3.0	115	50 48	116 00	4.0
83	54 27	126 45	3.1	116	49 6	116 54	4.1
84	56 44	121 55	3.2	117	50 08	118 34	4.1
85	53 40	122 25	3.2	118	50 55	120 25	4.1
86	59 16	129 37	3.2	119	54 47	127 17	4.2
87	54 45	127 17	3.2	120	53 04	121 31	4.2
88	58 44	124 55	3.3	121	51 02	115 58	4.3
89	50 54	119 49	3.3	122	50 55	120 25	4.3
90	50 55	120 25	3.3	123	49 6	116 56	4.3
91	49 11	120 36	3.3	124	50 50	119 50	4.3
92	50 00	120 36	3.3	125	50 42	120 24	4.4
93	54 56	126 34	3.4	126	51 33	119 44	4.4
94	51 30	117 18	3.4	127	49 44	117 09	4.4
95	53 40	122 25	3.5	128	49 44	115 31	4.5
96	50 55	120 25	3.5	129	50 39	116 00	4.5
97	54 46	127 17	3.6	130	51 50	120 03	4.5

Table 2 (continued)

Sample No.	Lat	Long	Elev in 1000 ft	Sample No.	Lat	Long	Elev in 1000 ft
	° '	° '			° '	° '	
131	49 03	117 00	4.6	145	49 6	117 58	4.9
132	49 47	115 27	4.6	146	49 17	115 58	4.9
133	51 00	119 50	4.6	147	49 24	116 10	5.1
134	49 44	117 09	4.7	148	49 03	117 00	5.1
135	51 50	120 03	4.7	149	49 06	116 58	5.1
136	50 46	119 33	4.7	150	50 05	119 40	5.1
137	50 55	120 25	4.7	151	50 47	119 52	5.2
138	49 12	118 00	4.7	152	49 07	116 54	5.4
139	50 33	119 30	4.7	153	49 6	117 1	5.4
140	50 59	119 33	4.7	154	51 12	116 05	5.5
141	50 48	119 52	4.8	155	49 20	116 06	5.6
142	49 5	120 46	4.8	156	49 15	117 22	5.8
143	50 42	120 25	4.8	157	49 29	116 08	6.7
144	51 50	120 03	4.9				

Table 3. Measurements of growth made on 150 spruce provenances, and measurements of factors of the environment at their place of origin.

Measurements		Code
1	Latitude.....	L
2	Altitude.....	A
3	Index of the vegetative period.....	D
4	Shoot length in first year.....	SL1
5	Root collar diameter in first year.....	RC1
6	Dry weight in first year.....	DW1
7	Shoot length in second year.....	SL2
8	Root collar diameter in second year.....	RC2
9	Dry weight in second year.....	DW2
10	Percentage dormant on June 30.....	DJ30
11	Percentage dormant on July 7.....	DJY7
12	Percentage dormant on July 14.....	DJY14
13	Percentage dormant on July 21.....	DJY21
14	Percentage dormant on July 28.....	DJY28
15	Percentage dormant on August 4.....	DA4

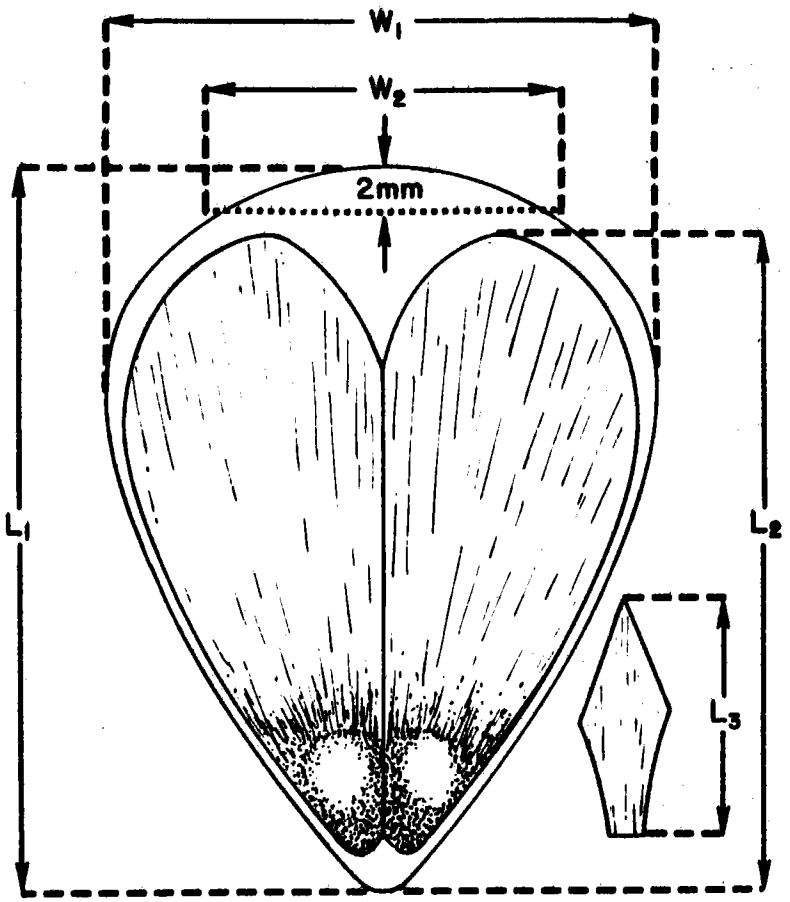

Figure 3. Diagrammatic representation of spruce scale and bract showing five basic measurements. The five derived measurements are L_1/L_2, L_1/L_3, L_1/W_1, L_1/W_2, and L_1/L_2 X L_3. The order of occurrence of these 10 measurements in all subsequent figures and tables is as follows:

1	2	3	4	5	6	7	8	9	10
L_1	L_2	L_3	W_1	W_2	L_1/L_2	L_1/L_3	L_1/W_1	L_1/W_2	L_1/L_2 X L_3.

The mean measurements were used to derive characteristic 'lines of shape' for each species. Species are compared by visual assessment of these lines of shape of cone scale morphology. For example, the mean values for white and Sitka spruce are given in Table 5, together with the ratios of the values Sitka/white spruce. In Fig. 4-1 white spruce (standard) is represented by a straight line with the value of 1. The angular line represents Sitka spruce plotted in relation to white spruce for each of the five measurements and five derivatives of cone scale morphology (Fig. 3). Similar comparisons are illustrated for other species combinations in Fig. 4-2, -3, -4, and Fig. 5.

When a cone scale sample is from a sympatric zone, and is doubtful or unknown as to species it can be graphed against the standard samples, using the means for the species represented in the sympatric zone. The greater the similarity between the unknown and the standard sample the greater the tendency for the line of shape of the unknown sample to form a straight line. Conversely, when the

Table 4. Cone scale morphology of black, white, Engelmann and Sitka spruce.

Species	S	L_1	L_2	L_3	W_1	W_2	L_1/L_2	L_1/L_3	L_1/W_1	L_1/W_2	$L_1/L_2 \times L_3$
BLACK	138-3	1.02	0.82	0.32	0.86	0.76	1.24	3.27	1.19	1.36	0.39
	143-3	1.09	0.82	0.30	0.93	0.75	1.33	3.67	1.19	1.46	0.40
	141-1	0.84	0.68	0.22	0.68	0.60	1.24	3.81	1.25	1.41	0.28
	145-5	1.13	0.83	0.31	0.97	0.80	1.37	3.80	1.17	1.46	0.42
	146-4	1.12	0.79	0.24	1.00	0.81	1.43	4.76	1.12	1.40	0.35
	$\bar{x}$	1.04	0.79	0.28	0.89	0.74	1.32	3.86	1.18	1.42	0.37
WHITE	64-1	1.16	0.99	0.45	0.91	0.82	1.18	2.63	1.29	1.42	0.53
	65-1	1.16	0.99	0.43	0.89	0.79	1.18	2.78	1.32	1.48	0.51
	70-1	1.17	1.01	0.46	0.93	0.82	1.17	2.60	1.27	1.44	0.54
	71-1	1.11	0.98	0.45	0.84	0.77	1.14	2.52	1.33	1.45	0.51
	72-1	1.20	1.00	0.42	1.05	0.92	1.20	2.96	1.14	1.32	0.50
	$\bar{x}$	1.16	0.99	0.44	0.92	0.82	1.17	2.70	1.27	1.42	0.52
ENGELMANN	93-1	1.21	0.86	0.59	0.92	0.67	1.41	2.09	1.32	1.92	0.82
	95-1	1.32	1.00	0.54	0.88	0.62	1.32	2.49	1.49	2.16	0.72
	99-1	1.51	1.15	0.64	0.97	0.59	1.32	2.37	1.56	2.60	0.84
	116-1	1.25	0.92	0.54	0.88	0.61	1.37	2.35	1.44	2.12	0.74
	118-1	1.34	0.99	0.59	0.83	0.57	1.35	2.28	1.61	2.39	0.80
	$\bar{x}$	1.33	1.00	0.58	0.90	0.61	1.35	2.32	1.48	2.24	0.78
SITKA	119-1	1.22	1.00	0.82	0.62	0.52	1.23	1.51	1.97	2.35	1.00
	120-1	1.48	1.06	0.87	0.76	0.51	1.40	1.73	1.97	2.97	1.21
	125-1	1.25	0.90	0.73	0.80	0.57	1.41	1.74	1.58	2.23	1.02
	128-1	1.62	1.11	0.98	0.89	0.52	1.46	1.66	1.83	3.15	1.43
	129-1	1.57	1.14	0.83	0.71	0.50	1.38	1.92	2.21	3.16	1.14
	$\bar{x}$	1.43	1.04	0.85	0.76	0.52	1.38	1.71	1.91	2.77	1.16

S - cone sample, L1, L2, etc., represent the measurements illustrated in Fig. 3.

