Proceedings of the twelfth
meeting of the committee on
Forest Tree Breeding in Canada

Comptes rendus de la douzième
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PROCEEDINGS OF THE TWELFTH MEETING OF
THE COMMITTEE ON FOREST TREE BREEDING
IN CANADA

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The Thirteenth Meeting of the Committee will be held at Prince George, British Columbia, in August 1971. Canadian and foreign visitors will be welcome. Detailed information will be distributed early in 1971 to all members and to others upon request.

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

PART 2

REPORTS AND PAPERS

Editor: E.K. Morgenstern

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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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TREE IMPROVEMENT IN NEWFOUNDLAND

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Tree improvement work continued to center around the local black spruce [*Picea mariana* (Mill.) B.S.P.] and trials of exotic species and races.

BLACK SPRUCE

Seed collections for a provenance study of local black spruce was initiated in 1967 and a nursery experiment was sown in the spring of 1968. Measurements of height and observations on dormancy were made in the fall of 1969. In general, there was a decrease in height growth with increase in latitude of the seed source. This was especially apparent with provenances from the Northern Peninsula which were significantly shorter than the others. They also set buds up to a month earlier than the other provenances. The distinct behavior of this group of provenances is thought to be related to the climate of that region which has comparatively colder winters and cooler, shorter summers.

Other work on black spruce was the sowing in the spring of 1970 of bulked seedlots of local provenances for outplanting experiments, and provision of local seed and acquisition of mainland seed for the cooperative all-range provenance experiment being coordinated by Dr. E.K. Morgenstern of PFES.

SITKA SPRUCE

A Sitka spruce [*Picea sitchensis* (Bong.) Carr.] provenance experiment was initiated in 1965. Twelve provenances, including a local black spruce control, were established in each of seven plantations in 1969 and two plantations in 1970. Plantation sites were selected on the better site types in most of the important forest growing regions of the Island. The experimental design was an eight-replicated randomized block with 16 trees per plot.

A combination spacing-fertilizer experiment using the black spruce and two of the Sitka spruce provenances was established in three locations. This project is being done in cooperation with a silviculturist.

WHITE SPRUCE

A plantation containing 31 white spruce [*Picea glauca* (Moench) Voss] provenances from the Great Lakes - St. Lawrence Region was established, in cooperation with Mr. Mark Holst of P.F.E.S., in central Newfoundland in 1963. A measurement at age of 10 years from seed was carried out in 1968. Survival of all provenances was generally good. Those showing the best height growth were from southeastern Ontario and southwestern Quebec, i.e. Algonquin Park and Beachburg, Ont., and Grandes Piles and Cushing, Qué.

TREE BREEDING IN THE MARITIMES REGION, 1968-69

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INTRODUCTION

The objectives of the Tree Improvement and Reforestation Support Area are as follows:

1. To provide direct support to the problem area programs of the Region by consultation, by supplying genetically improved tree materials, and by carrying out research on specific projects within defined problem areas.
2. To obtain information on the genetic variability of native and exotic species considered to be of present or future importance in the Region. This information will be used to produce improved strains or types of trees for reforestation and will provide a basis for genetic manipulation of existing forest stands.
3. To assist the provincial governments and industries of the region to develop economically sound methods of mass producing tree seeds and seedlings of improved genetic quality.

During 1968 and 1969, tree breeding work in the Maritime Region was concentrated on four projects: Breeding and breeding systems of forest trees - D.P. Fowler; Provenance and progeny testing - H.G. MacGillivray; Genecology of red and black spruce - S.A.M. Manley; Haploid and homozygous diploid trees - J.M. Bonga and D.P. Fowler.

BREEDING AND BREEDING SYSTEMS OF FOREST TREES

The objective of this project is to obtain the necessary information and breeding materials to make possible the mass production of genetically superior trees for the Maritimes Region. An understanding of the natural and potential genetic variability of native and promising exotic species is essential if genetic improvement is to be maximized.

Because of the present importance of *Picea* species and the potential importance of *Larix* species for reforestation, work has been concentrated on these genera.

Picea

Picea glauca (Moench) Voss (white spruce), *P. mariana* (Mill.) B.S.P. (black spruce), and *P. rubens* Sarg. (red spruce) are sympatric over much of the region. Hybridization and introgression between red and black spruce have been shown to be important features of the forests of the region (Manley 1969). No evidence of gene exchange between white spruce and red or black spruces has been found in the region, although white-black spruce hybrids have been reported elsewhere.

To further elucidate the genetic relationship between the three native spruces and to provide material for further genecological work, a series of controlled pollinations were attempted. In 1968 and 1969, all possible crosses between the three spruces were attempted. The summarized results are presented in Table 1. Only a few full seeds were obtained from any of the interspecific white spruce crosses (morphological examination of the seedlings will be required to determine if any hybrids were obtained). Considerable tree to tree variation in interspecific crossability was observed in black and red spruces. On the average, red and black spruces appear to be 25-50% cross-compatible. Self incompatibility is greater than interspecific incompatibility.

Table 1. Interspecific Hybridization Between Three Native Spruces - Average Number of Full Seeds per Cone.

Female parent		Male parent			
Species	Trees	*P. glauca*	*P. mariana*	*P. rubens*	Self
P. glauca	8	2.2[a]	0.01	0.01	0.71
P. mariana	4	0.07	9.3	4.0	3.1
P. rubens	4	0.05	2.5	9.8	0.65

[a]Open pollination.

In 1969, all possible crosses were attempted between three sets of the following phenotypes: pure black spruce, 25% red spruce, 50% red spruce, 75% red spruce, and pure red spruce. The results of these crosses have yet to be analyzed.

As part of a study to determine the interspecific relationship between the eastern Canadian spruces and exotic spruces, a number of controlled pollinations were attempted in 1968 and 1969. The summarized results are presented in Table 2. Seed yields from these crosses were very low and evaluation will be dependent on morphological examination of seedlings.

<u>Larix</u>

Due to their rapid juvenile growth, good form, high wood density, and ease of handling in the nursery, *Larix* species are of potential value for reforestation within the region. On the basis of species trials and provenance tests, it is evident that selected strains of *Larix laricina* (Du Roi) K. Koch, *L. leptolepis* (Sieb. and Zucc.) Gord., and *L. decidua*

Table 2. Interspecific Hybridization Using White Spruce as Female Parent.

Male parent	Crosses yielding full seed	Full seeds per cone	Total number of full seeds
<u>1968</u>			
P. asperata	6	0.20	106
P. koraiensis	5	0.01	7
P. koyamai	6	0.08	8
P. omorika	4	0.01	8
P. orientalis	4	0.01	6
<u>1969</u>			
P. omorika	3	0.01	4
P. schrenkiana	8	0.09	107

Mill. are promising. That interspecific *Larix* hybrids are often heterotic, has been well documented, thus species hybridization appears to be the most promising approach to *Larix* improvement.

The objective of the *Larix* improvement work is to determine the magnitude and pattern of variation in *L. laricina*, and to select or develop a superior strain or hybrid suitable for the Maritimes Region. Over the past decade, a good collection of *Larix* species and strains has been accumulated at the Acadia Forest Experiment Station. Much of this material is just beginning to produce ovulate flowers in the quantities required for controlled pollination work.

Five populations of the hybrid (*Larix laricina* x *leptolepis*) x *L. decidua* were produced in 1967. At the end of the second growing season, one of these populations appears heterotic in that it is clearly superior in height (avg 112 cm) to comparable populations of the three parent species (avg less than 100 cm for the next best population).

In 1968, all possible crosses (including self-pollinations) were made between two selected trees of each of *L. laricina*, *L. leptolepis*, and *L. decidua*. In addition, the hybrid *L. laricina* x *leptolepis* was backcrossed to both parent species. The summarized results are presented in Table 3.

Table 3. Results of 1968 Controlled Pollinations with Larch. Percentage of Full Seeds.

Female parent	Male parent					
	L. laricina		*L. leptolepis*		*L. decidua*	
	Tree 495	Tree 119	Tree 7	Tree 10	Tree 19	Tree 27
L. laricina (495)[a]	5.3	34.6[b]	0.0	0.9	28.1	1.4
L. laricina (119)	21.7	1.1	3.8	3.5	2.6	4.5
L. leptolepis (7)	0.2	0.0	4.9	78.3	2.2	5.1
L. leptolepis (10)	0.2	0.0	71.7	28.3	13.2	1.5
L. decidua (19)	0.8	0.0	24.0	37.5	0.3	12.2
L. decidua (27)	0.5	0.7	14.2	32.6	51.3	0.5
L. laricina x *leptolepis* (368)	12.5	-	-	10.2	-	-
L. laricina x *leptolepis* (352)	5.4	-	-	6.0	-	-

[a]Tree number in parentheses.
[b]Underlined numbers denote populations with living seedlings at age 4 months.

Pollen from two selected *L. decidua* trees was used in crosses with *L. laricina*, *L. leptolepis*, and *L. decidua*. The results are given in Table 4.

Although *L. laricina* can be crossed with both *L. leptolepis* and *L. decidua* (and often produces heterotic progenies), the very low seed yield, as well as differences in flower phenology will make mass production of hybrids difficult. Only if early evaluation of individual hybrids is successful and if commercially acceptible methods of vegetative propagation can be developed, will it be possible to produce these hybrids in quantity.

Pinus resinosa

Three small studies of maternal effects in *Pinus resinosa* Ait. were concluded in 1969. It was concluded that maternal effects, other than seed size, could cause approximately 10% variation in height growth of young red pine seedlings. Estimates of genetic variation based on evaluation of young provenance or one-parent progeny materials should be reduced accordingly.

Table 4. Interspecific Hybridization of Larch Species, with *L. decidua* as Male Parent - Number of Cones Harvested.

	Female parent		Male parent	
Species	Provenances	Trees pollinated	Tree 29	Tree 30
L. laricina	3	11	645	622
L. leptolepis	8	15	385	422
L. decidua	2	2	123	109
L. laricina x *leptolepis*	-	3	145	136

It is recommended that controlled pollination studies, including reciprocal crossing should be employed in future genetic evaluation of this species (Fowler 1970).

PROVENANCE AND PROGENY TESTING

The objective of this work is to determine the amount and nature of genetic variation within populations of desirable tree species, and to use this variation to improve wood production in the Maritime Region. The objectives of the individual experiments are diverse, but each has its place within the overall objective. The experiments include tests for volume of wood produced, insect resistance, suitability for adverse sites, all-range variation, and suitability for Christmas trees.

Picea

An all-range study of 1,100 provenances of *Picea abies* (L.) Karst. was planted in May 1968 at the Bronson Burn, near Chipman, N.B. This study is being conducted in cooperation with Dr. Olof Langlet and Mr. Peter Krutzsch of Stockholm, Sweden. Dr. Klaus Stern, Schmalenbeck, Germany assisted with the design. The Bronson plantation contains 11 randomized blocks each with 25 trees from each of 100 provenances for a total of 27,500 trees. The roots of the trees were washed free of soil in Germany and shipped air freight to New Brunswick. Despite this and the considerable handling they received in Germany and on their arrival in New Brunswick, survival in August 1969 was 80%.

Two replicated trials of provenance of *P. sitchensis* (Bong.) Carr. were established as coastal windbreaks, one in southern Nova Scotia, the other in northwestern Prince Edward Island. A third replicated provenance test of this species was planted at the Acadia Forest Experiment Station. Unreplicated observation plots were established in southern Nova Scotia.

Seed collections of *P. mariana* were made in the Maritimes for the all-range provenance study that is being directed by Dr. E.K. Morgenstern, PFES.

During 1968-69, data was collected from provenance tests of *P. abies* (partial range), *P. glauca* (one all-range and one partial range), and *P. rubens* (one all-range and one partial range). The data have not yet been analyzed.

Larix

Significant differences in average height and average basal areas (10 years from seed) were found among 20 provenances of *L. leptolepis* planted at Acadia Forest Experiment Station. This study also included two provenances of *L. laricina* and three provenances of *L. decidua*. Trees from the best *L. leptolepis* provenances were taller and of greater diameter at breast height than the *L. laricina* or *L. decidua*. The five best provenances of *L. leptolepis* were

Village	Prefecture	Elev m	Avg height m	Avg dbh cm
Nakawa	Nagano	1920	4.32	4.8
Tsumakoe	Gumma	1900	4.31	5.5
Kawakami	Nagano	1500	4.23	4.7
Kilamaki	Nagano	1750-1800	4.21	4.7
Mitake	Nagano	1380	4.19	4.8

Survival ranged from 83 - 92% for all provenances. Porcupines showed a definite preference for *L. decidua* over *L. leptolepis* or *L. laricina*. In *L. leptolepis*, no correlations were established between average heights and the seed source factors of latitude, longitude, or elevation.

Abies - (Christmas trees)

Abies balsamea (L.) Mill. free of damage by the balsam gall midge (*Dasineura balsamicola* Lint.) were selected by personnel of the Forest Insect and Disease Survey. These selections were made in areas where there were heavy infestations of this insect. Susceptible trees were also selected in each area for use as controls. Both the apparently resistant and the susceptible trees were propagated by rooting cuttings and by grafting. This material will be inoculated with gall midge to test further the apparently resistant clones.

Attacks by the balsam gall midge were more intensive on *A. balsamea* than on several non-native *Abies* growing in plantations at Acadia Forest Experiment Station. *A. homolepis* Sieb. and Zucc. appeared to be immune, apparently because its buds burst and needles flushed much later than *A. balsamea*, the normal host species in New Brunswick. The other non-native firs, whose phenology was closer to that of *A. balsamea* (*A. grandis* (Dougl.) Lindl., *A. koreana* Wil., *A. concolor* (Gord.) Engelm., *A. fraseri* (Pursh) Poir, and *A. sibirica* Ledeb.), also appeared to be less susceptible to attack by the gall midge.

A replicated nursery experiment was established in the spring of 1969 to determine if *A. balsamea* provenances from Newfoundland produce trees with superior foliage color for Christmas trees. No marked differences in foliage color were observed during the first growing season.

A replicated test of 13 provenances of *Pseudotsuga menziesii* (Mirb.) Franco, along with several *Abies* species (*A. balsamea*, *A. veitchii* Lindl., *A. sachalinensis* Mast.), and several provenances of *Pinus sylvestris* L. was planted at Acadia Forest Experiment Station. Observation plots of *P. menziesii* were planted by cooperating growers in the Maritimes.

Other species

Tests in coastal windbreaks involving several species and varieties of *Pinus* were planted in two locations in Nova Scotia and one on Prince Edward Island. Dead and missing trees were replaced in two all-range tests of *P. banksiana* Lamb. at the Blackville Fire Tower and near Little Bald Mountain. This was also done for the test of interprovenance hybrids of *P. banksiana* and hybrids of this species with *P. contorta* var. *latifolia* S. Wats.

An all-range provenance study in *Betula alleghaniensis* Britt. was established in the spring of 1968, in cooperation with Dr. K. Clausen, Institute of Forest Genetics, Rhinelander, Wisconsin. Some trouble was experienced in the spring of 1969 with white grubs that stripped the roots of the seedlings.

GENECOLOGY OF RED AND BLACK SPRUCE

Red spruce is highly susceptible to defoliation by spruce budworm (*Choristoneura fumiferana* Clem.); black spruce is relatively resistant. An assessment of the hazard to defoliation by cover type is difficult due to the array of intermediate types between red and black spruce. Difficulties in distinguishing the two species have been attributed to extensive hybridization. Morgenstern and Farrar (1964) presented convincing evidence to show that hybridization and further introgression are common where species are sympatric.

The objectives of this project are to develop satisfactory field methods for distinguishing red, black, and intermediate spruces; to establish the frequency and distribution of natural hybridization in central

New Brunswick and elsewhere in the Maritimes; and to evaluate ecological implications of hybridization.

A hybrid index, supplemented by quantitative measurements, was developed from study of experimental hybrids, provenance material, and natural stands (both pure and introgressed) and was used to identify individual trees and stands. Differences described in the index included needle configuration, apex shape, and color; twig ridges, bark color, and hair type; bud color and scale tips; color of mature and immature cones; cone shape, scale edges, stalk, flexibility, persistence, and location; branch size; mature bark; and crown shape.

The largest area of contact for the two species in New Brunswick proved to be the New Brunswick Lowland. The Lowland is a gently undulating plain, characterized by elevated bogs and hills with just enough elevation to support red spruce-tolerant hardwood mixtures. Contact is common along the gentle slopes and is further increased by the extensive disturbance that has occurred in the area. Selection of sample areas was related to configuration of landforms. Transects of plots were established along slopes reaching from red spruce-hardwood upland to black spruce bogs or flats. Continuous stands of "spruce" were described with a large local sample. Fifty plots were established. Two transects and a local sample were studied outside the Lowland to ascertain the effect of topography. Each site of the 50 sample plots was described in terms of:

1. Hybrid index of trees (12 trees were chosen at random in bogs or tolerant hardwood sites, 24 trees at the edges of "pure" stands, on intermediate slopes, or on flats).

2. Moisture regime (according to Hills, 1950).

3. Ground vegetation (percentage cover of each species on 0.1-acre plots).

4. Soil pH, soil profile, and forest cover type.

Data indicated that red and black spruces have hybridized extensively in the New Brunswick Lowlands. Introgressed stands and hybrid swarms were identified on all intermediate slope positions and flat plateaus. Introgression was two-directional but more frequently in favor of black spruce. Parental species remained phenotypically pure in their respective ecological niches. Logging and frequent fire, and possibly periodic budworm damage to red spruce, may be responsible for the predominance of black spruce. In several areas, introgressed stands and hybrid swarms represent the most common forest cover type over as much as 100 to 200 square miles. Hybridization was confined to areas where topography does not adequately separate red and black spruce. Large introgressed populations were not found in the central Highlands of New Brunswick. Field work in southern New Brunswick and Nova Scotia indicates similar trends.

Habitat relationships indicated that hybridization is closely correlated with site factors. Hybridized populations were found on sites that had combinations of the characteristics that are associated with the parental species. Wet, acid, sphagnum-dwarf shrub, or dry, acid, dwarf shrub sites characterized black spruce samples. Well-drained, moderately high pH, herb-rich sites characterized red spruce samples. The frequency of dwarf shrub vegetation increased with the frequency of black spruce types. In individual transects, the hybrid composition was related to moisture regime (M.R.) and pH. Lower pH values (3.5-4.5) and dry or wet sites (M.R. 2 or 5-6) were associated with black spruce. As moisture conditions improved, the proportion of red spruce types increased. Black spruce could be found in all but herb-rich sites after fire, a situation probably dependent on local forest composition and severity of the fire.

It was demonstrated that the severity of budworm damage was related to the genotype of individual trees. Sixty-six trees in a transect near Napodogan, N.B., were rated for budworm damage by personnel of the Forest Insect and Disease Survey. These same trees were scored by the hybrid index and it was found that the more closely an individual tree resembled red spruce, the greater was the severity of budworm damage (Manley and Fowler 1969).

On many intermediate sites, the species composition of the understory was observed to differ from that of the mature stand. Sapling hybrid index scores indicated a trend towards red spruce. To determine the successional trends, and to test the response of the parental species and intermediates to a shade factor, all possible crosses between three replicated sets of five trees intergrading from red to black spruce in 25% classes were control crossed to obtain hybrid progeny. The seedlings will be planted in natural stands (both pure and introgressed) for observation and measurement. The first crosses have been completed, and the seed is being extracted. The experiment will be repeated this year, provided there is adequate flowering.

The extent of hybridization in other areas of the Maritimes is being examined at present. Random samples were collected from spruce populations in parts of Nova Scotia. This work will be continued. Some line transect work over areas as large as 100 square miles is expected to determine more accurately the frequency of hybrid types.

HAPLOID AND HOMOZYGOUS DIPLOID TREES

Young mega- and microsporangiate strobili were collected at weekly intervals in late spring and early summer. Megagametophytes and microsporophylls carrying immature microsporangia, were dissected aseptically and transferred to a variety of culture media.

Megagametophytes collected between 2 weeks before and 2 weeks after fertilization grew in culture. Most growth was obtained on White's medium supplemented with casein hydrolysate and coconut milk. On this medium, small calluses developed from the gametophytic tissues. Inside the gametophytes, layers of spindle-shaped cells were formed in various locations.

Abundant callus was obtained in cultures of the microsporophylls. Some of this callus originated from the diploid sporophyll and sporangial tissues, and some developed from the immature microspores. Smear preparations of samples of the calluses from the microspores showed haploid mitotic configurations. These haploid calluses grew better on Brown and Lawrence's medium than on the supplemented White's medium. Cultures of pollen matured on the tree failed to produce callus.

The calluses derived from the immature microspores did not show any differentiation, but were considerably larger than those from the megagametophytes.

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INTERACTION OF GIBBERELLIC ACID AND PHOTOPERIOD ON REPRODUCTIVE AND VEGETATIVE GROWTH OF WHITE CEDAR SEEDLINGS (THUJA OCCIDENTALIS L.)

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Gibberellic acid (GA_3) has induced early flower formation in many plants including the western red cedar (*Thuja plicata* Donn) Pharis and Morf 1968) and eastern white cedar (Fraser 1969). Whereas Pharis and Morf did not treat their seedlings until they were 1 year old, Fraser was especially interested in the differential responses inherent with seedling age. To ascertain the earliest time of potential cone formation after the germination of seeds, freshly germinated seedlings were grown under different photoperiods (PP) in growth chambers at 21°C and treated weekly with an aqueous-Tween-20 foliar spray of 100 ppm GA_3.

Under 8-hr PP the seedlings grew about 5 mm in 3 weeks and then ceased growth (Fig. 1). The apical growth of the very young seedlings was completely inhibited by a combination of an 8-hr PP and GA_3 treatment. Under 16-hr PP growth continued indefinitely, but when GA_3 was applied, apical growth reached 10 mm in 3 weeks and then ceased. Under 24-hr PP, growth was again continuous. When GA_3 was applied to seedlings under this PP, apical growth continued for the first 3 weeks, then stopped for 7 weeks, to be resumed after this time. GA_3 usually has an inhibitory effect which is accentuated during the shorter PP. The initial GA_3 inhibition diminishes after 7 weeks of continuous treatment under the long PP.

The inhibitory effect of GA_3 is also evident when treatment is postponed until the seedlings are 2 months old (Fig. 2). Inhibition is again greatest under the shorter PP. That the length of the dark period is also critical for growth of white cedar was evident when growth under 6-hr Light (L) : 6-hr Dark (D) : 6-hr L : 6-hr D was compared with that under 12-hr L : 12-hr D PP. Elongation was greater under the 6 hr regime.

The above experiments have indicated that white cedar from Petawawa is sensitive to PP when the whole range of light and dark periods is investigated. The reaction to GA_3 varies with plant species and concentration, and this is even more distinct between softwoods and hardwoods (Fraser 1958).

Cone production has been induced within 3 months of seed germination under GA_3 and long PP treatment. Both the usual two seeds per cone-scale and more prolific multiples (3) were formed (Figs. 3 and 4). Investigations are continuing on the production of viable seed within a reduced time period from seed germination. The practical applications are obvious both for breeding purposes and quick seed production within a limited space. The application of foliar sprays of different sugars increases growth and food reserves.

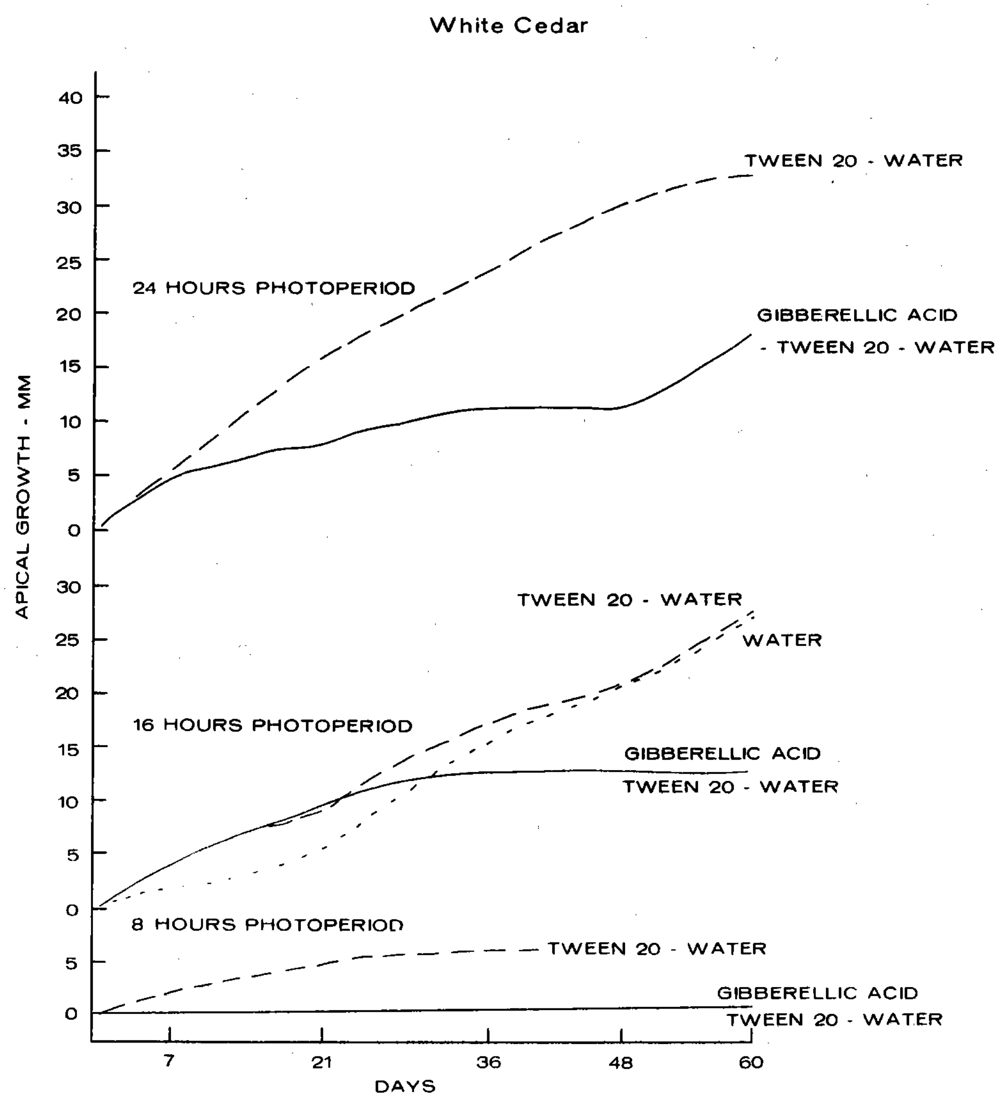

Figure 1. Growth of white cedar seedlings for 60 days after seed germination. Treatments included three photoperiods at an air temperature of 21°C and a foliar spray of 100 ppm GA_3 every week.

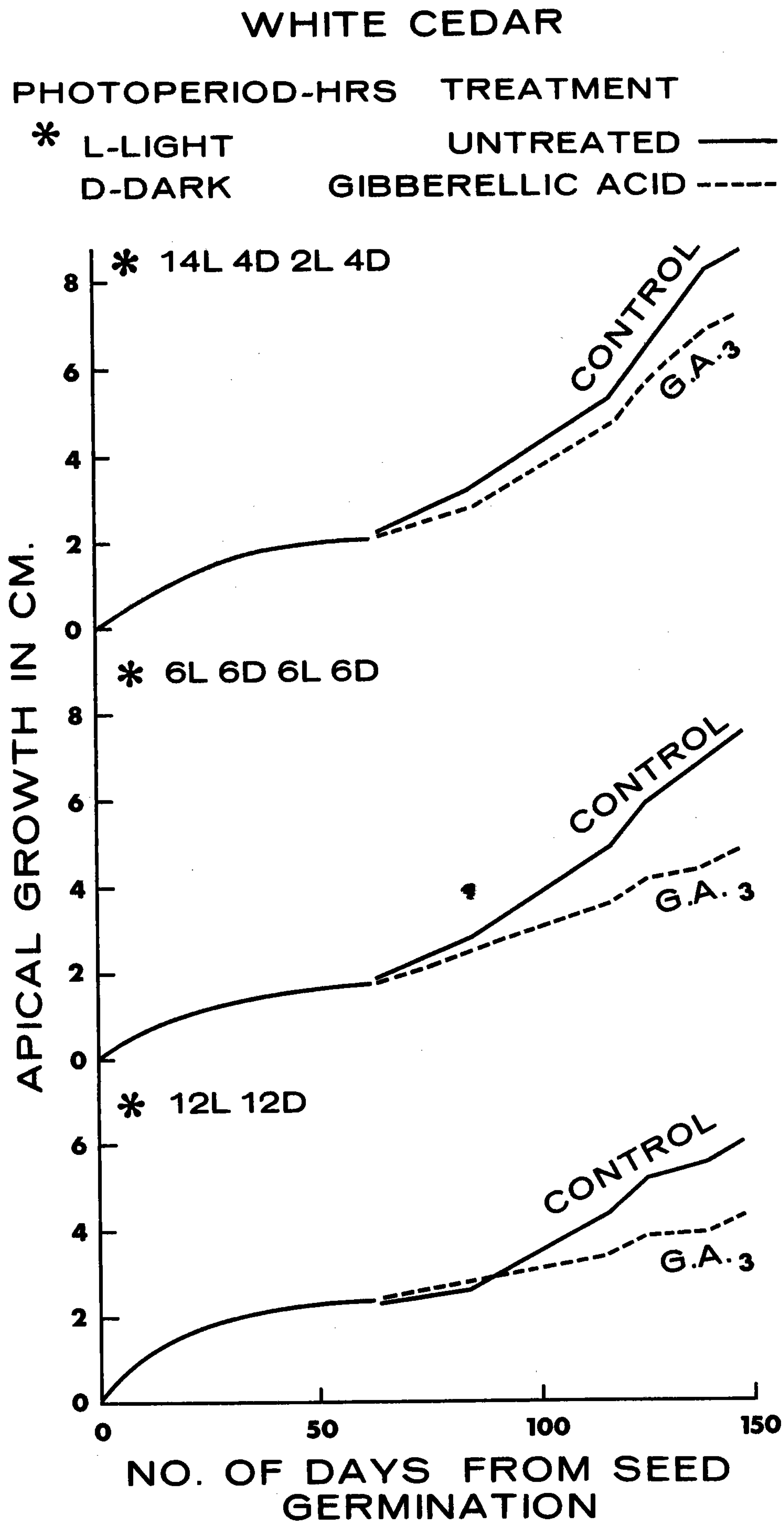

Figure 2. Growth of white cedar seedlings for 150 days after seed germination. Seedlings grown under three photoperiods at an air temperature of 21°C. Weekly GA_3 foliar treatments started when the seedlings were two months old.

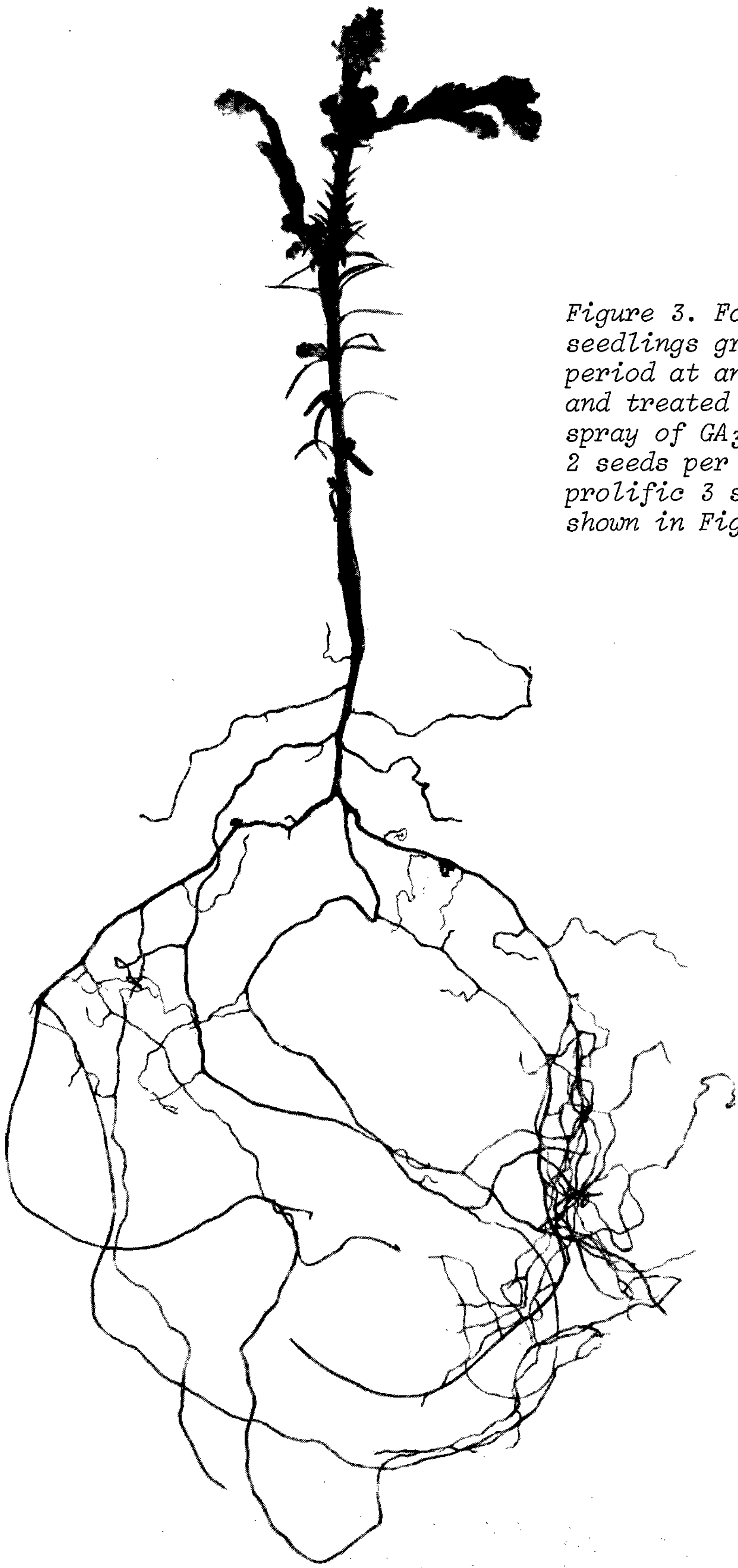

Figure 3. Four month old white cedar seedlings grown under 24-hr photoperiod at an air temperature of 21°C and treated with a weekly foliar spray of GA_3. Formation of the usual 2 seeds per cone scale and the more prolific 3 seeds per cone scale are shown in Figure 4.

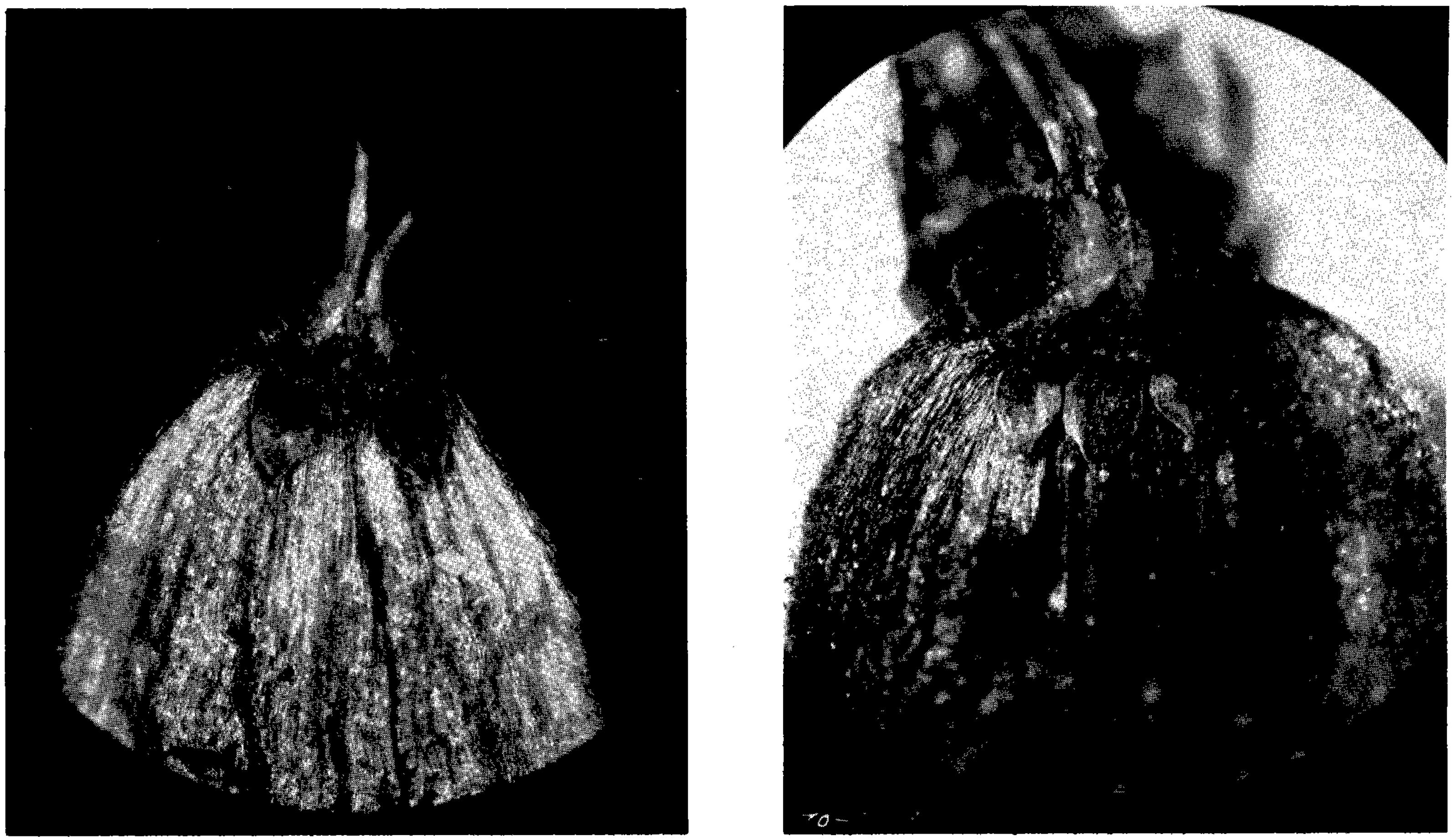

Figure 4. Formation of the usual two seeds per cone scale (left) and the more prolific three seeds per cone scale (right).