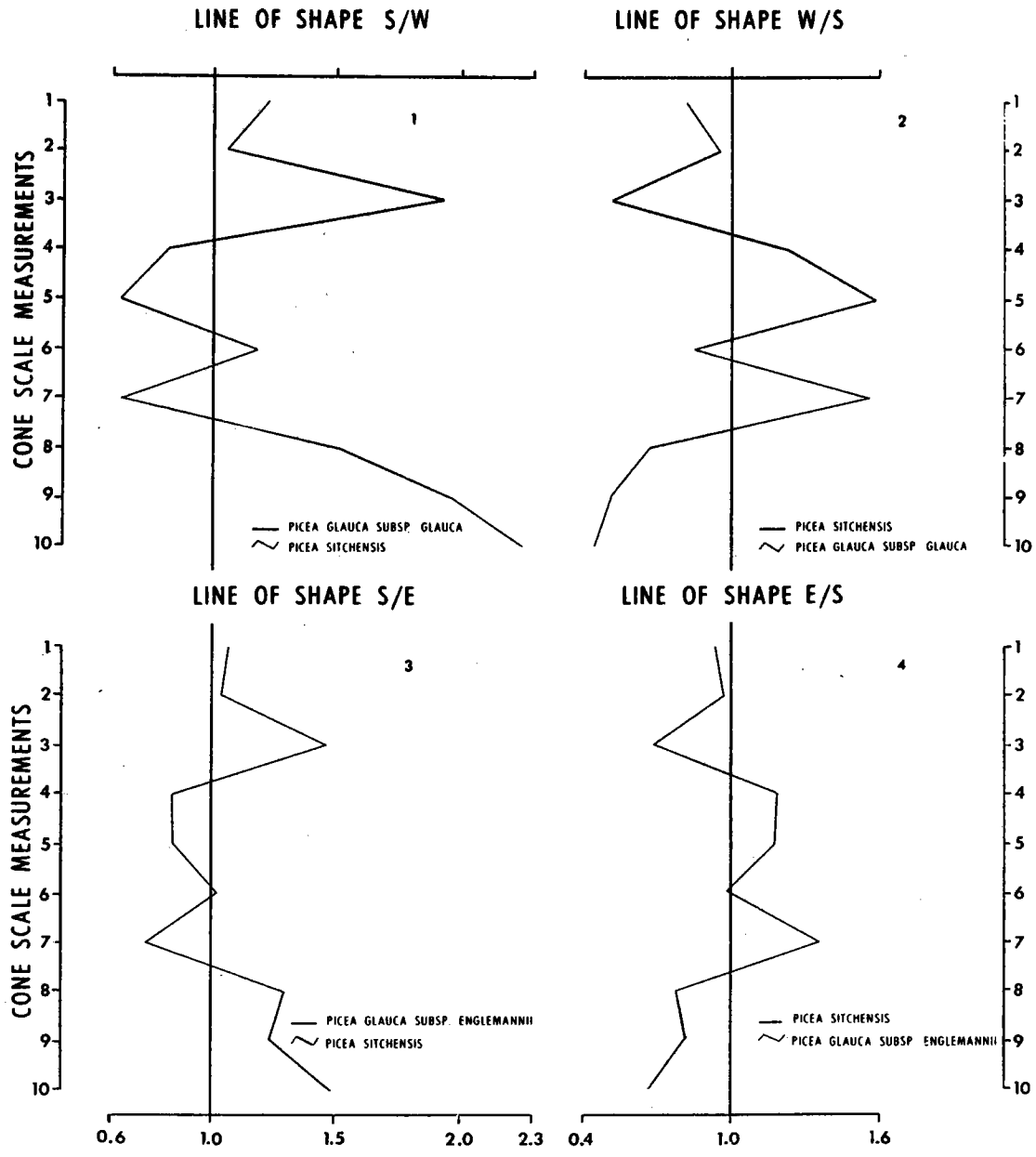

Figure 4. Characteristic curves obtained when cone scale morphology of populations from allopatric zones of white, Engelmann and Sitka spruce is compared by line of shape method.

The numbers 1 to 10 on the vertical bars represent the 10 cone scale measurements illustrated in Fig. 3. The numbers on the horizontal bars are the ratios of these measurements of one species to the other (see column 3, Table 5).
S - Sitka spruce, W - white spruce, E - Engelmann spruce.

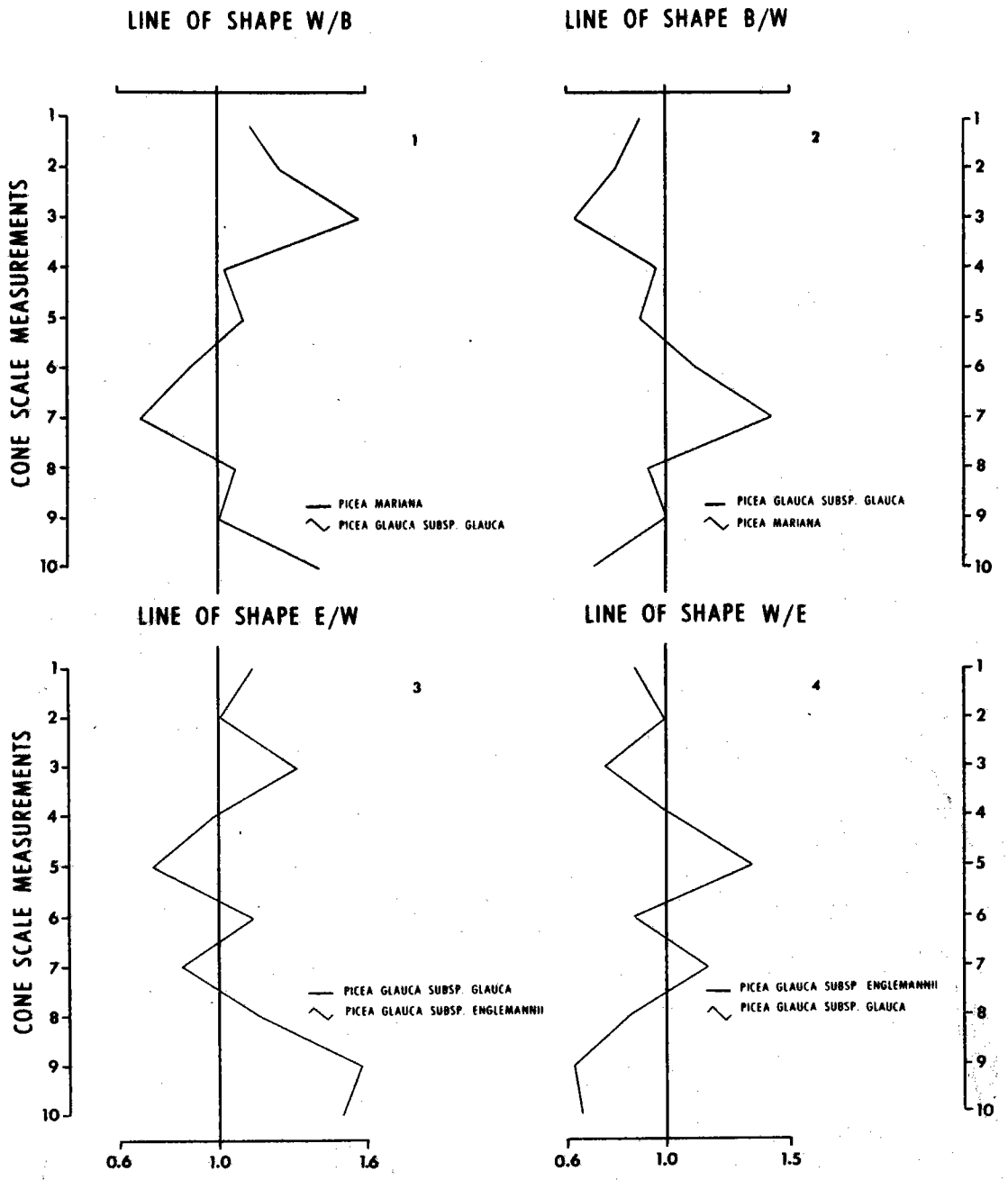

Figure 5. Characteristic curves obtained when cone scale morphology of populations from allopatric zones of white and Engelmann spruce is compared by line of shape method. The black spruce sample is not from an allopatric zone.

The numbers 1 to 10 on the vertical bars represent the 10 cone scale measurements illustrated in Fig. 3. The numbers on the horizontal bars are the ratios of these measurements of one species to the other (see column 3, Table 5).
S - Sitka spruce, W - white spruce, E - Engelmann spruce.

Table 5. Comparison of means of cone scale morphology of white and Sitka spruce.

Measurement*	1 White	2 Sitka	3 Sitka/White
L_1	1.16	1.43	1.23
L_2	0.99	1.04	1.05
L_3	0.44	0.85	1.93
W_1	0.92	0.76	0.83
W_2	0.82	0.52	0.63
L_1/L_2	1.17	1.38	1.18
L_1/L_3	2.70	1.71	0.63
L_1/W_1	1.27	1.91	1.50
L_1/W_2	1.42	2.77	1.95
$L_1/L_2/x\ L_3$	0.52	1.16	2.2

*L_1, L_2 etc. represent the measurements illustrated in Fig. 3.

standard and unknown samples are quite dissimilar, the line of shape of the unknown sample deviates markedly from a straight line. Therefore, by a visual assessment of the line of shape of a sample from a sympatric zone it is possible to determine the extent to which the unknown sample represents a known standard sample, and to assess the degree of putative hybridization occurring in the sympatric zone.

RESULTS

In general the pattern of variation in juvenile populations at Cowichan, and the pattern of variation in mature populations as assessed from cone scale morphology are mutually corroborative. Both indicate the importance of environmental factors associated with altitude in regard to selection and adaptation in the white-Engelmann complex (Figs. 1, 6 and 7 and Table 6). In the white-Sitka complex both studies indicate the extent and effect of the penetration of Sitka spruce genes into white spruce populations (Figs. 1, 2 and 8) in northwestern British Columbia. There is some indication that hybridization between black and white spruce is occurring along the Alaska Highway in northern British Columbia (Fig. 9).

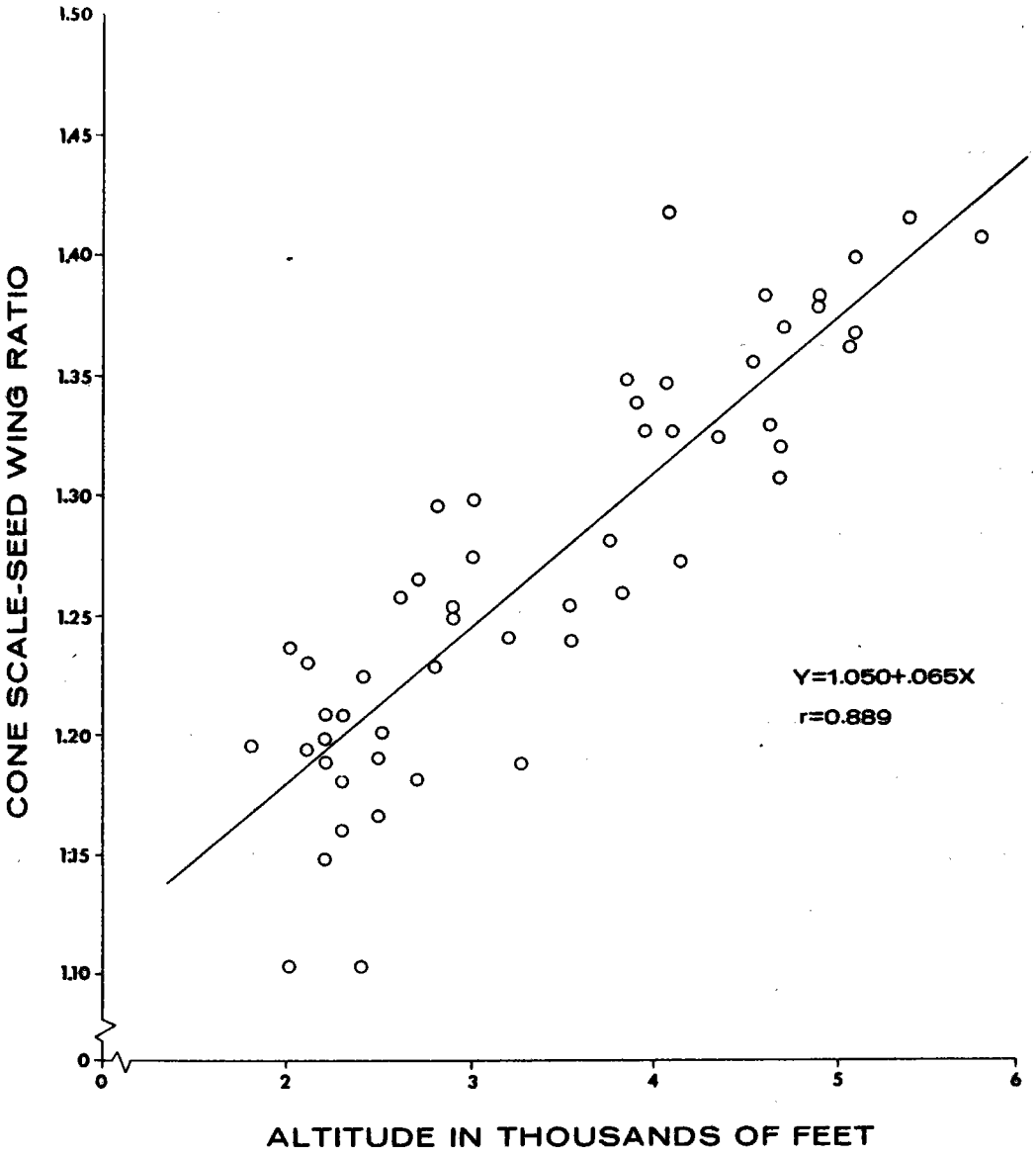

Figure 6. Relationship between elevation and spruce cone scale-seed wing ratio. Each point on the curve represents the mean of 100 cones. 1963 collection in the white-Engelmann spruce complex.

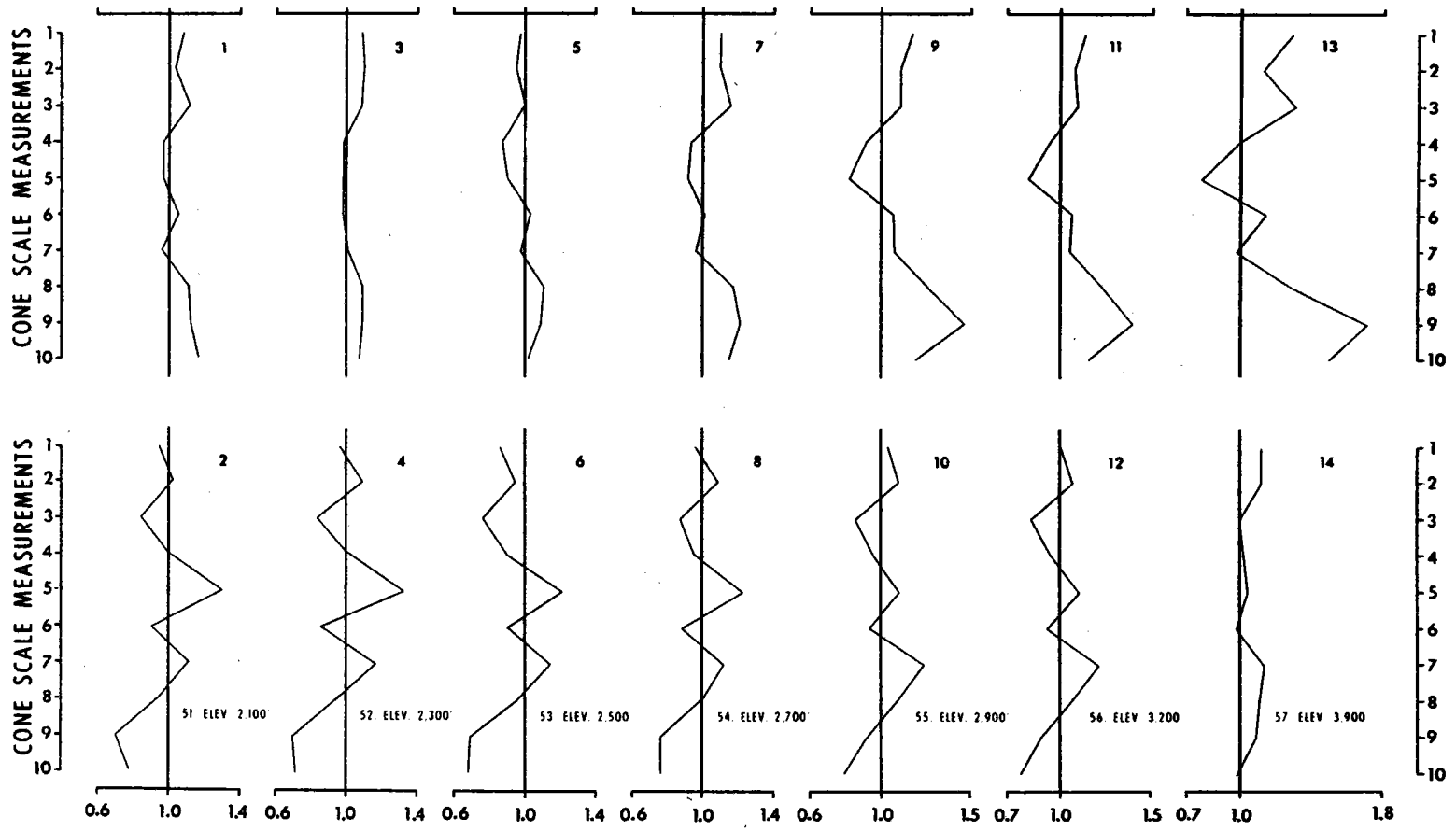

Figure 7. The pattern of variation in spruce cone scale morphology along an altitudinal transect at Stone Creek, south of Prince George (lat. ca. 54°00').