Investigations with other coniferous species, notably black spruce (*Picea mariana* (Mill.) B.S.P.), have shown promise. Foliar sprays with indole-3 acetic acid have produced copious side branch development. This is of practical significance, for such seedlings will provide more abundant material for reproduction of new individuals by layering. The use of photo- and thermoperiod, as described earlier by Fraser (1969), has proven effective in the stimulation of abundant cone production. Again a practical application is indicated by the abundant production of reproductive buds in a young plantation of black spruce in 1969, followed by their development into healthy cones in 1970 on the Corry Lake Tree Physiology Area at PFES.

ACKNOWLEDGMENTS

Members of the former tree physiology Section at the Petawawa Forest Experiment Station assisted in the conduct of the experiments and Graphic Services of the Department of Fisheries and Forestry helped in the preparation of the figures.

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SUMMARY REPORT ON FOREST TREE IMPROVEMENT 1968 - 1969

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HARDWOODS

Juglans nigra

A well defined pattern of genetic variation in winter hardiness among 17 provenances of black walnut and an old provenance plantation with significant resistance of the remaining trees after almost a century of growth led to the conclusion that some individuals that originated from the northern part of the natural range of black walnut can thrive in our latitude when the soil is also carefully selected.

These individuals constitute good material for breeding and could make possible the production of genetically improved trees.

In 1967, some of the best genotypes were then crossed, using five different female parents. A total of 493 nuts was produced. Nut collection in the fall of 1967 was followed by nursery stratification and sowing.

In 1968, a total of 329 seeds germinated and seedlings (1 - 0) were planted in the field the following year. Survival is 90% for this full-sib progeny test.

Grafting of black walnut met with little success - only 12% take.

Juglans cinerea

A genecological study was initiated in 1969 with material covering the entire natural range of the species. The preliminary data are recorded by M.D. Robert, graduate student.

Acer saccharum

Sugar content study. A 5-year study to evaluate the variation in sugar content of the sap led to the conclusion that significant variation although rare, exists (Parrot 1969).

Provenance study. A provenance plantation of some 26 origins has been established in 1969 in cooperation with the Northeastern Forest Experiment Station, Burlington, Vt., U.S.A.

CONIFERS

Picea glauca (Exp. 292-E)

In cooperation with Ministère des Terres et Forêts, Service de la Recherche, Québec, and the Department of Fisheries and Forestry, Québec

Region, three plantations, involving 40 provenances were established in different locations in western, central and eastern Québec. In western Québec, the material was divided into two large plantations: the first one being at Trécesson Co. of Abitibi-ouest (48°35'N); the second being at N-D-du-Nord Co. of Abitibi-est (47°35'N) near Lac Témiscamingue.

Picea abies (Exp. 310-A-4 and 277-D)

These two different experiments were also established in the same locations described above. The number of provenances for each experiment is 22.

Pinus resinosa (Exp. 216-D)

All data concerning yield, height, and phenology were taken during 1968-69 and correlated with climatic data. After eight growing seasons, heights ranged from 84 inches (210 cm) for No. 3140 to 113 inches (286 cm) for No. 3139. By extrapolation, a 30% increase in volume at the time of logging by planting the best provenances would be expected.

Pinus banksiana (255-A-5-I)

All data concerning leaf analysis of the main elements and height were taken and correlated.

ACADEMIC PROGRAM

The undergraduate course on forest genetics and tree breeding is given each year. Five students are preparing their thesis in this field.

Lectures at the graduate level were given last year and two graduate students are working for their Master's degree.

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FOREST GENETICS AND TREE IMPROVEMENT RESEARCH, IN QUEBEC

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Following the establishment of a seed laboratory for processing relatively large numbers of small seed lots, emphasis was directed towards the assessment of geographic variation in Quebec's major commercial species, black spruce (*Picea mariana* (Mill.) B.S.P., balsam fir (*Abies balsamea* (L.) Mill.), and yellow birch (*Betula alleghaniensis* Britton).

The justification for this approach may be stated as follows. First there is a pressing need for the establishment of seed zones so that the genetic potential of each seed lot used in expanding reforestation programs is fully exploited. Secondly, it is assumed that it is highly desirable to have a knowledge of genetic variation within the species before initiating a program of selection and breeding. A further assumption is that an introduced species may show superior growth in regions for which no suitable indigenous species is available.

Seed collections have been completed, and processed for both black spruce and yellow birch, and in the spring of 1969, 400 progenies representing 40 provenances of yellow birch were sown in six replications at the Valcartier research nursery. In the spring of 1970, 100 provenances of black spruce seed were sown in six replications in the same nursery, and black spruce seed was forwarded to four collaborators. Seed collections are not yet completed for balsam fir.

In addition to the major investigations referred to above, other provenance trials of native and exotic species involving small numbers of provenances were either measured or established. These included white spruce (*Picea glauca* (Moench) Voss), red spruce (*P. rubens* Sarg.), Engelmann spruce (*P. engelmannii* Parry), Norway spruce (*P. abies* (L.) Karst), jack pine (*Pinus banksiana* Lamb.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), and *Larix* and *Abies* species. Many of these species trials have been established with material supplied by the Petawawa Forest Experiment Station, and there is close cooperation between this Station and the Quebec Laboratory in regard to provenance investigations.

Inbreeding and intra- and inter-specific crosses have been completed using diverse provenances of red and black spruce. Laboratory studies of seed quality by X-ray and other techniques are continuing.

Genecological, breeding and seed quality investigations have provided experimental material and criteria for research projects which are now being developed within the same problem area research program. These include propagation of spruce by cuttings and physiological studies on seedlings of diverse black spruce provenances in controlled environments.

The principal objective of all studies within the Tree Improvement Problem Area Research Program in the Quebec Laboratory is to provide the silviculturist and forest manager with information which will allow the maximum utilization of the genetic potential of the species being planted. Thus the program is being developed in close cooperation with representatives of the Quebec Department of Lands and Forests, of Industry, and of the University of Laval.

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RAPPORT AU COMITÉ CANADIEN D'AMÉLIORATION DES ARBRES FORESTIERS

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INTRODUCTION

Devant l'importance grandissante du reboisement au Québec et de la ligniculture dans le monde en raison de la consommation croissante du bois, le Service de la recherche du ministère des Terres et Forêts a mis en oeuvre un "Programme général pour l'amélioration des arbres forestiers au Québec" rédigé par le Dr G. Vallée (1969), dont la rédaction était terminée en novembre 1969. Le programme fut présenté, et fut par la suite accepté par le Comité de coordination du Service de la recherche et par les autorités du Service de la restauration et de la Direction générale de la planification au ministère des Terres et Forêts. Dans ce programme, l'auteur expose les principes généraux qui devraient être observés dans les projets de recherche et d'application en amélioration des arbres forestiers au Québec.

Le programme a été soumis à la critique de spécialistes ou de praticiens directement ou indirectement reliés à ce sujet. Généralement, les personnes consultées ont été enthousiasmées par le programme et y ont été favorables, et leurs remarques et suggestions constructives ont permis d'apporter des modifications bénéfiques.

Entre-temps, des démarches ont été faites pour la création d'un "Comité technique de coordination des recherches en génétique forestière au Québec", sur demande des chercheurs et autres personnes intéressées par le sujet. La réalisation de ce comité et l'acceptation finale du programme sont entre les mains du "Conseil de la recherche et du développement forestiers du Québec".

Pendant ces deux dernières années, l'équipe de la section de génétique du Service de la recherche s'est appliquée à l'élaboration de l'infrastructure et à la mise en marche des projets de recherche conformes aux besoins immédiats du ministère des Terres et Forêts et de l'industrie forestière.

C'est ainsi qu'une pépinière répondant aux exigences de la recherche et deux serres avec une annexe sont en voie de parachèvement à Duchesnay, situé à 25 milles au nord-ouest de Québec. De plus, un réseau de secteurs expérimentaux a été commencé dès l'été 1969; il comprendra 22 stations réparties sur le territoire forestier du Québec. Ces secteurs nous permettront de regrouper les plantations comparatives faites au Québec pour une surveillance et un entretien plus attentifs et afin d'obtenir des informations pouvant être généralisées.

Le personnel actuel de la section de génétique, qui s'occupe de la réalisation des projets en cours, est composé de trois chargés de recherche, MM. Claude Chouinard, A. Stipanicic et Gilles Vallée, de deux techniciens, MM. Richard Dubé et Borromée Gaulin, ainsi que d'un coopérant technique français, M. Daniel Cornu, ingénieur agronome.

L'auteur tient à remercier tout ceux qui par leurs conseils et leur confiance l'ont encouragé à oeuvrer dans le domaine de l'amélioration des arbres forestiers.

PROGRAMME GÉNÉRAL POUR L'AMÉLIORATION DES ARBRES FORESTIERS AU QUÉBEC PROJET EN COURS DE RÉALISATION

PROGRAMME : 1

Sélection et établissement de peuplements semenciers "plus" dans les espèces autochtones et exotiques les plus utilisées dans les reboisements.

Plusieurs projets d'établissement de peuplements semenciers sont en voie de réalisation. Ces travaux sont coordonnés par des ingénieurs du Service de la restauration du Ministère qui veillent à faire respecter des normes strictes dans le choix et l'aménagement des peuplements.

PROGRAMME : 2

Sélection d'arbres "plus" et réalisation de vergers à graines.

Projet Sg 68-1 (*2 Po ai ta*)*. Sélection de peupliers des sections *Aigeiros* et *Tacamahaca* et leurs hybrides.

Dans une première étape, on a surtout réuni en pépinière quelques 175 clones provenant d'arbres croissant naturellement au Québec et appartenant aux espèces *Populus deltoides, P. nigra* et *P. balsamifera* et leurs hybrides. Au printemps 1969, trois plantations comparatives ont été établies, dont deux au populetum de Matane et une sur sol tourbeux à Duchesnay. Quelque 30 clones furent utilisés pour ces plantations, dont 10 sont des clones exotiques connus et 20 sont des clones provenant de la vallée du Saint-Laurent et qui semblent les plus prometteurs parmi la collection faite en 1968.

En septembre 1969, une première observation sur les maladies des feuilles a été faite, parmi les clones récoltés dans la vallée du Saint-Laurent; 18 de ces clones semblent totalement résistants ou peu vulnérables. D'autres observations seront faites en 1970 pour nous assurer de la résistance des clones aux maladies des feuilles et aux déformations de la pousse

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*Sg 68-1 (*2 Po ai ta*) signifie que c'est un projet de la division sylviculture (S) et de la section génétique (g) commencé en 1968 (68) en tant que premier projet (1) du programme 2 portant sur les *Populus* des sections *Aigeiros* et *Tacamahaca (2 Po ai ta)*.

terminale. Tous les clones ne montrant pas une résistance suffisante seront rejetés.

En ce qui regarde l'aptitude au bouturage, nous devons mentionner une très forte variation dans les populations de *Populus deltoides*.

Dans le bassin de la rivière Matane, des superficies de terrain ont été aménagées pour l'établissement d'un populetum. Les caractéristiques de ce secteur expérimental sont données aux tableaux 1 et 2. Ce populetum a été créé dans le but de sélectionner des clones et entreprendre des recherches sylviculturales sur le peuplier pour répondre aux besoins de la région où une usine de cartonnage est installée.

Pour 1970, nous prévoyons poursuivre la récolte de clones au Québec en utilisant la méthode de bouturage des pousses feuillées de l'année (Koster 1968), ce qui permettra de sélectionner des sujets exempts de maladies foliaires. De plus, nous espérons faire une récolte de lots de graines sur des peupliers poussant naturellement ou en plantation; ces graines seront ensemencées à la pépinière de Duchesnay en vue de sélection sur les semis.

Projet Sg 69-4 (*2 Po lc*). Sélection de clones de peupliers de la section *Leuce*.

Des semences de *Populus alba* et *P. tremula* ont été semées au printemps 1969 et ont donné 400 plants sur lesquels sera pratiquée une sélection.

Durant l'été 1969, nous avons trouvé 15 plants hybrides, probablement entre *P. alba* et *P. grandidentata* ou *P. deltoides*, dont certains étaient de très belle venue avec une croissance comparable à celle des plants de *P. deltoides* poussant aux mêmes endroits. Malheureusement, les essais de bouturage n'ont pas réussi mais nous comptons reprendre l'échantillonnage en 1970 et utiliser la méthode de Koster pour les bouturer.

Par l'entremise des accords de coopération technique France-Québec, nous espérons accueillir en 1970 du personnel français qui travaillera à la sélection de clones de *Populus tremuloides*, *P. grandidentata* et *P. balsamifera* à l'intérieur d'une région de l'est du Québec.

Projet Sg 69-9 (*2 P g*). Verger à graines réalisé à Duchesnay sur sol tourbeux à partir de semis 3-0 de *Picea glauca* (Moench) Voss obtenus d'une sélection massale. Ces semis proviennent de peuplement de belle venue de la pépinière de Grandes-Piles.

Projet Sg 69-8 (*2 P ab*). Verger à graines réalisé à Duchesnay et à Parke à partir de semis 3-0 de *Picea abies* (L.) obtenus d'une sélection massale. Ces semis proviennent des plantations de la région de Grandes-Piles, considérées comme une très bonne provenance.

PROGRAMME : 3

Projet Sg 68-2 (*3 spp*). Introduction d'espèces exotiques et création d'arboreta.

Nous avons écrit à environ 50 organisations de différents pays pour obtenir des semences d'espèces forestières pouvant présenter un intérêt, soit pour les reboisements au Québec, soit comme source de gènes. A date, nous avons reçu les semences de 60 espèces de 300 provenances différentes.

Au printemps 1969, nous avons ensemencé 25 espèces, issues de 65 provenances, à la pépinière de Berthierville. Nous prévoyons ensemencer 35 autres espèces au printemps 1970 à la pépinière de Duchesnay.

PROGRAMME : 4

Test de provenances et de descendances.

Projet Sg 69-5 (*4 P ab*). Test sur 22 provenances de Pologne et 22 provenances d'Europe de *Picea abies* (L.).

Projet Sg 69-6 (*4 P g*). Test sur 41 descendances de *Picea glauca* (Moench) Voss provenant surtout de la vallée de l'Outaouais.

Ces tests furent réalisés en collaboration avec le Dr L. Parrot et le Dr L. Roche. Trois dispositifs ont été installés par le Dr Roche à la Station de Valcartier tandis que nous en avons installé trois à l'arboretum de Trécesson, deux à celui de Guigues et trois à celui de Saint-Ignace-des-Lacs.

Les semis 2-2 utilisés pour les plantations comparatives ont été obtenus de la Station forestière expérimentale de Petawawa à qui nous adressons nos remerciements.

Les dispositifs de Trécesson et de Guigues seront étudiés par le Dr L. Parrot tandis que ceux de Saint-Ignace-des-Lacs seront suivis par le Dr Gilles Vallée et l'ingénieur Claude Chouinard.

Projet Sg 69-7 (*4 Ps me*). Test de provenances sur *Pseudotsuga menziesii* (Mirb.) Franco.

En 1969, nous avons obtenu 59 provenances de Sapin de Douglas du *Working Group for Procurement of Seed for Provenance Research* auquel a adhéré le Service de la recherche du ministère des Terres et Forêts du Québec.

Au printemps 1970, un dispositif à blocs complets comprenant quatre répétitions sera ensemencé à la pépinière de Duchesnay. L'étude de ce dispositif nous permettra d'élaborer et de planifier les tests qui seront entrepris sur ces provenances.

Projet 69-10 (*4, 2 Pi bk*). Test de provenances et de descendances sur *Pinus banksiana* Lamb.

Une récolte de semences par arbre a été commencée à l'automne 1969 et sera continuée en 1970 et 1971.

Pour chaque provenance nous avons choisi une vingtaine d'arbres de belle venue sur lesquels des cônes et des ramets sont récoltés et gardés séparément pour chaque individu. Ce test nous permettra de constituer des vergers à graines par la sélection de famille et de semis tout en fournissant des informations sur la population du Pin gris au Québec. Nous remercions M. J.M. Conway, ing.f., de la Consolidated-Bathurst, qui a facilité une récolte de graines dans le bassin de la rivière Mattawin.

PROGRAMME : SE

Projet Sg 68-SE. Réalisation d'un réseau de secteurs expérimentaux pour l'amélioration des arbres forestiers.

Le titulaire de ce projet est M. Claude Chouinard. Les principes suivis pour la réalisation de ce réseau ont été exposés dans le "Programme général pour l'amélioration des arbres forestiers".

Ces secteurs sont destinés aux études suivantes: (a) introduction d'espèces exotiques, (b) tests de provenances et de descendances, (c) vergers à graines, (d) "pool" de gènes et (e) sélection clonale. Les superficies de terrain réservées pour les secteurs sont aussi disponibles pour les chercheurs et praticiens d'autres organisations.

Les secteurs expérimentaux seront distribués en fonction des grands écosystèmes afin d'obtenir une représentation adéquate des diverses conditions écologiques du Québec forestier, nous permettant ainsi de généraliser les résultats obtenus. Ces secteurs seront établis sur les sols les plus représentatifs des sections forestières tout en tenant compte de l'utilisation future de ceux-ci.

Pour répondre aux objectifs fixés, chaque secteur expérimental comprendra une superficie d'au moins 500 acres. Graduellement, des superficies de terrain seront préparées (dégagement du terrain et scarifiage des sols) pour permettre l'établissement de dispositifs expérimentaux.

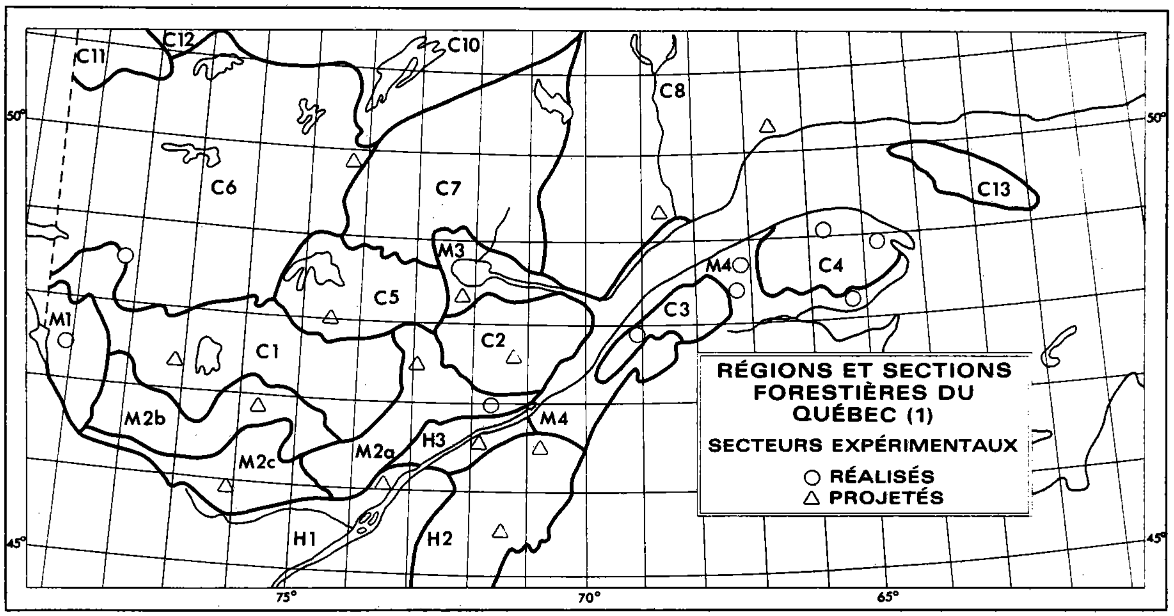
On trouvera ci-joint une carte montrant la distribution des secteurs et deux tableaux donnant les caractéristiques écologiques, climatiques et géographiques des secteurs actuellement établis.

RÉFÉRENCE ET PUBLICATIONS

Koster, R. 1968. Outdoor propagation from leaf cuttings of *Populus deltoides*, balsam poplar and hybrids. FAO, Fo: CIP/13/3.

Vallée, G. 1969. Programme général pour l'amélioration des arbres forestiers au Québec. Service de la recherche, Direction générale de la planification, ministère des Terres et Forêts, Québec.

Vallée, G. 1969. La culture de l'arbre peut accroître considérablement la production ligneuse au Québec. Papetier, février 1969.



D'Après Villeneuve 1946 (Quebec Dept. Lands and Forests, Meteorol. Bur. Bull. 6) et Rowe 1959 (Can. Forest. Br. Bull. 123).

Tableau 1. Caractéristiques écologiques des secteurs

Arboreta	Lieu	Principales séries	Bioclimat	Vocation	Dépôts de surface	Drainage
Parke	Cté Kamouraska, Canton Parke, rangs C et B, Réserve cantonale de Parke	Sapinière à Bouleau blanc	Froid, continental	Forestière	Till limono-schisteux	Bon
Matapédia	Cté Matapédia, Seigneurie du Lac Matapédia	Érablière à Bouleau jaune	Frais, continental	Agro-forestière	Till limono-calcaireux	Assez bon
Lac-St-Ignace	Cté Gaspé-Nord, Canton Tourelle, rang XI, lots rétrocédés	Sapinière à Bouleau blanc	Froid, continental, humide	Forestière	Till schisteux avec blocs erratiques	Très bon
Gaspé	Cté Gaspé-Nord, Canton Baie de Gaspé-Sud, Forêt domaniale de Gaspé	Sapinière à Épinette noire	Très froid, continental, humide	Forestière	Till grèseux et schisteux avec blocs erratiques	Très bon
Bonaventure	Cté Bonaventure, Canton Cox, rangs XIII et XII, lots vacants	Sapinière à Érable rouge et érablière à bouleau jaune	Relativement chaud, maritime	Agro-forestière	Till calcaire mince	Bon
Matane (Populetum)	Cté Matane, Canton Cuoq, rang III, lots 17 à 21	Sapinière à Bouleau jaune	Très frais, continental	Forestière	Till schisteux fluvio-glaciaire et dépôts alluvionnaires	Bon
Duchesnay	Cté de Portneuf	Érablière à Bouleau jaune	Relativement chaud, continental, humide	Forestière	Till indifférencié granitique sur substratum rocheux	Très bon
Trécesson	Cté Abitibi-Est, Canton Trécesson, rangs I et II	Épinette noire	Très froid, continental, relativement sec	Forestière	Dépôts lacustres argileux et sablonneux	Variable, très bon à médiocre
Guigues	Cté Témiscamingue, Canton Guigues, rangs III et IV	Érablière à Bouleau jaune	Relativement chaud et sec	Agro-forestière	Dépôts fluviaux et lacustres argileux à limon sablonneux	Bon

Tableau 2. Caractéristiques géographiques et climatiques des secteurs expérimentaux.

Secteurs expérimentaux	Altitude	Latitude	Longitude	Température F		Précipitation annuelle (pouces)	Longueur de la saison sans gel (jours)
				moyenne juin, juillet, août	minimum absolue		
Bonaventure	500-800	48°10' N	65°20' O	60.7	- 33	45	100-120
Duchesnay	500-1100	46°52' N	71°37' O	59.7	- 43	46	120-140
Gaspé	660-1100	48°50' N	64°40' O	61.2	- 44	36	100-120
Guigues	600-700	47°37' N	79°30' O	62.9	- 45	37	120-140
Lac St-Ignace	1500-2150	49°00' N	66°20' O	58.9	- 44	39	100-120
Matapédia	600-800	48°30' N	67°25' O	60.1	- 45	35	80-100
Matane (popul.)	300-1000	48°40' N	67°15' O	57.5	- 45	35	80-100
Parke	1100-1200	47°30' N	69°30' O	61.2	- 43	39	80-100
Trécesson	1000-1200	48°40' N	78°30' O	59.0	- 56	33	80-100

SEED ORCHARDS AND SEED PRODUCTION AREAS IN ONTARIO

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SEED ORCHARDS

There were no additional seed orchard sites established in the past two-year period. A proposed seed orchard site for white and black spruce of Site Region 4W source has been located in Pearson Township, Thunder Bay District. Initial plantings at this location are being considered for the spring of 1971. Seed orchards previously established were enlarged in 1969 and 1970. Table 1 shows the number of clones and acreage planted in the last 2 years and total to date.

Table 1

		Planted 1969		Planted 1970		To Date	
Species	Location	No. of Clones	Acres	No. of Clones	Acres	No. of Clones	Acres
White Pine	Lindsay District Orono Nursery	x	refill	-	-	x	24.5
Red Pine	Swastika District Grenfell Township	11	1.0	-	-	59	23.0
White Spruce	L. Simcoe District Nursery	5	refill	7	refill	21	4.0
White Spruce	Thunder Bay District Camp 503	21	4.0	20	3.0	31	15.0
Black Spruce	L. Simcoe District Midhurst	11	refill	8	1.0	29	7.0
Black Spruce	Thunder Bay District Camp 503	15	2.0	17	2.0	52	12.0

White Pine

In 1969, a small collection of cones was made from the white pine seedling seed orchard, Nepean Township, Kemptville District. The collection yielded 26 oz containing 36,700 viable seeds. This was an open-pollinated collection from resistant x resistant trees which should give an estimated 20% resistance in the progeny.

Red Pine

The red pine seed orchards in Gurd Township, Parry Sound District and Grenfell Township, Swastika District are at the final size at 11.0 and 23.0 acres respectively. No additional clonal seed orchards in red pine are planned. Grafting is confined to provision of refill stock. A small collection from the Gurd Township seed orchard in 1969 yielded 5.1 g of seed, 510 viable seeds. Trees are 6 years old from planting.

White and Black Spruce

Progeny testing for general combining ability began in 1969 at the black spruce seed orchard, Midhurst Nursery and in 1970 at the white and black spruce seed orchards, Thunder Bay District. This work is being carried out with the assistance of Miss R.M. Rauter, Tree Breeding Unit, Research Branch, Maple. A tentative site for out-planting of the progeny has been selected in Gurd Township, Parry Sound District.

SEED PRODUCTION AREAS

Three seed production areas have been established and one area was enlarged in the past 2 years as follows:

Table 2

Species	Location	Site Region	Acres	Development
Red Pine	Pembroke District, Head Twp.	5E	enlarged from 32 to 56 acres	Thinning 1970
White Spruce	Thunder Bay District, O'Connor Township	4W	12.0	Thinned 1969 1970
Black Spruce	Kenora District, Satterly Township	4S	13.0	Thinning 1970
Red Spruce	Tweed District, Effingham Township	5E	15.0	Partial thinning 1968

Red Pine - Willington Township

A collection of 49 bushels of cones from this seed production area in 1969 yielded 883,000 viable seeds weighing 254 oz. This represents 13% of the red pine seed in storage for Site Region 5S.

Red Pine - Lynn Tract - Oro Township

Collections of 34 bushels and 151 bushels were made from this seed production area in 1968 and 1969. The latter collection yielded 4.8 million viable seeds weighing 1,555 oz. This represents 16% of the red pine seed in storage for Site Region 6E.

An estimated 140 bushels can be collected from this area in 1970. With a collectable cone crop on the area for 3 years in succession, it would appear that the annual ammonium nitrate application and periodic brush control is assisting in overcoming the problem of periodicity in red pine seed crops. Cultural treatments are at least tending to level off the wide swings from failure to heavy crops. In view of the changed emphasis from seed orchards to seed production areas in red pine, confirmation of this trend will be of considerable benefit in the management of red pine stands for seed production purposes.

Jack Pine - Meglund Township

A 1969 collection of 6 bushels from a high quality stand in the Dryden area at the time of logging yielded 228,000 viable seeds weighing 27 oz.

SEED COLLECTION

In 1968 and 1969, 8,240 and 17,725 bushels of cones and rough seed, respectively, were collected. Seed requirements for the fall of 1970, to maintain the necessary reserve, are for the equivalent of 23,700 bushels of cones and rough seed.

The seed inventory as of 1 June 1970 at the Ontario Tree Seed Plant at Angus, is 2.38 billion viable seeds of 47 species weighing 12.5 tons. 1968 was a poor crop year for most species. About half of the volume collected was black walnuts. 1969 was a poor crop for spruce. However, 4,130 bushels of red pine were collected, the largest quantity collected in at least the past 25 years. There is still a shortage of red pine seed. 6,350 bushels are required in 1970.

TREE IMPROVEMENT AT THE ONTARIO TREE SEED PLANT

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GRAFTING PROGRAM

The grafting program at Angus in the past three seasons is summarized in tables 1 and 2.

Table 1. White Spruce

Season	Total No. of Grafts	No. of Clones			Survival in Greenhouse	Survival in Nursery	
		New	Established	Total	%	1 year %	2 year %
67-68	1,114	22	11	33	96	95	50
68-69	3,127	25	-	25	81	92	77
69-70	2,158	12	28	40	90	91	-

Table 2. Black Spruce

Season	Total No. of Grafts	No. of Clones			Survival in Greenhouse	Survival in Nursery	
		New	Established	Total	%	1 year %	2 year %
67-68	1,914	21	30	51	97	94	83
68-69	2,962	25	-	25	90	90	59
69-70	1,743	21	39	60	94	95	-

Red Pine and White Pine

In the spring of 1969, 155 red pine grafts and 42 white pine grafts made at Midhurst nursery were transferred to and lined out at Angus. The 1-year survival was 91% and 99%, respectively.

In the 1969-70 season, 33 red pine grafts were made from three old clones for re-filling purposes. Percent success in the greenhouse was 100.

White Spruce and Black Spruce

For both white and black spruce, air freight was used to ship scions to Angus whenever possible. Scions could be collected and attached to the rootstock within the same day. Fresh scions tend to take more successfully.

In an attempt to improve survival in the nursery, grafts were planted in sided frames and covered with slat shades at the outset. The shades were removed in early August and put back on after the first snow fall.

SEED PRODUCTION AREA

Cone Collection

The red pine seed production area at the Lynn Tract, Simcoe County Forest, produced a light crop of cones in 1968 and a medium crop in 1969. Cones were harvested from this area in both years. All trees (708 on 7 acres) were numbered before collection and the number of cones picked from each tree was recorded.

In the fall of 1968, 34 bushels were collected from 196 trees. Number of cones from individual trees ranged from 20 to 810.

In the fall of 1969, 151 bushels were picked from 626 trees. Number of cones from individual trees ranged from 10 to 1,023.

To mechanize the picking operation, an "Uppup" (portable utility platform) was tried out in both years. This unit consists of a platform (3 x 2.5 feet) resting on a telescoping hydraulic cylinder and is powered by a 3,000 watt portable generator. Raising and lowering the platform was controlled by a foot switch operated by the persons on the platform. Its maximum extended height was 24 feet. The unit was mounted on a two-wheeled trailer, towed by a tractor.

Supervised by Department staff, inmates from the Department of Reform Institutions field camp picked cones with the Uppup during the week and high school students were hired on the weekends.

Due to the roughness of the ground and the low crown of the trees, the Uppup could not be moved as freely as it should be. Collecting the cones from each tree required two or three settings of the machine, and took a total of 20 to 30 minutes.

The collection costs for the two seasons are summarized in Table 3.

In 1969 a comparison was made between collecting cones with the Uppup and with ladders. It was found that, on a per-man basis, men on the Uppup generally picked twice as many cones as those using ladders. It was also found that there was a difference among pickers. One picker consistently

Table 3. Collection Costs

		1968		1969	
Collection Dates		8 Sept.-7 Oct.		18 Sept.-20 Oct.	
Total Volume Picked (bu)		34		151	
Salaries	permanent	508.12		1,205.84	
	students	186.24		2,442.39	
	inmates	-		-	
sub-total		$694.36		$3,648.23	
cost per bushel			$20.42		$24.16
Rental Uppup		330.00		330.00	
Generator		144.00		144.00	
Trailer		26.00		26.00	
Prov. tax		25.00		25.00	
Repairs		5.00			
sub-total		$530.00		$525.00	
cost per bushel			$15.58		$ 3.47
Grand total		$1,224.36		$4,173.23	
Total cost per bushel			$36.00		$27.63

picked more cones than the others did. The potential of the Uppup in cone picking was well demonstrated in the Lynn Tract. Two units were purchased by the Timber Branch in the winter of 1969. In the Lynn Tract, in order to direct more nutrients to the cone bearing upper crown and to facilitate the movement of cone picking machines, all trees were pruned to a height of 8 feet right after cone collection in 1969.

OBSERVATIONS ON CONE AND SEED CHARACTERISTICS

During the cone picking operations in Lynn Tract, observations were made on the cone-tree relationships. Tree height and dbh were measured on randomly selected trees. Twenty-four years after planting, the trees were 20 to 39 feet tall with diameters ranging from 6 to 12.5 inches. Sizes of cones from sample trees were measured. Their average and the percentage of large cones were compared. Correlation coefficients were calculated from the data. A summary of the results and their significance are given as Table 4.

It appears from the table that larger trees tend to produce more cones, that trees producing more cones also produce larger cones and a higher percentage of them.

Table 4. Correlation Coefficients for Some Red Pine Cone-tree Relationships in Lynn Tract, 1968 and 1969.

Relationship	No. of Trees Measured		Correlation Coefficient	
	1968	1969	1968	1969
No. of cones per tree vs dbh	53	158	0.263	0.576**
No. of cones per tree vs tree height	53	158	0.227	0.379**
No. of cones per tree vs average cone size	53	156	0.603**	0.524**
No. of cones per tree vs % of cones above 45 mm in length	53	-	0.513**	-

** Significant at 1% level.

Cone boring insects have been present in the Lynn Tract for many years. They infested part of the cone crop to different degrees and thus reduced seed yield. To find out the extent of damage done by these insects, 10 trees were selected randomly in each year. The cones from each sample tree were sorted and separated into two lots - sound or infested. Each lot was measured, weighed and extracted separately. Seed germination was carried out with Jacobsen test. One hundred seeds from each lot were stratified at 38°F for 30 days and were then germinated at 80°F under a 16-hr photoperiod. From the 6th day on, germination counts were made at 2- or 3-day intervals. Table 5 shows the results from the averages of 10 trees.

Table 5. Comparison of Red Pine Seed Yield and Seed Quality from Sound and Infested Cones in Lynn Tract, 1968 and 1969.

Year	No. of Trees Sampled	Cone Quality	% of Cones	Cone Length mm	Wt of 100 Cones kg	No.of Seed/ Cone	Wt of Seed mg	Germination %
1968	10	sound	83.6	42.3**	0.98**	40.1**	6.9	93.7
		infested	16.4	37.6	0.70	5.1	7.5	90.5
1969	10	sound	80.8	46.1**	1.28**	38.8**	8.6	85.2
		infested	19.2	41.3	0.87	9.0	8.6	83.0

**Difference significant at 1% level.

It is evident that most of the cones harvested were sound, and that sound cones were usually larger and heavier than the infested ones. However, the most significant difference between sound and infested cones lies in the average number of seeds per cone. Sound cones produced from 4 to 8 times the seed produced by infested cones.

It was observed during the extraction process that although an infested cone was deformed only on a small area, many scales on the sound portion did not open and the seeds below it were small and shrunken. This seemed to indicate that the damage done to the cone extended beyond the boring path of the insect.

The average germination percentages of seeds from sound cones were higher. However, the differences in both years were non-significant. It appears that as long as an embryo can go through all the developmental stages and become a seed, it will be viable either in a sound or infested cone.

In the 1969 picking operation, opportunity was present for an observation on seed quality from cones collected on different dates. Five trees were randomly selected and marked for this purpose. Five cones were picked from each sample tree at weekly intervals. All cones picked in each week were pooled for measurement and testing. Results are summarized in Table 6.

Table 6. Relationship of Red Pine Seed Quality to Characteristics of Cones Collected on Different Dates, 1969

Date of Collection	Cone Appearance	Float in 50:50 Kerosene Linseed Oil %	Average sp gr	Germination %
26 Aug.	green	0	1.07	40.0
2 Sept.	green with purple-tipped scale	0	1.02	82.0
9 Sept.	purplish, scale tips brown	0	0.97	92.5
16 Sept.	deep purple	12	0.89	89.5
23 Sept.	dark purple	56	0.83	90.0
30 Sept.	brown	72	0.80	92.0
7 Oct.	brown	96	0.76	91.5
14 Oct.	light brown some scales open	100	0.66	74.0

According to the results, the period between 2 Sept. and 7 Oct. seemed to be the optimal time to collect red pine cones in Lynn Tract. Before the last week of August the cones had not ripened. After 14 Oct, the seeds started to lose their viability.

SEED ORCHARD

Progeny Test

In the fall of 1967 open-pollinated cones were collected from 20 clones of the timber-type Scotch pine seed orchard near Midhurst nursery and from 14 clones of the Faulkner series Scotch pine at Angus nursery. The cones were extracted according to clones and the seeds were stored separately. Seeds from the 34 clones were sown as an unreplicated 1-parent progeny test in Midhurst nursery in October 1968. Germination counts and subsequent observations were made by establishing random plots within the clones. The germination percentages tallied in the spring of 1969 of the timber-type clones ranged from 47.1 to 99% with an average of 69.2%. Those of the Faulkner clones ranged from 17.4 to 84% with an average of 54.3%. The beds were thinned to about 40 seedlings per square foot in the fall of 1969. The over-winter survival from all clones was over 95%. In the spring of 1970 first-year heights were obtained by measuring 10 randomly selected seedlings in each plot. The average height among the clones in the timber-type series ranged from 3.60 cm to 6.81 cm. The clonal average in the Faulkner series ranged from 5.02 cm to 6.88 cm. There was a definite difference in foliage color between the two series. A blue tinge appeared on the Faulkner series which indicated possible Christmas tree quality in addition to their fast growth.

OBSERVATIONS ON REPRODUCTIVE PHENOLOGY

During the springs of 1969 and 1970, reproductive phenology in the Site Region 3E white and black spruce seed orchard in Vespra Township was followed by regular observations. Male and female flowers produced by each tree were counted and recorded. Results showed that, on both species, certain clones were particularly fertile with many ramets producing female flowers in both years. It was also found that many grafts start to produce male flowers. Summaries of the dates on which different stages were observed in the two seasons are given in Table 7.

Table 7. Reproductive Phenology in the Site Region 3E White and Black Spruce Seed Orchard in Vespra Township in 1969 and 1970

	Female Flower				Male Flower						
					Scale		Strobili	Pollen Flight			
Species	Swelling	Open Tip	Early Receptive	Full Receptive	Thickening	Closed	Succulent	Initial	Full	Late	Fade
White Spruce	May 5	May 8	May 11-16	May 15-20	May 19-28	May 22 June 2	May 8	May 9-11	May 11-15	May 15-19	May 21
Black Spruce	May 11-15	May 13-19	May 19-23	May 21-28	May 28-30	June 2	May 19-23	May 21-28	May 25-30	June 2	June 5

A NEW LOOK AT THE WHITE PINE WEEVIL[1]

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A 3-acre plantation of *Pinus strobus* was established in 1957 and field-grafted in 1961, 1962 and 1963, in 3 series, with 2320 scions of 51 clones of *P. strobus* and related species and hybrids, previously found resistant to *Cronartium ribicola*. Observations on weevil (*Pissodes strobi*) attack were made in 1963 to 1967, including annual determination of leader size, as a basis for weevil attack during the following year. The grafts were maintained in a one-leader condition by pruning, with an average overall frequency of weevil attack of 17 per cent. Screening for weevil resistance, based on combined frequency of attack and recovery from attack, resulted in the selection of 9 clones of *P. strobus* and one clone of *P. peuce*. The results were interpreted with Painter's three general resistance mechanisms - tolerance, non-preference and antibiosis - applied to these materials as a working hypothesis. It was concluded that old-field white pine is tolerant to the weevil and its present abundance is one of the long-term ecological consequences of a land use favorable to the establishment and maintenance of open-grown stands. Examples of the non-preference and antibiosis reaction types were found in the more advanced stages of succession from open-grown to closed stands. Some guidelines are presented to breeding for weevil resistance, in the work cited in the footnote, as in the long run being more important than breeding for resistance to weevil attack. At present, clones combining the non-preference and antibiosis reactions are the most desirable for use in eastern Canada. Under more advanced silvicultural conditions, the use of the antibiosis type, more open to attack, but with high recovery rates from largely unsuccessful attacks, could result in a more or less self-regulating weevil resistance situation. Several exotic species and hybrids showed poor survival after grafting and poor weevil resistance, possibly because of poor adaptation.

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[1]Summary of the paper entitled "Screening of *Haploxylon* Pines for Resistance to the White Pine Weevil (*Pissodes strobi* Peck). II. Further Observations on the Resistance of *Pinus strobus* L. and Related Species and Hybrids" by C.C. Heimburger and C.R. Sullivan, 1970. Based on the results of experiments established by the Ontario Department of Lands and Forests, at Thessalon, Ontario and evaluated in cooperation with Dr. C.R. Sullivan, Department of Fisheries and Forestry, Ontario Region, Sault Ste. Marie, Ontario.

SPRUCE BREEDING AT THE SOUTHERN RESEARCH STATION, MAPLE, ONTARIO

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The spruce program has two broad objectives, both designed to produce genetically improved trees for Ontario. The first objective is aimed at improving the spruce species through breeding, hybridization, and selection in order to produce hybrid material which will exhibit superior characteristics such as faster growth, better form, improved wood quality, and resistance to pests. The second is the development of clonal material on it's own root system by means of vegetative propagation of cuttings so that each promising variety can be properly evaluated and the superior material quickly propagated.

ACQUISITIONS

The following material was acquired in the form of scions:

Species	Origin	No. of Clones	No. Successful Grafts
P. sitchensis	Coastal B.C.	1	8
P. smithiana	Brett Pinetum, Conn.	2	13
P. mariana	Calgary, Alta.	10	104
P. mariana x *rubens*	Fredericton, N.B.	10	92
P. abies	Finland	20	195
P. obovata	Finland	1	8
P. glehnii	Finland	1	1
P. mariana	Geraldton, Ont.	16	123
P. mariana	Kapuskasing, Ont.	5	44

The following material was acquired in the form of seed:

Species	Origin	No. of Populations	No. of Seedlings
P. abies	Wellington County, Ont. open pollinated	1	54
P. glauca	Southern Research Station, Maple open pollinated	1	18
P. koyamai	Winchester, England open pollinated	4	122
P. mariana	St. Williams, Ont. open pollinated	1	54
P. pungens	Southern Research Station, Maple open pollinated	1	31
P. schrenkiana	Winchester, England open pollinated	4	80
P. mariana	Northern Ontario open pollinated	30	several hundred

SELECTION

The following material was selected, regrafted, and (or) used in hybridization:

Species	Locality	No. of Trees
P. abies	Midhurst, Ont.	1
P. asperata	Maple, Ont.	11
P. sitchensis x *glauca*	Petawawa, Ont.	9
P. rubens	Maple, Ont.	49

HYBRIDIZATION

The following crosses were made in 1968 and 1969:

Parentage	No. of Female Clones (= No. of (Crosses)	No. of Cones	Total No. Seed	No. Full Seed	No. of Seedlings*
1968					
P. abies x *glauca*	3	23	4154	0	0
P. abies x *mariana*	3	9	1588	0	0
P. abies x *rubens*	3	19	3087	0	0
P. asperata x *glauca*	1	6	828	0	0
P. asperata x *mariana*	1	1	197	0	0
P. jezoensis x *glauca*	1	19	1030	3	0
P. jezoensis x *mariana*	1	16	856	0	0
P. schrenkiana x *rubens*	2	2	371	0	0
P. (*sitchensis* x *glauca*) x *abies*	1	0	0	0	0
1969					
P. glauca x *abies*	4	138	12140	1	1
P. glauca x *sitchensis*	4	141	8453	2898	1964
P. glauca x *jezoensis*	4	139	7884	434	262
P. glauca x *mariana*	4	293	11536	1	0
P. glauca x *asperata*	4	70	2911	1	0
P. glauca x *schrenkiana*	5	115	4803	5	3
P. jezoensis x *glauca*	1	11	711	41	33
P. koyamai x *omorika*	1	1	167	0	0

*Authenticity of hybrids yet to be verified.

APOMICTIC PROPAGATION

Apomictic propagation was started in an attempt to produce clonal material by means of rooted cuttings. The purpose of this study was to determine the variation in rooting ability between and within species. Since August 1967, several series of experiments have been established, many with very encouraging results.

Experiments were started in the spring of 1968, summer 1968, winter 1968/69, spring 1969, and winter 1969/70. Species which have been used in these trials are *P. glauca*, *P. mariana*, *P. schrenkiana*, *P. glehnii*, *P. koyamai*, *P. abies*, *P. omorika*, and *P. schrenkiana* x *glauca*. Unconfirmed hybrids obtained from Williamstown, Mass. this past winter include *P. glauca* x *jezoensis*, *P. glauca* x *engelmannii*, *P. jezoensis* x *glauca*, *P. omorika* x *koyamai*, *P. omorika* x *orientalis*.

To date high rooting percentages have been obtained in many of these species of spruce, but greater variation seems to occur within a species than between species. Large differences occur even with progeny originating from the same population. Although material used has been from 1- to 16-year-old stock, efforts have been concentrated on the younger stock in an attempt to find the best means to vegetatively propagate the most promising hybrids for clonal testing.

Initially the cuttings were placed in beds of coarse sand and covered with a tent of aluminum painted plastic. The cuttings were manually watered at frequent intervals. With each succeeding set of experiments, methods were modified so that presently flats containing 200 cuttings in plastic tubes are placed in a misting chamber. An outdoor chamber was erected in the nursery for the spring and summer experiments, an indoor chamber in the greenhouse for the winter experiments.

In the summer of 1968, cuttings of *P. mariana* were used to compare age differences and IAA treatments. Three-year-old material averaged 55% rooting, whereas 15-year-old material averaged 7%. High concentrations of IAA (200 ppm) were detrimental to rooting, although lower concentrations had little effect. In another experiment involving 3-year-old material of *P. glauca*, *P. schrenkiana*, *P. glehnii*, and *P. koyamai*, the rooting percentages varied from 96% for *P. glauca* to 76% for *P. koyamai*.

In the winter of 1968/69, cuttings taken from the same *P. mariana* trees as were used in the summer experiment demonstrated quite different results in rooting. No IAA treatment was used in this series. The average of the 3-year-old material dropped to 28%, the 15-year-old material to 6%.

Experiments established in the summer of 1969 again showed *P. glauca* and *P. schrenkiana* to consistently produce a high percentage of rooted cuttings. Five-year-old stock of *P. mariana* from 18 populations averaged 44% rooted. Some of these clones had 0% rooted, whereas others had 95% rooted. No population trend was evident, only that tree-to-tree variation for this species is extreme with respect to rooting ability.

The rooted cuttings will be kept and observed for 3 years to determine growth habits such as bud break, topophysis, growth rate, and lateral shoot development.

DISCUSSION

Since the spruce program was established in 1964, the work has branched into several important fields in attempts to improve the spruce species. Previously interspecific breeding was done mainly on an exploratory level, to determine the crossability patterns of this genus. Now, more emphasis is being placed on interspecific breeding of known combinations to improve silvicultural characteristics and to extend the range of the native species.

Although the results for the vegetative propagation of spruce are encouraging, much work has yet to be done. It will be useful to determine the rooting capabilities of the various species and their hybrids, the differences in rooting of individuals of different age classes, and the variations in rooting ability within the same population. If a particular method can be established and a selection for rooting accomplished then it will provide possibilities for clonal testing of the hybrids and provide good clones for the field faster and cheaper.

In the cooperative work with our Timber Branch, through plus tree selection and seedling seed orchard establishment, variation and heritability studies will be made and superior material for breeding work will be acquired.

SUMMARY REPORT ON POPLAR AND PINE BREEDING IN 1968 AND 1969

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The objectives of the aspen, cottonwood, white pine and hard pine breeding programs, and the work accomplished in 1968 and 1969 are described in this report.

ASPEN

The improvement of native aspens and the development of hybrid aspen clones and varieties of superior growth, good form and desired wood quality, resistant to pests and suitable for the future needs of aspen timber production under varying conditions in Ontario are the objectives of this program.

The following methods are being used: (i) population studies; (ii) selection in native populations; (iii) acquisition of gene pools of exotics and development of breeding arboreta; (iv) interspecific crosses; (v) polyploidy induction; (vi) progeny testing and heritability studies; (vii) vegetative propagation; and (viii) field testing.

In 1968 and 1969 the work concentrated on: (i) selection of superior trees in the plantations of hybrids and in native stands; (ii) production of *P. tremuloides* x *tremula* and *P. tremuloides* x *sieboldii* F_1 hybrid generations with desired characteristics for central and northern Ontario's conditions; (iii) multiple crosses of unrelated hybrid parents to produce heterogeneous populations with outstanding individuals which could be used for the development of superior clonal varieties for southern and central Ontario's conditions; (iv) *Leuce* x *Aigeiros* and *Leuce* x *Tacamahaca* intersectional crosses from which the production of entirely new types of poplar hybrids and the induction of rooting ability is expected; (v) rooting trials and vegetative propagation of superior genotypes to secure a clonal basis for field testing; and (vi) acquisition of population samples of exotic poplars.

Acquisitions

Species	Origin	No. of One-Parent Progenies
P. alba	Romania	3
P. alba	Hungary	4
P. alba	Italy	1
P. canescens	Italy	1
P. canescens	Romania	7
P. tremula	Hungary	1
P. tremula	Czechoslovakia	2
P. tremuloides	Prairie Provinces, F.B. Armitage's collection	50

Selection

Species or Hybrid	No. of Trees Selected
P. tremuloides	34
P. alba x *grandidentata*	21
P. alba x *davidiana*	24
P. alba x *sieboldii*	6
P. grandidentata x *alba*	10
P. grandidentata x *davidiana*	1
P. canescens x (*alba* x *grandidentata*)	9
P. canescens x (*alba* x *tremuloides*)	1
P. alba x *adenopoda*	1
P. canescens x *grandidentata*	4

These trees were selected in native stands and in plantations of hybrids, and vegetatively propagated for the purpose of clonal testing.

Hybridization

Parentage	No. of Crosses Made		Total
	successful	unsuccessful	
P. tremuloides x *tremula*	5	2	7
P. tremuloides x *sieboldii*	3	1	4
P. tremuloides x *deltoides*	1	1	2
P. tremuloides x (*tacamahaca* x *deltoides*)	1	1	2

Parentage	No. of Crosses Made successful	unsuccessful	Total
P. tremuloides x *trichocarpa*		1	1
P. tremuloides x *balsamifera*		4	4
P. tremula x *tremuloides*	13		13
P. tremula x *deltoides*	2	2	4
P. tremula x (*tacamahaca* x *deltoides*)	1	3	4
P. grandidentata x *alba*		1	1
P. grandidentata x *canescens*	1		1
P. alba x *grandidentata*	1		1
P. alba x *sieboldii*	2		2
P. alba x *deltoides*	1		1
P. alba x (*tacamahaca* x *deltoides*)		1	1
P. alba x *trichocarpa*	1		1
P. canescens x *alba* x *grandidentata*)	1		1
P. canescens x (*alba* x *sieboldii*)	1		1
P. canescens x (*alba* x *davidiana*)	1		1
P. canescens x (*alba* x *adenopoda*)	1		1
P. canescens x *deltoides*	1		1
P. canescens x (*tacamahaca* x *deltoides*)	1	1	2
P. sieboldii x *canescens*		1	1
P. sieboldii x (*alba* x *tremula*)	1		1
P. sieboldii x (*alba* x *grandidentata*)	1		1
P. sieboldii x (*alba* x *adenopoda*)	1		1
P. sieboldii x (*alba* x *davidiana*)	1		1
P. (*alba* x *grandidentata*) x *canescens*	4	1	5
P. (*alba* x *grandidentata*) x (*alba* x *davidiana*)	2		2
P. (*alba* x *grandidentata*) x (*alba* x *sieboldii*)	1		1
P. (*alba* x *grandidentata*) x (*alba* x *adenopoda*)		1	1
P. (*alba* x *grandidentata*) x (*alba* x *tremula*)	1		1

Parentage	No. of Crosses Made successful	unsuccessful	Total
P. (*alba* x *grandidentata*) x *sieboldii*	1		1
P. (*alba* x *grandidentata*) x *davidiana*	1		1
P. (*alba* x *grandidentata*) x *deltoides*	1	1	2
P. (*alba* x *grandidentata*) x (*tacamahaca* x *deltoides*)		1	1
P. (*alba* x *grandidentata*) x *trichocarpa*		1	1
P. (*alba* x *sieboldii*) x (*alba* x *grandidentata*)	1		1
P. (*alba* x *sieboldii*) x *grandidentata*	1		1
P. alba x *davidiana* - self pollinated	1		1
P. alba x *tremula* - self pollinated		1	1
P. (*grandidentata* x *davidiana*) x (*alba* x *grandidentata*)	1		1
P. (*grandidentata* x *davidiana*) x (*alba* x *tremula*)	1		1
P. (*grandidentata* x *davidiana*) x (*alba* x *sieboldii*)	1		1
P. (*grandidentata* x *davidiana*) x (*alba* x *adenopoda*)		1	1
P. deltoides x *tremuloides*	2	3	5
P. deltoides x *tremula*		2	2
P. balsamifera x *tremuloides*		1	1

Irradiated intermediate pollen (10,000 R/min for 20 min to a total of 200,000 R) was used in the intersectional crosses (*Leuce* x *Aigeiros*, *Leuce* x *Tacamahaca*). The self-pollinated poplars were hermaphrodites.

Rooting Trials and Vegetative Propagation

Efforts were made to propagate selected trees by stem cuttings and suckers.

The propagation by stem cuttings was tried with hybrids of silver poplar and aspen parentage. Replicated trials showed significant variation in rooting within and between the families of hybrids. Some genotypes rooted consistently better. The clonal propagation of a larger number of hybrids is underway.

Pure aspens cannot be propagated by stem cuttings. Efforts were made to use their suckering ability for vegetative propagation. Root pieces of selected trees were placed in sand in the greenhouse and the emerging succulent suckers were planted in tubes for rooting. The following observations were made: (i) intensive suckering was observed in a 60-day period; (ii) the rooting of the suckers was successful; and (iii) large within- and between-population variation was observed in suckering as well as in rooting of the suckers. A fast initial propagation can be achieved by using this method. Once this phase of the propagation is achieved, it could be continued in a simpler way in the nursery, by taking advantage of the suckering capacity of the outplanted rooted suckers.

Polyploids

The chromosome counts were continued on the poplar plants which were first produced and treated for polyploidy induction. Fifty-two polyploid and 77 mixoploid plants were found. Some of the plants were analysed for the second or third time. A plantation of the polyploid and mixoploid poplars was initiated in the Maple arboretum area.

COTTONWOOD

The development of fast growing cottonwood clones with superior silvicultural characteristics and a northern extension of the range of cottonwood are the objectives of this program. The following methods are being used: (i) selection; (ii) acquisition of gene pools of exotics and development of breeding arboreta; (iii) breeding; (iv) polyploidy induction; (v) progeny testing and heritability studies; (vi) vegetative propagation; and (vii) nursery and field testing.

During 1968 and 1969 emphasis was on the following works: (i) selection of superior trees in native populations; (ii) interspecific breeding; and (iii) clonal and population testing for winter hardiness.

Acquisitions

Species or Hybrid	Origin	Number
P. nigra	Yugoslavia	10 one-parent progenies
P. nigra	Czechoslovakia	1 one-parent progeny
P. deltoides	Prairie Provinces, F.B. Armitage's selection	74 one-parent progenies
P. deltoides	Ontario	5 one-parent progenies
P. deltoides	Manitoba	7 clones
P. deltoides	Italy	1 clone
P. x *euramericana*	France	9 clones
P. x *euramericana*	Germany	10 clones

Species or Hybrid	Origin	Number
P. x *euramericana*	Holland	2 clones
P. x *euramericana*	Italy	9 clones
P. x *euramericana*	Spain	3 clones

The *P.* x *euramericana* material represents a selection of the best known clones from European countries. The *P. deltoides* seed was collected from selected trees in the Saskatchewan, Missouri and Red River systems, while the cottonwood clones represent a selection from the Prairie Provinces.

Selection from Ontario

Species	No. of Trees Selected
P. deltoides	12
P. x *Jackii*	6
P. balsamifera	3

The majority of these trees were selected by Mr. H.C. Larsson, who kindly provided the scions and cuttings for the vegetative propagation. The propagation of these trees, for the purposes of clonal testing, is underway.

Hybridization

Parentage	No. of Crosses Made		Total
	successful	unsuccessful	
P. deltoides x *nigra*	13	4	17
P. deltoides x *Jackii*	9	3	12
P. deltoides x *trichocarpa*	2	-	2
P. tacamahaca x *deltoides*	-	1	1
P. x *Jackii* x *deltoides*	-	2	2
P. x *Jackii* x *nigra*	2	1	2

P. deltoides and *P.* x *Jackii* were crossed with *P. nigra* in an attempt to induce hybrid vigor, and to obtain resistance to *Marssonina* and to the bacterial canker. By crossing *P. deltoides* with *P. balsamifera* and *P.* x *Jackii* the production of hybrids for a northern extension of cottonwood is expected.

Winter Hardiness Tests

Euramerican poplar clones of European origin were planted in nurseries across Ontario to test their winter hardiness. The majority of these clones were winter hardy in Orono and Kemptville nurseries, but they were seriously frost damaged in Swastika and Thunder Bay nurseries.

Field Testing

Two clonal tests of winter hardy euramerican poplar clones were established in southern Ontario to demonstrate their growing potential and to select the ones which could be recommended for local planting.

WHITE PINE

The objectives of the white pine breeding program are to improve the eastern white pine and to develop hybrid white pine varieties of fast growth and desired silvicultural characteristics, with a reasonable degree of resistance to blister rust and weevil. The following methods are being used: (i) selection; (ii) variation studies; (iii) completion and maintenance of a gene bank and of the breeding arboreta; (iv) intraspecific and interspecific breeding; (v) progeny testing and heritability studies; (vi) vegetative propagation studies; (vii) studies of the pest inoculation techniques and of the nature of resistance; and (viii) field testing.

In 1968 and 1969 efforts were made in the field of: (i) vegetative propagation; (ii) blister-rust-resistance testing and detection; (iii) testing the blister-rust-resistance-transmitting ability of the seemingly resistant *P. strobus* trees; and (iv) *P. griffithii* x *strobus* breeding and testing.

Acquisitions

Species	Origin	Number
P. koraiensis	Japan	1 population
P. monticola	Idaho, U.S.A.	6 populations
P. strobus	Petawawa F.E.S., Ont.	6 populations
P. pumila	Japan	5 trees
P. monticola	Saratoga, N.Y., U.S.A.	10 trees

Selection

The following trees were selected and propagated by grafting:

Species of Hybrid	No. of Trees Selected
P. monticola	7
P. monticola x *peuce*	26
P. peuce x *strobus*	1
P. strobus	26
P. griffithii	8
P. griffithii x *strobus*	3
P. griffithii x *pentaphylla*	2
P. cembra	5

Hybridization

Crosses Made in 1968

Parentage	No. of Crosses	No. of Seeds Total	No. of Seeds Full
P. koraiensis x *lambertiana*	4	12	1
P. strobus x *monticola*	15	1546	49
P. (*strobus* x *griffithii*) x *monticola*	2	147	0
P. (*peuce* x *strobus*) x *monticola*	1	326	75
P. strobus x (*griffithii* x *strobus*)	5	140	16

Crosses Made in 1969

Parentage	No. of Crosses Made	No. of Cones Set
P. griffithii x *strobus*	13	222
P. strobus x *griffithii*	4	124
P. strobus x (*griffithii* x *strobus*)	4	38
P. (*griffithii* x *strobus*) x *strobus*	5	131
P. (*griffithii* x *strobus*) x (*griffithii* x *strobus*)	5	39

Blister-Rust-Resistance Testing and Blister-Rust Detection

Tubed seedlings are being raised in flats and arranged in randomized replications. The seed is sown in January. The blister rust inoculation takes place in late August. The entire test is concentrated in a small area and inoculated at one time. The seedlings are returned to the greenhouse in January, when observations on needle infection are made. In the early summer the seedlings are moved to the cold frames and from there to the nursery. In late August they are again inoculated with blister rust. In January the seedlings are taken back to the greenhouse. In a short time the aecia appear on the seedlings which have completed two seasons of growth. The testing period is significantly shortened.

Observations were made on the needle infection of the 1-year-old seedlings, and bark samples were analysed for the blister rust mycelium. Six months after inoculation the blister rust was present in the stems of all analysed seedlings with heavy needle infection and in the majority of the seedlings with light needle infection. The small seedlings were infected to a significantly lesser degree than the tall seedlings. Significant differences in the intensity of needle infection appeared between the 17 *P. strobus* full sibs in the test.

Significant differences in the number of seedlings with aecia appeared between the same full sibs. The correlation between the intensity of needle infection and the number of seedlings with aecia was positive, but weak.

Vegetative Propagation

Cuttings and needle fascicles were planted in coarse sand in plastic tubes and placed in a plastic tent or in a mist bed in the nursery. The possibilities of rooting cuttings, needle fascicles with fascicular buds and needle fascicles without fascicular buds of *P. strobus* and *P. griffithii* x *strobus* trees of different age were investigated. The within- and between-population variation in rooting ability was studied. The following observations were made: (i) the cuttings and needle bundles taken in early spring and in late summer rooted the best; (ii) the cuttings rooted as well as the needle fascicles; (iii) the needle bundles without fascicular buds rooted better than those with fascicular buds; (iv) the rooting in 3/4-inch diameter, 3-inch-long plastic tubes was as good as in flats. The cuttings rooted in tubes developed an evenly distributed and balanced root system in contrast to the unilateral roots developed in flats; (v) the rooting ability did not decrease when stock up to 10 years of age was used; (vi) within- and between-population variation in rooting ability was observed. and this became more pronounced with age; (vii) *P. griffithii* x *strobus* rooted better than *P. strobus*; (vii) the rooting of the same clones in the consecutive years was not consistent; and (ix) cuttings as well as needle fascicles taken from single trees rooted up to 100%.

HARD PINES

The improvement of 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's conditions are the objectives of this project. The methods used involve: (i) selection and intraspecific breeding in red pines, emphasizing the crosses of geographically distant provenances and of evidently distinct genotypes; (ii) completion and maintenance of breeding arboreta; and (iii) interspecific crosses.

In 1968 and 1969 emphasis was on *P. nigra* x *densiflora* x *silvestris* crosses and attempts were made to produce interspecific hybrids of red pine by using irradiated red pine pollen as an intermediate.

Acquisitions

A *P. nigra* provenance trial representing 61 provenances with a total of 5,500 seedlings was received from Schmalenbeck, Germany.

Selection

The following trees were selected from our experimental plantations and grafted for further purposes:

Species	Origin	No. of Trees Selected
P. densiflora f. *erecta*	Korea	1
P. densiflora	Japan	2
P. densiflora	Pennsylvania	1
P. nigra f. *cebennensis*	France	7
P. hwangshanensis	China	1
P. montana f. *uncinata*	France	3
P. leucodermis	Holland	5

Hybridization

Crosses Made in 1968

Parentage	No. of Crosses	No. of Cones	No. of Seeds full	empty
P. tabulaeformis x *leucodermis*	4	32	0	261
P. (*densiflora* x *silvestris*) x *nigra*	8	299	2821	5310
P. (*nigra* x *densiflora*) x *silvestris*	2	19	0	2
P. resinosa x *resinosa*	10	90	2515	821
P. resinosa x (*nigra* + *resinosa* irradiated)	6	49	2*	332
P. resinosa x (*silvestris* x *resinosa* irradiated)	3	17	0	90
P. resinosa *leucodermis* *resinosa*	5	19	0	59

Crosses made in 1969

Parentage	No. of Crosses	No. of Cones
P. resinosa x *resinosa*	11	49
P. resinosa x (*nigra* + *resinosa* irradiated)	8	69
P. resinosa x (*densiflora* x *silvestris* + *resinosa* irradiated)	10	67
P. resinosa x (*silvestris* + *resinosa* irradiated)	7	59
P. resinosa x (*densiflora* + *resinosa* irradiated)	7	62

The pollen was irradiated at 10,000 R/min to a total of 200,000 R.

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*The authenticity of the hybrids is not verified yet.

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RESEARCH STUDIES IN THE SWAMPS OF SOUTHWESTERN ONTARIO 1969-70

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The objectives of the swamp silvicultural research program are to develop practical techniques for the selection, mass production, establishment and culture of fast growing veneer-quality phenotypes of the commercially important hardwood species.

To accomplish these objectives, intensive reconnaissance surveys have been underway since 1957 in the major swamps of southwestern Ontario for locating exceptionally fast growing high-quality phenotypes of silver maple (*Acer saccharinum* L.), eastern cottonwood (*Populus deltoides* Marsh.), and Jackii poplar (*Populus* x *Jackii* Sarg.). At the present time 18 silver maple, six eastern cottonwood and four Jackii poplar have been selected for propagation. In addition 16 clones of European willow (*Salix alba* L.) and the progeny of five strains of lumber-type European alder have been grown for out-planting in the swamps.

A hardwood nursery of approximately 0.4 acres was established in the spring of 1969 to accommodate the silver maple progeny and the ever increasing clones and cuttings of eastern cottonwood, Jackii poplar and silver maple. It was expanded to almost 1 acre in the spring of 1970.

A misting bed with bottom heat was also established at the same time to increase the production of the silver maple clones.

SILVER MAPLE

Location and Selection of Phenotypes

No new silver maple phenotypes have been located in southern Ontario over the past 2 years. However, of the 23 that had been selected, four have since been rogued for defects which were not obvious at the time of selection.

Breeding Program

In 1968 seven parent trees were crossed under greenhouse conditions to produce 16 strains totalling about 1,200 seedlings. In 1969 eight parent trees were crossed under similar conditions to produce 18 strains totalling 800 seedlings.

In 1970 a limited breeding program was initiated by crossing only two parent trees of silver maple. However, at the same time a reciprocal cross was successfully made between silver and red maple. The cross was more successful when the silver maple male was crossed with the red maple female than when the red maple male was crossed with a silver maple female.

In all 3 years, the seed from the resultant crosses was sown in the greenhouse in plastic flats in mid-April and transplanted into the hardwood nursery in mid-May of the same year. Here they remain for 2 years before being outplanted in the swamps of southwestern Ontario.

Establishment Studies

A progeny test was established in the spring of 1969 in the Newell Tract of the Beverly Swamp by planting 2-year-old seedlings in a replicated design. The trees were spaced 6 feet apart within and between rows. Testing continued in the spring of 1970, by planting the progeny from seven parents in the Ellice, Beverly, Luther and Greenock swamps. Half of the trees were planted with roots and the other half were planted with only the root zone. The latter method of planting is faster and if successful will greatly reduce the costs of planting silver maple under swamp conditions.

Clonal Studies

Fifteen of the selected phenotypes have been reproduced either by budding, layering or cuttings. Cuttings appear to be the most efficient method of reproducing this species asexually. The best results to-date were procured when greenwood cuttings were planted in a misting bed in July and early August. Unfortunately the first roots which are formed on the cuttings are almost non-functional for the first year. It is therefore important that the young cuttings are not disturbed until May of the following year.

EASTERN COTTONWOOD AND JACKII POPLAR

Location and Selection of Phenotypes

A total of 11 eastern cottonwood and five Jackii poplar have been located since 1967 in the Burford, Beverly, Wainfleet, Luther and Greenock swamps. Of these 16 selections, four of the eastern cottonwood have been rogued either for minor defects or for canker. The remaining 12 trees are being propagated at Maple.

Establishment

One of the Jackii poplar clones was out-planted in the Ellice, Burford, Beverly, Puslinch, Luther and Greenock swamps in the spring of 1970. It will be evaluated as to growth and survival.

Clonal Studies

Over the past 4 years, eastern cottonwood and Jackii poplar have been propagated almost entirely by dormant, hardwood cuttings. Generally they root within 6 weeks of planting and by the end of the first growing season they are from 4 to 8 feet tall.

Greenwood cuttings procured in July from the best eastern cottonwood and Jackii poplar phenotypes were rooted in the rooting bed at Maple. Rooting success was almost 90% but when outplanted in the field in the spring of 1970, only the Jackii poplar cuttings survived. The root system of the eastern cottonwood clone appeared to be rendered non-functional after disturbance by transplanting.

EUROPEAN WILLOW

Sixteen clones of European willow were outplanted in a replicated and randomized design in the Newell Tract in the Beverly Swamp complex in the spring of 1969. The cuttings rooted well and approximately 90% of all cuttings survived the first growing season. Unfortunately there was a mouse epidemic in the winter of 1969-70 and over 80% of the cuttings were completely or partially girdled. The injured cuttings were cut off above the girdle and replanted in the early spring of 1970.

EUROPEAN ALDER

In 1962, seed from five lumber strains of European alder from Germany were procured through the late Dr. F.U. Klaehn of Syracuse University. They were sown in the Orono Nursery in the same year and were outplanted in three swamps in the spring of 1965 under natural conditions. They were measured after five growing seasons. They ranged in mean height per clone from 13 to 19 feet and with a mean diameter per clone from 1 to 2 inches. These trees not only grew well but they were not attacked by mice, rabbits or deer. Such a species might be valuable in a mixture for soil improvement as well as for lumber.

QUALITY CRITERIA FOR BLACK SPRUCE

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INTRODUCTION

For several years the Wood Science Section of the Ontario Research Foundation (ORF) has been engaged in research centering on the relationships between the properties of paper and the attributes of the wood from which it is made. Up to the time of writing, the work, which is sponsored by the Ontario Department of Lands and Forests, has been almost entirely with black spruce (*P. mariana*). However, it is planned to carry out some investigations on white spruce (*P. glauca*) and white spruce hybrids in the near future.

A lengthy investigation directed at the establishment of criteria which would allow the quality sampling of standing (black spruce) trees was completed in 1969. In this work the morphological and chemical characters in 16 samples of black spruce wood were examined with a view to determining, by multiple regression analysis, their efficiency as predictors of paper strength. The 16 samples consisted of four samples of like age taken from each of four trees. The four trees were part of a larger sample of 20 randomly selected from a Class 1 site in Parnell Township, Ontario. From each of the trees a 2-foot bolt was removed from the 10-percent, 25-percent, 50-percent and 75-percent-height levels. The present investigation centered on material from the 25-percent-height level. Confirmatory work involving all height levels in all 20 trees is in progress at the time of writing.

While the assessment of the relative efficiency of paper strength predictions was the principal object of the investigation, it was also thought desirable to examine the morphological and chemical characteristics of the 16 samples in some detail, as little is as yet known of the properties of black spruce wood.

Information was obtained on 65 wood characters in all. Determinations made on samples of chips included: specific gravity, both extracted and unextracted, lignin, pentosan and extractive content. Measurements made on macerated fibers included fiber length, fiber diameter, as measured at the mid-point, and the number of bordered pits. Measurements, with a microscope of cross-sections of selected rings included the cross-sectional dimensions of tracheids (fibers), lumens, and cell wall thickness, both tangential and radial and in both early- and latewood, the numbers of early- and latewood fibers per file and the total number of fibers per file, ring width and the width of latewood; the width of medullary rays and their frequency, both absolute and in relation to the number of tracheid files; the frequency of fusiform rays; and the size and frequency of vertical resin ducts. Counts were also made of the number of fibers per unit area, which, together with estimates of cell wall percent, led to expressions of the average cross-sectional dimensions of fibers and average cell wall thickness.

Measurements on tangential sections in selected rings included fiber length, and the height, width and frequency of medullary and fusiform rays.

VARIABILITY OF SAMPLE MATERIAL

Fiber length as determined from tangential sections of the latewood was found to increase from an average of 0.77 mm at the outer boundary of ring 2 to 3.78 mm in ring 100, with fluctuations in the middle years presumably associated with (observed) changes in growth rate. (Rings were counted from the pith.) Average fiber lengths, as determined from macerations, were consistently greater than fiber length in the latewood. Average tangential diameter of earlywood fibers increased rapidly from 13.4 μ in the ring nearest the pith to 20.4 μ in ring 10, with a further steady increase to 24.8 μ in ring 100. Radial diameter of earlywood fibers increased on the average from 15.4 μ in ring 1 to 23.8 in ring 10 and to 30.7 μ in ring 100. Tangential diameter of latewood fibers corresponded closely with that of earlywood cells. Radial diameter of latewood fibers increased from 10.22 μ in ring 1 to 13.92 μ in ring 10 and then increased but little if at all from that ring outward. The thickness of fiber walls in earlywood fibers changed little from ring 1 to ring 100. In latewood fibers the wall thickness increased fairly steadily from ring 1 outwards, to reach a maximum of 5.61 μ in ring 100 in the case of the radial walls and 4.21 μ in the case of tangential walls.

Latewood production was found to be meagre. Average number of latewood fibers produced increased from 8 in ring 1 to 15 in ring 10 with a decline thereafter to an average of 5 in ring 100. Values for latewood percent, calculated on the basis of measured width, were 40% in ring 1, with a decline to 20% in ring 10, and fluctuations thereafter. Values given by basing latewood percent on the relative number of latewood fibers present, a faster method, gave consistently higher percentages.

Medullary ray frequency in the four trees was highest in the ring nearest the pith, decreased rapidly in the first 10 rings, and less rapidly thereafter, so that in ring 100 the frequency of rays was about half that near the pith. From ring 1 to 10 the average height of medullary rays decreased and their average width decreased. Thereafter there appeared to be little change in their dimensions. Total ray cross-sectional area followed the trend for ray frequency. Fusiform rays were sparsely distributed with a frequency 1/40 that of the medullary rays. The average height of fusiform rays increased from the pith outwards. The number of vertical resin ducts was highest in the ring nearest the pith with an average of 7.28 ducts per mm^2. The frequency then fell abruptly to less than 1 duct per mm^2 in ring 10, with minor fluctuations in frequency thereafter. Vertical resin canal diameter, on the other hand, increased steadily from an average of about 30 μ in the ring nearest the pith to over 50 μ in ring 100. Total resin duct area tended to follow the trend for duct frequency.