The top series of curves show the line of shape of the unknown samples when compared with the standard white spruce sample. The bottom series show the line of shape of the same samples when compared with the standard Engelmann spruce sample. Means are calculated from a 100-cone sample at each altitude. See Figs. 4 and 5 for further explanation.

Table 6. Relationship between growth and dormancy in 150 spruce provenances and factors of the environment at their place of origin.

			L	A	D	SL1	RC1	SL1/RC1	DW1	SL2	RC2	SL2/RC2	DW2	DJ30	DJY7	DJY14	DJY21	DJY28	DA4
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Factors of the Environment	L	1	1.000																
	A	2	-.682	1.000															
	D	3	.308	-.906	1.000														
Growth First Year	SL1	4	-.020	-.548	.724	1.000													
	RC1	5	-.555	.128	.154	.645	1.000												
	SL1/RC1	6	.427	-.814	.813	.806	.078	1.000											
	DW1	7	-.190	-.286	.483	.892	.842	.521	1.000										
Growth Second Year	SL2	8	.085	-.594	.724	.936	.530	.810	.805	.999									
	RC2	9	-.163	-.405	.622	.835	.706	.534	.798	.878	1.000								
	SL2/RC2	10	.446	-.596	.517	.625	.020	.824	.428	.696	.276	1.000							
	DW2	11	-.038	-.538	.722	.868	.598	.653	.793	.909	.954	.395	1.000						
Dormancy Second Year	DJ30	12	-.661	.057	-.733	-.538	.140	-.821	-.308	-.623	-.367	-.717	-.510	1.000					
	DJY7	13	-.635	.856	-.745	-.566	.117	-.839	-.328	-.645	-.400	-.711	-.543	0.981	1.000				
	DJY14	14	-.562	.862	-.796	-.616	.065	-.857	-.361	-.678	-.461	-.671	-.603	0.928	.951	1.000			
	DJY21	15	-.430	.827	-.828	-.698	-.050	-.871	-.428	-.733	-.560	-.623	-.682	0.843	.869	.953	1.000		
	DJY28	16	-.131	.699	-.834	-.768	-.293	-.752	-.523	-.752	-.735	-.687	-.800	0.607	.638	.760	.875	1.000	
	DA4	17	-.089	.656	-.803	-.727	-.274	-.713	-.497	-.672	-.644	-.364	-.720	0.583	.610	.720	.813	.923	1.000

Coefficients of correlation between pairs of variables

See Table 3 for explanation of symbols
r > .159 is significant at .05 level of probability
r > .208 is significant at .01 level of probability

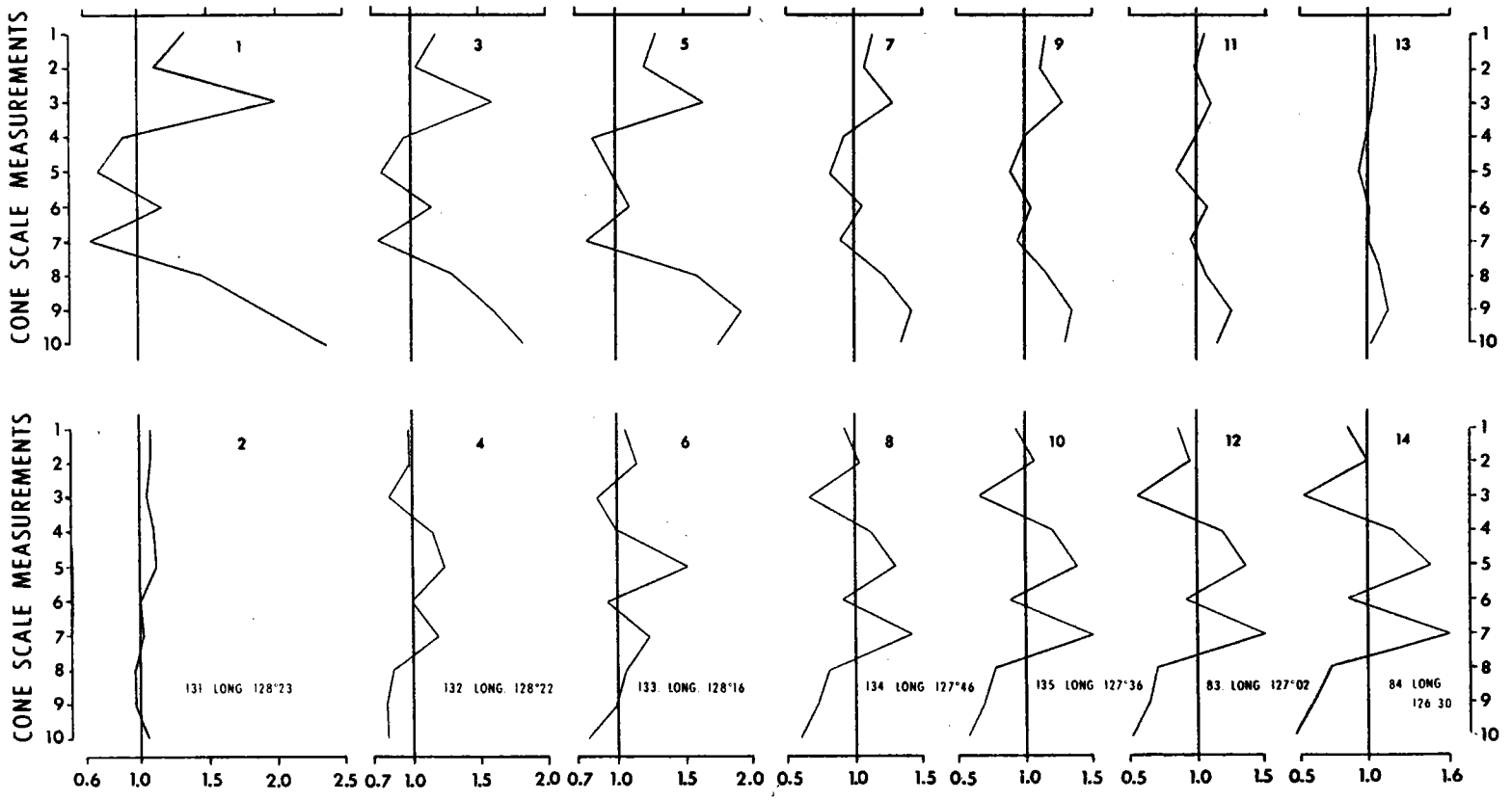

Figure 8. The pattern of variation in spruce cone scale morphology along a longitudinal transect from coastal Sitka spruce forest to montane white spruce forest.

The top series of curves show the line of shape of the unknown samples when compared with the standard white spruce sample. The bottom series show the line of shape of the same samples when compared with the standard Sitka spruce sample. Means are calculated from a 100-cone sample at each altitude. See Figs. 4 and 5 for further explanation.

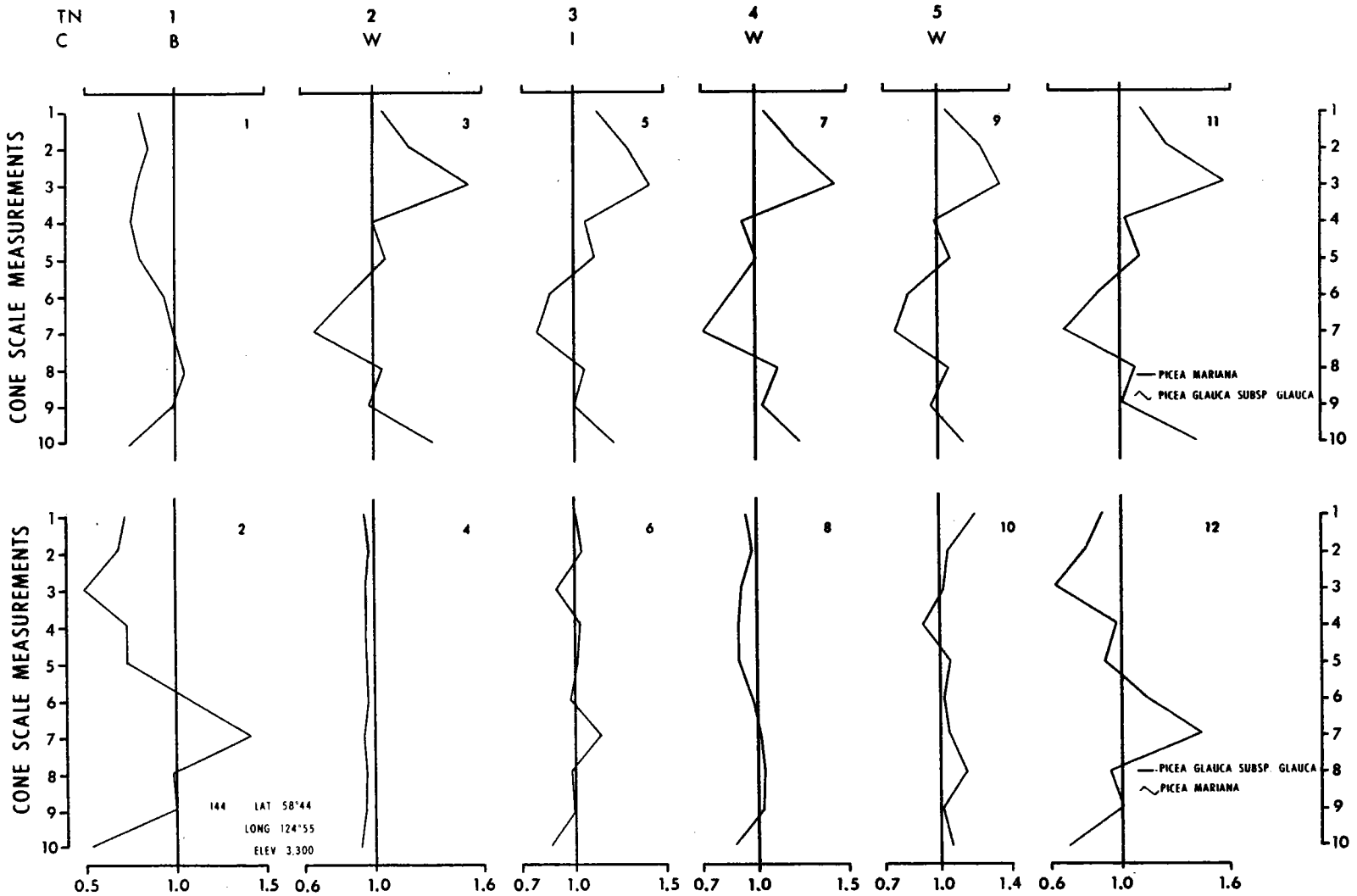

Figure 9. Variation in cone scale morphology in a spruce population in the boreal forest of northern British Columbia. Each of the five trees in this population have been classified as to species by comparing the line of shape of the cone scale with the standard samples 11 and 12. 11 is the characteristic curve of pure white spruce on pure black. 12 is the characteristic curve of pure black on pure white. TN - tree number, C - classification, B - black spruce, W - white spruce, I - intermediate form.

DISCUSSION AND CONCLUSIONS

It is clear from the results that geographic variation in the white-Engelmann spruce complex is habitat-correlated. The assumption is warranted, therefore, that this variation is genetically based (Heslop-Harrison 1964 p. 217). The selection pressures associated with altitude will, as a rule, vary progressively and consequently it is to be expected that the transition from pure white spruce, through the hybrid swarms to pure Engelmann will be progressive. This situation is clearly shown by the pattern of variation in cone scale morphology along a single altitudinal transect at Stone Creek, south of Prince George, illustrated in Fig. 7, and the high correlation between time of entering dormancy and altitude (Fig. 1, Table 6).

The survival value of a particular growth rhythm in a given population is obvious; what is not so obvious is the extent to which variation in cone scale morphology *per se* confers a survival advantage on spruce populations. The characteristic shape of the scale of high and low elevation populations in the white-Engelmann spruce complex, for example, may have a direct effect in facilitating pollination at varying elevations; for the characteristic shape of the scale is already present in young female strobili at the time of pollination, both in high and low elevation populations. More likely, however, this variation in cone scale morphology is a "neutral" character, and therefore a selective value must be ascribed not to the character as such, "but to the influence of the genes responsible for it upon the relative variability of a specific gene combination in a specific local environment" (Timofeeff-Ressovsky 1940 p. 123).

Low elevation, southern latitude provenances from the white-Engelmann spruce complex in the interior of British Columbia were remarkably late in entering dormancy at the Cowichan nursery. Since there is a high correlation between times of entering dormancy and total growth (Table 6) these provenances were considerably taller than provenances from high elevations which entered dormancy at an earlier date. For example, provenance 20 (Table 1), which is from Birch Island in the North Thompson River, was one of the last provenances to go dormant. This same provenance produced the tallest seedlings of the white-Engelmann complex in the Cowichan nursery. In fact it grew as rapidly as Sitka spruce in this nursery.

Because of the high correlation between altitude and time of entering dormancy (Fig. 1, Table 6) the growth behavior of the Birch Island provenance, and similar provenances from the white-Engelmann complex, is explained in terms of the environment at their place of origin rather than in terms of heterosis resulting from hybridization. Hybridization has occurred, but the resulting hybrid swarms have been subjected to environmental pressures similar in kind to those acting on the parental forms.

Provenances from the general region of the Nass, Skeena and Bulkley river basins entered dormancy later than provenances from further east but at similar elevations. For example, all provenances from Doughty (ca. 55°00'N, ca. 127°30'W, elev. 2000 ft.) north of Smithers, and from the region of Hazelton, entered dormancy much later than provenances from further east, e.g. Fort Babine (ca. 55°20'N, ca. 126°28'W, elev. 2300 ft.).

The pattern of variation in mature populations in the same general region of the Nass, Skeena and Bulkley river basins, as determined by cone scale morphology, presents strong evidence as to why the progenies of spruce populations in this area behave as indicated above when grown in a uniform environment. It seems clear that there is a broad sympatric zone of white and Sitka spruce in northwestern British Columbia, and that Sitka spruce genes appear to have penetrated along the valley bottoms as far east as Hazelton and Smithers, and southeast into the valley of the Morice River (Figs. 1, 2, and 7). As will be seen from Fig. 8 there is every gradation in cone scale morphology from that of pure Sitka (sample 131) to that of pure white (sample 84). There is, therefore, considerable evidence that introgressive hybridization is occurring in this area.

It is suggested, therefore, that the variability in cone scale morphology in northwestern British Columbia is the result of introgressive hybridization between white and Sitka spruce in this region. Subsequent selection and adaptation gives a pattern of variation which varies parallel with the progressive change in environment.

In the boreal forest region along the Alaska Highway north of latitude 57°00', white spruce is typically associated with black spruce on muskeg over a very large area. Consequently it is not exceptional that intermediate forms of black and white spruce are represented in these samples (Fig. 9), and, although the evidence is not conclusive, it is possible that introgressive hybridization is occurring between these species. In the field it is frequently impossible in many areas north of latitude 56°00' to distinguish between the species on the basis of crown form, bark type, or cone morphology (Roche 1965).

Natural hybrids of white and Sitka spruce, and white and black spruce have already been identified and described. The white-Sitka hybrid was described from material collected on the Kenai Peninsula in Alaska. The white-black hybrid was described from material collected in Minnesota (Little 1953; Little and Pauley 1958). It appears, however, from the evidence presented in this study, that both hybrids also occur in British Columbia, though, clearly, much more detailed taxonomic work in the sympatric zones demarcated for these species is required before it will be possible to select such hybrids in British Columbia for tree improvement work.

The varietal epithet *albertiana* should be discarded, for as Taylor (1959) has pointed out, and as indicated by the present study, it refers to the white-Engelmann hybrid.

There is no evidence from this study indicating the presence of Engelmann spruce along the Hart and Alaska highways north of latitude 55°30'. The Porsild variety of white spruce does not occur extensively in northern British Columbia. It is possible that the small population at Telegraph Creek, is of this variety (Roche 1965). If so, it is obviously worthy of further investigation to determine its correct taxonomic status, and the value of the population in regard to tree improvement work.

REFERENCES

Baker, K.F., 1957. The University of California system of producing healthy container plants. Manual 23, California Agr. Exp. Sta., Berkeley, California. 331 pp.

Jentys-Szaferowa, J. 1959. A graphical method of comparing the shapes of plants. The Review of the Polish Academy of Sciences, 4:9-37.

Heslop-Harrison, J. 1964. Forty years of genecology. In J.B. Cragg, ed. Advances in Ecological Research, 2:159-247.

Little, E.L. 1953. A natural hybrid in Alaska. J. Forest., 51: 745-747.