Cell wall percent was highest in the ring nearest the pith with a sharp decline to ring 10, followed by a less steep decrease to ring 20. Cell wall percent then tended to increase but it never reached the value for ring 1. Specific gravity patterns reflected these trends. Lignin content tended to increase from about ring 25 outwards while pentosan content decreased from pith to bark, as did extractive content.

It was concluded from this examination that the core- or innerwood, comprising the region of anomalous wood near the pith, probably does not extend more than 10-15 rings from the pith in black spruce. The volume of corewood produced in relation to the whole merchantable bole would be therefore small, so that from the practical point of view the presence of corewood in the species may probably be safely ignored. From the patterns of variation outward, it was also concluded that black spruce is an unusually uniform wood. With comparatively few latewood cells, the character of the wood is probably dominated by the earlywood fibers, which vary little in wall thickness from pith to bark.

In general, variability outward appeared to be associated with radial distance from the pith, rather than with age or ring width.

CORRELATIONS WITHIN SAMPLE MATERIAL

Correlation coefficients were calculated between all 65 wood characters using averages for the 16 samples (14 df). The correlation coefficient between average ring width in the samples and unextracted specific gravity was -.522* and with extracted specific gravity -.538*. The correlation coefficient between specific gravity, unextracted and extracted, and latewood percent based on width of latewood, was found to be +.434 and +.424, NS. at the 5% level. Latewood percent based on relative number of latewood fibers, however, gave +.534* and +.501*. Latewood percent was negatively correlated with ring width.

Average and latewood fiber length were highly correlated at r = +936***. Average mid-point fiber diameter, as determined on macerations, was found to be more closely correlated with the radial diameter of earlywood fibers (r = +.812***) than with any other cross-sectional fiber dimension. Examination of the 12 correlations linking the radial and tangential measurements of fiber diameter, lumen diameter and cell wall thickness in both early- and latewood fibers showed that the tangential diameter of latewood fibers was significantly correlated with all but two of the 11 other cross-sectional fiber dimensions, and latewood radial wall thickness and the radial diameter of earlywood lumens all but three. On the other hand, the radial diameter of latewood lumens was significantly correlated with only one of the other 11 cross-sectional fiber dimensions. The correlation between average fiber length and average mid-point diameter was found to be r = +.669**. Correlations with precise cross-sectional dimensions were higher with fiber length/tangential latewood fiber diameter giving r = +.830***.

Specific gravity was found to be significantly correlated with only one cross-sectional fiber dimension - radial wall thickness in the earlywood.

No significant correlation was found between the height and width of medullary rays. Total ray area per mm^2(TS) was found to be closely correlated with ray frequency (r = +.840***), less closely correlated with average ray width (r = +.633***), and not significantly correlated with ray height (r = +.049). Ray frequency was strongly correlated with both average and latewood fiber length (r = -.879*** and -.849***), suggesting ray frequency, an easily measured feature, might be used to predict approximate fiber length.

Lignin content was found to be significantly correlated with latewood but not average fiber length (+.564* and +.451 NS). Lignin content was also correlated with radial fiber wall thickness with r = +.605* (earlywood) and +.662** (latewood); but there was no significant correlation with tangential fiber wall thickness (r = -.182 NS and +.337 NS). There was no significant correlation between lignin content and either ring width, age or radial distance from the pith.

Pentosan content was positively correlated with ring width, distance from the pith, ray frequency, and the width of latewood, but not with latewood percent.

Extractive contents were positively correlated with the frequency of medullary and fusiform rays, but negatively correlated with the size and distribution of resin ducts.

RELATIONSHIPS BETWEEN PAPER STRENGTH AND WOOD CHARACTERS

Duplicate cooks of 10 g samples of chips (oven-dry weight) from each of the 16 fractions were carried out in bombs of 150 ml capacity using the bi-sulphite process. Cooking times were 3, 3.5 and 4 hr at 160°C. Cooking of the 96 batches (16 fractions x 3 cooking times x duplicates) was to a predetermined randomised design.

For each of the three paper strength properties obtained, tensile strength (breaking length), burst and tear, linear regression equations were calculated with all 65 wood characters entered as independent variables in sub-sets of one, two and three in all combinations. Four series of regression analyses were made for each paper strength property with the four innerwood fractions included (N = 16) and excluded (N = 12), and with the dependent variables (paper strength) as based on the same cook-time (4 hr) and as based on the same residual lignin content (K = 45).

The analyses were carried out by computer which was programmed to include in the print-out only those regression equations in which each and every independent variable was found to be significant at or over the 5% level. The output included a total of more than 4000 equations. Examination of these showed that almost every one of the 65 independent variables entered was significantly related, either when taken alone or in combination, to one or other of the paper strengths. It was also found that the relative superiority of certain wood characters as predictions of paper strength depended on whether the paper strengths entered were those based on a common cook-time or those corrected for residual lignin; and also on whether the four innerwood fractions were included or not.

The equations were screened firstly for those wood characters, or combination of characters, occurring in all four series of analyses for each of the three paper strengths, i.e. those characters showing a relationship with paper strength, whatever basis was used to arrive at paper strength and whether the innerwood fractions were included or not. These characters would appear to be the most reliable and persistent indicators. A second screening was carried out for characters showing a relation with strength values corrected for residual lignin and appearing both in the presence and absence of the innerwood fraction, i.e. it was no longer required that a relation be maintained whatever the base used to derive paper strengths. A third screening was made for the characters showing strong relationships in the absence of the innerwood fractions (N = 12) and with corrected strength values only. These characters were deemed to be the least reliable. For the sake of simplicity the characters or criteria emerging as a result of the three screenings were termed Grade A, B and C, in decreasing order of reliability. Only the ten 'best-fits' in each category were examined. The three factor combinations giving the 'best-fits' are listed below.

<u>Tensile Strength</u>

Grade A criteria - best fits were given by:

specific gravity (-)***)
tangential lumen diameter earlywood fibers (-)**) $R^2\%$ = 82.5
ratio of tracheid files to medullary rays (+)**)

lignin content (-)**)
total solubles (-)**) $R^2\%$ = 81.6
width of medullary rays (+)*)

- other significant combinations included:

tangential diameter latewood fibers (-)
tangential diameter latewood lumen (+)
frequency of medullary rays (-)
radial distance from the pith (+)
age from pith (-)

Grade B criteria - best fit given by:

radial wall thickness latewood fibers (-)***)
specific gravity (-)**) $R^2\%$ = 85.3
frequency of medullary ray cells (-)**)

- other significant combinations included chemical constituents and medullary ray features as for Grade A, as well as fiber length - latewood (+).

Grade C criteria - best fits were given by:

radial wall thickness latewood fibers (-)***)
frequency of medullary rays (-)**) $R^2\%$ = 86.8
average cross-sectional area of fibers (+)**)

radial wall thickness latewood fibers (-)***)
specific gravity (-)**) $R^2\%$ = 85.3
frequency of medullary ray cells (-)**)

- other significant combinations included:
radial lumen diameter latewood fibers (+)
fiber length/mid-point diameter (-)
area of vertical resin canals (+)
ring width (-)
number of fibers per unit area of cross-section and derived measurements (as in the best-fit combination above)

Burst Strength

Tensile and burst strengths were highly correlated. Values based on common cook time gave r = +.892***. Values corrected for residual lignin gave r = +.920***. As might be expected, there were close similarities between the best-fit equations for the two strength values. Generally speaking the best-fit equations accounted for a higher proportion of the variation in burst, than they did for tensile strength. The Grade A three factor combination giving the best fit for burst strength was:

radial wall thickness latewood fibers (-)***)
radial diameter earlywood fibers (+)***) $R^2\%$ = 91.0
specific gravity (-)**)

A Grade A combination involving chemical constituents was:

lignin content (-)**)
total solubles (-)*) $R^2\%$ = 79.9
width of medullary rays (+)*)

Tear Strength

The number of characters found to be significantly related to tear strength was greater than those found for tensile or burst.

Grade A criteria - none

Grade B criteria - best fits were given by:

tangential diameter earlywood fibers (-)***)
frequency of medullary rays (-)***) $R^2\%$ = 86.3
tangential wall thickness latewood fibers (+)**)

Grade B criteria - alcohol/benzene + alcohol solubles (-)**)
tangential diameter earlywood fibers (-)**) R^2% = 81.7
latewood percent - by width (-)*)

- other significant combinations included expressions of ray frequency together with cross-sectional fiber dimensions

Grade C criteria - best fit was given by:
pentosan content (+)***)
alcohol/benzene + alcohol solubles (-)***) R^2% = 95.4
latewood percent - by number of cells (+)***)

- other significant three factor combinations included, besides those in the combination above:
tangential wall thickness of earlywood fibers (+)
cell wall percent (+)
average number of fibers per unit area of cross-section (+)
radial distance from pith (+)

Almost without exception unextracted specific gravity gave better fits than extracted specific gravity. Latewood percent as based on number of cells rather than on width gave superior fits in many cases.

The criteria selected for further testing include the chemical constituents, specific gravity, the frequency of medullary rays and the frequency of fibers per unit cross-sectional area, together with the average fiber dimensions derived from this frequency.

The investigation showed that it was possible to establish statistically strong relationships between wood characters and paper strength even when the amount of wood actually pulped was very small.

Almost every one of the 65 wood characters entered was found to be apparently related to paper strength, either when entered alone or in combination with other characters. In many cases this was presumably due to strong correlations between one character and another. In other cases the reason for the appearance in the output of certain wood characters may have been connected with some underlying non-linear relationship. Such relationships will be looked for in the confirmatory study.

The emergence of so many wood characters as significantly related variables would appear to cast serious doubts on the validity of any conclusions regarding the sources of strength in the paper sheet, when such are based on measurements in the unprocessed wood.

FURTHER WORK

As stated above, a confirmatory study on black spruce covering 20 trees at two height levels is already under way. In this work the relationships between paper strength and a 'short-list' of wood properties will be investigated further. Also planned are investigations of the paper making properties of material from 'plus' black and white spruce and from white spruce hybrids supplied by the Northeastern Forest Experiment Station in connection with a cooperative study between that establishment and the Research Branch of The Ontario Department of Lands and Forests.

BIOSONICS

It may also be mentioned that the ORF has been carrying out work in connection with the effects of ultrasound on living organisms. The Ultrasonics Applications Section of the Department of Metallurgy has been active in the industrial field for several years and has acquired considerable expertise particularly in respect to the development of instrumentation and measurement techniques. Because of this, ORF has recently received funds from the Federal Department of Health and Welfare to carry out a comprehensive literature review of the effects of ultrasound on biological material; while other contract work under way concerns the effects of ultrasound on the growth and development of fish and of domestic chickens. ORF funded pilot studies of the effects of ultrasound on the seeds of Scots pine (*P. sylvestris*) and a dwarf variety of tomato are showing that with certain frequencies an enhancement in the rate of germination may be expected. These studies are continuing and it is hoped that further results of interest will be forthcoming.

AN INDUSTRIAL TREE IMPROVEMENT PROGRAM IN NORTHERN ONTARIO

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The main area of activity during the past 2 years has been the clonal orchard. It consists of white and black spruce in separate compartments and now contains 681 grafts representing 93 plus trees. Some flowering occurred in 1969 and a limited number of black spruce cones was produced. These were collected and the seed sown in the nursery. There were not enough white spruce cones to warrant collecting.

In June 1969, controlled pollination was carried out on two black spruce clones, using pollen from a single source. In September the cones were collected and the seed was sown in flats in the greenhouse in April 1970.

The white spruce progeny test, started in 1967, is continuing. Approximately 2,000 seedlings, representing nine clones, will be moved to transplant beds in the spring of 1970.

Two hundred superior black and white spruce trees from the nursery have been added to the seedling orchard. Work on the Lydia Lake seed forest has been suspended until an economically feasible method is developed for collecting cones from black spruce 60 - 70 feet high.

RECOGNITION OF DEVELOPMENTAL PATTERNS IN CELL CULTURES OF PINUS BANKSIANA LAMB. AND PICEA GLAUCA (MOENCH) VOSS

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Previous reports (Durzan and Steward 1968, 1970) have established methods to obtain large quantities of freely suspended cells of jack pine and white spruce. This report deals with observations on the behavior of single and multiple cells of jack pine and the morphogenetic patterns that accompany the growth of cells derived from callus (Fig. 1). An attempt is made to recognize potentially organizing, patterns of growth at early stages of development. The approach arises from problems of vegetative propagation of conifers and the need for more information about the adventive embryogeny of somatic cells. For conifers, the latter is yet a distant goal and it is because this achievement would have great possibilities for forestry that a preliminary statement is presented.

From the start (Durzan and Steward 1968, 1970), studies indicated that many patterns of cellular associations could be derived from single cells and that the evaluation of temporal patterns needed a quantititive basis. When cells organized into structures, similar to that of the proembryo, the early patterns appeared to have few alternatives. By contrast, poor patterns, that generated more callus, were unpredictable in their ability to yield organized growth. One approach may be to attribute informational properties to patterns (e.g. Brillouin 1956, Elsasser 1968). Thus any regularities in pattern, e.g. symmetry, which would duplicate or repeat information, could be dealt with by the concept of redundancy.

To show that temporal patterns, which organize into proembryoids[1], have a few alternative courses, a way must be found to produce these patterns consistently that would tell us how many different patterns can be discriminated in the end product. From the total set of cellular patterns, meaningful subsets can hopefully be distinguished in such a way that symmetry becomes a usual concomitant of small subsets of cell pattern as well as redundancy, but not a necessary one. The important relation to be stressed is that poor patterns are unorganized and have many alternatives, good patterns show symmetry and polarity and have few alternatives, and the very best patterns, that would yield proembryoids and successful vegetative propagation, may be unique or at least highly organized. The product of the latter may be at an early stage highly predictable from the initial tactical displacement of cells into a basic pattern.

[1]Proembryoid is defined as a proembryo-like structure that originates from a cell other than a zygote.

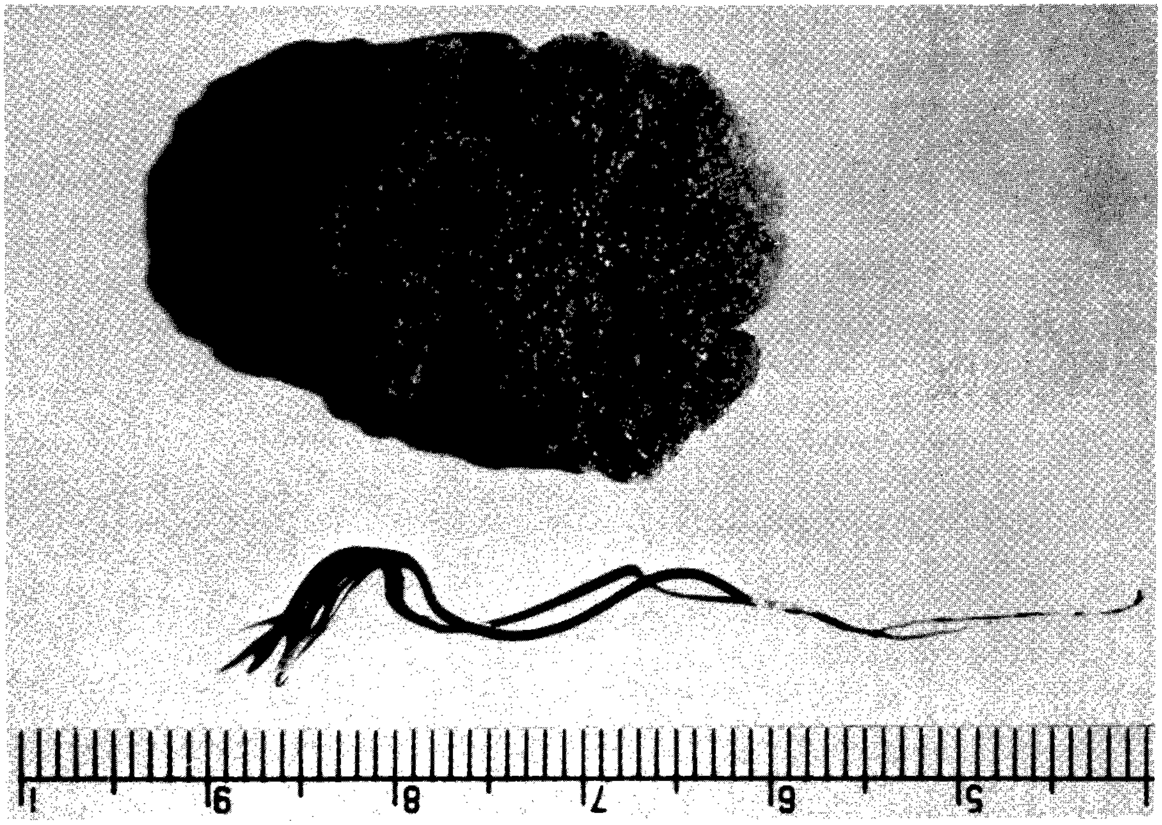

Figure 1. Growth and form of a one-week-old jack pine seedling compared to callus, derived from 2 mg of hypocotyl and grown for 6 weeks on 0.5% agar media containing White's basal supplemented with 10% coconut milk and 5 ppm α-naphthalene acetic acid. The contrast shows the ease by which growth of plant tissue can be disorganized by chemical means.

One approach to the evaluation of temporal patterns derived from the growth of totipotent cells is to generate through appropriate stimuli, specific patterns (e.g. Figs. 2, 3) where each cell could have only one of two possible alternatives (viz. to divide or not to divide) and this choice monitored by time lapse photography. If we were to deal with patterns derived from eight cells then altogether there would be 2^8 or 256 different sequences to deal with. Two of these are shown in Figures 3A and 3B. Clearly from experimental observations, many sequences are meaningless, do not occur, and do not involve organized growth. Of interest is the observation that cleavage polyembrony is an efficient way of eliminating unfit embryos and would presumably delete any deviations from a non-specific developmental pattern (Buchholz 1926).

The growth of somatic cells *in vitro* poses a problem that the observer cannot tell one pattern from another unless the starting point of the sequence is known. If we assume that an organizing pattern of cell associations starts with two cells yielding a specific pattern (e.g. filament) then this can be referred to as a *basic* pattern. Observations of cell

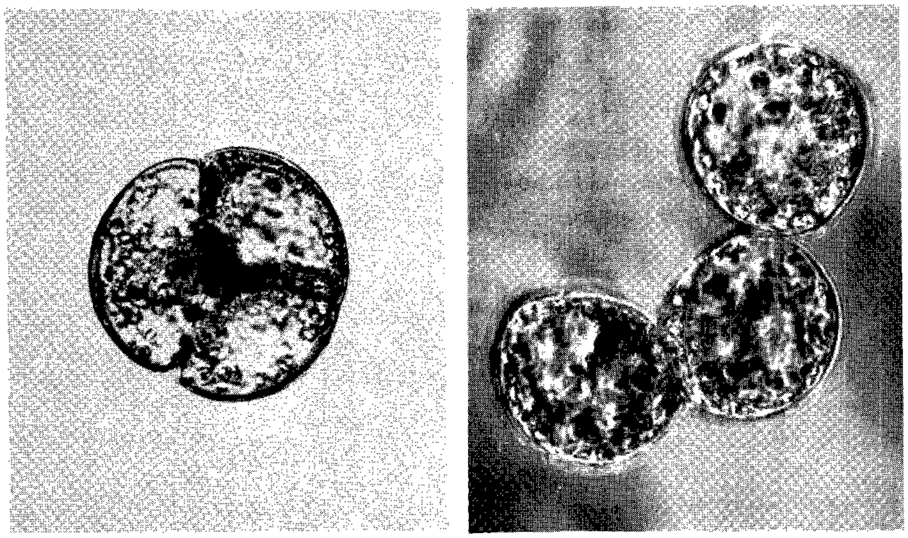

Figure 2. Compact clump of 3 pine cells (A) contrasts in pattern with the filamentous array of loosely attached cells (B) grown in liquid culture media of same composition as Figure 1.

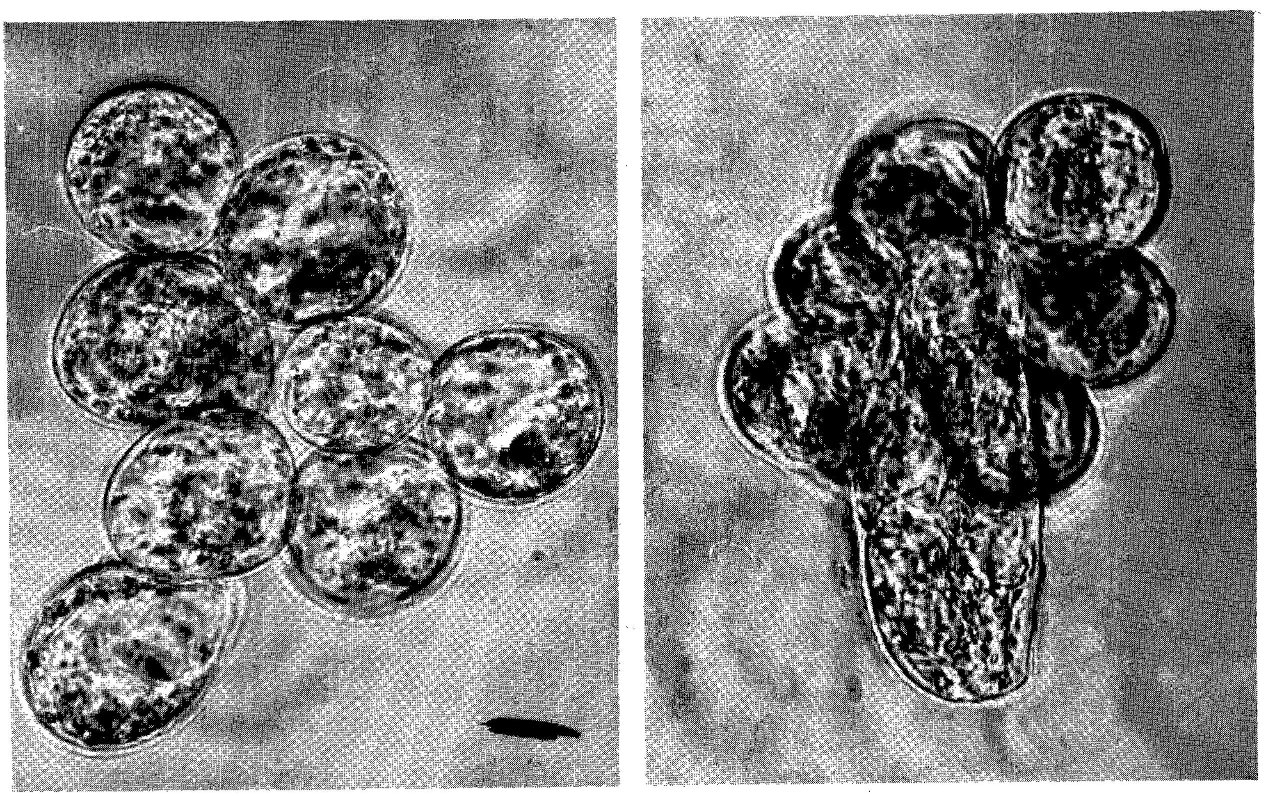

Figure 3. Contrast of patterns of 8 pine cells in a 2-dimensional triangular array (A) and in a more compact pattern showing polarity and a suspensor-like cell (B) X450.

behavior indicate that organizing patterns showing symmetry, polarity, etc., have few starting points but the poor ones all producing further callus, have many (Durzan and Steward 1970). The starting point of new and redundant patterns may eventually be more amenable from a molecular approach if synchronization of cell behavior could be attained. It follows then that the smaller the number of acceptable starting points, the shorter the time it should take for the sequences of cellular growth to become organized into a proembryoid.

The occurrence of a general asymmetry of cellular associations that occasionally appear signifies that perhaps sooner or later the temporal processes may with appropriate stimuli produce organized patterns regardless of how unorganized the pattern was to start with. In a few cases, a proembryo-like protrusion of cells from spruce callus has been observed (Fig. 4).

With gymnosperms, an approach to recognizing developmental patterns of somatic cells must take into account function and the problem of a suspensor apart from the tactical displacements of cells relative to one another. With function we face the ability of our methods to discriminate geographical divisions of labor, segregation of labor during development, and the differentiation of cells. Although the location and growth of seeds in a pine cone can be described by a few initial relations and the Fibonacci number

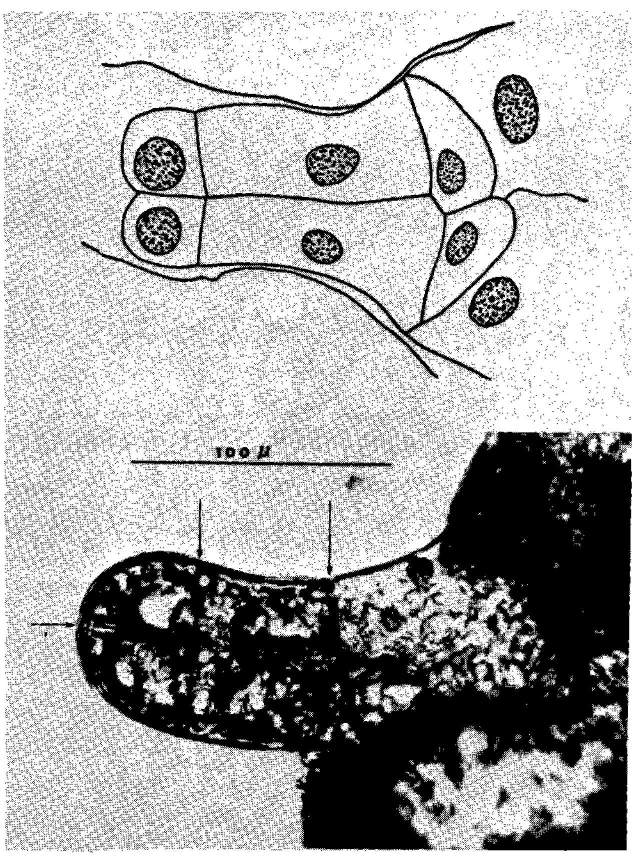

Figure 4. Similarity between (A), the form of the proembryo in a conifer seed after Johansen (1950), and (B), a proembryo-like protrusion from a small clump of spruce cells in suspension culture X500.

series, the metabolism in the cone leading to this pattern would require a very complex set of equations to describe their dynamics let alone the events leading to pattern formation in the embryos of seeds.

In embryo development, the suspensor is an absorptive organ or cell that thrusts proembryonal cells into the storage reserves of a massive maternal and haploid gametophyte until the differentiating cotyledons at the apical pole acquire the function of absorption. In our studies, the liquid culture medium is analogous to the nutritive gametophyte. From observations with other plants in the laboratory of Prof. F.C. Steward (Steward *et al.* 1969, 1970) it appears that in natural development, the more self-contained the proembryo is *in situ*, the easier it may be to evoke embryogenesis from free somatic cells. The more complex the development of the embryo and the more a reciprocal dependence exists between a proembryo and its suspensor, the more difficult it may prove to be to stimulate embryogeny from free cells. Thus we should expect that gymnosperms with their massive suspensors and complicated embryogeny might prove to be especially difficult but useful material for studies of this kind.

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THE TREE GENETICS AND BREEDING PROGRAM AT PETAWAWA FOREST EXPERIMENT STATION 1968-70

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INTRODUCTION

The purpose of this report is to outline the developments in the tree genetics and breeding program at Petawawa during the past 2 years, as a precursor to the individual reports by Petawawa scientists in the Proceedings.

The tree genetics and breeding program began at Petawawa in 1935. In the early stages Dr. C. Heimburger was largely responsible for the research program. There was a lull in activity during World War II, but soon afterwards Mr. M.J. Holst took over the program and developed many provenance trials and an extensive gene pool on the Station, as well as cooperative experiments with provincial forestry organizations and the forest industry in Alberta to New Brunswick. The approach was on a broad front and involved many species, both native and introduced. At present there are more than 600 genetics and breeding experiments on the Station's files.

Even before the current period of austerity, it was apparent that, in common with most long established tree improvement programs, the man-power and resources needed to maintain all the experiments exceeded the man-power and resources available. The onset of austerity made it even more urgent that we establish priorities and put the main research effort where it would be most effective.

PROGRAM APPRAISAL AND REORGANIZATION

The 2 years since the last meeting have been spent in reappraisal of existing experiments and reorganization of the program. The experiments were scrutinized individually, and decisions made on each one as to whether it should be terminated, kept on a care-and-maintenance basis, or kept active. In addition, whereas the four scientists involved in genetics research had previously worked cooperatively on several species, each scientist has now been given a clear-cut responsibility for development of a program on the genetic basis for improvement of individual species or a group of species. Consequently Mr. M.J. Holst is now responsible for introduced species and red pine (*Pinus resinosa* Ait.), Dr. C.W. Yeatman for jack pine (*Pinus banksiana* Lamb.), Dr. E.K. Morgenstern for black and red spruces (*Picea mariana* Mill. B.S.P. and *P. rubens* Sarg.), and Dr. A.H. Teich for white spruce (*Picea glauca* (Moench) Voss). Dr. C.W. Yeatman is also involved in studies of genotype-environment interactions of trees in controlled environments.

During the 2 years the Seed Unit under Mr. B.S.P. Wang has more than doubled its activity. The terms of reference of the Unit have been defined; its main function is to provide a store of information on seed availability, a testing service, and a bank of small quantities of seed of known origin mainly for the Canadian Forestry Service. The Unit also provides information and small quantities of seed to external organizations on request, and is concerned with investigations of seed testing and storage methods.

In the same period, research on seed germination and growth mechanisms was reoriented so as to support the tree genetics and breeding research. Mr. J.W. Fraser (Fraser 1970a, b) studied the effects of temperature on germination of seed of different provenances of white spruce and other species; recently Mr. Fraser has been transferred to other duties, and this program is in abeyance. Mr. K.T. Logan and Dr. D.F.W. Pollard are at present engaged in developing investigations of the growth mechanisms of trees to provide a basis for early screening methods for high growth potential. These scientists are also investigating methods of accelerating seedling growth to reduce the breeding cycle, developing an earlier program of Dr. C.W. Yeatman. There is already good evidence that provenances of jack pine differ in their seasonal patterns of assimilation.

Since the last meeting, an on-Station computer facility has been developed consisting of a PDP-8L computer, a 4000-word core memory, a 32,000-word disc memory, a rapid tape reader and associated peripheral equipment. This has made possible the analysis of a considerable back-log of data from the many experiments, and the results are being published (see Publications). It has also enabled us to develop a cost/benefit model for white spruce improvement, which also has wide silvicultural implications (Carlisle and Teich 1970).

Considerable effort has been put into reviews of tree genetics, breeding and seed production in Canada, and the economic benefits we can expect from producing genetically superior seed. An attempt is also being made to forecast the need for improved seed in Canada's expanding program of planting and seeding. All this information is being accumulated as a basis for program planning.

RESULTS FROM RESEARCH

The results and progress of experiments with the individual tree species and in different problem areas are described in the papers by Carlisle, Holst, Logan, Morgenstern, Pollard, Teich, Wang and Yeatman in the present Proceedings. Some highlights of the work are the formulation of rules of seed transfer for black spruce (Morgenstern and Roche 1969); the designation of provenances of jack pine from Quebec which appear to be resistant to *Scleroderris lagerbergii* Gremmen (Teich and Smerlis 1969); and the location of some promising provenances of white spruce from the Upper Ottawa Valley and further south at Peterborough, Ont. with height growths superior to both the average (by 17%) in the tests and the local populations (by 14%), and generally better survival (5%).

We are now considering the question, particularly as regards white spruce, as to how soon we can make tentative seed collection prescriptions. Most of the experiments are still young (10-15 years, occasionally 20 years), and we feel that we should be cautious. Tentative prescriptions will be made in the near future with adequate safeguards against moving a provenance too far from its origin. The white spruce results are supported by results from the Lake States experiments and we feel on reasonably safe ground.

The problem remains as to how research results can be translated into seed production on an operational scale to meet the growing demands for improved seed in eastern Canada. In the next 2 years discussions will be held with provincial forestry organizations, industry and universities to see how the gap between research and development can be bridged, and an integrated tree improvement program evolved.

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RESEARCH ON THE GENETIC BASIS OF IMPROVEMENT OF RED AND BLACK SPRUCE, PETAWAWA, 1968-70

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INTRODUCTION

A rational approach to genetic improvement of any species requires information on: (1) variation and variation patterns; (2) the percentage of genotypic variance in phenotypic variance (heritability) of the characters selected for improvement; and (3) the mode of inheritance of these characters, i.e. the relative importance of additive, dominance and epistatic genetic variance. Information in the first category is obtained by provenance studies and in the second and third by progeny tests of open- and control-pollinated populations. This report presents a general review of the work done and progress made. Details of methods and results can be found in published papers. Reference to related physiological and seed studies with the same species at Petawawa is also made.

PROVENANCE STUDIES

The red spruce (*Picea rubens* Sarg.) provenances replicated in nine experiments with similar designs (Exp. 95 A-N) in eastern Canada completed their 15th growing season in 1969 and were measured. Mr. H.G. MacGillivray, Maritimes Region, Dr. L. Roche, Quebec Region, and the writer, each in charge of three experiments, pooled total height and survival data to investigate the provenance-environment interactions. The statistical analysis was completed and a joint report is now being prepared.

The range-wide study of black spruce (*Picea mariana* (Mill.) B.S.P., received final approval early in 1969. Cooperating in this study are: from the U.S. Forest Service, Mr. D.H. Dawson and Dr. H. Nienstaedt, Institute of Forest Genetics, North Central Forest Experiment Station; and from the Canadian Department of Fisheries and Forestry, Mr. J. Nicholson, Newfoundland Region; Mr. H.G. MacGillivray and Dr. D.P. Fowler, Maritimes Region; Dr. L. Roche, Quebec Region; and the writer. During the past 3 years each cooperator made seed collections in his area. Valuable assistance in this phase of the program was also provided by Mr. F.B. Armitage, formerly of the Manitoba-Saskatchewan Region; Dr. A.K. Hellum, Prairies Regions; and Mr. J. Gass, Yukon Forest Service, Department of Indian Affairs and Northern Development.

All collections were made on a single-tree basis; provenance origin includes:

Area	Number of Collections	
	Provenances	Single Trees
Newfoundland-Labrador	5	69
Maritime Provinces	36	670
New England States	4	47
Quebec	45	527
Ontario	32	480
Lake States	20	229
Manitoba-Saskatchewan	17	270
Alberta	7	56
British Columbia	8	66
Yukon and Northwest Territories	8	79
Alaska	7	83
Total:	189	2,576

Plans were made for experiments involving provenances (bulk lots of seed) and single trees. The first series of experiments based on provenances is being sown in 1970 or in 1971 in Newfoundland, New Brunswick, Quebec, Ontario, Wisconsin and possibly Alberta. This series will combine nursery studies with the production of stock for field experiments to be planted in 1974-75. The delimitation of seed zones across the country is its major objective. All cooperators contributed ideas to the experimental design. Of the 100 provenances sown at each location, only 50-60 will be transplanted to produce stock for the field experiments. Provision was made for overlap of provenance groups used by different investigators to allow for the analysis of provenance-environment interaction, particularly in field experiments. Single-tree progeny experiments will be restricted to areas where black spruce is economically important and where a tree breeding program is anticipated.

The nursery sowing of provenance lots at Petawawa Forest Experiment Station was completed 25-28 May 1970. Single-tree progeny seedlots will be sown in 1971.

Experiences from the extraction of the range-wide seed collection are being reported by Mr. B.S.P. Wang elsewhere in these Proceedings. Mr. J.W. Fraser described results of germination experiments with black spruce provenances, particularly cardinal temperatures, in a separate publication (Fraser 1970). Mr. John Santon has published his results on stratification of freshly harvested seed, which included black and red spruce (Santon 1970).

CONTROLLED POLLINATION AND PROGENY TESTS

In 1966 Mr. M.J. Holst crossed individual mother trees in nine northern black spruce provenances with Petawawa black spruce represented by a pollen mixture (Exp. 358). One greenhouse experiment was established in 1968 and transplanted into the nursery in 1969 in a family-block design with six replications. Measurements were made of total height and winter desiccation of needles. Additional nursery and greenhouse experiments are being established (1970) from the seed. Following early evaluation, field experiments will be established along a south - north transect in 1971 or 1972. Growth responses of a general nature and general combining ability (additive genetic variances) can be determined from these provenance crosses.

For a more detailed genetic analysis, including general and specific combining ability (additive, dominance and epistatic variances), seven individual trees were pollinated in the spring of 1970 in all possible combinations to produce a diallel cross.

BREEDING AND TESTING METHODS

The wide distribution of some native tree species and the attendant large amount of genetic variation require recognition in sampling and design of experiments. In some parts of Canada, the ecological regions established on the basis of consistent criteria appear to be valid subdivisions of species ranges and have facilitated the establishment of seed zones (Hill 1959; Haddock and Sziklai 1966; Fowler and MacGillivray 1967). These regions or zones will be of importance if we move from the stage of present exploratory studies to a well planned test series upon which to build future breeding programs. This has already been recognized in Ontario where the plus-tree selection program in black spruce is based on seed zones (Dyer 1968). In this respect it has been emphasized recently that results of progeny tests (providing estimates of heritability and genetic gain) will be realistic only if populations have been adequately sampled and then tested over the range of sites where they would be normally planted, i.e. within seed zones (Namkoong *et al.* 1966). Because each seed zone would require its own test series, this all adds up to a large program. It becomes quite clear that effective cooperation in the planning and execution of such a program between all forestry organizations is required.

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RESEARCH ON THE GENETIC BASIS OF WHITE SPRUCE IMPROVEMENT, PETAWAWA 1968-70

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Progress in white spruce research at the Petawawa Forest Experiment Station in 1968-70 consisted of analyses of provenance experiments, identification and recommendation of superior seed sources, analyses of single-tree progeny tests, and a cost-benefit study of white spruce improvement. The latter is reported elsewhere in these Proceedings (Carlisle and Teich *loc. cit.*).

PROVENANCES FROM THE CENTRAL PART OF THE GREAT LAKES - ST. LAWRENCE, BOREAL AND ACADIAN FOREST REGIONS

Seed was collected from 89 natural stands before 1954, mostly from central Canada, as illustrated in Fig. 1, in order to identify superior seed sources for forestation. The large number of collections in Ontario and Quebec were appropriate because that is where most of the white spruce is being planted. The seed was distributed for planting in many locations in Canada and the United States. The outplantings, now 8 to 15 years old, have recently been measured for height and survival.

A typical outplanting contained three replications of 25 provenances, with trees spaced 6 x 6 feet in 144-tree plots. An early group of outplantings was nursery sown in 1954 and contained provenances mainly from the central part of the Great Lakes - St. Lawrence Forest Region, while the later group, sown in 1959 contained provenances from the three forest regions.

At Chalk River the local provenance was the tallest in one out of four replicated experiments, exceeding the experimental mean by 32% in height. In the other three experiments it was about 10% taller than the experimental mean, but other provenances were from 12 to 21% taller than the experimental mean. At Owen Sound, Ont. (80.47°W, 44.40°N) the local provenance was 14% taller than the experimental mean but another provenance was 19% taller than the experimental mean. At Kapuskasing, Ont. (83.50°W, 49.33°N) the local provenance was 22% shorter than the experimental mean, while the provenance from near Iroquois Falls, Ont. was 31% taller than the experimental mean.

Of those replicated experiments nursery sown in 1959, 11 were measured for height and survival in 1968 and 1969. In none of these was the local race the tallest. All locations considered, the local race was 3% taller than the experimental mean, while the tallest races were 22% taller than the experimental mean. While differences in survival were not statistically significant, the tallest races had 5% more survival than average.

A provenance from near Peterborough, Ont. (78.05°W, 44.06°N) was 17% taller than average and had 5% more survival than average in all 11 locations in which it was planted. Considering that the test sites covered a range of 1200 miles (30 degrees) of longitude and 350 miles (7 degrees) of latitude, this provenance exhibited an exceptional ability to thrive in a wide climatic spectrum. An attempt was made to collect large quantities of seed from the original source for larger scale studies, but the original stand no longer exists. This provenance will have to be reproduced by propagation from experimental trees.

In one of the replicated experiments at Chalk River 17 trees of 11 provenances bore female flowers at 6 years of age. Flowers of a given tree were all of one color: red, pink or green. The chi-square method was used to test the hypothesis that flower color was controlled by two alleles of a single gene in Hardy-Weinberg equilibrium; the test supported the hypothesis (Teich 1970).

TWELVE PROVENANCES FROM ACROSS THE WHITE SPRUCE RANGE

This study, initiated by the Lake States Forest Experiment Station (U.S. Forest Service) consisted of 24 replicated experiments, one of which is at the Petawawa Forest Experiment Station. At Petawawa mortality was high due to drouth following planting. Provenances differed considerably in survival: one, from Pagwachuan Lake, Ont. (86.11°W, 49.67°N), had 64% survival compared to the experimental mean of 37%. Height differences at 10 years of age, while considerable, were not statistically significant at the 10% level of probability.

EFFECTS OF TEMPERATURES ON GERMINATION OF SEEDS OF DIFFERENT PROVENANCES

Variation in the effect of temperature on the germination of six provenances of white spruce seed was studied by Mr. J.W. Fraser. Northern provenances had cardinal temperatures of 45°F compared to 50°F for southern provenances. Provenances also varied in optimum and upper cardinal temperatures, but with no apparent relationship with latitude of seed source.

PROVISIONAL SEED SOURCE RECOMMENDATIONS FOR SOME AREAS OF EASTERN CANADA

Currently, 50 million white spruce seedlings are planted annually on about 50,000 acres, and each year the number of seedlings planted increases. White spruce accounts for 28% of the planting and seeding in Canada. There is an urgent need to designate desirable seed sources to ensure that plantations will be highly productive and well adapted to their environment. Seed is now chosen by 'proximity to planting site' to minimize the loss resulting from the introduction of unadapted races. With the information now available from replicated provenance studies it appears possible to increase productivity by introducing races which grow more rapidly than the indigenous ones. Although there is some risk of loss involved in introducing provenances after only a short period of testing, there is also a risk of loss in using slower growing local seed.

A list of recommended provenances is proposed using the advice of Morgenstern and Roche (1969) in not moving seed more than 2° latitude. Limitations on longitudinal displacement are based on a map of plant hardiness zones (Ouellet and Sherk 1967). In preparing hardiness zones a number of climatic factors which influence plant survival were taken into account: minimum winter temperatures, length of frost-free period, summer rainfall, maximum temperatures, snow cover and wind. In choosing a provenance for a particular site within a hardiness zone peculiarities of microclimate should be considered.

The list of recommended provenances in Table 1 is proposed as "provisional". In time, as more experimental results become available, changes are likely, but for the present, the provenances currently recommended appear to grow more rapidly than the native provenances and are very likely of equal or greater hardiness. To postpone the recommendation of seed sources until a "certain" answer is produced would be wasteful of our forest lands now being planted.

GENETIC VARIATION OF INDIVIDUAL WHITE SPRUCE AT CHALK RIVER

Seed was collected from 12 plus trees at Chalk River, and planted in two local replicated experiments to estimate the potential improvement by plus tree selection and progeny testing. Progeny height was measured at 11 and 19 years of age. The three tallest at 11 years of age were still the tallest at 19 years of age, supporting evidence quoted by Nienstaedt (1969) that early height growth is a good criterion of height closer to maturity in this species. The tallest progeny exceeded the mean by 40% at 11 years of age and 16% at 19 years of age.

GENETIC VARIATION OF INDIVIDUAL TREES AND STANDS IN THE UPPER OTTAWA VALLEY

In a study by Dr. C.W. Yeatman, 2-year-old seedlings representative of 76 progenies from 13 stands and a control population from the Upper Ottawa Valley were transplanted in 1967 into prepared beds of a uniform soil mixture. The experimental design was randomised block with 10 replications of 7-tree plots. Analyses of 4-year-old tree height, leader increment, late season growth and bud break demonstrated significant differences among and within stands in all characters. Range tests indicated that there are as large and significant differences among stands within a 5 mile radius of the Petawawa Forest Experiment Station as within an area extending 30 miles southeast and west. In comparison to the slowest growing population (which was also the control), a Petawawa population from Corry Lake (six progenies) was 30% taller, and one from Westmeath (seven progenies) was 28% taller. Corresponding values for fourth-year increment were 38% and 49% respectively. The experimental material was transplanted to the field where the identity of the individual trees was retained. Their growth will be compared with nursery performance to determine the validity of early screening for rapid growth.

Table 1. Recommended White Spruce Seed Sources for Ten Locations.

Test Location (a) and Recommended Seed Source (b)[2]	Hardiness Zone[1]	Degree		Recommended/ Local Provenance-%	
		Long. W	Lat. N	height	survival
1. a) Kapuskasing, Ont.	2a	83.50	49.33	168	123
b) seed source 9	2a	80.02	48.07		
2. a) Owen Sound, Ont.	5b	80.47	44.40	118	98
b) seed source 29	5b	75.35	45.12		
3. a) Chalk River, Ont.	4a	77.42	46.00	112	101
b) seed source 40	4a	73.09	46.75		
4. a) Fort Frances, Ont.	2b	93.40	48.60	107	93
b) seed source 75	2b	80.12	48.10		
5. a) Swastika, Ont.	2a	80.10	48.10	100	100
b) seed source 75	2a	80.12	48.10		
6. a) Thunder Bay, Ont.	3a	89.22	48.33	144	129
b) seed source 66	3a	71.37	48.30		
7. a) Fredericton, N.B.	5a	66.53	46.00	110	103
b) seed source 52	5a	76.53	46.53		
8. a) Baskatong Lake, Qué.	3a	75.50	46.75	121	104
b) seed source 75	3a	80.12	48.75		
9. a) Casey, Qué.	4b	74.20	47.80	121	107
b) seed source 46	4b	77.83	46.83		
10. a) Jacques des Piles, Qué.	4a	72.70	46.60	120	100
b) seed source 39	4a	73.27	45.65		

[1]Ouellet and Sherk 1967.

[2]See Figure 1.

OUTLOOK FOR FUTURE ACTIVITIES IN WHITE SPRUCE RESEARCH

A reasonable plan for white spruce research is a complete survey of the species' genetic resources by a comprehensive sampling of seed from the species' range, adequate testing and the implementation of the resulting information in tree planting programs.

Currently our studies cover only a small part of the species' range. Other parts of the range are worthy of study, particularly in northwestern Canada where white spruce grows well. Future testing of seed sources can be made more efficient by utilizing existing experimental data to calculate the most efficient field designs in terms of plot size and number of replications. Methods to implement research results must also be refined to allow the maximum, valid, extrapolation of experimental results from the experimental site to planting sites. In refining these methods the currently available growth and survival data and their interaction with climatic factors will be useful.

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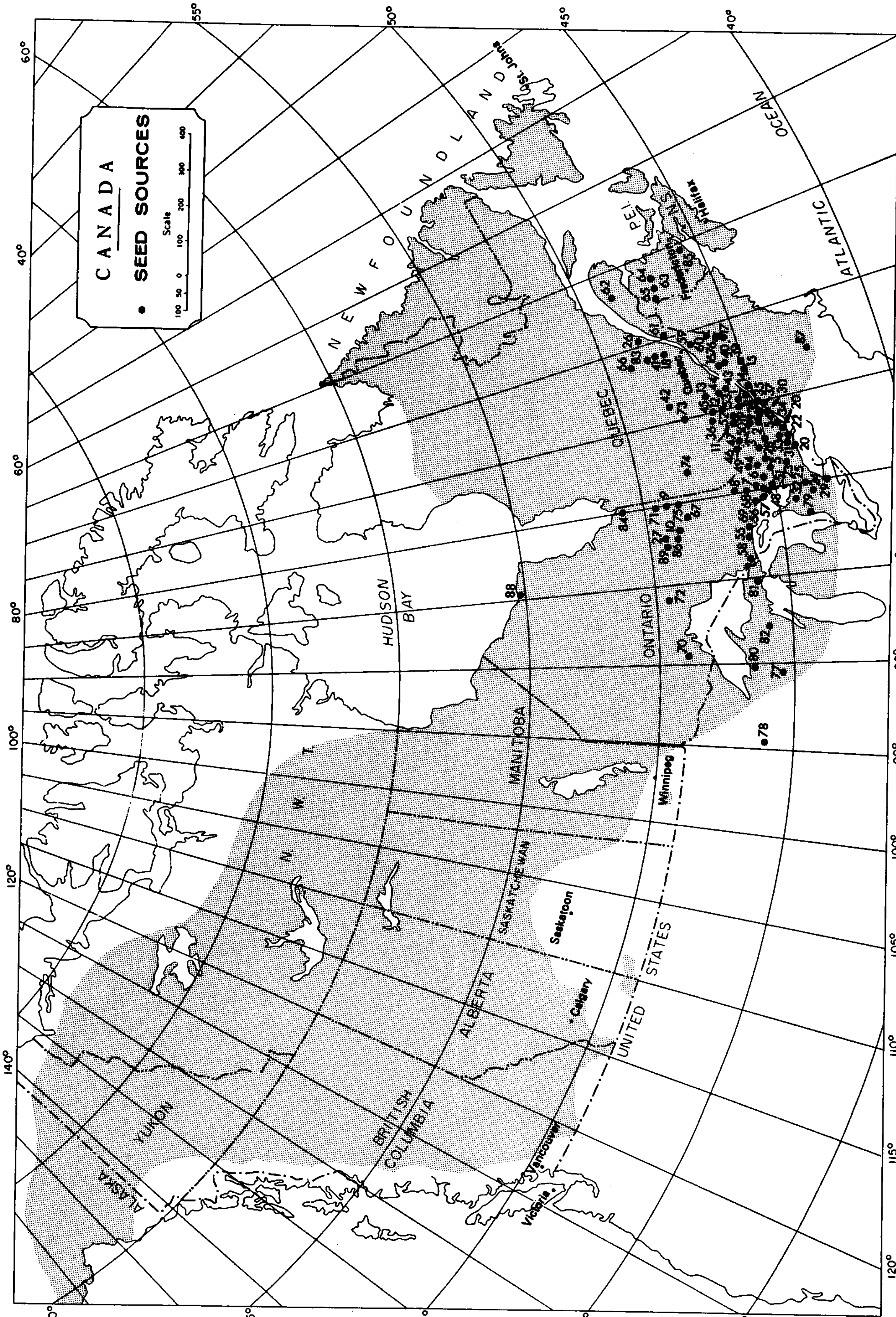

BOTANICAL RANGE OF WHITE SPRUCE

GENETICS OF JACK PINE, SEEDLING RESPONSE TO CO_2 AND POLLINATION STUDIES, PETAWAWA, 1968-70

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INTRODUCTION

The objective of genetic studies in jack pine (*Pinus banksiana* Lamb.) at the Petawawa Forest Experiment Station is to determine the genetic basis for selection of seed sources for current reforestation program and for breeding improved strains required for intensive forest management in the future. Population and progeny tests established at a number of locations in central and eastern Canada during the past 20 years provide the foundation for present work with this species. Field tests are supplemented by laboratory and nursery studies of seedlings for early evaluation of genetic potential and to provide the basis for selecting only the best material for further field testing.

To advance these aims for jack pine and other conifers, techniques have been developed to test genotype-environment interactions and to accelerate growth of seedlings in controlled environments. Other studies have included investigations of methods for controlled pollination and testing the viability of stored pollen.

During the period under review initial evaluations were made of all-range jack pine provenance and provenance hybrid tests planted in Ontario and Quebec in the years 1965-66. Seedlings of jack pine progenies from 10 local stands were grown in a nursery and in controlled environments for early estimation of genetic components of variation. Carbondioxide enrichment of the atmosphere was used to increase the growth of pine and spruce seedlings grown in controlled environments. Determinations were made of seed yields from cross- and self-pollinations of white spruce using tree crown isolation tents and standard isolation bags. Controlled pollinations were made of pine and spruce to test the viability of pollens held in storage.

JACK PINE

Provenance Studies

The first complete records of tree height and survival were made of the all-range jack pine provenance tests planted in Ontario in 1966. The eight locations range from Turkey Point, on the shore of Lake Erie in the south, to Red Lake in the north-west of the Province. Initial analyses of the data are summarised in Table 1 where higher variance ratios indicate a greater discrimination among provenances at the southern locations. Maximum height decreases from the warm south to the cool north, but the minimum

Table 1. All-range jack pine provenance tests in Ontario measured at 6 years from sowing. Variance ratios (F) of tree height and 1969 height increment, and mean heights of shortest and tallest provenances at each location. Summaries based on trees with single leaders only.

Location	Experiment Degrees N. Lat.	Number of Provenances	Provenance Shortest cm	Provenance Tallest cm	Variance Ratio Height F	Variance Ratio Increment F
Turkey Point	43	81	48	150	17.3	20.1
Petawawa F.E.S.	46	98	54	155	11.5	12.2
Swastika	48	81	66	149	7.6	7.7
Cochrane	50	81	46	112	3.9	3.7
Espanola	47	43	52	89	3.6	2.5
Caramat	50	49	55	106	3.6	2.7
Kakebeka	48	72	86	134	3.2	3.4
Red Lake	51	56	60	116	4.9	5.4

height remains about the same, with a tendency to increase with latitude. This first measurement is intended primarily as a base record for future observations, although further analyses will be made for interpretation of performance to date.

Two of the first jack pine field tests planted at Petawawa including Ontario and Quebec provenances were measured in 1969 at 17 and 19 years of age. As found at younger ages, height was significantly correlated with growing degree-days at the seed origin, but rank order had changed and relative differences were reduced, e.g. from 24% at 11 years to 11% at 19 years. Sufficient variation remains within geo-climatic regions to warrant systematic sampling and comparison of productivity among populations to identify preferred seed sources. For example, in each of the two tests mean tree volume of the Petawawa provenance was exceeded by 6 and 11% respectively by trees of the Barry's Bay source, some 35 miles to the south west. Heavy snow accumulation caused severe damage to trees of the faster growing provenances in 1964 and again in 1967. Much of the damage is ascribed to severe root pruning of large transplants at the time of planting which gave rise to asymmetric and unstable root systems.

A number of tests of jack pine provenance hybrids planted in Ontario were measured in 1969 but the data are not yet analysed. Evaluation of 6-year-old jack pine provenances, provenance hybrids and hybrids with lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) planted near Longlac in northern Ontario demonstrated the superiority in winter hardiness and growth of climatically adapted populations. The tallest seedlot was a provenance from western Quebec at about the same latitude as the planting area. That additive polygenic inheritance of factors affecting survival and growth is involved was indicated by the performance of the hybrids which was intermediate between provenances representative of the regions of the parental populations.

In continuing studies of jack pine provenances resistant to *Scleroderris lagerbergii* Gremmen, artificial inoculation of three eastern Quebec sources and two from Ontario substantiated the relative resistance of the Quebec sources observed earlier in a nursery test at Longlac (Teich and Smerlis 1969). In fall 1969, Dr. A.H. Teich collected seed from 50 trees in three stands north of the St. Lawrence River, east of Quebec City, for further testing and selection for disease resistance.

Mr. K.T. Logan (*loc. cit.*) found seasonal differences among jack pine provenances in rate of photosynthesis. This approach is to be followed up with studies of seedlings to determine the earliest age at which photosynthetic differentiation can be discerned.

Progeny Tests

The initiation of a progeny test of 10 stands of jack pine from the Upper Ottawa Valley was reported in the 1968 biennial report to the Committee. Stem analyses were completed of 50 parent trees as a basis for later parent-progeny correlations. Seedlings were grown for 2 years in 10 replications of a nursery test. In the spring of 1970 two field tests were planted and seedlings for a third trial to be planted in 1971 were transplanted in the nursery. A test of 50 progenies in 12 replications in growth cabinets is in progress. In the nursery test, seedling size was affected by unavoidable variations in stocking and analyses of mean dry weight failed to differentiate among the progenies. The results are more promising from a harvest of 40-day-old seedlings grown in growth cabinets where stocking was uniform and other micro-environmental influences were consistent within replicates. The main evaluation of the laboratory test will be of 3-month-old seedlings.

GROWTH ACCELERATION WITH CO_2

A three- to five-fold enrichment of carbon dioxide in the atmosphere increased growth (dry weight) of seedlings of jack pine, Scots pine (*Pinus sylvestris* L.), white spruce (*Pinus glauca* (Moench) Voss) and Norway spruce (*P. abies* (L.) Karst.) by 20 to 80% when grown for 3 months at two light levels in growth cabinets. The positive effect of additional CO_2 could be detected as early as 3 weeks after germination. A high light intensity (2,800 ft-c) suppressed shoot elongation but increased dry matter accumulation in shoots and roots in comparison with shade (1,100 ft-c). At 5 months of age, spruce seedlings grown in full light and enriched atmospheres were shorter than those grown at the ambient CO_2 level due to maintenance of bud dormancy in the former treatment combination. Pine seedlings grown for 5 months in high light intensity and with additional CO_2 had short roots characteristic of plants with well developed mycorrhiza.

Seedlings from all treatments were subjected to short days in a greenhouse for 6 weeks to induce bud information on all seedlings, and chilled for a further 9 weeks at 2-4°C. Subsequently a second flush of growth was induced in growth cabinets at normal temperatures (20-22°C) and in a 14-hour photoperiod. The preconditioning effects of the CO_2 and light treatments on shoot length and seedling dry-weight were minimal beyond maintaining a height advantage by plants from the earlier shade treatment.

The experiment demonstrated that two periods of growth could be compressed within less than 12 months by manipulating light and temperature regimes to promote, successively, germination, shoot growth, bud formation and maturation, winter dormancy (chilling requirement), and shoot growth for the second period. At the conclusion of the test, seedlings of all four species were healthy, of normal form, with good root systems and ranged in size from 100 to 250 mm (4-10 inches).

A three- to five-fold enrichment of CO_2 in the atmosphere could be used to advantage to accelerate growth and development of seedlings of spruce and pine of special breeding value or of genetic interest, or for the rapid production of container-grown planting stock.

CONTROLLED POLLINATION TECHNIQUES

Seed Yield in White Spruce

X-ray photography was used to determine the yields of filled seed following controlled crossing, selfing, and open pollination of six white spruce trees. Both small isolation bags and tree-crown isolation tents had been employed as reported in the previous Proceedings. Analysis failed to show any consistent differences in yield due to male or female parent. The yield of filled seed (percentage of total seed extracted from cones) was consistently lower from self pollination (3-11%) than from cross pollination (16-60%) which, when using small isolation bags, varied above and below the yield from open pollinated cones. Yields of filled seed from cross pollinations in tents were disappointingly low (2-5%) in view of large total seed yields (filled + empty) in excess of 100,000 per pollination. The cones were healthy and developed normally and it is concluded that a more efficient method of pollen introduction and dissemination must be employed to increase the rate of fertilization of flowers enclosed within tents. Flowers isolated in a tent and not pollinated yielded less than 0.1% of filled seed, confirming the effectiveness of the method for isolating large numbers of spruce flowers from wind borne pollen.

Viability of Stored Pollen

In the spring of 1969, controlled pollinations were made in white, black (*Picea mariana* (Mill.) B.S.P.), red (*P. rubens* Sarg.), red x black and Norway spruce, jack and red pine (*P. resinosa* Ait.) with pollen held in frozen storage for as long as 13 years. Fresh pollens were used for control. All pollens were apparently viable when tested in 1% sucrose solution in the laboratory. Seed analyses and germination tests are in progress for the spruce which was collected in autumn of 1969. Cone yields were good for all species except white spruce in which cone insects caused losses of cones and seed.

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THE GENETIC BASIS OF IMPROVEMENT OF RED PINE, PETAWAWA, 1968-70

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The broad objective of provenance research in red pine (*Pinus resinosa* Ait.) is to study the genetic and environmental components of phenotypic variation associated with geographic source. Studies of heritability are conducted to estimate genetic gain in quality traits. The objectives for provenance and species hybridization are: to study the genotype-environment interaction of growth rate, hardiness and quality traits; to produce fast growing hybrids for specific environments; and to combine quality traits into heterotic provenance hybrids.

During the period 1950-67 the geneticists and tree breeders at Petawawa Forest Experiment Station established 50 red pine experiments on 57 acres in eastern Canada. Eight experiments were planted by cooperators on 16 acres in the United States. Seed for eleven experiments was sent overseas. The Ontario Department of Lands and Forests have planted four red pine provenance experiments of their own (Exp. 196-A to C) testing 16 Ontario provenances. These will eventually be compared with our experimental series.

Canadian and American red pine provenance experiments have shown that the best provenances are about 10% higher than the mean. In Ontario height is correlated with length of growing season and provenances from western Ontario are more frost hardy. The experiments planted should provide a fairly broad survey of variation within the range. There are, however, many local problems which have not yet been solved.

In 1967 eleven red pine experiments (Exp. Nos. 38, 39, 74-B, 74-C, 81, 96-G, 97, 207-A, 215-B, 216-B, and 216-C) were measured at PFES and cooperators provided measurements for the same series located in Quebec, the Maritime Provinces and the Lake States. Reports on them will be published when we get the data from the Turkey Point planting in southern Ontario.

The red pine provenance experiments are old enough to give valuable leads of broad regional significance, particularly in eastern North America. The Angus red pine provenance which we have identified is being used for seed orchards in Ontario and the Lake States.

Dr. D.P. Fowler's red pine population study (sponsored by the Ontario Department of Lands and Forests) containing selfings and within-stand and between-stand crosses was field planted in the spring of 1966 (Exp. No. 207-C) and first measurement taken the same fall. This material will again be measured in the fall of 1970. Additional provenance hybrids of the same material were field planted in 1967 (Exp. Nos. 207-D and 207-E) and will also be assessed in the fall of 1970.

Thirty-five crosses were made in a cooperative study of provenance hybrids between red pines from Trout Lake, Wisc., and Angus and Petawawa, Ont. Red pine seed was sown in 1967 in Wisconsin (Exp. No. 305-A) and New Brunswick (Exp. No. 305-C) as well as at the PFES (Exp. 305-B); the plants in the Petawawa nursery were measured in 1969 when they were 3 years old. The provenance hybrids were on the average 5-6% taller than the Petawawa control. Of the 14 families available for comparison, nine were taller, two were of the same height, and three were smaller than Petawawa x Petawawa. Specific combining ability is evident in this material.

Scions were grafted from good and poor trees selected in a virgin stand of red pine at Angus, Ont. This population has proven to be fast growing in all our experiments. It will be preserved in a breeding arboretum because seed collected from the original stand is liable to be the result of contamination by pollen from surrounding plantations of unknown origin.

A wide variety of grafts of red pine plus trees and population samples have been assembled over the years and will soon be ready for assessment and controlled hybridization. These grafts do not commence flowering until they have attained a large size. A description of this material is being prepared for publication.

THE INTRODUCTION AND SELECTION OF EXOTIC TREE SPECIES, PETAWAWA, 1968-70

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The objectives of this work are to study hardiness and performance of exotic species and provenances; to breed winter-hardy, fast growing, weevil-resistant Norway spruce (*Picea abies* (L.) Karst.); to breed superior Scots pine (*Pinus sylvestris* L.) types for Christmas trees and timber; to breed hardy, straight, and fast growing larch (*Larix* spp); and to test and select other exotics of interest to our tree breeding program.

NORWAY SPRUCE

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

As provenance material established in Canada is still rather limited, we started seven new tests between 1965 and 1968. One includes 25 of the fast growing, but perhaps somewhat frost-tender provenances from the eastern and southeastern extension of the range, i.e., mainly the Carpathian Mountains (Exp. No. 277). Another is a test of the somewhat hardier types from both sides of the "spruce-free corridor" in Poland (Exp. No. 310-A) and consists of 24 well documented provenances provided by Dr. M. Giertych of the Kornik Arboretum. 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). To assess the southern outlier populations of the Norway spruce range, four Yugoslavian provenances and six Bulgarian stands (represented by 56 single-tree progenies) were sown in 1967 together with three control provenances (Exp. No. 350-A). These provenances are remarkable because of their uniform growth rate and light green needles. They are of particular interest because they represent relicts of one of the gene centers for Norway spruce. The last test was sown in 1968 and consists of 29 provenances from the Baltic States and White Russia (Exp. No. 349-A). These are of particular interest in the colder (western) part of the Great Lakes-St. Lawrence Forest Region and in parts of the Boreal Forest Region. In all of these tests an attempt was made to assess the within-provenance variation in 4-year-heights (coefficient of variability) as well as provenance mean height and hardiness. From earlier tests we know that some provenances perform very well in the nursery test but fall behind when planted in the field. Most of these tests will be widely planted in eastern Canada and in New England.

In 1969 the Carpathian and the Polish provenances were field-planted on an acid site at PFES (Exp. Nos. 277-A and C and 310-A-1) and on a calcareous site near Lake Dore, Ont. (Exp. Nos. 277-B and 310-A-2). Plants were also distributed in the Quebec Region.

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

New winter-hardy and weevil-free trees have been selected and propagated, particularly the fast growing Istebna, Poland, provenance (Exp. No. 304). In a frost pocket at Harrington Forest Farm of Canadian International Paper Company in Quebec, additional winter-hardy trees were selected and grafted for the establishment or a seed orchard of the Istebna provenance.

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

OTHER EXOTIC SPRUCES

A number of Danish Sitka x white spruce hybrids (*Picea sitchensis* (Bong.) Carr. x *P. glauca* (Moench) Voss) and back crosses, as well as white and Sitka spruce provenances were planted in eight locations on the West Coast to test their growth rate and resistance to Sitka spruce weevil (*Pissodes sitchensis* Hopk.). Sitka spruce grew best followed closely by the Sitka x white spruce hybrids. A few white spruce provenances from the perhumid area of Quebec with long growing seasons had acceptable growth rates while provenances from the dryer and more continental climates grew poorly. If eastern white spruce eventually shows resistance to the Sitka spruce weevil (as it is resistant to the white pine weevil in its native habitat) we shall know where to look for suitable provenance for planting on the West Coast.

Twelve similar experiments were planted in eastern North America to find out whether Sitka spruce and Sitka x white spruce hybrids have a silvicultural advantage along the wind swept Atlantic Coast and how much they are attacked by the white pine weevil. Some of these experiments were planted inland to test hardiness and performance when under climatic stress. In the continental climate at Petawawa the British Columbia Sitka spruce froze in the nursery stage and Alaskan Sitka spruce grew very slowly and had the lowest survival in the field test (Exp. No. 139). With increasing white spruce component in the British Columbia Sitka x Danish white spruce hybrids heights, hardiness and survival was increasing. The Danish white spruce that originally came from the Atlantic Seaboard was slower growing than local Petawawa white spruce. The white pine weevil is present in the area but has not attacked any plants. In this continental climate the Sitka x white spruce hybrids are silviculturally unacceptable. However they may fare better in coastal climates along the Atlantic or Pacific oceans.

No new spruce hybrids were made, but older selections were field planted. A provenance material of *Picea glehnii* (Fr. Schmidt) Mast. had to be retained in the nursery as the plants were not large enough for field planting. Both in this feature as well as in other characteristics, *P. glehnii* is like red spruce (*P. rubens* Sarg.).

In 1968 Dr. D.P. Fowler's *Picea omorika* (Pancic) Purkyne x self, *omorika* x *omorika*, and *omorika* x *mariana* (Mill.) B.S.P. (Petawawa) were field planted in a long term nursery test together with our own Kapuskasing black spruce crossed with *P. omorika* and *P. glehnii* - as well as *P. rubens* (Quebec) x *mariana* (Petawawa) crossed with both *P. omorika* and with *P. glehnii* (Exp. No. 341-A-1). In another test Dr. D.P. Fowler's controlled hybrids were compared with various black spruce provenance hybrids (Exp. No. 341-A-2). Other spruce hybrids were field planted in the Spruce Hybrid Area (Exp. No. 341-B).

SCOTS PINE

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

In 1967 the Russian and Siberian Scots pine provenance experiment (Exp. No. 201-A) was measured and compared with other experiments planted in Ontario and the Prairie Provinces. These provenances from the southern fringe of the Scots pine range in European Russia (Orel, Woronesh and Kiev) grew very well in all locations (Teich and Holst 1970). Total heights were nearly the same on a medium acid sand at Petawawa, Ont., and on a rich Oxbow clay loam at Indian Head, Sask. Thus soil fertility compensated for the relatively shorter growing season at Indian Head. These provenances also grew very well on the limy sands at Turkey Point in southern Ontario. As both growth rate and form is superior to west European provenances, these provenances are very valuable material for further selection and breeding. At Indian Head, Sask., seed orchards have been established with this material.

In 1966 two new clonal tests of 31 Scots pine clones were field planted to assess their susceptibility to the white pine weevil (Exp. No. 280-A-1, A-2). Ten of these clones were used in a heritability study of Christmas tree characteristics, weevil resistance, eastern gall rust (*Cronartium quercuum* (Berk) Miyabe ex Shirai) resistance and of precocious flowering. A complete reciprocal crossing scheme was used. Four field tests with this material were established at PFES (Exp. Nos. 272-A, B, C, and D) and two tests in southern Ontario (Exp. Nos. 272-E and F). A paper was published on the genetic control of cone clusters and precocious flowering in this material (Teich and Host 1969).

OTHER HARD PINES

In the Arboreta at Petawawa and at Turkey Point in southern Ontario we have (in cooperation with the Ontario Department of Lands and Forests) over the years established test plots of a number of exotic hard pines. A final assessment of this material should be done and selected individuals used for interspecific hybridization.

LARCH

The larch experiments planted on PFES and on the Harrington Forest Farm in western Quebec give a fairly good indication of what can be planted with confidence in the middle part of the Great Lakes - St. Lawrence Forest Region. On suitable sites, i.e. fairly deep and well aerated soil, larch has shown very rapid height growth. However porcupines can ruin a larch plantation and must be kept under control. European, Japanese, Siberian, Korean and Kurile larch (*Larix decidua* Mill., *L. leptolepis* (Sieb. & Zucc.) Gord., *L. sukaczewii* Djil., *L. gmelini* var. *olgensis* (Henry) Ostenf. & Larsen, *L. gmelini* var. *japonica* (Reg.) Pilger) provenances, local tamarack (*L. laricina* (Du Roi) K. Koch), and a limited number of larch hybrids have been under study.

The European larch has its main distribution area in the Alps with smaller ranges occurring in the Sudeten Mountains, the mountains of Slovakia, in the Polish lowland as well as in the mountains of southern Poland that border on Czechoslovakia. Thus we have Alp larch, Sudeten larch, Slovakian larch and Polish larch.

Of these the Alp larch from natural stands have proven entirely unsuitable for our area. The improved Alp larch that comes from improved stands or seed orchards in Denmark and Germany is of intermediate growth, and stands have been located that give progenies of exquisite form.

The Slovakian larch provenances from granitic soils are 7% - 9% shorter than improved Danish larch of Alp origin, and provenances from limestone soil are 16% shorter when grown on the acid granitic till at PFES. Thus Slovakian larch - for the time being - cannot be recommended.

The Polish larch provenances are all fast growing but of variable form; nearly 90% of some Polish provenances have cork screw stems and are totally unacceptable, while others vary in their number of acceptable trees. Thus Polish larch is a mixed lot that cannot be generally recommended although it holds much promise for further selection and breeding in eastern Canada. The only Polish material which can be used with confidence in eastern Canadian silviculture is the Zagnansk provenance from a Danish seed orchard.

The Sudeten larch is known for its rapid growth and its tendency to basal sweep. In our experiments it is also fast growing, but direct imports from native stands have a strong tendency for basal sweep while an improved type of Sudeten larch from Rundforbi, Denmark, has very little basal sweep (80% acceptable trees) and is the only stand that can be generally recommended.

The Japanese larch is somewhat frost susceptible and is slower growing than European larch in the continental climate at Petawawa. The stem form is often uncertain. The Japanese larch provenances we have tested at Petawawa have been exposed to very severe culling for late spring frost, early fall frost and winter frost in our nursery; even then the Japanese larch is not fully frost hardy when field planted. In our tests only one stand has good stem form, as it had been vigorously selected for this trait by District Forester Just Holten in Denmark. However, this stand also shows signs of introgression with Korean or Kurile larch. Japanese larch holds great promise in the Maritime Provinces but in the middle part of the Great Lakes - St. Lawrence Forest it should be planted on selected sites only.

The European x Japanese larch hybrid is very fast growing and shows pronounced hybrid vigor in terms of height and diameter growth. The stem form is not so good as that of European larch, but much better than Japanese larch. Hardiness is intermediate and branches tend to be heavy. The European x Japanese larch hybrid can be planted with confidence on upland sites in the middle and eastern part of the Great Lakes - St. Lawrence Forest Region and is readily available from European seed dealers. Second generation hybrids (F_2's) are not recommended as they are very variable. The European x Japanese hybrids we have tested came from seed orchards of European larch of Alp origin and Japanese larch both selected in the lowlands of maritime northwestern Europe. Better adapted hybrids could be produced by selecting both parent species in Canada using only the types that are adapted to our climate and soils. Furthermore, in the case of European larch we should use the faster growing Polish and Sudeten larch in preference to the slower growing Alp larch, and the Japanese larch should be severely culled for frost hardiness, drought resistance and form.

We have several lots of Siberian larch (*L. sukaczewii*) from the famous Raivola larch stands in Finland (Lat. 60°N) which originally came from Archangelsk (Lat. 64°30'N). When planted in Canada the growth rate was much better (50% higher) in the Boreal Forest Region on calcareous soils near Kapuskasing, Ont. (Lat. 49°20'N) than on acid soils at Petawawa (Lat. 46°N) where the Raivola Siberian larch has only half the height of European larch. Thus the Raivola larch perhaps is preadapted to boreal climates, calcareous soils and long days - none of which we can provide at PFES. The relative growth rates of Alp larch, Raivola larch and Raivola x Alp larch are: 100:70:48. Thus the hybrids with Alp larch are not very promising in the Great Lakes - St. Lawrence Forest Region. Another collection of Siberian larch came from the Arboretum, Hörsholm, Denmark, and consists of grafted trees selected in arboreta in Sweden and Denmark, and from plantations in Iceland. This lot contained many species hybrids. The relative growth rates of Alp larch, Siberian larch, Siberian x (Japanese x Korean), and Siberian x Sudeten larch are: 100:89:108:125. Thus the Danish collection of Siberian larch is faster growing than the Raivola larch and has produced frost hardy and vigorous hybrids with Sudeten larch. These Siberian larch hybrids have a potential use in the more continental (western) part of the Great Lakes - St. Lawrence Forest Region where the European x Japanese hybrids would be a silvicultural risk due to their susceptibility to frost and drought. Thus the Siberian larch is an interesting crossing partner for production of hardy species hybrids. New tests should be established to explore this species further.