Little, E.L. and S.G. Pauley. 1958. A natural hybrid between black and white spruce in Minesota. Amer. Midland Natur., 60:202-211.

Roche, L. 1965. A note on spruce branching habit and bark type. B.C. Forest Service Research Review for year ended March 1956. pp. 44-47.

Taylor, T.M.C. 1959. The taxonomic relationship between *Picea glauca* (Moench) Voss, and *P. engelmannii* Parry. Madroño, 15:112-115.

Timofeeff-Ressovsky. 1940. Mutations and geographical variations. In J. Huxley, ed. The new systemics. Oxford University Press, London. 583 pp.

Whitford, H.N. and R.D. Craig. 1918. Forests of British Columbia. Commission of Conservation, Ottawa, 1918. 409 pp.

USE OF SELF-COMPATIBILITY FOR SEED ORCHARDS

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Self- and cross-compatibility of seedtrees within one or more species provides a tool for mass production of hybrid seed for a specific combination by natural pollination from isolated crossing blocks. This breeding technique has been extensively used in vegetables (onions, tomatoes, cucumbers, etc.) for commercial production of hybrid seed. Breeding studies in progress at the Indian Head Tree Nursery (formerly the Forest Nursery Station) since 1947 have developed procedures for the application of this technique for production of hybrid seed of Colorado spruce (*Picea pungens* Engelm.). Following is a brief description of the steps in a breeding program using this technique for coniferous tree species.

Seedtrees are selected on the basis of specific phenotypic characters. Thus the criterion for selection would be inherited characters such as vigor, growth habit, wood quality, disease or insect resistance. In our studies we have selected for intensity of the blue-needle coloration factor of Colorado spruce.

The self- and cross-compatibility and natural set of each selection is determined for two or more years. Six branches of coneflowers are isolated by covering with cellulose (sausage casings) bags in the bud stage. All male flower buds are removed. When the flowers are receptive, those in two bags are self-pollinated, three are cross-pollinated with pollen from three outstanding selections, and one is left as a non-pollinated check. Two branches of coneflowers are tagged and recorded as open-pollinated checks. The resulting cones are harvested and the yields recorded as seeds-per-cone, to provide indices of the respective self-, cross-, and open-compatibility of each selection. These seedset data indicate the respective self-compatibility and cross-compatibility, as well as the potential capacity for seed production of each selection. Generally, the seedset per cone following self-pollination is much less than by cross- or open-pollination, but seed weights and germination capacity of the seed are similar. Some self-incompatible selections have also proven to be cross-incompatible. Those selections proving self-incompatible are propagated by grafting.

Small samples of the selfed and hybrid seed are sown to evaluate seed variability and to identify selections carrying deleterious characters. Those selections carrying albino or other undesirable seed and seedling characters are discarded. Larger samples of hybrid seed from each selection are sown to produce small progenies for preliminary evaluation of the hybrid characteristics.

Evaluations, in 1966, of the blue-needle character for 10-year-old progenies from three hybrid combinations revealed that one combination produced almost 60% "intense blue" seedlings as compared to 39 and 20% for the other two progenies. As a result the two parents have been propagated and are being planted as two adjacent rows to establish an isolated crossing block. One of these selections is self-incompatible, so all the seed harvested from these grafted plants will result from natural cross-pollination and be true hybrids of the desired type. Thus mass production of hybrid seed by natural pollination is possible and presents the most economic means of improving conifer tree production.

Subsequently combinations providing superior progeny will be identified for further improvement in the quality of the hybrid material.

VARIABILITY OF FLOWER AND CONE PRODUCTION IN NORWAY SPRUCE

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On the grounds of the Ballston Spa, N.Y., Country Club, 109 Norway spruce (*Picea abies*) trees of seedling origin were planted in 1940. The exact age of the planting stock and origin of the seed is not known. The trees are probably of continental European origin, exhibiting several forms ranging from the dense upright branching type to the hanging lateral type, sometimes called the "comb" type. The trees were planted about 30 feet apart, and thus represent the spacing common in a seed orchard or seed production area. For this reason, it seemed of interest to count the mature cones produced on each tree.

The count began in 1962 and continued to 1968 for a total of seven seasons. Starting in 1964, an estimate was made of the number of both male and female flowers and their location on the tree. Observations were also taken on the stage of flushing of the terminal vegetative buds at the time of flowering. In 1966, the diameters and heights were taken for some of the trees. In 1968, the trees were classified as to type of lateral branching. The rainfall records at the nearby Saratoga Nursery were tabulated. The purpose of this paper is to summarize the data and observations taken during this 7-year period.

It became apparent, after 5 years of counting cones, that trees varied greatly and that certain individuals produced the majority of the cones. With the exception of one year, more than 90% of the total cones for the 109 trees were produced by 21 trees. These trees were designated as "coners". The cone counts for these trees are shown in Tables 1-3, along with the count of another group of 21 "non-coner" trees, and the total cone counts for all trees. The 21 non-coners were designated as those which had produced no cones during the 5-year observation period. These 5 years can be considered poor crop years. In 1967, a heavy crop matured. At this time the non-coners fruited for the first time, but bore only 787 cones as compared with 8,921 cones produced by the 21 coners. In 1968, there was an increase in both groups over the previous poor years and some inconsistency among the individual trees. Twelve trees of the non-coner group produced some cones again in 1968.

Table 1. Cone production for 7 years of a Norway spruce open grown stand.

Coner Group Tree No.	1962	1963	1964	1965	1966	1967	1968	Total
1	65	11	2	101	6	272	25	482
13	13	31	5	20	14	263	36	382
19	27	65	0	0	1	750	34	877
32	2	8	1	0	10	293	0	314
33	1	1	1	0	1	97	13	114
39	50	1	4	0	26	687	0	768
47	140	69	21	0	65	497	282	1074
49	2	10	18	32	19	321	3	405
54	43	23	3	36	35	497	27	664
56	35	3	40	0	4	237	1	320
61	1	46	3	6	2	177	66	301
62	11	27	0	0	3	325	28	394
72	30	9	0	0	2	614	0	655
75	12	0	20	0	2	175	0	209
83	80	90	9	56	30	192	21	478
87	19	20	3	0	0	314	57	413
205	11	29	0	0	9	329	192	570
210	12	30	5	45	31	195	32	350
212	15	6	21	7	0	233	62	344
215	32	10	40	35	5	145	39	306
216	110	1	26	4	20	258	43	462
Totals -	711	490	222	342	285	6871	961	9882

Table 2. Cone production for 7 years of a Norway spruce open grown stand.

Non-Coner Group Tree No.	1962	1963	1964	1965	1966	1967	1968	Total
2	0	0	0	0	0	0	1	1
4	0	0	0	0	0	7	0	7
6	0	0	0	0	0	2	0	2
10	0	0	0	0	0	92	16	108
12	0	0	0	0	0	3	0	3
15	0	0	0	0	0	4	4	8
20	0	0	0	0	0	17	2	19
24	0	0	0	0	0	111	0	111
29	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	5	5
43	0	0	0	0	0	81	38	119
51	0	0	0	0	0	113	0	113
60	0	0	0	0	0	19	3	22
65	0	0	0	0	0	8	1	9
70	0	0	0	0	0	181	0	181
81	0	0	0	0	0	9	7	16
88	0	0	0	0	0	17	6	23
200	0	0	0	0	0	49	0	49
201	0	0	0	0	0	65	3	68
202	0	0	0	0	0	0	0	0
214	0	0	0	0	0	9	3	12
Totals -	0	0	0	0	0	787	89	876

Table 3. Summary of cone production for 7 years of all groups.

	Number of Cones by Years							
Groups	1962	1963	1964	1965	1966	1967	1968	Total
21 Coners	711	490	222	342	285	6871	961	9882
21 Non-Coners	0	0	0	0	0	787	89	876
Remaining 67	75	39	5	3	81	8555	592	9350
Totals -	786	529	227	345	366	16213	1642	20108
Percentages								
21 Coners	90.4	92.6	97.8	99.2	77.8	42.4	58.5	49.1
21 Non-Coners	0	0	0	0	0	4.8	5.4	4.4
Remaining 67	5.6	7.4	1.2	.8	32.2	52.8	36.1	46.5
Totals -	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Number of Trees of the 109 with cones -	41	31	19	10	25	103	68	-
Percentages each year -	38.0	29.0	18.0	9.0	23.0	94.5	62.2	-

The reason for the heavy cone crop in 1967 is unknown. This condition was similar in other localities nearby. The rainfall recorded at the Saratoga Nursery, some 3 miles away on the same elevation, is shown in Table 4 for the months of April-July for the years 1961-1968. This shows a more or less normal pattern except for a low in April and a high in June 1966 which probably coincided with the time flower bud primordia were forming. One can also note a low in June 1964, and a high in July 1962. These apparently did not affect the cone set the following year. Matthews (1961), in reviewing the production of forest tree seed, states that water supply can affect the formation of flower buds. Was the heavy cone crop in 1967 related to the high rainfall in June 1966? If so, would a heavy irrigation in June increase the number of flower primordia formed in the same year? Both the coner and non-coner groups were well distributed throughout the planting, with no pattern that would indicate any effect of the site or location on their coning characteristic.