At Petawawa the Sakhalin larch (*L. gmelini* var. *japonica* (Reg.) Pilger) grew poorly and cannot be recommended for planting in eastern Canada. It has limited use in species hybridization.

THUJA

A *Thuja occidentalis* L. provenance experiment that originated from the Institute of Forest Genetics, Rhinelander, Wisc., was field planted in 1969 on granitic soils at PFES (Exp. No. 373-A) and on limestone soils near Lake Dore (Exp. No. 373-B). Eighteen provenances were compared with two local controls of which one was collected on an acid site and the other on a limestone site.

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THE FOREST TREE SEED UNIT, PETAWAWA, 1968-70

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INTRODUCTION

Since the last progress report, the Forest Tree Seed Unit has continued to provide information on seed procurement, to supply seed and to test seed quality for all Canadian Forestry Service establishments, handle external requests for small quantities of seed for research purposes and exchange seed with other organizations. Demands for services from all sources have nearly tripled since 1967.

The following report describes our progress in various aspects of tree seed information, procurement, distribution, testing and storage.

INFORMATION FILE

Information on where and what seed is available has been continuously gathered, accumulated and indexed. A total of 20 requests for information on seed procurement, seed periodicity, seed treatment and x-radiographic technique was received and answered during the last 2 years, the majority in 1969.

SEED PROCUREMENT AND DISTRIBUTION

Good seed crops were borne by red (*Acer rubrum* L.) and silver maple (*Acer saccharinum* L.), and jack pine (*Pinus banksiana* Lamb.) in 1968, and 1969 was a good seed year for eastern white cedar (*Thuja occidentalis* L.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), bur oak (*Quercus macrocarpa* Michx.), and white (*Fraxinus americana* L.), red (*Fraxinus pennsylvanica* Marsh.) and black ash (*Fraxinus nigra* Marsh.) in the Upper Ottawa Valley area. Red pine (*Pinus resinosa* Ait.), trembling (*Populus tremuloides* Michx.) and largetooth aspen (*Populus grandidentata* Michx.), and balsam poplar (*Populus balsamifera* L.) produced a moderate crop in 1969. A total of 54.5 bushels of bulk cone collections of red and jack pine, eastern white cedar, bur oak and white, red and black ash, and 67 single-tree collections of trembling and largetooth aspen, eastern hemlock, beech (*Fagus grandifolia* Ehrh.), red and silver maple, and black spruce (*Picea mariana* (Mill.) B.S.P.) were made by local staff and cooperators. In order to meet requests for seed for research from various organizations, 44 additional seedlots of native and exotic tree species were procured from Regional Offices of the Canadian Forestry Service, universities, foreign governments, research organizations, and the seed trade.

In 1970 the Forest Tree Seed Unit joined the seed scheme sponsored by the IUFRO Working Group on Procrement of Seed for Provenance Research.

This gives access to tree seed of known origin and quality of many native species from the Pacific Northwest and Alberta regions. A similar cooperative scheme is needed to cover eastern tree seeds.

In answering 98 requests for seed for research, 249 seedlots of 34 tree species were distributed to 16 countries and Canada. The number of requests for seed in 1969 represents more than a 100% increase over 1968.

SEED EXTRACTION AND YIELD

Eight hundred and thirty-six seedlots of bulk and single-tree collections were processed by the Seed Unit's extractory in 1968 and 1969. Improvements were made in processing techniques and equipment, and seed yield, seed quality and efficiency of handling cones have all been noticeably increased (Table 1). Further assessment of the seed extraction was made with black spruce cones collected in 1969 by Drs. E.K. Morgenstern and A.K. Hellum in northern Alberta, British Columbia, and Yukon Territory, and with red pine cones collected locally in 1969. The results showed that cones damaged by insects did not open adequately under standard kiln drying temperature (dry bulb 60°C; wet bulb 32°C) due to partial destruction of the cone scales. It was also ascertained that for maximum seed yield with the Moore kiln, black spruce and red pine cones not only required presoaking but also three kiln dryings as the percentage of the total seed yield from the second and third kiln drying was 48% and 29% respectively for black spruce, and 63% and 10% for red pine.

SEED TESTING AND RESEARCH

In addition to testing the seed stored in the seed bank, four requests for testing service were fulfilled for the Canadian Forestry Service's Regional Offices in 1968 and 1969. One was to determine possible causes of poor quality of a white spruce (*Picea glauca* (Moench) Voss) seedlot from Newfoundland. X-radiographs of the seed showed that 32% of the seed had underdeveloped embryos, no embryos or shrunken megagametophytes which might have resulted from selfing.

An investigation (using x-radiography) of embryo size in relation to laboratory germination of red pine seed was completed. Findings revealed that radicle emergence, which is commonly used for evaluating the viability of seed, was unreliable for predicting germinability of seed in the nursery or field because seeds with underdeveloped embryos germinate with emergence of the radicle but do not develop further. In seed testing, it is essential that laboratory test criteria be capable of producing estimates of field germinability rather than the total viability. To find a true measure of evaluating the germinability of seed, test criteria based on germinant vigor in the laboratory were developed for red pine. A preliminary analysis indicated that the criteria were significantly correlated with nursery germination. The germination criteria will be tested further with other tree seeds. A report will be prepared.

Table 1. Seed Yield in 1968 and 1969.

Species	Clean Seed Yield Per Bushel of Fruit or Cones		No. of Filled Seeds per Cone
	grams	pounds	
Fraxinus americana L. (Ruby, Ont., 1969)	4876.0	10.000	-
Fraxinus nigra Marsh. (Chalk River, Ont., 1969)	4264.0	8.800	-
Fraxinus pennsylvanica Marsh. (Petawawa, Ont., 1969)	2716.0	5.982	-
Picea mariana (Mill.) B.S.P. (N. Alta. & B.C., and Yukon, single trees, 1969)	-	-	4.8
Pinus banksiana Lamb. (Chalk River, Ont., 1969)	240.0	0.528	31.0
Pinus banksiana Lamb. (Sioux Lookout, Ont., 1968)	224.7	0.495	30.8
Pinus banksiana Lamb. (Grand Calumet River, Que., single trees, 1969)	154.3	0.340	23.1
Pinus resinosa Ait. (Chalk River, Ont., 1969)	316.5	0.862	40.9
Pinus resinosa Ait. (Sioux Lookout, Ont., 1968)	233.0	0.501	29.5
Pinus resinosa Ait. (Gambo, Nfld., 1968)	138.7	0.306	13.4
Tsuga canadensis (L.) Carr. (Algonquin Park, Ont., single trees, 1969)	882.0	1.944	23.0
Thuja occidentalis L. (Lake Dore, Ont., 1969)	514.0	1.062	4.8

The effect of stratification on white spruce and balsam fir (*Abies balsamea* (L.) Mill.) seed was investigated, and data will be analyzed and reported.

SEED STORAGE AND SEED CERTIFICATION

A review of seed storage with special reference to hardwood seeds is near completion and a report will be prepared. A review of forest tree seed certification in Canada was completed and published.

PUBLICATIONS

Wang, B.S.P. and O. Sziklai. 1969. A review of forest tree seed certification. Forest. Chron. 45:378-385.

Wang, B.S.P. 1970. A list of seeds in the seed bank at Petawawa Forest Experiment Station. Can. Forest. Serv. Inf. Rep. PS-X-13. 10p.

TREE PROPAGATION WORK AT PETAWAWA 1968 TO 1970

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INTRODUCTION

The nursery produces and maintains experimental plant material for the Tree Biology Section and other sections at PFES and other Canadian Forestry Service establishments, universities, and industries cooperating in Petawawa research.

Experiments designed to solve specific problems in the propagation of experimental forest trees are carried out in association with the nursery operation.

NURSERY PRODUCTION 1968-70

1969

20 seed lots were sown for one experiment and general use.
37,400 2-0 seedlings were transplanted for two experiments and general use.
74,500 2-2 transplants were lifted for 13 field experiments and general use.
2,220 potted plants were produced in a greenhouse; some were planted in a nursery experiment (1,900) and others used for photosynthesis studies (320).
795 grafts were made of 14 clones.

1970

290 seed lots were sown for six experiments and general use.
58,000 2-0 seedlings were transplanted for 11 experiments and general use.
12,00 2-0 seedlings were lifted for two field experiments.
11,500 2-2 transplants were lifted for four field experiments and general use.
1,400 grafts of 84 clones were made.

SEED GERMINATION AND STRATIFICATION

A germination and stratification experiment with fresh, mature, non-stored seed of six pine and spruce species was finished and the results were published (Santon 1970b). Most germination and stratification experiments do not mention the age of the seed used. While seed of such species as jack and red pine do not show any sign of dormancy after a winter's cool storage, this experiment shows that fresh, mature seed of all the tested species needs stratification for various periods of time before satisfactory germination takes place under the given conditions.

The minimum stratification requirements were found to be:

for jack pine (*Pinus banksiana* Lamb.)	2 weeks
red pine (*P. resinosa* Ait.)	2 weeks
white pine (*P. strobus* L.)	4 weeks, or perhaps more
black spruce (*Picea mariana* Mill. B.S.P.)	3 weeks
Norway spruce (*P. abies* (L.) Karst.) (brown cones)	3 weeks
Norway spruce (green cones)	2 weeks
red spruce (*P. rubens* Sarg.)	3 or 4 weeks
white spruce (*P. glauca* (Moench) Voss.)	2 or 4 weeks

ROOT SYSTEM DEVELOPMENT IN CONTAINERS

An observation on the root development of aspen seedlings raised in greenhouse and later transplanted to nursery beds was published (Santon 1970a).

Trembling aspen seed was sown in plastic tubes. One month after sowing one batch was transplanted into peat pots, and one batch was kept in the plastic tubes. Both batches were planted in the nursery 2 months after sowing. The plants in the peat pots developed well-balanced and well-distributed root systems. Plants in plastic tubes developed one-sided or unbalanced root systems, and at the end of the second growing season they were smaller than those in peat pots. The plastic tubes seem to suppress the development of lateral roots on the upper part of the main root, while the peat pots allow the roots to develop freely in all direction from the very base of the stem.

A new type of paper pot from Japan seems to have some advantages over plastic tubes and peat pots. It is available in a number of sizes and paper qualities, and as the paper walls soften the roots of the seedlings are able to grow through them. A small experiment was started in June 1970 to compare the root development and growth of seedlings raised in this type of paper pots with those raised in plastic tubes.

EASTERN GALL RUST ON SCOTS PINE GRAFTS

One Scots pine (*Pinus sylvestris* L.) clone (V. 842) at PFES Pine Graft Arboretum has shown a high degree of susceptibility to eastern gall rust (*Cronartium quercuum* (Berk) Miyabe ex Shirai). None of the surrounding Scots pine clones have any sign of gall rust. This clone and 18 other Scots pine clones in the arboretum were regrafted in 1968 in connection with controlled cross pollination between groups of these clones. In the fall of 1969 gall rust was noticed in the clone (V. 842) and a count showed that 100% of the ramets had one or more galls. Some of the galls were developed on the lower part of the scion wood around the graft union. None of the rootstocks (a seed lot of Scottish origin) or any of the other clones have shown any sign of gall formations. A lengthwise cut through a graft union shows that the galls develop only in the scion wood and not in the rootstock wood. The graft union stands out as a sharp line between attacked and not attacked wood. An early and brief survey of seedlots in the experiment shows that progenies with V. 842 as mother have a much higher percentage of trees with galls than progenies of other clones. Geneticists working with the experiment may be able to determine the degree to which susceptibility to eastern gall rust is inherited.

GERMINATION AND SURVIVAL OF RED PINE IN DIFFERENT MEDIA

Germination and survival of greenhouse-sown red pine seedlings as affected by soil mixture, soil compaction, covering media and treatment with Captan fungicide was influenced more by the covering media than by any other treatment. Though the statistical analyses of the results is not yet complete, a trend is clear. The total germination of all soil and cover combinations for untreated seed was 86.6% and for Captan-treated seed 83.3%; the total survival was 81.8% and 80.4% respectively. For seed covered with perlite the germination for untreated seed was 97.9% and for Captan-treated seed 98.6%; the survival was 90.6% and 94.3% respectively. For seed covered with sand the germination for untreated seed was 75.5% and for Captan-treated seed 67.5%; the survival was 72.6% and 66.6% respectively. Damping-off occurred sporadically and randomly without any apparent connection to treatment or soil and covering media.

REFERENCES

Santon, John. 1970a. An observation on the root development of aspen seedlings raised in plastic tubes. Can. Forest. Serv. Inf. Rep. PS-X-16. 6 p.

Santon, John. 1970b. Effect of stratification on germination of freshly harvested seed of several spruce and pine species in eastern Canada. Can. Forest. Serv. Inf. Rep. PS-X-17. 22 p.

COST AND BENEFIT ANALYSIS
OF WHITE SPRUCE (PICEA GLAUCA (MOENCH) VOSS) IMPROVEMENT

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During the past year an attempt was made to place a value on the increases in yield which arise from using genetically improved seed. Initially a review of all the literature on costs and benefits of tree improvement programs was made, followed by the development of a model for white spruce (*Picea glauca* (Moench) Voss) improvement costs and benefits. The model was developed using a PDP-8L computer, and took into account site index class, tree spacing, yield, economic rotation, interest, stumpage value, inflation rate, establishment costs, management costs and percent increase in yield. Usingthese parameters, present net worth of the merchantable wood, change in present net worth due to increased yield, and internal rate of return were calculated (Carlisle and Teich 1970). In addition the effects of varying establishment and management costs on present net worth and internal rate of return were studied.

Some of the results from this work will be described at the Symposium on Tree Breeding and Silviculture in Canada, associated with the present meeting. In brief, however, it was found that it would be difficult to find a cheaper way of increasing yield.

The model was weighted to minimize benefits, but even so there was good evidence that in the limited context of seed production to sale on the stump, genetic improvement of white spruce is a good investment.

REFERENCE

Carlisle, A. and A.H. Teich. 1970. The costs and benefits of tree improvement programs. Can. Forest. Serv. Inf. Rep. PS-X-20. 28 p.

THE STIMULATION OF FLOWERING IN SPRUCE AND PINE

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The purpose of this report is to describe results from an empirical study of flower stimulation carried out in support of the tree breeding program. The project is currently being phased out.

Tree breeders are keenly interested in shortening the notoriously long period between generations in forest trees. These can be shortened somewhat by accelerating the growth in controlled environments, by various flower stimulating techniques applied directly to seedlings or grafts, by using specific flower-stimulating rootstocks, or by finding genes for early flowering which may be bred in and out of the breeding populations at will.

Our objectives are to find methods that will induce male and female flowering in juvenile and mature spruce and pine, and to explore techniques of vegetative propagation leading to early and abundant flowering of ramets of selected trees.

Studies have been made of effects of fertilizers, sprays, root and branch pruning, and girdling on flowering in white, black and Norway spruce (*Picea glauca* (Moench) Voss, *P. mariana* (Mill.) B.S.P., *P. abies* Karst.) and in red, jack and Scots pine (*Pinus resinosa* Ait., *P. banksiana* Lamb., and *P. sylvestris* L.). Root pruning promoted flowering in spruce, but has a negative effect in pine. In pine, ammonium nitrate promoted female flowering, but reduced male flowering. Spraying with anti-auxins promoted male flowering in pine. All treatments must be timed carefully.

RED PINE

Flowering of the red pines in Drury Forest has been recorded annually since 1953. Various treatments were given, including different fertilizers and different times of application (Exp. No. 167). Untreated controls have been maintained that are suitable for a study of the effect of climate on flowering. These observations were terminated in 1966. From these experiments we learned that ammonium nitrate was particularly effective in increasing female flowering.

In a timing experiment with ammonium nitrate we found that May 20th and June 24th applications stimulated female flowering in the upper four whorls by 50% the first year after application, but reduced female flowering by 16% 2 years after application. The July 28th application stimulated the female flowering in the upper two whorls by 24% the first year and reduced female flowering by 13% the second year, while female flowering in whorls three and four were slightly reduced (7%) the first year and slightly stimulated (7%) the second year. The August 20th and September 19th applications had no effect on female flowering the first year (flowering was slightly reduced by 5%), while the second year after application female flowering was stimulated by 66% in the upper two whorls and by 121% in whorls three and four. In other experiments with red pine we noted that early June application of ammonium nitrate stimulated female flowering the first year after application with a very severe reduction in the second year; and a less severe reduction in the third year; in the fourth year fertilized trees flowered as much as the controls. For this reason we thought that the ammonium nitrate fertilizer stimulation of female flowering was a "one-shot" response.

To investigate which part of the ammonium nitrate is effective - the ammonium ion or the nitrate ion - new experiments were conducted using ammonium nitrate, potassium nitrate and ammonium sulphate. The 25-year-old red pines in the Drury Forest near Barrie, Ont., were fertilized in mid-June 1965 with the three fertilizers. The fertilizer doses were adjusted to give gram-equivalent amounts of nitrate or ammonium as follows: ammonium nitrate (17 gm N/m^2), ammonium sulphate (8 gm N/m^2) and potassium nitrate (9 gm N/m^2). Fertilizers increased female flowering by 251 to 330%. The difference in flowering response between potassium nitrate and ammonium sulphate can be explained as a total nitrogen effect - as both fertilizers were given at relatively low levels. At the higher fertilizer levels, ammonium nitrate gave the most females but the response per gram nitrogen was one-third lower than for the other fertilizers. All three fertilizers reduced male flowering in the upper part of the crown. For ammonium nitrate this reduction was twice that of potassium nitrate and ammonium sulphates. In the lower part of the crown, potassium nitrate stimulated male flowering by about 20%, while ammonium sulphate and ammonium nitrate had no effect on male flowering in the lower crown.

During the late 1950's, a treatment combination of bud pinching, branch pruning and various doses of ammonium nitrate was carried out on young red pine in a plantation near Rolphton, Ont. Early bud pinching stimulated slight male flowering, but this effect disappeared when bud pinching was combined with ammonium nitrate fertilizers. Branch pruned trees without fertilizer treatment remained healthy, while the new shoots and buds became very frost susceptible when ammonium nitrate was given.

Reciprocal grafting of red, jack and Scots pine indicated that red pine on jack pine and jack pine on red pine were completely incompatible as all grafts died within a year. The red pine on Scots pine and Scots pine on red pine grafts faded away over a longer period (over 10 years), and the red pine on Scots pine faded away earlier than Scots pine on red. Jack pine on Scots pine and Scots pine on jack pine were completely compatible. None of these combinations stimulated flowering.

JACK PINE

In jack pine, female flowering was strongly stimulated by ammonium nitrate fertilizer while male flowering was reduced. The effect was very pronounced in seedlings up to 4 feet high and in saplings up to 8 feet high while the effect on the taller trees was less spectacular. Early May application of ammonium nitrate gave more female flowers than early June applications. Early July application had no effect while early August application reduced female flowering.

To look into the problem of whether the stimulation of female flowers by ammonium nitrate is a general fertilizer effect or whether it is a true stimulation induced by some as yet unknown hormonal change, a new experiment was started in the Pine Graft Arboretum (Exp. No. 316) in 1965 when a late (June 29) application of ammonium nitrate, ammonium sulphate and potassium nitrate (all adjusted to 20 gm N/m^2) was given to 11-year-old jack pine grafts which all grew on a relatively fertile site that had been fertilized with NPK (160 lb. 20-20-20 per acre) in 1955. Two years after the first application (on 24 May 1967) the same fertilizer treatments were given. The year after the first (late) application, ammonium nitrate stimulated female flowering by 23% while ammonium sulphate and potassium nitrate had only a slight effect (respectively 4 and 6%). Male flowers on sample branches in the lower crown were stimulated mostly by ammonium sulphate (18%), less by ammonium nitrate (6%), and were reduced 8% by potassium nitrates. The year after the second (early) fertilizer treatment, female flowering was stimulated 14% by ammonium nitrate, and 9% by both ammonium sulphate and potassium nitrate. Male flowers in the lower crown were stimulated mostly by ammonium sulphate (28%) and less by ammonium nitrate and potassium nitrate (both 4%). In the upper three whorls male flowering was reduced by 20% by ammonium nitrate but stimulated by ammonium sulphate (9%) and by potassium nitrate (24%). Thus the response to these fertilizers was the same for jack and red pine.

During the late 1950's some very promising results were obtained in young jack pines sprayed with anti-auxins. Both female and male flowering were stimulated - even if the treatments were started too late in the growing season. These experiments were repeated with better timing in 1968.

During the 1968 growing season 7-year-old jack pine seedlings were sprayed with two anti-auxins, 4-chloro-2-methylphenoxyacetic acid (4,2-D), and 2,3,5-triiodobenzoic acid (2,3,5-T). A treatment of alcohol and water was included to check on the solution used for 4,2-D and 2,3,5-T. Starting on 17 May the trees were sprayed for six 2-week periods. In each 2-week period half the trees were sprayed twice a week for 1 week and the other half twice a week for 2 weeks. Growth data and flowering data were recorded for each tree. In 1969 a similarly timed spraying with 2-chloroethanol was done in the same area and flowers were counted again. The final assessment will be made in 1970.

OTHER HARD PINES

Scots pine responses to ammonium nitrate and root pruning were very similar to those of red pine and jack pine. Scots pine flowers later than jack pine but earlier than red pine. Early and abundant flowering Scots pine clones have been observed for several years and have been crossed to see whether genes for early flowering can be bred into and out of a population at will, and to test whether early flowering seedlings will stimulate early flowering in grafts more than normal late flowering root stocks. To explore this idea further, in 1969 we grafted three populations of early, medium and late flowering Scots pine progenies produced by controlled hybridization in nine combinations and planted these in a replicated nursery test to observe what effect the root stock had on flowering (Exp. No. 364-B). Another test of various parent clones grafted onto the same populations could not be done due to lack of plants (Exp. No. 364-A).

SPRUCE

All flower stimulation techniques for white, black and Norway spruce should be given early in the spring. Root pruning and girdling are still the best methods to induce the various spruces to flower, but have the drawback that the more severe treatments have resulted in extensive injury to the trees. To explore new techniques, a new series of spruce experiments was initiated with container grown plants. Norway spruce clones (in large plastic containers) were given five different fertilizer treatments, and three different drought periods at four different dates to determine if a combination of early drought and fertilizer would induce flowering (Exp. No. 313).

An experiment with reciprocal grafts of black, red, white and Norway spruce indicated that there is no graft incompatibility between these species. All species grafted on red spruce root stocks have had relatively poor height growth (Exp. No. 212-A). None of the rootstocks stimulated early flowering.

PUBLICATION

Teich, A.H. and M.J. Holst. 1969. Genetic control of cone-clusters and precocious flowering in *Pinus sylvestris* L. Can. J. Bot. 47:1081-1084.

MECHANISMS OF SEEDLING GROWTH IN IMPROVED ENVIRONMENTS

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A new project was set up in spring 1970 in support of the tree breeding program at Petawawa Forest Experiment Station. Its objectives are to develop methods for rapidly assessing the growth requirements of tree seedlings, and to develop prototype low-cost greenhouses in which these requirements can be met. The principal purpose is to reduce the time required to grow seedlings to a size suitable for planting out; at present tree breeders have to wait up to 4 years before placing their experimental material on trial. Results of the project may also find application in the general production of nursery stock, especially when seedlings are reared in containers.

The plan is to extend the growing season and to increase the daily growth rate. There will not be an early attempt at growing seedlings continuously for the whole year. The approach begins with an experimental phase, to be executed mainly in the laboratory. Photosynthesis and respiration will be measured by infra-red gas analysis in seedlings grown under controlled conditions. Growth of these same seedlings will be measured as dry matter accumulation and as height growth. A key goal of the project is to predict growth responses to environment from the more rapidly assessed responses of photosynthesis and respiration.

The environmental factors selected for initial investigations are day and night air temperature, photoperiod, and carbon dioxide concentration of the atmosphere. These factors were selected because of their proven importance to growth and because they are relatively simple and cheap to control in large greenhouses.

The second phase will comprise tests of the applicability of results from the experimental phase. We are asking if the results of laboratory experiments can be repeated at low cost on a nursery scale. Particular attention will be paid to form and hardiness of seedlings during this phase; high rates of dry matter production or height growth are not sufficient criteria for suggesting changes in nursery practice. The tests will be conducted in a four-compartment plastic greenhouse, with independent temperature (heating and cooling) control during optional day and night periods in each compartment; in two unheated greenhouses, one with automatic forced ventilation, the other with manually controlled free ventilation; and in standard nursery beds for comparison.

All investigations are beginning with one local collection each of *Picea glauca* (Moench) Voss and *Pinus banksiana* Lamb. Later, studies will expand to examine intraspecific variation in seedling requirements and will be tied in with a project concerned with physiological bases of genetically controlled differences in growth.

PHYSIOLOGICAL GROWTH PARAMETERS FOR TREE SELECTION

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The selection of tree breeding material, such as provenances and plus trees, is usually based on the outward manifestation of several physiological characters. If these physiological characters can be identified in seedlings, it should be possible to reduce the time required for selection and breeding of this material. The objective of this project is to identify characters whose genotypic variation lead to differences in growth among genotypes and to develop methods for rapid appraisal of these characters in parent or progeny. The physiological characters or parameters of tree growth selected for this study are rate of photosynthesis, leaf area, duration of growth, and respiration. All of these are genetically controlled and are influenced by environment.

A rapid method of measuring gas exchange has been developed to determine rates of photosynthesis of detached shoots of conifers. Rates of photosynthesis of 10 provenances of jack pine (*Pinus banksiana* Lamb.) were measured in this system between early July and November. These provenances were collected from regions extending from the Atlantic Coast to the Northwest Territories. Seedlings were 8 years old and differences in growth between provenances were already clearly expressed. The results showed that only at certain times of the year could rates of photosynthesis be correlated with growth. The study is being extended to 1- and 2-year-old seedlings from the same provenances to determine the utility of this method for identifying superior progeny.

THE PINE GENETICS PROGRAM IN MANITOBA AND SASKATCHEWAN

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In consequence of the austerity program announced in 1969, the Manitoba-Saskatchewan Region of the Canadian Forestry Service has been absorbed by the new Prairies Region, with headquarters in Edmonton. The Birds Hill Research Nursery, recently developed near the former Winnipeg laboratory will be disposed of. Tree breeding material sown at the nursery in 1969 will be maintained until it can be planted. The poplar breeding program initiated by Mr. F.B. Armitage became essentially inactive when Mr. Armitage left Winnipeg for a Research Manager position in the British Columbia Region. Dr. K.J. Roller is reporting separately on his program in these Proceedings.

JACK PINE BREEDING PROJECT

The program described in the 1968 Proceedings has been carried forward.

Collection of breeding materials has been completed for the western breeding district, extending from central Saskatchewan into Alberta.

A small progeny test was planted in spring of 1970 from the eastern district sowing done in 1968. Owing to cool, rainy weather during that season and low viability of some of the seedlots, there was not sufficient material for a full-scale progeny test. We planted 125 progenies in a cubic lattice design, with two-tree plots, twelve replicates, and 3-foot spacing. Sites ranging from very dry to moist were disc-plowed and harrowed. The planting will serve as a pilot test of establishment procedures and data on handling for the cubic lattice design. Genetic information may also be obtained.

Further selection was carried out in the eastern breeding district in 1969, to replace the inviable seedlots. The eastern district breeding population was sown in spring and fall of 1969 at Birds Hill Research Nursery. Germination was excellent for the spring sowing; and seedlings from the fall sowing were beginning to appear in early June. Ample material should be available for a progeny test planting in spring 1972.

ALL-RANGE JACK PINE PROVENANCE EXPERIMENT

Seed from 78 sources in the range-wide collection was received from Petawawa Forest Experiment Station. Three sources were added from regional collections. Four replicates of the augmented collection were sown at Birds Hill Research Nursery in 1969. Ample seed remains for further sowing.

A 10-replicate lattice-square design was used for planting in north-central Saskatchewan in June 1969. Container-grown seedlings were used. Survival level appeared marginal in September. The site may be replanted when the seedlings sown in 1969 are of adequate size.

RUSSIAN SCOTS PINE PROVENANCE EXPERIMENT

Two Manitoba plantings of this cooperative experiment, planted in 1960, were measured in 1969. Kiev, Voronezh, and Orlov provenances had the best height, the more northerly central-Russian provenances were intermediate, while the eastern group of populations (52°E and greater) were the shortest. Height differences among populations, and current plot stocking, were greater at Piney (eastern Manitoba) than at Carberry (southwestern Manitoba). Mortality has been light at both plantings in recent years; the major portion of the mortality occurred in the second summer after planting.

At Piney, the root-collar weevil (*Hylobius radicis* Buch.) and globose gall rust (*Endocronartium harknessii* (J.P. Moore) Hiratsuka) are currently causing minor losses. Infected trees were cut in an attempt to control the latter problem. White pine weevil (*Pissodes strobi* (Peck) damage is far more serious. Few trees in the planting appear to have escaped attack. Frequency of attack was found to vary among populations and to be inversely related to height. This result is contrary to the usual pattern in eastern white pine, and bears further investigation.

At Carberry there was little evidence of root-collar weevil, globose gall rust, or white pine weevil. Few dead trees were found, but many trees present in 1965, the previous examination, were absent. Theft of trees in this planting has apparently been occurring for the past several years. A number of trees were removed between May and July of 1969, indicating that this problem islikely to continue. This planting is, however, the only test of its kind in the area and can continue to be of some use despite a certain loss of accuracy.

A report on the 1969 measurement is in preparation.

RESULT OF A PROJECT FOR BREEDING POPLAR CULTIVARS FOR MANITOBA

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"In countries such as ours, the only hope of forestry is in growing timber rapidly" A. Henry, 1910

INTRODUCTION

In the summer of 1970 the Winnipeg Forest Research Laboratory was closed because "various services to which the Department had become committed are somewhat too costly to be supported in toto in a period of austerity" (Hon. J. Davis, 1970). Unfortunately, the project titled "Breeding poplars for Canadian Plains area" was discontinued.

The project commenced in 1965 and intensive research has been carried out on the poplar cultivars in use in the prairie regions. Results will be recorded in this paper for future reference.

In the prairies, poplar cultivars are planted for protection against soil erosion, drought and wind and for aesthetic reasons in recreational areas. Poplar timber produced on non-agricultural lands of the prairies contributes raw materials for pulp, veneer and lumber.

Most of the poplar hybrids in eastern North America were developed by the Oxford Paper Company of Rumford, Maine; in the Great Plains by the Department of Agriculture Station at Morden, Man.; and by the Prairie Farm Rehabilitation Administration Nursery at Indian Head, Sask.; or by the late F.L. Skinner, Dropmore, Man. Besides the artificially produced hybrids, ortets of numerous natural hybrids from open-pollinated poplar stands were and are used as clones by these agencies.

At Indian Head, a clone-bank of some of these hybrids was established to meet the demands of tree planters in the Great Plains. Dr. W.R. Cram, head of the Indian Head Forest Tree Nursery, suggested in 1964 that an extensive regional test might be advisable in Manitoba to parallel the test plantings in Saskatchewan, undertaken by the provincial Department of Natural Resources. Screening of poplar cultivars in current use in Manitoba and Saskatchewan is based mostly upon the material grown at Indian Head.

In 1965, when this project was initiated by the author, it became evident that many of the cultivars in use were poorly defined as to their origin and identification. Therefore work was begun with identification of morphological and phenological characteristics. This was followed by the evaluation of the characteristics listed in Table 1, then by the selection of the best adapted clones. Finally, the production of new types by hybridization was initiated.

Both the cultivars and the native species i.e., aspen, balsam poplar, cottonwood and black poplar, offered attractive possibilities for genetic improvement. Substantial variation exists in traits related to ability to root from stem cutting, growth rate, branching habit, disease and frost resistance, and onset of winter dormancy. In support of the above program development, maturation and storage of pollen and seed were being investigated.

RESULTS

Identification of Cultivars

First the most commonly planted hybrid poplars were selected for taxonomic identification. The vegetative parts used in description were collected from test plantings established by the author in Manitoba. Since all of the cultivars were of the same age and had been grown under similar conditions, they provided comparable data for vegetative descriptions. Cultivars usually reach maturity in their vegetative parts at approximately 4 or 5 years of age. For sex determinations, reproductive branches were secured from Dropmore, Man. and Mortlach and Indian Head, Sask.

Branch habit, bark, long shoots, vegetative and sexual buds, leaves and, if available, inflorescences, were used for identification. A "Guide to Identification of Selected Cultivars in the Prairie Regions" will be published. Data from the key, enclosed in the Guide, elucidate several characteristics of the cultivars which have not been described before.

Table 1 indicates that the majority of cultivars are male. The early poplar breeders in the prairie regions selected male clones rather than female for the need of farmers. When ripening, the fluffy cotton-like fruit of female trees falls to the ground and becomes quite bothersome in the upkeep of the farmyard.

Offspring of balsam poplar were used by the early poplar breeders for selection in most cases from stands and groups of trees where balsam poplar grew with lanceleaf cottonwood, *Populus acuminata* Rydb., narrowleaf cottonwood, *P. angustifolia* James, black cottonwood, *P. trichocarpa* Torr. & Gray, and plains cottonwood, *P. Sargentii* Dode. These species, with the exception of the plains cottonwood, grow in natural stands in western Alberta and in northwestern United States. This suggests that cultivars which have close morphological or phenotypical similarity in leaf shape and inflorescence with these species, likely originated in the hybrid swarms of Alberta and Montana, e.g., the 'Brooks', 'Dunlop', 'Volunteer' and 'Wheeler' poplars. However, 'Brooks' and 'Dunlop' poplars have male and female forms in the provincial plantation at Mortlach. The male and female trees are morphologically identical for both cultivars. The trees were planted from 1945 to 1960 and labelled by R.H. Dunlop.

The preceding cultivars exhibit definite morphological characteristics of balsam poplar, but the 'FNS #44-52' clone appears to be a cottonwood phenotype without any marks of introgression with balsam poplar. The leaves resemble those of narrowleaf cottonwood. However, the inflorescence, rhytidom, vegetative and reproductive bud and habit of the clone are identical to those of plains cottonwood.

The 'Cordeniensis' poplar (misspelled by several authors as cardeniensis and cardienensis) is assumed to be a close relative of *P. tristis* Fish., both having yellow mottled young shoots, similar leaf shape and branchy habit. 'Cordeniensis' was introduced into the prairies by the Morden nursery in the forties. The ortet originated from the Agricultural Station at Ottawa. Unfortunatley, the species origin of this clone was not recorded there, and accurate identification is not available. Its morphology leaves no doubt, however, that it belongs to the Tacamahaca group.

It was found that *P.* x *Berolinensis* and *P.* x *Petrowskyana*, both distributed from Indian Head, are male clones and show close similarity in taxonomic characteristics. Their common origin is reported by several authors (Rehder, Manual 1950; Borsdorf, Züchter 35:327-335. 1965; FAO, Publ. No. 12, 1958). Borsdorf, on the basis of his broad investigations, states that Petrowskyana is a female hybrid of *P. laurifolia* with *P. nigra* var. *Italica*. Therefore the identity of Petrowskyana grown at Indian Head appears to be dubious. Supposedly, the clone in question is a *Berolinensis* rather than an authentic Petrowskyana. Whatever its identity, this clone has demonstrated higher frost tolerance than typical Berolinensis in the test plantings established in Manitoba from 1965 to 1970.

Several other Berolinensis-type hybrids, very susceptible to *Septoria musiva* Pk., occur in the prairies under the name of 'Russian poplars'. At Mortlach, female and male clones of 'Russian poplars' were detected in the provincial plantation. Probably, the female clone represents *P.* x *Petrowskyana* if one accepts Borsdorf's statement. On the other hand, these 'Russian poplars' might be *P.* x *Rasumowskyana* Schr., that originated from the same cross as *P.* x *Petrowskyana*, or they might be clonal hybrids of the female *P. Maximowiczii* Henry with *P.* x *Berolinensis*. The latter was produced by Dr. E. Schreiner in 1934 for the Oxford Paper Company in Maine and proved to be susceptible to cankers (FAO 1958).

Many of the clones distributed from the Skinner Garden are named as *P. Songarica* with Anon. author. Some stem cuttings were introduced into Manitoba by Skinner from Kew, England in 1947, after which the cuttings from the introduced ortets were widely distributed over the prairie regions. Skinner had identified the clone as *P. songarica* which originated from Asia. As for the author's correspondence with the Royal Botanic Garden, at Kew, the name *P. "Songarica"* appears to be invalid. The parent trees of Skinner's ortet at Kew were obtained from Dode in 1903 and according to J.R. Sealy, who examined the tree at Kew in 1965, this name cannot be traced; the herbarium notes at Kew (H.0950/61) state that "the plant is a form of *P. nigra* between the glabrous variety *nigra* and the hairy variety *'betulifolia'*." The male ortet growing in the Skinner Garden has a desirable phenotype, and therefore is promising material for breeding. It is one of the most worthwhile clones in Manitoba, having good growth rate, nice form and excellent rooting ability; it produces highly viable pollen which is compatible with the female of any poplar - species and cultivars - growing in the prairies and induces exceptionally sound seed. Cross-breeding of this clone with cottonwood of extreme northern provenance is highly recommended.