Mean values of diameter breast height and tree height of each group were of special interest. The 21 coners had a mean diameter of 11.4 inches, as compared with 10.6 inches for the non-coners. Again, the coners had a mean height of 35 feet and the non-coners 31 feet. The coner trees were, therefore, somewhat larger than the non-coners. Ranges were: in diameter breast height: for coners 7.3 - 15.6 inches, for non-coners 7.7 - 14.4 inches; in height: for coners 31 - 43 feet,

Table 4. Rainfall and primordia bud formation.

Year	April	May	June	July	Year Cone Crop Affected*	Cone Crop
1961	4.19	3.35	4.20	3.72	1962	786
1962	4.03	2.60	2.14	6.61	1963	529
1963	2.22	3.02	2.70	2.26	1964	227
1964	2.46	1.50	.33	2.55	1965	345
1965	2.68	2.00	1.81	2.16	1966	366
1966	1.43	3.97	7.30 **	3.04	1967	16213
1967	4.74	4.10	2.77	3.85	1968	1642
1968	3.46	4.78	5.49		1969	?

*Primordial flower buds expected to be laid down during a period of 4 months, with June being the prime month.
**4.19 inches recorded for 26 June 1966.

for non-coners 22 - 40 feet. The largest tree in height and diameter, a coner, tree No. 47, also produced the largest number of cones (1,074) in 7 years.

At the time flowering was recorded, the terminal vegetative buds were observed on all trees. There was considerable variation among individuals ranging from no open buds to new growth up to 2 or 3 inches. When coners and non-coners were compared the former were later in flushing than the latter. In each year of measurement the coners had less terminal growth than the non-coners, with mean shoot lengths of 1.5 and 2.2 inches respectively.

The location of the male and female flowers on the tree crown is of interest in relation to probability of self pollination and for the effect on seed production of crown topping to facilate cone collection. The relative abundance of flowers in each of 5 years was scored in three portions of the crown (Table 5). For each tree, the upper, middle and lower third of the crown were rated by eye according to a classification of 0 - 5 for each kind of flower. The accuracy of the method was verified by a correlation of the total ratings for 5 years with the subsequent cone count. The correlation ($r = 0.78$) was significant at 0.1% level using Student's t-test. For each class of abundance of female flowers there appeared on the average 20 mature cones.

From Table 5, it is evident that the male or staminate flowers were better distributed throughout the depth of the crown, with 18% in the lower third, and the remaining 82% equally divided in the upper two-thirds of the crown. Only 9% of the female or ovulate flowers were in the lower one-third and 91% in the upper two-thirds. Also the upper-third had nearly 60% of the total female flowers. Wright (1953) observed the fruiting records on seven individual *Picea abies* at the Morris Arboretum for 5 years, and found variation among the trees. One produced no fruiting for the period, three produced

Table 5. Location of flowers on Norway spruce.

Portion of Crown	Total Ratings Each Year*											
	1964		1965		1966		1967		1968		Total	
	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%	Rating	%
MALE												
Upper Third	77	39.7	86	48.6	145	44.0	228	36.6	124	47.8	660	41.6
Middle Third	84	43.3	72	40.7	130	39.6	266	42.4	82	31.7	634	40.0
Lower Third	33	17.0	19	10.7	54	16.4	133	21.2	53	20.5	292	18.4
Total -	194	100.0	177	100.0	329	100.0	627	100.0	259	100.0	1586	100.0
FEMALE												
Upper Third	63	85.1	41	68.4	90	60.0	304	55.3	71	57.2	569	59.4
Middle Third	10	13.5	17	28.3	51	34.0	183	33.3	39	31.5	300	31.3
Lower Third	1	1.4	2	3.3	9	6.0	63	11.4	14	11.3	89	9.3
Total -	74	100.0	60	100.0	150	100.0	550	100.0	124	100.0	958	100.0

*Rating: each tree is scored for abundance of flowers ranging from 0 for none to an increasing abundance from 1 - 5.

some fruiting for 1 or 2 years, while the remaining three produced heavily for 2 to 4 years of the period. He also observed that Norway spruce bears its female flowers over the entire crown but they tend to be more abundant in the top. The male flowers were borne over the entire crown. A topping operation which would remove the upper one-third would at the same time reduce the cone producing potential to 40% of the whole tree. Topping can be done during a year of a heavy crop, such as 1967, and the crop utilized. It is possible that by opening the crown to introduce more light, physiological changes might increase cone production in the lower two-thirds. However, topping increases the proximity of the male to the female flowers on the same tree and more selfing may be expected.

Holst (1955) and others have classified Norway spruce crown types according to branching habit. This was also done for the 109 trees included in this study. Branch type (1 - 5) was related to flower production and attack by white pine weevil (*Pissodes strobi*) (Table 6). Type 1 is the typical comb spruce, with the laterals on

Table 6. Relation of tree branching habit to flowers, cone and weevil attack.

	Tree Type					
	1	2	3	4	5	Total
Number per Type	5	16	38	33	17	109
Total Rating of Male Flowers	189	317	647	289	119	1561
Average Rating* per Tree per Year	6.3	3.3	2.8	1.5	1.2	2.4
Total Rating of Female Flowers	123	198	393	166	80	960
Average Rating* per Tree per Year	4.1	2.1	1.7	.8	.8	1.5
Total Cones	1819	4303	9405	3380	1552	20464
Average Cones per Tree	364	269	248	102	91	188
Total Weevil Attacks	3	34	79	64	33	215
Average Weevil per Tree	.6	2.1	2.1	1.9	1.9	2.0

*Each of the three levels of the crown were rated 0 - 5, making a possible maximum score of 15.

the branches hanging downward and it is quite open in the crown. The remaining types become more and more dense and the crown more closed. It can be seen that types 4 and 5 produced the lesser number of flowers and cones per tree. Contrary to the situation reported by Holst, the weevil attack was somewhat less on the comb, or 1 type, and almost equal on all the other types. The weevil attack was relatively light, with an overall average of two infestations per tree.

Those interested in seed procurement are frequently concerned with expected yields/acre of seed production areas and seed orchards. In this planting of Norway spruce, the 109 trees at 30 x 30 feet spacing occupy about 2 acres. Over the 7-year period, some 20,108 cones were counted. Converting this into seed/acre/year, based on 283 cones per bushel and a yield of 9 ounces of seed per bushel, the yield for all trees was 3 lb. of seed/acre/year. If all 109 trees produced proportionately as many cones as did the 21 coners, the seed yield would be 7.5 lb./acre/year.

REFERENCES

Holst, Mark J. 1955. An observation of weevil damage in Norway spruce. Can. Dep. North. Affairs Natur. Resources, Forest Br., Forest Res. Div. Tech. Note No. 4, Ottawa. 3 p.

Matthews, J.P. 1961. The production of seed by forest trees. Proc. 13th. I.U.F.R.O. Congress, Vienna. 22/9. 24 p.

Wright, J.W. 1953. Notes on flowering and fruiting of northeastern trees. U.S. Dep. Agri. Northeastern Forest Exp. Sta., Paper No. 60. 38 p.

ABSTRACTS OF SPECIAL PAPERS

These papers will be published in full in the Proceedings of the 17th Northeastern Tree Improvement Conference.

ROOTING SOFTWOOD CUTTINGS OF LARCH

David B. Cook[1] and Charles H. Frommer[2]

ABSTRACT

A decade ago, Dr. Clyde Chandler of Boyce Thompson Institute developed a technique for rooting softwood cuttings of larch. As this could have considerable use in seed orchard management, we decided to give it a try.

On 4-5 July 1965, low branches were taken from four young (12 year) trees - one F-1 Dunkeld, two F-2 Dunkeld and one pure European. Cuttings were immediately set in sand in a mist chamber. After 4 1/2 months, they were potted up, overwintered in a cool greenhouse, field planted the next spring. Survival at out-planting ranged from 100 down to 33%, averaged 55%.

All cuttings tended to grow horizontally; this might have been cured by staking. As of mid-July, 1968, many plants were 1 - 1 1/2 feet tall, vigorous and making real effort to straighten up.

On the basis of this informal test, and in spite of many remediable hazards, it would seem that the rooting of softwood cuttings of larch is a workable technique for producing genetically uniform material.

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RELATIONSHIP OF SPECIFIC GRAVITY AND TRACHEID LENGTH TO GROWTH RATE AND PROVENANCE IN SCOTCH PINE

Donald E. Dorn[1]

ABSTRACT

The effects of growth rate, cambium age, and provenance upon tracheid length and specific gravity in Scotch pine were studied. The research material was obtained from a 1940 IUFRO provenance test planted in New York State. Samples from 10 trees in each of 10 provenances were selected and divided into 5-year growth segments for analysis.