Test Plantings

Before any breeding work with poplars was done, it was considered best to test the local cultivars of the prairie regions for pest resistances, frost tolerance, growth rate and habit. Also assessed were the dates of bud burst, height growth cessation, and time of leaf drop.

Successful introductions of species and cultivars in Manitoba during the 5-year period commencing in the spring of 1965 are listed in Table 1. More cultivars and natural hybrids from various sources were tested, but failed to survive the climate, e.g., *P.* x *euramericana* clones from Maple, Ont. and Schmalenbeck, West Germany; natural hybrids of *P. laurifolia*, (*P. monilifera* x *P. balsamifera*) x ?, *P.* x *Scherill* from Wooster, Ohio. These hybrid plants sustained winter injury in the first year of introduction, and died back the following summer.

A total of 5 acres of test plantings was established in different areas of Manitoba with about 4,000 rooted cuttings of the successful hybrids and species, using various spacings and different arrangements of randomized blocks.

The case history of the test plantings was presented in an internal report of the Winnipeg Laboratory (MS-101, 1969). A complete report on pest resistance of the cultivars in use was given by H. Zalasky *et al.* (Plant Disease Reporter, 52(11), 1968).

To provide a broader basis for the rating of cultivars in use, information was collected from other tests of the same cultivars set out in several areas of Saskatchewan and Manitoba since the early forties. Observations on frost tolerance, growth rate and habit, and suggestions for further utilization are given in Table 1.

The following general comments may be helpful to those who intend to work with the material tested.

Data obtained in various test plantings, located in different areas of Manitoba, show variability of phenological characteristics within cultivars due to differing climatic conditions in successive years, and among test planting locations.

Most of the cultivars grow better in the south than in the north. From north to south they exhibit a definite increase in height growth and pest resistance. However, 'Cordeniensis' and *P.* x *Petrowskyana* do not indicate differences in growth rate and pest resistance in the northern and southern plantations. Otherwise, it was found that cultivars belonging to the same taxonomic groups (sections) exhibit similar tendencies across planting sites in habit, pest resistance, rooting ability and tolerance of soil deficiencies. Correlation between date of leaf fall and frost hardiness suggests a slight possibility of dieback following winter frost for cultivars which shed leaves in the late fall, e.g., 'FNS #44-52' and *P.* x *euramericana*, 'Gelrica'.

Observations on pest resistance (Table 1) are confirmed by Zalasky's statement (1968): "None of the introduced clones and cultivars tested can be considered immune to infection by either *D. tumefaciens* or *S. musiva*. However, we were able to find clones with some degree of tolerance to both organisms."

There is little evidence of natural pruning among the tested cultivars. Their trunks are usually covered from the ground upward with branches or even limbs, which grow either horizontally or vertically. The branching habit within a clone is identical under various climatic conditions and indicates strong genetic control of this character. However, several cultivars, such as 'FNS #44-52' and 'Brooks', have relatively fine, flexible, twigs on their trunk, can be pruned easier and heal the wounds faster than the others. These cultivars are potentially useful for industrial plantations (Table 1).

<u>Hybridization</u>

The purpose of control-pollination was to produce new crosses valuable for farmstead and amenity plantations, and for reforestation on marginal and nonagricultural lands. Nevertheless, it was considered necessary to back-cross also in order to clarify the probable origin of several cultivars.

Fifty different cross-combinations of 18 species and hybrids were attempted. Beyond the cultivars listed in Table 1, four aspen, three cottonwood, two balsam poplars and eight *P.* x *monilifera* (Ait.) x *P.* x *tacamahaca* Mill. female clones from the Skinner Garden were secured.

Sexual branches were collected from different regions of Saskatchewan and Manitoba in February. February appears to be the most suitable period for collecting branches for control-pollination. Branches collected earlier than February usually dropped their catkins before seed maturation. Clean water was used to support the development of flowering and seed maturation. More than 4,000 hybrid seedlings were raised in the greenhouse and nursery bed. Seedlings suffered heavy losses in the greenhouse from red spiders. Seedlings of aspen origin, especially in cases of female parentage, were most commonly affected. A large number of young seedlings was killed by top damping-off also.

It was found that flowers taken from young female aspen trees (age about 20 years) easily produce sound hybrid seeds with cottonwood and balsam poplar under favorable conditions; i.e., moderate relative humidity (70%), about 60-65°F temperature and regular changing of water in the jars. Surviving seedlings exhibited great variability in growth rate and resistance to leaf pests, providing an opportunity for selection. However, tests for rooting ability of aspen hybrid have not been carried out so far because the seedlings obtained are in an early stage of development.

Table 1. List of Poplar Cultivars Introduced to Manitoba from 1965 until 1969

Name or Parentage (and Sex)	Introduced from	Used for Cross	1. Pest Reaction 2. Frost Tolerance 3. Growth Rate 4. Habit	Suggestions
P. alba L.	Italy CSSR Hungary Poland	No	1. No canker infection; susceptible to leaf pest 2. Tolerant 3. Slow 4. Long bole	Test, cross-breeding.
P. canescens (Ait.) Sm.	CSSR Hungary Poland	No	1. Same as *P. alba* 2. Tolerant 3. Slow 4. Long bole	Test, cross-breeding
P. tomentosa Carr.	Poland	No	1. Same as *P. alba* 2. Tolerant 3. Slow 4. Short bole	Demonstration.
P. canescens (Ait.) Sm. x *P. tremuloides* (Michx.)	Appleton, Wisconsin	No	1. No infection 2. Tolerant 3. Slow 4. Short trunk	Test.
P. alba L. x *P. grandidentata* Michx. (♂)	Orangeville, Ontario	No	1. No infection 2. Tolerant 3. Moderate 4. Long bole	Test for industrial plantations in south, amenity.
P. nigra L. var. *betulifolia* (Purh.) Torr., 'Songarica' (♂)	Kew, England	Yes	1. Moderately susceptible *D. tumefaciens* and *S. musiva* 2. Tolerant 3. Fast 4. Long bole	Test for industrial plantations, cross-breeding amenity.
P. x *euramericana* (Dode) Guinier, 'I 45/31' (♂)	Casale Monferrato, Italy	No	1. Susceptible leaf pests 2. Not tolerant 3. Very fast 4. Long bole	Test, cross-breeding for frost tolerance.
P. x *euramericana* (Dode) Guinier, 'Gelrica' (♂)	Indian Head, Sask.	No	1. Highly susceptible *S. musiva*, less susceptible *D. tumefaciens* 2. Not tolerant 3. Moderate 4. Divided into suckers	Amenity, demonstration.

Table 1. (continued)

Name or Parentage (and Sex)	Introduced from	Used for Cross	1. Pest Reaction 2. Frost Tolerance 3. Growth Rate 4. Habit	Suggestions
P. x *euramerica* (Dode) Guinier, 'Vernirubens' (♂)	Indian Head, Sask.	No	1. Less susceptible *D. tumefaciens* very susceptible *S. musiva* 2. Tolerant 3. Fast 4. Divided into suckers	Amenity, demonstration or discard.
P. x *deltoides* Marsh., 'FNS #44-52' (♀)	Indian Head, Sask.	Yes	1. Less susceptible *D. tumefaciens* and *S. musiva* 3. Very fast 4. Long bole	Test for industrial plantations, cross-breeding amenity.
P. x *deltoides* Marsh., 'Northwest' (♂)	Indian Head, Sask.	Yes	1. Less susceptible *D. tumefaciens* and *S. musiva* 2. Tolerant 3. Moderate 4. Long bole	Cross-breeding, amenity.
P. tristis Fish. (♂)	Kew, England	Yes	1. Susceptible *D. tumefaciens* and *S. musiva* 2. Tolerant 3. Moderate 4. Short trunk	Cross-breeding for pest resistance.
P. x *Berolinensis* Dipp. (♂)	Indian Head, Sask.	No	1. Less susceptible *D. tumefaciens*, strong *S. musiva* 2. Not tolerant 3. Moderate 4. Short trunk	Amenity, demonstration or discard
P. x *Petrowskyana* Schn. (♂)	Indian Head, Sask.	No	1. Moderately susceptible *S. musiva* and *D. tumefaciens* 2. Tolerant 3. Fast 4. Divided into suckers	Cross-breeding for long bole
P. x *tacamahaca* Mill., 'Brooks' (♂)	Brooks, Alberta	Yes	1. Susceptible *S. musiva*, less *D. tumefaciens* 2. Tolerant 3. Fast 4. Long bole	Test for industrial plantations, cross-breeding.
P. x *tacamahaca* Mill., 'Cordeniensis' (♂)	Indian Head, Sask.	No	1. Highly susceptible *S. musiva*, moderately susceptible *D. tumefaciens* 2. Moderately tolerant 3. Very fast 4. Forky trunk from base.	Demonstration or discard.

Table 1. (concluded)

Name or Parentage (and Sex)	Introduced from	Used for Cross	1. Pest Reaction 2. Frost Tolerance 3. Growth Rate 4. Habit	Suggestions
P. tacamahaca Mill., 'Dunlop' (♀) and (♂) clones	Mortlach, Sask.	Yes	1. Less susceptible *D. tumefaciens* 2. Tolerant 3. Fast 4. Long bole, dense vertical branches	Cross-breeding for shape (fastigiate), amenity.
P. tacamahaca Mill., 'Saskatchewan' (♂)	Indian Head, Sask.	Yes	1. Highly susceptible *S. musiva* and moderately *D. tumefaciens* 2. Tolerant 3. Moderate 4. Short trunk	Discard.
P. tacamahaca Mill., 'Volunteer' (♀)	Indian Head, Sask.	No	1. Moderately susceptible *S. musiva* and *D. tumefaciens* 2. Tolerant 3. Fast 4. Forky stems	Amenity or discard.
P. tacamahaca Mill., 'Wheeler' (♂)	Indian Head, Sask.	Yes	1. Highly susceptible *S. musiva* and moderately *D. tumefaciens* 2. Not tolerant 3. Moderate 4. Forky stems, dense suckers	Discard

After a preliminary selection of hybrid seedling populations based on growth-rate and resistance to leaf pests, the following new hybrids were retained for further tests:

P. tacamahaca	x *P.* x *deltoides* Marsh., 'Northwest'
	x *P. tristis* Fish.
	x *P. nigra* L. var. *betulifolia* (Purh.) Torr.
P. tacamahaca Mill., 'Russian'	x *P. tremuloides* Michx.
	x *P.* x *tacamahaca* Mill., 'Dunlop'
P. trichocarpa Torr. and Gray	x *P. tacamahaca* Mill.
P. tremuloides Michx.	x *P. tristis* Fish.
	x (*P. monilifera* Ait. x *P. nigra* L. var. *betulifolia* (Purh.) Torr.)
P. monilifera Ait.	x *P. deltoides* Marsh.
	x *P. nigra* L. var. *betulifolia* (Purh.) Torr.
(*P. monilifera* Ait. x *P. tacamahaca* Mill.)	x *P. nigra* L. var. *betulifolia* (Purh.) Torr.
P. deltoides Marsh.	x *P. nigra* L. var. *betulifolia* (Purh.) Torr.
P. x *deltoides* Marsh., 'Brooks'	x *P. tremuloides* Michx.
P. deltoides Marsh., 'FNS #44-52'	x *P. tremuloides* Michx.
	x *P. nigra* var. *Italica* Muench.
	x *P. nigra* L. var. *betulifolia* (Purh.) Torr.
	x *P.* x *deltoides* Marsh. 'Northwest'

Many of the new hybrids appear promising because they surpassed their parents, at least during the first year of their life, in rate of growth, habit and resistance to bark and leaf diseases. Seedlings obtained by means of multi-clonal crosses are extremely heterogeneous in appearance, growth rate and resistance to leaf pests. Nevertheless, the number of seedlings that survived is not large enough to judge their genetic potential.

The best hybrids on account of their early growth rate were the hybrids of *P. deltoides* Marsh. x *P. nigra* L. var. *betulifolia* (Purh.) Torr. and *P. tremuloides* Michx. x *P. tristis* Fish.

The author is convinced that the results from this project improved the planting stock of poplar cultivars in use and provides useful suggestions for more successful plantations and further research in the prairie regions. Continued demand for poplars for shelterbelt, amenity and industrial use in Manitoba and Saskatchewan suggests that there is economic justification for continuation and development of this program.

ACKNOWLEDGMENT

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SHELTERBELT TREE BREEDING

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The tree breeding program has been drastically curtailed, due to the transfer of Dr. Cram to administrative duties. Investigational staff have been assigned for solving nursery production problems. A brief summary of present breeding activities by species is presented.

Ulmus pumila

Field and greenhouse sowings of 3 years have indicated that the Siberian elm carries a lethal seedling character. It has not been established whether or not this is a genetical factor or if it is caused by some environmental condition. The affected seedlings develop tube-like cotyledons, a characteristic tentatively designated as 'fused cotyledons'. Terminal bud development is obstructed and the 'fused' seedlings fail shortly after germination. A study, involving germination of open-pollinated seed of 127 progenies, indicated that 29 trees did not produce any seedlings with 'fused' cotyledons, 67 trees produced from 1 to 20%, 31 trees produced over 21%, and all seedlings of one tree had 'fused' cotyledons. Losses occurring in production fields from this character have averaged 15% of the emerged seedlings.

Picea pungens

A program was initiated in 1954 with the objective of mass-producing 'blue' needled trees for farm shelterbelts. Segregation for needle color is being continued for hybrid progenies, which were field planted in 1963 and 1965. A severe frost in the spring of 1969 damaged most new growth and made evaluation impossible. One hybrid combination, PC6 x RC1, appears promising and has produced 78% blue and 22% green progeny. Previous studies have indicated that 10 to 12 years of growth from seed are required before needle color stabilizes.

Caragana Species

The breeding program for *Caragana arborescens* L. has been relegated to a holding capacity due to pressure of other work. Hybrid seed from a 1959 natural crossing block, consisting of adjacent rows of one self-incompatible (A1) and one self-compatible (B5-1A) clone, has proven satisfactory. Progeny from this cross are being included in regional performance trials. Work is also in progress to study the suckering habit of *Caragana frutex*.

Populus Hybrids

One selection (P7-22), from a cross of the cultivars 'FNS #44-52' x 'Saskatchewan' has demonstrated superior vigor and low susceptibility to septoria canker. This selection is being propagated to establish cutting material for regional trials. A program to evaluate clonal performance of poplars by regional plantings was initiated in 1965. Interim results favor eight poplar clones (cultivars): '44-52', 'Cordeniensis', 'Vernirubens', 'Gelrica', 'B.L. #3', 'Brooks #1', '38P38' and 'Volunteer'.

Pinus sylvestris

A provenance planting of 11 sources was established in 1959 in co-operation with Mr. M. Holst of the Canadian Department of Forestry. The most vigorous provenances were from Kiew, Orel, Woronesh and Molotow in Russia, which were significantly taller than the planting mean and exhibited superior needle color. Ranking by height indicated that plants assume relative vigor for mature trees in about 8 years. A seed orchard has been started by grafting the Kiew and Orel strains.

Pinus ponderosa

A cooperative provenance study, consisting of 80 seed sources, was initiated in 1966 with the U.S.D.A. Forest Service. Seedlings from a California source failed to survive the first winter in the seedbed; field survival of New Mexico and Arizona sources was poor. Survival of 1967 transplants in 1968 was inferior to *P. sylvestris*, but exceeded that for *P. pungens* and *P. glauca*. Interim evaluations of 1968 field test plantings will be made in 1973.

Eleagnus angustifolia

A provenance planting was established in 1969 consisting of seed from the 33 most vigorous Russian selections growing at the Cheyenne Horticultural Station in Wyoming, U.S.A. Survival was 84%, and one progeny (D833) appears most vigorous.

A SIMPLE DISTRIBUTION PATTERN FOR SEED WEIGHT IN WHITE SPRUCE FROM ALBERTA

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ABSTRACT

Seed weight in white spruce (*Picea glauca* (Moench) Voss) varies with latitude in Alberta. Three zones were established: 49°-53°N, 53°-57°N, and 57°- 60°N, based on seed collected from 116 locations well distributed over the Province. Seeds from the central zone were by and large the lightest (1.99 mg/seed) while those from the other zones were 2.26 and 2.20 mg/seed respectively. Reasons for this zonation were not established.

INTRODUCTION

It is well-known that seed size is positively correlated with seedling height during the first years of growth in *Picea glauca* (Moench) Voss (Burgar 1964). This information is not utilized generally in reforestation because seed weight is very variable. It changes from year to year within stands, within trees, and within tree crowns, and the positive influence of seed weight (or size) also diminishes with time, disappearing as an effect on seedling size five or more years after germination. If it could be shown that seed weight also varies by geographic region or zone irrespective of year, the seed weight parameter might become more useful when selecting seed.

It is the purpose of this study to determine if seed weight in *P. glauca* varies by geographic zone in Alberta, or if external influences on the tree make it impossible to establish boundaries for seed collection purposes. A secondary purpose is to draw attention to the potential value of seed weight as an important factor in early seedling growth in *P. glauca*.

METHODS

A total of 116 samples of seed were collected for or by the Alberta Forest Service from several trees per location between 1959 and 1968 throughout Alberta (Fig. 1). All seeds were cold-stored before weighing in 1969. The samples contained 5% empty and partly filled seeds and between 4% and 8% moisture when weighed. Two thousand seeds were weighed, in two batches of 1,000 seeds, to establish average sample weights.

Correlation analyses were made between seed weight and the following factors: latitude and altitude of sample, frost-free period (Longley 1965),

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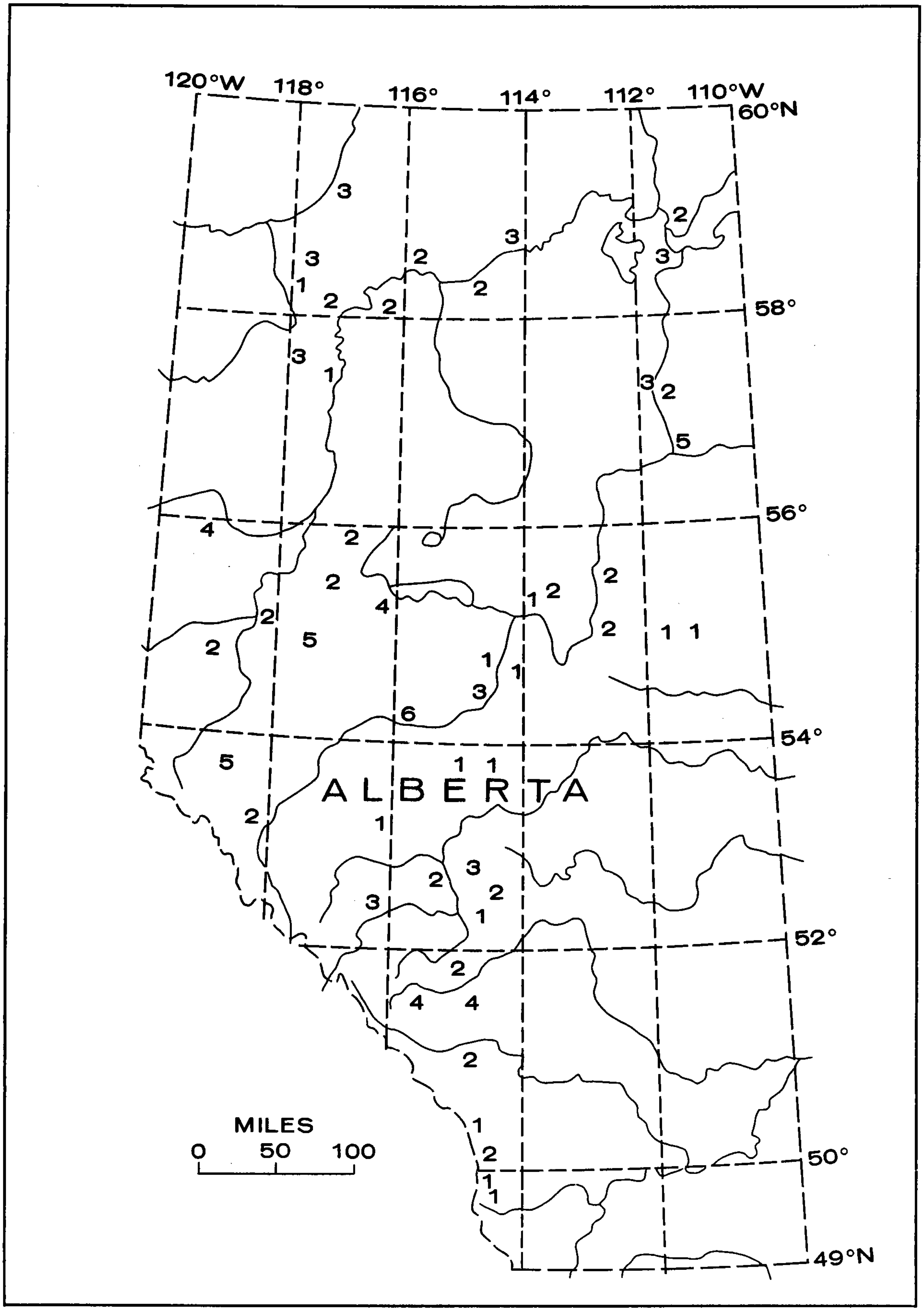

Figure 1. Map of Alberta with approximate locations of seed samples. Numbers indicate the number of seed samples collected per location. Each sample includes seed from several trees.

precipitation between 1 May and 30 September, mean daily temperature for July and August, and mean number of degree-days above 42 F from 1 May through 30 September (McKay 1965), using long-term averages of climatic data.

RESULTS

Among all the variables tested which might influence seed weight in *P. glauca*, only latitude proved significant. Alberta can arbitrarily be divided into three zones on the basis of the 116 samples. These zones have the following boundaries: 49°-53°N, 53°-57°N, and 57°-60°N. This zonation gives least internal variation of numerable groupings tested. The boundaries were established with a one-in-a-thousand chance of error based on "t" tests (Table 1). The seeds from the central zone were significantly lighter (1.99 mg/seed) than those from the northern (2.20 mg/seed) and southern (2.26 mg/seed) zones. Trees in both the northern and southern zones produced seeds of comparable weight.

The central zone has the longest frost-free season of the three and data on degree-days also suggest, if anything, that it is slightly warmer than the other two zones. In contrast, both July and August mean daily temperatures and precipitation data are similar for all three zones based on the sample locations in question. The average altitude of the samples from south to north is: 4,460 feet, 2,410 feet, and 1,050 feet above sea level.

Table 1. Tests of differences among seed samples grouped into three latitudinal zones. Unequal sample sizes have been accounted for.

Seed Weight Zones (latitude N)	Sample Size N	Seed Weight: Range (mg/seed)	Seed Weight: Mean and Standard Error (mg)	"t"-Tests (adjacent zones)	"t"-Tests (49°-53° vs 57°-60°)
49° - 53°	28	1.9 - 2.7	2.26 ± 0.17	6.2*** (49°-53° vs 53°-57°)	0.9 N.S.
53° - 57°	56	1.4 - 2.5	1.99 ± 0.05	5.2*** (53°-57° vs 57°-60°)	
57° - 60°	32	1.8 - 2.6	2.20 ± 0.08		

*** - significant at 99.9% level of confidence.

N.S.- not significant even at the 90% level of confidence.

DISCUSSION

Attempts to link climatic data to seed weight failed to establish significant boundaries. The central zone, between 53°N and 57°N, with the most favorable climate as defined by the measures listed above, might have been expected to support trees with heaviest seeds, but the opposite was the case. This study was therefore not successful in identifying an optimum climate for production of heavy seeds in *P. glauca*. The conclusion that seed weight varies by latitude in Alberta for *P. glauca* is strengthened by the facts that the seeds were collected from a relatively large number of locations, from over a 10-year period, and from many trees per location.

An interpolation was made of Burgar's data (1964) on the correlation between seeds per pound and seedling height 65 days after germination. The seeds from the central zone in the present study might, by Burgar's data, be expected to produce seedlings which are 10% shorter than those from the northern or southern zones. A maximum 10% difference in growth for *P. glauca* seedlings from the various zones is of practical significance for survival (Burgar 1964) even if it has so far only been demonstrated for the first year of growth.

Foresters might pay heed to the proposed zones of latitude when rearing seedlings and collecting seeds from *P. glauca* in Alberta. Significant differences are to be expected among zones in both survival and growth of seedlings on the basis of seed weight differences.

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AN APPROACH TO THE IMPROVEMENT OF THE WHITE-AND-ENGELMANN SPRUCE COMPLEXES OF BRITISH COLUMBIA

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OUTLINE OF PROGRAM

The main objective of this project is the production of genetically improved seed of white-and Engelmann spruces (*Picea glauca* (Moench) Voss and *P. engelmannii* Parry respectively) in commercial quantities at the earliest possible date. The schedule followed in order to achieve this goal is as follows:

1. Selection of candidate trees within artificially designated areas where the climatic conditions are considered to be relatively equal. Phenotypic characteristics are used as criteria for selection.

2. Establishment of the candidate trees in seed orchards by way of vegetative propagation.

3. Half-sib progeny trials using seed collected from selected trees.

4. Genetic selection of plus trees based on the results of the progeny trials.

5. Selective breeding and full-sib progeny trials.

6. Selection within the half- and full-sib progenies for candidates at the next level of improvement.

7. Interspecific hybridization and testing the performance of resulting hybrids.

8. Investigation of various climatic zones and soil types in order to establish the most productive location for the seed orchards.

PROGRESS TO DATE

Selection within two of the designated areas has been completed in 1968 and 1969 and is presently in progress within the third one. One hundred seventy-five trees were selected near Prince George. Most of these trees have been successfully established in a clone bank at Red Rock by grafting. Seedlings for the progeny trials are in their second year at the Red Rock Research Nursery.

One hundred thirty-two trees were selected in the East Kootenay region of British Columbia, most of which were also successfully grafted. Seeds will be collected from these selected trees as soon as there is an appreciable crop.

The third area presently being selected is located about 250 miles West of Prince George in the Smithers area.

NOTES OF INTEREST

Fall grafting in the greenhouse appeared far superior to spring field or greenhouse grafting. Some of the fall-grafted ramets grew as much as 6 inches during the winter.

A number of the fall-grafted scions possessed flower buds at the time of grafting. These developed into normal cones and some, pollinated artificially, produced viable seeds.

Several clones grafted in the spring of 1969 exhibited flowers in the spring 1970. Most of these flowers were males.

GEOGRAPHIC VARIATION IN PINUS CONTORTA

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This study arose from a consideration of the potentialities for improved yields of lodgepole pine through both breeding and racial selection. It was commenced in 1967, when, in cooperation with an IUFRO cone collection party, a range-wide collection of cones, seed, foliage and increment cores was assembled (Fig. 1). Details of sampling design, collection procedures and general methodology have been published (Illingworth 1969, 1970).

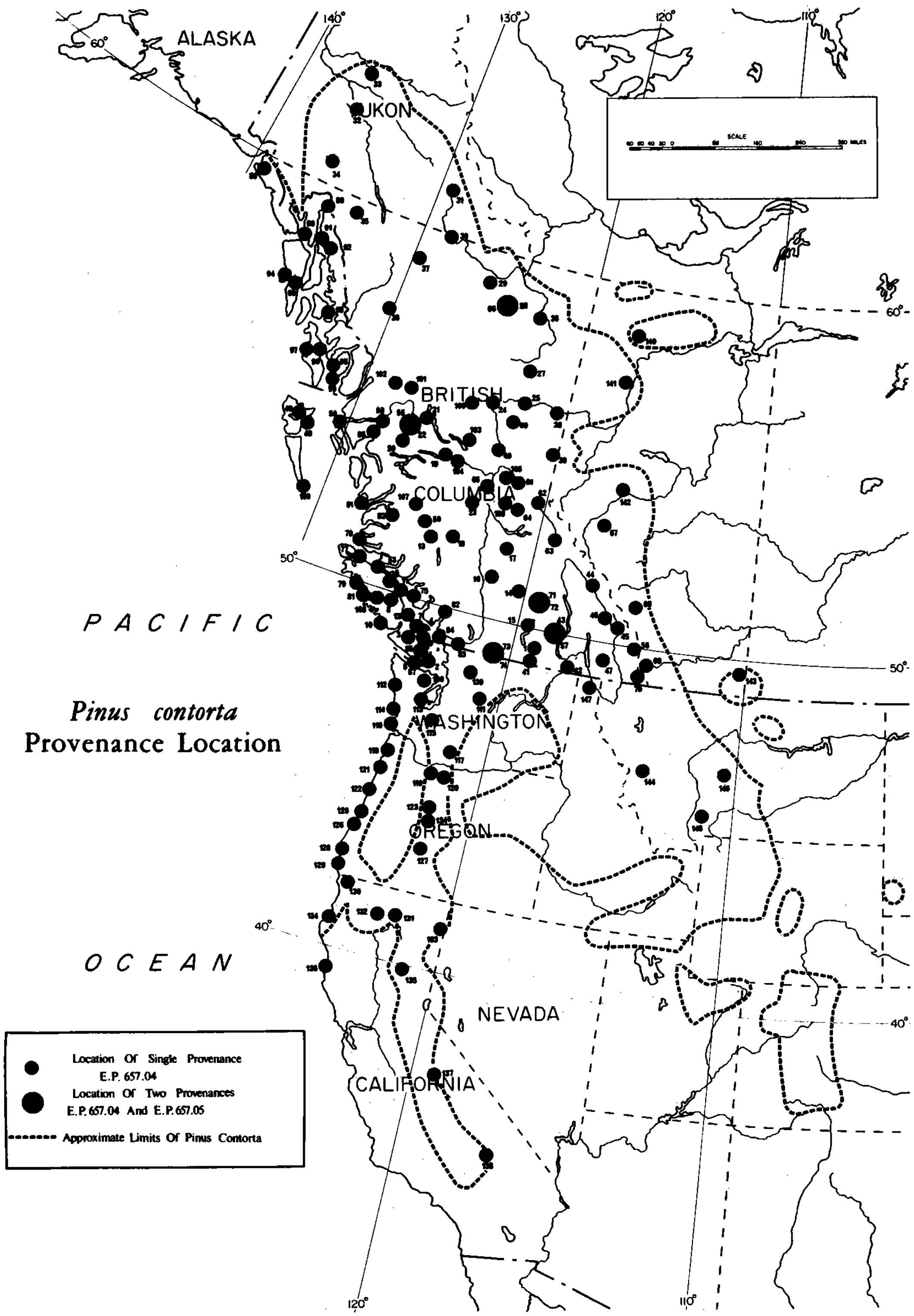
The project comprises several studies, collectively designed to: (1) define broad patterns of geographic variation; (2) locate populations outstanding in some desired trait, e.g. vigor, form, wide ecological adaptability; (3) establish criteria for provenance transfer for reforestation purposes; (4) provide material for a germ plasm bank and breeding arboretum.

To facilitate the design and subsequent interpretation of long-term field tests, initial efforts are concentrated on objective 1. This is being approached through (a) morphometric analysis of a mass collection of cones and foliage, (b) comparative cultivation of provenances in two geographically distant nurseries.

In May 1969, following a year's preliminary observation of the growth behavior of thirty provenances, three replications of 144 provenances (E.P. 657.04) were sown in research nurseries at Red Rock (53°45' N., 122° 42' W.) and Cowichan Lake (48°49' N., 124°08' W.). To interpret within-provenance variation, a supplementary series of 147 half-sib families from two elevations at each of five latitudes was sown in a similar design (E.P. 657.05). Data relating to these sowings include seed weight and embryo development, germination pattern, seedling morphology and phenological aspects of growth. At the time of writing this report, data are still being collected and results analysed.

To meet objective 4, trees from these sowings will be selected in 1972 for inclusion in a 160-acre breeding arboretum, currently being prepared near Red Rock. Additional selections will be made among four replications of 645 wind-pollinated families representing 43 Canadian provenances, and sown specifically for this purpose in 1969 at Red Rock. To accommodate frost tender provenances from south coastal regions, the establishment of a subsidiary germ plasm bank at a coastal locale has been proposed.

Breeding arboreta will also include clonal material. Rootstock has been prepared to receive, in 1970, scions from some 71 lodgepole pine plus trees; to be selected north of latitude 56 by representatives of Swedish Cellulose Company through the cooperation of the British Columbia Forest Service.


ALASKA
YUKON
BRITISH
COLUMBIA
WASHINGTON
OREGON
NEVADA
CALIFORNIA
PACIFIC
OCEAN
Pinus contorta
Provenance Location
Location Of Single Provenance
E.P. 657.04
Location Of Two Provenances
E.P. 657.04 And E.P. 657.05
Approximate Limits Of Pinus Contorta
SCALE
60°
50°
40°
140°
130°
120°
110°

REFERENCES

Illingworth, K. 1969. E.P. 657-Variation in *Pinus contorta* with particular reference to British Columbia. Forest Res. Rev. year ended March, 1969. p. 42-46.

Illingworth, K. 1970. E.P. 657-Variation in *Pinus contorta* with particular reference to British Columbia. Forest Res. Rev. year ended March, 1970. (In press).

WESTERN HEMLOCK TREE IMPROVEMENT

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Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is second only to Douglas-fir in commercial importance in coastal British Columbia. There is an increasing demand for hemlock in the planting programs of the region. However, virtually nothing is known of the genetics of western hemlock. Consequently, during the summer of 1968, a tree improvement program was initiated for this species in cooperation with members of the Tree Improvement Board of the Tree Farm Forestry Committee.

The objectives of the program are 1) to determine the patterns and degree of natural variation of western hemlock populations; 2) to identify populations of superior genetic constitution with regard to volume growth, to test them on a crop basis over a range of environments; 3) to estimate the heritability of important traits such as height growth, form, budset and flushing; 4) to develop control-breeding techniques; and 5) to establish a clone bank and "half-sib" progeny test, designed to function as a breeding arboretum and seed orchard.

During the fall of 1968, many hemlock stands were inspected on Vancouver Island and the coastal mainland of British Columbia. These stands had been chosen by industrial foresters as above average for their respective areas with regards to growth rate and form. Of these, 12 "plus" stands were selected for sampling. In addition, four control stands were chosen in current logging or seed collection areas. Cones were collected from 10 trees in each of the 16 stands; cuttings were taken from all sampled trees of the 12 "plus" stands. The seeds were kept separate by parent tree.

Two approaches are being followed in the testing phase of the "plus" stands: 1) the testing of populations on a crop basis over a range of environments; and 2) the testing of half-sib progenies to obtain estimates of genetic variation and heritability. Seeds for both studies were sown in "bullet" planting containers during May 1969, and grown at the Victoria nursery.

POPULATION STUDY

Equal quantities of cleaned seed per tree were bulked on a stand basis. Approximately 8,000 seeds per population were sown, resulting in an average germination and seedling establishment of about 65%. A subsequent resowing (with changes in culture techniques aimed at improving germination conditions) resulted in an average of 80-85% seedling establishment. After the first growing season, 15% of the seedlings were assessed for height and 5% for diameter. These data are awaiting computer analysis; however, a preliminary analysis showed that some real differences did exist between populations. Several albino seedlings were detected and the parent was tentatively identified.

During the spring of 1970 the seedlings were transplanted into plug moulds, in which they will be grown for another year. They will then be planted in test plantations on forest industry lands.

HALF-SIB STUDY

Families included in this study are the same as those used in the bulked seedlots. Initially, 114 families were sown resulting in about 12,000 established seedlings. First-year height data were recorded for all seedlings and individual seedling identities will be maintained throughout the study. This sowing was repeated during the spring of 1970. Plans are to outplant the 2-year-old seedlings on a test site close to Victoria. In addition, a growth room study was initiated to obtain dry-matter production estimates on a family basis and to compare growth room with nursery performance.

ROOTING OF CUTTINGS

The cuttings collected in 1968 were incorporated into a rooting study conducted by Dr. H. Brix at the Victoria laboratory. Approximately 2,000 cuttings representing 120 clones were successfully rooted. Some clones have 40 or more ramets. In the spring of 1970, 70 rooted cuttings produced female strobili. This result is especially promising since the primordia were initiated in the rooting beds. The strobili were pollinated and are developing normally.

Although our first collections were limited to sampling stands within the more intensively managed forest areas of Vancouver Island and vicinity, we intend to expand our sampling program; possibly even to a range-wide one. Also, attempts will be made to select and propagate phenotypically superior trees during the population test period; the selections will be made in both the test plantations and natural stands. Thus, when the results of the population test appear conclusive, we hopefully will have superior, individual tree, breeding material established. Also, interim results should provide a basis for establishing seed production areas.

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

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

ACADEMIC PROGRAM

The forest genetics course offered to the third-year forestry students during spring term was taken by 19 and 26 students in 1968/69 and in 1969/70 respectively.

Three graduate students completed their program:

El-Lakany, H.M., Ph.D (1969), "Studies on the effect of ionizing radiation on some western coniferous species". 250 p.

Ho, R., M.Sc. (1968). Some observation on germination of *Pseudotsuga menziesii* pollen. 60 p.

Addison, J.W., M.F. (1968). Some factors affecting survival of planted Douglas-fir seedlings in the coastal forest of British Columbia. 136 p.