Statistical analyses revealed that both provenance and cambial age had very highly significant effects on both tracheid length and specific gravity. Using tree height as a criterion of growth rate, no significant effect on tracheid length was found.

The results of the study concerning the effect of growth upon specific gravity were inconclusive. Further studies are suggested to determine what components of specific gravity are affected by growth rate and the magnitude of the resultant change.

The data obtained indicates that the control of wood properties by limiting the growth rate is not to be recommended. It is suggested that the greatest wood volume of desirable quality may be obtained by maximizing growth rate by genetic and silvicultural means. It is further suggested that final decisions concerning the type of wood desired must relate to an end product, thus requiring cooperation between the forest scientist and the industrial technologist.

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PRELIMINARY REPORT ON THE EFFECTS OF GAMMA-IRRADIATION ON THE GERMINATION OF SOME WESTERN CONIFEROUS SPECIES

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ABSTRACT

The effects of different doses of γ irradiation on seed germination of *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir), *Picea sitchensis* (Bong.) Carr. (Sitka spruce), and *Tsuga heterophylla* (Raf.) Sarg. (western hemlock) were studied. The given doses were 0, 500, 2000, 5000, and 10,000 r at a dose rate of 139 r/sec. Irradiation enhanced the germination per cent of stratified seeds of Douglas-fir and Sitka spruce, but not of western hemlock. The tolerance decreased in the following order: Douglas-fir, western hemlock and Sitka spruce.

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MASS TESTING FOR SUGAR CONTENT IN SAP IN SEEDLINGS OF SUGAR MAPLE (ACER SACCHARUM MARSH.)

William J. Gabriel[1]

ABSTRACT

One of the characters investigated in a rangewide study of variation in sugar maple was sugar content in sap. Sap sugar determinations that were attempted on 1,900 seedlings ranging in diameter from 0.1 to 0.9 centimeters were only partially successful in spite of refined measurement procedures and the control of the climatic factors known to influence sap flow. The sap flow mechanism in young seedlings is evidently influenced by factors other than those of climate, and these are apparently outgrown early in life. Measurements of sap sugar concentrations were successful in other studies where sugar maples ranged from 0.6 to 8.5 centimeters in diameter.

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SOME OBSERVATIONS ON GERMINATION OF *PSEUDOTSUGA MENZIESII* (MIRB.) FRANCO (DOUGLAS-FIR) POLLEN IN VITRO

R.H. Ho and O. Sziklai[1]

ABSTRACT

Dry pollen grains of Douglas-fir appeared in cup shape. The turgid pollen grains were spherical or elliptical without a trace of bladders. The exine was thin, about 2 microns, and quite smooth. The intine was thick, about 8 microns, and was of uniform hyaline appearance. The pores in the exine and intine were visible. Pollen germination was stimulated by growth-promoting substances. Ten to fifteen per cent of sucrose provided a favorable osmotic milieu and elongated pollen growth. Pollen grains, cultured in stock solutation, 10 ppm IAA, and sucrose in 5 days, were found in four cell stages (tube cell, two sperm cells, and stalk cell) with two degenerated prothallial cells.

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EARLY RESULTS OF A SUGAR MAPLE IMPROVEMENT STUDY

George E. Howe[1]

ABSTRACT

In 1964 the Northeastern Forest Experiment Station initiated a 30-origin provenance study of sugar maple (*Acer saccharum* Marsh.) to assess the nature and extent of variation and provide juvenile-mature correlations of several characters. Analysis of variance of mean height at age 2 years showed the differences between provenances to be highly significant. A large portion of these growth differences may be due to nursery artifacts rather than to genetic differences. Stem forking varied from 7 to 28% forked seedlings, with the bulk of the provenances falling in the 18 to 23% range; provenance survival ranged from 24 to 52% in the first year. The best surviving provenances came from the Northeastern United States. Mortality after the first year was negligible. Analyses will be continued and expanded in the outplanting phase which is now underway.

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POSSIBILITIES IN THE PHYSIOLOGICAL ANALYSIS OF GROWTH

F. Thomas Ledig[1]

ABSTRACT

An attempt was made to measure growth in terms of dry matter relative to three physiological criteria: 1) photosynthetic and respiration rates, 2) distribution of the photosynthate for growth between leaves and the remainder of the plant, and 3) duration-intensity aspects of the seasonal pattern of assimilation. It is emphasized that measurements of photosynthesis at a single period of time cannot account for growth. Variation among individuals in the amount of photosynthate allocated for leaf growth can affect productivity. Further, a seedling whose genotype enables it to carry on photosynthesis at a high rate at one stage of development may not be superior in this aspect at another stage. Intraspecific variation in seasonal patterns of net assimilation rate was reported in loblolly pine and areas under the curves of net assimilation rate during one growing season were used to explain differences in growth.

Certain models are mathematically expressed which take these concepts into account. The effect of photosynthetic rate and relative leaf growth on accumulation of dry matter was demonstrated through computer simulation using simple models. A final step in the development of the model of growth is to express photosynthesis as a function not only of time but of light, temperature, and moisture, thereby extending its applicability to natural environments.

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GENETICS AND BREEDING OF AMERICAN ELM[1]

Donald Lester[2]

ABSTRACT

Preliminary genetic evidence for the autotetraploid nature of American elm was presented and the consequences of tetraploidy for genetic analysis and for breeding of qualitative traits was discussed. An unsuccessful attempt to produce polyhaploid seedlings was described. Self-fertility was shown to be an obstacle in genetic and breeding studies although the range of variation in self-fertility suggests that self-sterile individuals may exist.

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EMBRYOLOGY OF PICEA GLAUCA (MOENCH) VOSS

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ABSTRACT

The purpose of this study was to follow the development of white spruce strobili prior to pollination until seed maturity. The strobili were collected from four trees at the Southern Research Station, Maple, Ontario. Collections were made in September 1966, February 1967, early May 1967, bi-weekly for a month after pollination, and weekly until seed maturity in mid-September. Pollinations were carried out on 25 and 29 May 1967. Microscopic examinations were made from prepared slides.

The male, female, and vegetative buds could readily be distinguished at the time of the first collection in September. Little change was observed in the February collection. By the beginning of May the megaspore mother cell had already undergone meiosis and the megaspore was in the free nuclear stage. Free nuclear divisions could still be observed in some megaspores on 29 May, but cell walls had been laid down in others. The first pollen grains appeared in the micropylar canal on 29 May. These were located on the nucellus by 1 June, but pollen germination was not observed until 5 June, 7 to 10 days after pollination. By 12 June, the archegonium within the megagametophyte had formed. On 19 June fertilization had taken place. Various stages of development could be seen at this date, ranging from the single nucleate zygote, through the four and eight nucleate stages of free nuclear division, to the point where the suspensors had elongated and pushed the embryonal tier into the gametophyte tissue.

The embryo developed rapidly, and within 2 weeks the apical and basal meristematic zones, the rib meristem, and the cotyledon primordia could be identified. The vascular system did not appear until the cotyledon primordia were well formed. At about the same time, an epidermal layer formed which surrounded the cotyledons and the embryo, except for the base of the embryo which was attached to the suspensors. Little change was observed within the ovule from the beginning of August until seed maturity in the middle of September.

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SELECTION AND IDENTIFICATION OF MONOPLOID *POPULUS TREMULOIDES* MICHX.

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ABSTRACT

Results are described for selecting and increasing the frequency of monoploid *P. tremuloides* seedlings among progeny of controlled crosses of *P. tremuloides* and *P. alba pyramidalis* as female and male parents, respectively. Putative monoploid seedlings exhibit a low frequency of epidermal hairs on emerging leaves and stems compared with interspecific hybrid siblings. A method for the identification of monoploid seeds resulting from crosses using *alba* pollen labelled with P^{32} proved unsuccessful. It was shown that detectable quantities of P^{32} were translocated from pollen tubes not effecting fertilization so that monoploid embryos developing from unfertilized eggs could not be identified by the lack of radioactivity of the seed. One putative monoploid, however, was obtained in these experiments. Two approaches are being studied to increase the frequency of monoploid embryos, namely, (1) colchicine treatment of staminate *alba* flowers following meiosis so that either no functional sperm or a single diploid sperm is produced in the pollen tube, and (2) NAA (naphthalene acetic acid) treatment of developing capsules of trembling aspen which have not been fertilized to prevent abscission of catkins prior to fruit maturation. Two putative monoploids occurred among the progeny of crosses using colchicine-treated pollen, but additional research is necessary as we have no evidence that the colchicine treatment is effective. The NAA treatment appears promising as premature abscission of catkins developing from flowers pollinated with dead pollen, or ones which had not been pollinated, was significantly less frequent for the NAA treated groups than the non-treated controls. Four seeds were harvested, but death due to damping off of two seedlings at the cotyledon stage and failure of germination of the other two, probably due to dessication, prevented determination of the chromosomal complement of these embryos. Attempts to confirm the haploid nature of the putative monoploids by chromosome counts have not been successful. A dimorphism in leaf characteristics attributable to the trembling aspen parent in one of the experiments is reported.

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