Presently Ho, Marshall and Meagher are in residence and working toward Ph.D degrees, while Kiss (Ph.D) and Yao (M.F.) are in absentia.

RESEARCH PROGRAM

In vitro studies of pollen germination included besides *Pseudotsuga, Larix, Tsuga* and *Pinus* genera. Four nucleate stage developments were recorded.

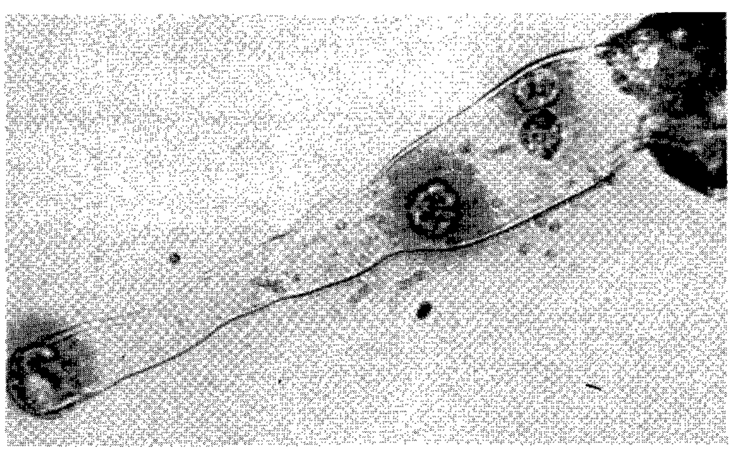

Figure 1. Growing pollen tube containing the tube cell, the stalk nucleus and the two sperm nuclei.

The Douglas-fir cone collection (IUFRO Section 22 project) now represents samples from 1,823 trees and 126 locations. Morphological studies on cone and seed characteristics are complete. Nuclear volume and DNA content studies are in progress.

Hybridization work in Douglas-fir was limited during the last 2 years due to the absence of flowering. Intra- and inter-specific crosses were attempted on western and mountain hemlock this year.

Data from 6-year-old progenies from complete diallel crosses of four Douglas-fir trees (A, B, E and 11) were analysed as described by Yates in 1947, using the model of self sterility without group incompatibility. The additive genetic component of height growth was consistently highest for tree 11, while the other three trees A, B and E differed significantly from 11 but not from each other.

TREE IMPROVEMENT

Four coastal companies (B.C. Forest Products, Crown Zellerbach, Rayonier and Tahsis) successfully completed intra-specific crosses on selected Douglas-fir clones in 1968. The 244 crosses provided 21,034 filled seeds. A cooperative progeny test representing 100 families will be planted out in four locations in a single-tree progeny test design during the spring of 1971.

The Fellowship in Forest Genetics ($5000 per year) was renewed by British Columbia Forest Products Ltd. for another 3-year period.

A PROVENANCE STUDY OF COASTAL DOUGLAS-FIR

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The objectives of this study (Experimental Project 599, see Schmidt 1969) are concerned with developing seed transfer rules for application in reforestation projects.

Fourteen test sites involving a total of 100 acres have been established in several coastal climatic zones in British Columbia between lat. 48°24' N and 52°23' N.

Seventy-seven coastal provenances were planted at three large test sites in different climates on southern Vancouver Island. At one of these test sites 11 additional provenances from the interior of British Columbia were included. It is anticipated that phenological assessments will be made at one of these test sites in 1970.

The remaining 11 test sites involve comparison of five provenances from contrasting climates plus one of local origin.

Establishment of additional test sites will continue for several years.

REFERENCE

Schmidt, R.L. 1969. E.P. 599 - A provenance study of coastal Douglas fir. Forest Res. Rev. year ended March, 1969. p. 37-38.

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

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SELECTION AND PROPAGATION

As was shown in the last report to this committee, the emphasis formerly placed on plus tree selection in coastal Douglas-fir has now been reduced in favor of work on evaluation, the production of improved seed and the concurrent research phases. Some industrial members of the Tree Improvement Subcommittee, the cooperative body involving industry, universith and federal and provincial forest services, have continued to submit candidates for inspection and registration. A further 21 trees have been accepted bringing the current total of coastal plus trees of Douglas-fir to 445.

Grafting has been discontinued on the B.C. Forest Service Clone Bank at Cowichan Lake but, with the help of Dr. H. Brix of the Canadian Forestry Service, attempts have been made to maintain the collection through rooting. Dr. Brix has developed rooting techniques which show considerable promise and these have also been applied at the experiment station. Graduate studies on the morphology of adventitious root initiation in mature Douglas-fir cuttings are also in progress.

A plan has been drawn up covering the initial phases of a second-generation selection procedure using progeny of crosses between plus trees. The clone bank at the Cowichan Lake Experiment Station is now well established and it is hoped that reproductive buds should be produced in the near future. When these do arise, the grafted clones will be used for controlled crossing between plus trees within eight broad provenance zones. The seedlings will be subjected to selection as they develop and will eventually provide a base population for future breeding work. Selection is planned at present to be based upon form and vigor, while phenology will also be considered. It is hoped in this way to advance the breeding population as a whole, and with an initial population of 445 trees the scale of a more intensive program cannot at present be undertaken. At this stage the plan calls for the selection of 48 seedlings per cross in the transplant stage and these will be planted within the fenced area on the experiment station. The area is relatively uniform and subjective selection of the individual genotypes is at present planned. Cross-pollinated seedlings have already been made available by Dr. A. Orr-Ewing from another project and as soon as a cone crop occurs, the crossing will be expanded.

SEED ORCHARD ESTABLISHMENT BY THE B.C. FOREST SERVICE

The production of improved seed, involving seed orchard establishment and maintenance, is at present the responsibility of the Reforestation Division of the B.C. Forest Service, with active cooperation by the Research Division. Three seed orchards of coastal Douglas-fir are at present in the process of establishment but, as yet, the productive stage has not been reached.

Ten acres of clonal seed-orchard remain at the Campbell River site and the remainder of the 16-acre field has been established as a seedling seed orchard, based on wind-pollinated progeny from the plus trees. Some 600 strong 1-0 seedlings were planted directly in 1968 and these have become well established. The remaining positions were planted in 1969. The older grafts were made in 1963 but although 800 female strobili were isolated in 1970 for controlled crossing, very little seed has yet been produced. Cross-pollinated seedlings from these clones will be used to expand the seedling portion of the orchard.

This first orchard is designed to produce seed suitable for the higher elevations on Vancouver Island.

A 10-acre seedling seed orchard, also based on wind-pollinated seedlings from plus trees, was planted in the spring of 1970 at Duncan. This will provide seed for the higher elevations on the lower mainland. A further 10-acre area is being selected and will be prepared for planting in 1971 for wind-pollinated material collected from plus trees of the more northern coastal area.

It is hoped that these initial orchards, based only on wind-pollinated material, will gradually be replaced or augmented with those in which material obtained by controlled crossing between plus trees is used.

The Reforestation Division also took an active part in the tree improvement program in 1969 and raised 60,000 seedlings in containers at the Duncan nursery. These came from the industrial cooperators of the Tree Improvement Subcommittee and represented 470 separate seed lots of controlled and wind-pollinated origin from the registered plus trees. Most of these will be used in a cooperative testing program being directed by Dr. O. Sziklai of the University of British Columbia, who acts as technical adviser to the Subcommittee. Other companies have test plans of their own.

BREEDING PSEUDOTSUGA IN BRITISH COLUMBIA

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INBREEDING STUDIES WITH DOUGLAS-FIR

A distinct segregation into dwarf and tall forms in two S_2 families of Douglas-fir was first observed in 1967; the details have been previously reported (Orr-Ewing 1969). Investigations into the occurrence of dwarfism are being continued in 1970, for example, backcrosses were made with the two S_1 parents and the ancestral (S_0) trees. In 1970, three seven-year-old S_2 inbreds from two families produced sufficient female and male strobili for some single crosses to be made.

INTRASPECIFIC CROSSES WITH DOUGLAS-FIR

Nineteen test sites have now been established on Vancouver Island and the lower mainland, some 37,786 seedlings having been planted since 1966. A further eight test sites will be established in 1971. No further intraspecific crosses will be made in the immediate future as the present objective will be to critically evaluate the crosses already made before proceeding to the next stage of the program. As is evident from Table 1, which summarises the range and elevations of the pollen parents used, sampling has been extensive in spite of difficulties in obtaining pollen.

Table 1. The Range and Elevations of the Pollen Parents Used in the 1963-68 Crosses

Province or State	Number of Parents	Ranges		
		N Lat	W Long	Feet Above Sea Level
British Columbia	11	49°03'-54°30'	117°08'-128°15'	200-3825
Alberta	1	51°06'	114°15'	3500
Washington	8	45°50'-48°05'	120°58'-124°01'	100-2500
Oregon	30	42°40'-44°45'	121°39'-123°45'	150-4400
California	9	37°55'-39°00'	120°41'-122°45'	1200-3900
New Mexico	1	36°20'	105°20'	9500
Arizona	2	33°54'	109°07'	9850
Mexico	3	29°10'	108°10'	7500

Survival examinations were made on all the 19 test sites in the autumn of 1969 and both total height and current growth were measured on those twelve established in 1969 and 1967. In spite of browsing and some disease, results have been generally satisfactory. On one test site, which was planted on the west coast of Vancouver Island in 1966 where five crosses had been made on the same local tree, the 6-year-old plants with an Oregon pollen parent had a 24% superiority in height over the average of all crosses. These same plants had a 54% superiority in height over those with a pollen parent from the interior of the province and a 14% superiority over those with a local plus tree as a pollen parent.

The breeding arboretum is being rapidly expanded so that all future racial crossing can be much more conventiently carried out. The range and elevations of the 148 provenances already planted (Table 2), has been extensive. It is hoped that the arboretum can be completed within the next few years.

Table 2. Range and Elevations of the Douglas-fir Provenances Established in the Breeding Arboretum by March 1970

Province or State	Number of Provenances	Ranges		
		N Lat	W Long	Feet Above Sea Level
British Columbia	27	49°10'-54°30'	115°45'-125°30'	1400-4200
Alberta	1	50°	114°	4500
Washington	44	45°37'-48°35'	117°03'-124°24'	100-2800
Montana	12	45°25'-48°50'	112°-115°55'	2200-7800
Oregon	10	42°07'-45°46'	119°-124°12'	200-5400
Idaho	4	42°-43°20'	112°15'-116°55'	5000-7500
Wyoming	2	41°18'-44°30'	106°40'-109°	8000
California	11	38°46'-41°15'	120°30'-124°00'	1000-4700
Colorado	11	37°45'-40°40'	104°50'-106°55'	6000-9000
Utah	6	37°30'-40°25'	111°-112°15'	8500-9000
New Mexico	7	32°55'-36°15'	105°50'-107°50'	8500-10000
Arizona	10	31°30'-36°48'	109°07'-112°15'	5000-10000
Mexico	3	19°40'-29°10'	98°07'-108°10'	7000-8000

REFERENCE

Orr-Ewing, A.L., 1969. Inbreeding to the S_2 Generation in Douglas-fir. Invited Paper, Second World Cons. Forest Tree Breeding, Washington, D.C. FAO. FO-FTB-69-8/16. 13 p.

SYMPOSIUM : TREE BREEDING AND SILVICULTURE IN CANADA -- NEEDS AND OBJECTIVES

INTRODUCTION

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We have come together to discuss here today one of the most significant developments in Canadian forestry: the increase in reforestation. As our population and industry grow, forest utilization accelerates and calls for more efficient silviculture. New forests must be established promptly, and sowing and planting need to be applied on a large scale. Even during the past decade much progress has been made. Statistics indicate that in 1958 about 50 million trees were planted in Canada, but in 1968 three times as many. Very likely this trend will continue. Cayford and Bickerstaff (1968) estimated the acreage of artifically established forest as 183,000 in 1965, which would rise to more than 500,000 by 1985. Long-term objectives of forest policy in each of our 10 provinces are related to this development. To reach these objectives, much technical information is required and numerous administrative problems need to be solved.

It is important to realize that many of the technical problems are interrelated. For example, site classification and forest inventory provide basic information for the establishment of new forest, i.e., species and area requirements, and a guide to establishment methods. This information in turn governs the amount of seed and planting stock needed and permits planning of seed procurement through general collection, seed production areas, and seed orchards. Technical problems and bottlenecks in any of these phases must be identified early to permit further research and development. Satisfactory progress depends upon advances in all phases of the program.

A large-scale program to establish new forests offers great opportunities to use genetically improved seed and planting stock, but the strategy to be followed in improvement is critical. Information on the relative importance of the different species is of basic significance in developing such a strategy; better still would be a ranking of the relative importance of their characteristics - such as variability, rate of growth, hardiness, disease resistance, wood quality traits - and of the physiological basis of these characteristics. The genetic complexities of forest trees and the long testing periods and generation intervals make progress in this field difficult enough, and without basic information from silviculturists, physiologists, and utilization specialists the tree breeder is seriously handicapped. Even though many of the questions that need to be answered require much more study than has been undertaken so far, no time should be lost in disseminating the information that is available.

In this situation the Committee on Forest Tree Breeding can fulfill a useful role. Our objectives, as stated in the terms of reference, are to facilitate the exchange of information and to support the work of active members. This time we felt that we should arrange specifically for a meeting with foresters who are closely allied with silvicultural programs. We have invited speakers from all provinces and a number of additional specialists from universities and the federal Canadian Forestry Service. The speakers associated with provincial programs have been asked to outline where the greatest needs in reforestation exist. We believe that this is the first step in the greater exchange of ideas and more effective cooperation required to succeed in the task before us.

REFERENCE

Cayford, J.H. and A. Bickerstaff. 1968. Man-made forests in Canada. Dep. Fish. Forest., Forest. Br. Publication 1240. 68 p.

PRÉLIMINAIRE

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Nous voici réunis aujourd'hui dans le but de discuter ensemble d'un des développements importants touchant le domaine forestier au Canada: l'importance grandissante du reboisement.

A mesure que s'accroissent notre population et notre industrie, l'utilisation de la forêt prend de plus en plus d'importance et requiert une sylviculture plus appropriée. De nouvelles forêts doivent être mises sur pied rapidement et la plantation doit s'effectuer sur une grande échelle. La dernière décennie nous apporta bien des progrès en ce domaine. Les données statistiques montrent en effet qu'en 1958 quelques 50 millions d'arbres furent plantés à travers le Canada et qu'en 1968, ce chiffre avait triplé. Il semble bien que cette tendance ira en s'accentuant. Cayford et Bickerstaff (1968) estimèrent qu'en 1965 les superficies artificiellement reboisées au Canada se chiffraient à 183,000 acres (73,200 ha.) et que celles-ci dépasseraient 500,000 acres (200,00 ha.) en 1985.

Les objectifs à long terme de la politique forestière des 10 provinces canadiennes sont intimement reliés à ce développement. Une abondante documentation technique est encore nécessaire à l'atteinte de ces objectifs de même que la solution d'un grand nombre de problèmes administratifs.

Nous devons réaliser que plusieurs de ces problèmes techniques sont interdépendants. Signalons, à titre d'exemple, que la classification des sites et l'inventaire forestier fournissent les données de base nécessaires à l'implantation d'une forêt nouvelle, telles que les besoins en espèces et en superficie de même que celles touchant les méthodes à utiliser. Cette information aide à déterminer les quantités requises en semences et en semis, permet de planifier l'obtention de graines par l'entremise de récoltes globales et par l'établissement de superficies dites de production de semences et des vergers à graines.

Tout problème technique ou obstacle existant à quelque niveau que ce soit doit être rapidement décelé afin de permettre la poursuite de la recherche et du développement en ce domaine. Le résultat escompté dépend intimement des progrès réalisés aux différents niveaux de programme. De fait, un tel programme de mise sur pied de nouvelles forêts conçu sur grande échelle, présente de grands avantages si l'on utilise une semence et un matériel de plantation qui soient génétiquement améliorés. Par contre la tactique à suivre peut être critique dans la façon d'effectuer cette amélioration. Toute connaissance de l'importance relative qu'occupent les différentes espèces forestières constitue la pierre angulaire de la mise en pratique de cette tactique. Mieux encore serait de connaître les degrés d'importance de leurs caractéristiques telles que variabilité, taux de croissance, rusticité, résistance aux maladies, qualité du bois de même que les fondements physiologiques de ces caractéristiques.

De fait, la complexité génétique des arbres forestiers, les périodes d'essais relativement longues et l'intervalle naturel entre les générations ralentissent passablement les progrès souhaités. De plus, l'améliorateur forestier se trouve sérieusement en difficulté s'il ne peut profiter des connaissance du sylviculteur, du physiologiste, et de l'exploitant. Il va sans dire que le grand nombre de questions auxquelles il faudra répondre nécessite davantage d'études comparativement à celles déjà entreprises. Il faut faire connaître dans toute la mesure du possible les résultats connus en ce domaine.

Dans cette optique, le Comité canadien d'amélioration des arbres forestiers peut remplir un rôle utile. Nos objectifs, que nous mentionnons ici en termes de référence visent à faciliter les échanges d'informations et à encourager le travail des membres actifs. C'est la raison pour laquelle nous avons cru bon organiser ce symposium groupant en plus des améliorateurs forestiers, les personnes intimement liées aux programmes sylvicoles. Nous avons également invité des représentants des 10 provinces canadiennes, ainsi qu'un certain nombre de spécialistes des universités et du Service canadien des forêts. Les conférenciers que touchent de très près les programmes de reboisement de leur province sont invités à exposer les problèmes et les besoins que cause le reboisement en leur milieu. Nous sommes assurés qu'il s'agit là d'un premier pas en vue d'un échange plus efficace d'idées duquel découlera une plus grande collaboration et ce, si nous voulons réussir dans cette tâche qui nous incombe.

TREE BREEDING AND SILVICULTURE IN ALBERTA - NEEDS AND OBJECTIVES

L.L. Kennedy
Alberta Department of Lands and Forests, Edmonton

RÉSUMÉ

Notre programme actuel englobe les faits suivants:

(1) Un reboisement annuel de 55,000 acres occasionné par les coupes à blanc.

(2) Une responsabilité qui incombe directement au Service forestier de l'Alberta à la suite de la perte par le feu de 67,000 acres annuellement, et

(3) Un reboisement de quelques centaines de milliers d'acres (chiffres inconnus à date) à effectuer sur une superficie productive dite de "back-log".

Pour satisfaire à (1) et (2) notre besoin actuel s'élève approximativement à 1,700 livres (765kg) de semences par an (scarification, utilisation de semis ordinaires et récipients).

Ce montant présente un certain problème (mais pas extrême) si on songe utiliser des semis ordinaires (400 livres - 180kg) au lieu de la scarification et de l'ensemencement (tendance bien définie en Alberta pour l'avenir). Ce chiffre pourrait être diminué davantage si l'emploi du récipient perce finalement comme méthode première.

Avec ces prévisions essentielles en semences, source première de tout programme de reboisement, nous ne pouvons nous permettre d'utiliser une semence quelconque; nous devons déployer tous nos efforts afin d'utiliser la meilleure qui soit.

Nous avons réservé des superficies de production de semences, au moins une par forêt (11 forêts), par espèce, sous la direction du Service canadien des forêts et une sélection d'arbres - "plus" s'y pratique. Cependant, afin de subvenir à nos besoins dans l'emploi "de la meilleure semence" nous devons mettre de l'avant, en Alberta, un programme de recherche en amélioration des arbres, ce qui n'a pas encore été établi à date.

* * *

I am very pleased to have the opportunity to tell you where we, in Alberta, think we are in relation to the topic we are discussing here today. Tree-breeding is a field in which I believe we are a very long way behind our competitors, especially those in the southern United States, and this does not apply only to Alberta. Where we have failed is not so much, perhaps, in the knowing of what has to be done as in getting out and doing it.

In 1959 we initiated the basis of a tree-improvement program when, in combination with a good cone crop, we set up a seed-registration program similar to that of the British Columbia Forest Service. Shortly after we sent out our first directive to the Forests (forest districts) regarding plus trees and indicated that all collections were to be made from the best phenotype stands available. We did not fully reach that objective the first year, nor have we done so yet in all cases, but most of our collections do come now from some of the best stands we have, and the fact that these stands are all over the province will help to ensure that we do not completely erode the gene pool.

But, what are our needs in this respect? How much do we have to do to safisfy them? I would like to review briefly the need we have for seed and to emphasize that it is not necessarily very great.

As was indicated in the summary given to you, the reforestation section of our silvicultural program in Alberta must meet two primary requirements:

(1) the reforestation of current cutovers within a 10-year period, and

(2) the reforestation of recently burned-over areas and other potentially productive land (including old burns and old cutovers).

The first requirement is easy to define, since it involves two major types of areas:

(a) those currently cutover since the establishment of our quota system in 1966, which stipulates that reforestation must be carried out within 10 years after cutting. This currently concerns some 55,000 acres annually, of which 10,000 are expected to be planted and 10,000 will require seeding. We rely on natural seed sources (slash in pine and surrounding timber in spruce) in combination with scarification to get regeneration on some of the remainder, part of which is, of course, already stocked with advanced growth, and

(b) those areas cutover before 1966, which should be reforested to maintain age class distribution. We do not have an acreage count on these old cutovers, but they are included in the next group.

The second requirement, including old burns, old cutovers, and recent burns (5 to 15 years) is somewhat harder to define at this time.

We are at present undertaking reconnaissance surveys to establish this acreage, but on the basis of the detailed inventories of only 16 of our 130 management units, we know that 450,000 acres are in need of some form of reforestation (if we plant only 50% of this, it would require a 20-year program of 5 million seedlings per year). An additional area would also be scarified and seeded.

Of some 67,000 acres burned as an annual average (a substantial amount is nonproductive), 20% would have to be planted, requiring approximately 5 million seedlings. More acreage here would also be scarified and seeded.

Considering the average figures just given in (1) and (2) we could assume for this discussion that there is need to plant 36,000 acres; and, as our present trend indicates, we would probably consider an additional 36,000 acres for scarification and seeding. As you are no doubt aware, the two species we deal with primarily are white spruce and lodgepole pine. Pine cones are relatively easy to get any year, but spruce seed-years of any consequence are from 3 to 7 years apart in Alberta; so the collecting of spruce cones can be critical to an extensive program of this nature.

In view of the foregoing comments, what would be our seed needs? They would vary in relation to the type of reforestation program we would carry out. As already mentioned, however, we would normally have about 36,000 acres of scarification (in need of seeding) and 36,000 acres of planting with both conventional and container stock. That is, if we carry out the program as envisaged. To me it is inevitable that our scarification and seeding program will diminish and that planting will nearly replace seeding in spruce cutovers; but I believe scarification of pine cutovers will continue in nearly all pine types for some time because of the much lower cost.

But where are we right now, this year? Our seed need for conventional stock seeded this spring was some 85 pounds (estimated 7 million 3-0 seedlings for 1973). This will increase to some 120 pounds in 1973 for an estimated 10 million seedlings for conventional planting. For container grown seedlings our needs were only 20 pounds, since we expect to produce 1.5 million until a better container is available. So a total of 105 pounds is required for our current planting-stock needs. At our present rate of scarification an additional 2,500 pounds is needed for seeding. With such a requirement can we afford to use anything but the best, especially for our planting stock? No! Certainly not.

Even if our program were stepped up to meet our total requirements, we would need only something like 200 pounds of seed for seedling production; but, as needs would reach approximately 7,000 pounds, scarification with seeding could be our undoing.

Well, what are we doing or what have we done about it? In 1959, as I noted earlier, we initiated a seed-registration program. With this registering of all seed, we set up the policy of restricting the use of the seed collected to within 50 miles of and 500 feet above or below the collection site. At the same time the need for good seed from our better stands was and is continually stressed. It would be a fallacy, however, to say, particularly with regard to 1959, that all our seed came from the best stands. It would be fair, though, to say that the bulk of it now comes from better-than-average stands and much of this from individually selected trees. Individual tree selection is carried out where logging is current: special timber permits are issued specifically for cone collection.

Besides establishing the registration program, we have selected a few seed-production areas during the past year, utilizing help from the Canadian Forestry Service. However, until a genetics program is initiated in Alberta, we can do little more. We cannot have an active plus-tree selection program even though each fall we do "pot up" both lodgepole pine and white spruce rooting stock for grafting purposes should some exceptional trees be found in cruising and other forest activities. We will continue to reserve any plus trees found and to reserve stands as seed production areas with the goal of at least one per forest and in some cases one per management unit (possible total of 130). This will at least help to ensure that at some time we will be able to select the 'best' from the 'better'. I might add here that we do not have a research group in the Alberta Forest Service and rely solely upon the Canadian Forestry Service for such programs.

In effect then what we are doing now is far short of what needs to be done.

I have stated current needs in Alberta. Let me reiterate:

Annual acreage of cutover under quota	- 55,000 (20,000 in need of seeding or planting)
Annual acreage burned over	- 67,000 (27,000 in need of seeding or planting)
Potentially productive acreage (a few management units only)	- 450,000 (20,000 per year in need of planting for a 20-year project - at least)

These acreages may be changed somewhat as a result of our stocking reconnaissance surveys, but they will not diminish.

If we were to plant all of this at the rate of 500 trees per acre this would mean over 30 million seedlings annually. However, perhaps as much as 20% of the area will be in pine cover types, and for the time being these areas will be scarified. Spruce scarification will continue too because we cannot physically plant the area that this total project would require. So, we expect to reach 17 million seedlings and then level off for the time being.

I have said a number of times, with this type of requirement for planting stock, we cannot afford to use any but the best seed. Selection of the best, propagation of the best - this we must insist upon. If we continue to scarify and seed at our present rate, the use of any and all seed might be necessitated for this phase of the program.

I think it was Dr. Bruce Zobel who said in Montreal a year ago that they were showing in the southern United States increases in volumes of between 10 and 15% in the first generation after selection and suggested up to 20 or 25% additional volumes in the second generation. Gentlemen, we must keep up! Dr. Zobel went on to report that they have 4-year-old trees 15 feet high and 7½-year-old trees producing 2.6 cords per acre with an average diameter of 8 inches and growth of 1.5 to 2.7 cords per acre per year. He further indicated that he felt we should concentrate on growth, not necessarily form, and that industry on its own land must be totally involved. I believe this can refer also to our industry, even if its holdings are, as in Alberta, totally Crown land.

It was L.S. Davies who indicated in the Journal of Forestry that returns of 2.5 to 4% over that of normal seed were enough to make tree improvement a sound financial investment.

I agree with what these two gentlemen say. I'd like to be able to say we now have enough seed-production areas and are getting that 10 to 15% return. We are not, but most of our seed is from selected stands and perhaps we are getting some return.

Louis Blackerby, Associate Editor, Forest Industries magazine, quoted one eminent forest geneticist (unmentioned) who said that "productivity increases on the order of 25 percent can reasonably be expected in what are now considered as productive types". This geneticist further stated that the gains can be even higher in many circumstances. The estimate of 25% productivity increase is based "on the assumption that there will be no change in the inherent ability of a fully stocked stand to convert solar energy to stored energy in carbohydrates....Increases can take place if per-acre growth rate is not changed but merely concentrated on fewer trees, or on finer-branched trees, or on trees which are not subject to pests. However, the inherent photosynthetic efficiency is only one or two percent and there seems a very real possibility that it can be increased. If so, productivity increases of much more than 25 percent can be expected." Furthermore, he notes that these improvements "may be over and above those resulting from other types of forestry research".

The future looks very bright indeed, but we must get moving!

There is no doubt that we need trees that grow faster and have better form, more uniform wood, higher resistance to disease and greater adaptability to adverse conditions of site and weather - not singly but all together. As Louis Blackerby also said, "genetically based variability is known to exist for volume production, straightness, limbiness, wood density, fiber length, disease and insect resistance. And such relevancy is expected to exist for other characteristics." I would suggest that for white spruce the characteristic we really need most is early height growth. On our best sites, this slow early height growth is the main problem.

Trials of exotic species became extensive in 1968 when, in cooperation with Canadian Forestry Service personnel, plantations were established from Footner Lake in the north to the Bow River Forest in the south. Seed-production-area selection was initiated earlier and included the entire province. Provenance trials were only put on the books in 1970 and will be carried out next spring. They will involve most of our forests.

We have been asking for a cooperative program in tree improvement in Alberta for some time. The transfer of much of the Canadian Forestry Service staff from Manitoba to Alberta, though a loss to the former area to some extent perhaps, has been to us potentially a great gain. I believe we can and will take a great stride forward in this work in the immediate future. Gentlemen, we must do this in cooperation with improved management if we are to remain in the running for fiber production.

ACCENT SHIFTS TO QUALITY IN MANITOBA REFORESTATION

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RÉSUMÉ

Les forêts du Manitoba se trouvent limitrophes de la grande région des prairies, région reconnue pour la sévérité de son climat et le manque de précipitation. Très tôt dans l'histoire de cette province a-t-on compris qu'une régénération naturelle laissée à elle-même fournirait un faible rendement sous les conditions moyennes du milieu et deviendrait aléatoire durant les périodes de sécheresse. Ainsi, n'est-il pas surprenant de constater que les premiers projets de reboisement remontent au début du siècle (1905) et se sont continués sans interruption jusqu'à ce jour.

Le reboisement connut une ère d'expansion durant les années 1950 et 1960 grâce à l'aide financière du gouvernement central par suite de l'Acte Forestier Canadien et du support tangible du gouvernement provincial.

Le programme mis de l'avant au Manitoba le classa ainsi au quatrième rang à travers le Canada à la suite d'un mandat du Cabinet provincial de mettre tout en oeuvre pour décupler le programme du reboisement.

La suspension récente de l'aide du gouvernement central associée au programme d'austérité du gouvernement provincial entraînèrent un ralentissement d'un plus grand développement quoique les coupures ne se soient pas encore fait sentir.

Le moment est venu de ré-examiner les buts du programme de reboisement avec cette idée d'expansion qui existe toujours. Il est certain que l'accent sera davantage orienté vers une amélioration dans la qualité du matériel utilisé remplaçant ainsi l'idée première basée alors sur une simple production accrue. Cet accent nouveau permet à la province d'établir un programme à long terme de régions d'utilisations des semences, suivi par la délimitation de régions de productions de graines et de vergers à graines forestières.

Il se produit cependant une brèche importante dans ce domaine de l'amélioration des arbres forestiers au Manitoba; cette situation avait été temporairement modifiée à la suite de la formation d'une Section d'amélioration des arbres du ministère canadien des Forêts. Cependant, ce projet fut littéralement abandonné peu de temps après sa naissance. Ainsi, le Manitoba se trouve dans une position telle qu'il doit poursuivre sa route au moyen de connaissances provisoires en amélioration des arbres forestiers basées sur une recherche antérieure et suivant les méthodes d'aménagement.

* * *

The year 1970 marks a milestone in reforestation in Manitoba. The 50 millionth tree will have been planted before the current planting year terminates. To those of you who plant 50 million trees each year, this may not be impressive, but keep in mind that we, in Manitoba, broke through the 1 million tree barrier only 15 short years ago.

Our province was not well endowed with a great abundance of valuable tree species. For this reason our earliest planting programs, which date back to 1905, included a variety of exotic tree species which were tested alongside of plantations of native species. Early records make mention of Scots pine, lodgepole pine, ponderosa pine, Norway spruce, Colorado spruce and Siberian larch. Most of these plantations are preserved to the present day as examples of success and of failure.

Regeneration failures are not an uncommon occurrence in our part of the country. One has only to examine the map of Manitoba to realize that the forest zone of the province borders the vast grassland area to the west known as the prairie. Owing to climate this grassland area is essentially treeless. Although a planted tree may be induced to grow on a prairie site, the total precipitation in any average year is not sufficient to allow forest tree species to reproduce themselves. It follows, therefore, that where succession cannot be a continuing phenomenon under natural conditions, tree growth cannot persist. Needless to say, our climatic condition has influenced the pattern of vegetative growth, and climate and vegetation together have influenced our soil types. It is not just coincidence, therefore, that, starting in the southwest and proceeding northeastward, we have dark brown, black, grey black, grey-wooded and podzol soil zones, and these soil zones reflect a gradual progression from mixed grass to tall grass, aspen grove, mixed forest and, finally, coniferous forest. Naturally, the commercially exploitable timber is found in the mixed-wood and coniferous zones.

Due to the general proximity of the forested zone to the grassland zone, regeneration does not always come about spontaneously. Indeed we have dry cycles, in which natural regeneration simply could not occur, and we have wet cycles, which bring about conditions favorable to natural regeneration. When conditions are average, the prospects for natural regeneration are marginal, to say the least. Considering that our annual precipitation at any point in the province rarely exceeds 20 inches, we can never hope to be overwhelmed by the ferocity of our seedling growth.

It became evident at a very early stage, that if we, in Manitoba, were to seriously consider maintaining our forest in a productive state, reforestation would have to become a way of life. Indeed, the records show that planting programs have continued without a break, from the initial effort in 1905 to the present day. For many years, planting programs were very modest, principally because the provincial budgets of those years were equally meager. In the first 50 years of planting no single annual program had reached 1 million trees planted. Along the way, however, some important milestones were recorded.

In 1951 the Canada Forestry Act agreement provided the stimulus, through the injection of federal funds, for the first significant expansion of the provincial reforestation program. By virtue of this agreement, the province was able to establish a major new nursery and to scrap a number of very small nurseries, none of which had any significant potential for production. It was at this stage that Manitoba's reforestation program began to attain some degree of respectability.

A little later (in 1959), a provincial interdepartmental committee was appointed to look into ways and means of improving the bad economic situation prevailing in the southeastern part of the province. This committee put forward a recommendation for a ten-fold increase in reforestation planting (from 1 million per year to 10 million per year) by 1970. This recommendation was approved by the Provincial Cabinet of the day, and planning was initiated for a major expansion of what was still a modest program. In our severe conditions, planning for tenfold expansion is no mean task. In the center of the continent, we experience the coldest cold one can imagine, the hottest heat, the driest drought, and we frequently set records for wetness. However, we counted on a certain amount of adversity and managed to get well along the way toward the 10-million-tree goal.

What we did not count on was adversity of a different kind. We did not count on the sudden federal withdrawal from the Canada Forestry Act agreement. Our whole plan was based on the continuing infusion of federal funds, and although the federal move did not kill the program outright, it became increasingly difficult for the province to continue expansion according to the original plan. As if this were not enough, the general economic situation deteriorated to the point that the province was forced to adopt austerity measures in the interests of maintaining solvency. Fortunately most legislators look upon reforestation in the same light as motherhood. No one of them suggested anything so rash as cutting back on reforestation programs, but when they tell you that no additional dollars will be available next year, the message comes through clear enough. There is no way that expansion can continue without the availability of the necessary extra funds.

Austerity is now a positive reality. Because of it, our 10-million-tree goal for 1970 could not be achieved; at present the program is stalled at 6½ million. At the moment there are no signs on the horizon to indicate any improvement in the economic situation. It is therefore doubtful whether Manitoba's reforestation program will undergo further expansion, at least in the immediate future.

I do not wish to convey the impression that the reforestation picture in our province is totally gloomy. Our program gives us fourth rank in Canada, after the three big provinces. We have a production plant of respectable size that is capable of being reactivated as soon as the provincial economy allows it. The slowdown of the present day may, in fact, be a blessing in disguise. For the past 15 years we have been preoccupied with the problem of increasing production -- each year the program had to be bigger than the year before. We now have an opportunity to regain our bearings, reassess our methods, re-examine our objectives. Looking back over the past decade, we have to admit that the planning was not altogether bad, for we were able to move forward more or less as the plan required. It is the planning we did not do that seems to have caused the problems. For example:

We lunged into a substantial program of plantations without attempting to project what kind of wood the forest industry might need at the time when the plantations are ready to cut. For a quarter of a century Scots pine was a substantial component of our planting programs, yet no one today can really say what was the purpose of planting it. Was this bad judgment, or should we subscribe to the philosophy that fiber is the important thing -- fiber of any kind -- and let technology find a way to utilize it when the time comes?

As a result of our inability to foresee extensive development of forest industry in the north, we find ourselves getting into northern programs involving the supply of seed and seedlings, but as yet provincial seed zones have not been delineated. This is something we intend to rectify within a year or two, as we would be committing some kind of criminal offense if we were to use southern seed for far-northern programs.

Our ability to achieve adequate site preparation has not kept pace with our ability to increase the volume of seedling production. This causes enormous problems for nursery management, as you can imagine. The nurseryman, moreover, is seldom given enough lead time to enable him to produce the right amount of the right species to fill everyone's needs at the right time.

Lastly, we are more than somewhat distressed that, out of our total annual consumption of seed, not more than 5% originates in a seed-production area. There is great need to improve our entire approach to seed collection, and one wonders how such a basic need can be passed over for so long. It seems that foresters have not been sufficiently impressed with evidence that good seed begets good progeny. Somehow it must be possible to get foresters committed to producing and using improved seed, thereby reducing the number of plantations we like to keep hidden from view. We have examples of plantation drought kill that might have been avoided if a meaningful improvement program had been carried out in the field of drought-resistance selection. Similarly we need to tackle the problem of frost hardiness through selection of late-flushing plants to avoid late frost damage. We need selection for disease resistance, insect resistance, better form and higher yield. Then we will need to know more about mass production of improved material.

Our hopes were raised in 1967 when for the first time a Tree Improvement Section was assembled by the federal organization in Winnipeg. This group had barely started to function when, in 1969, the whole organization was decimated, and competent and talented personnel were dispersed to greener pastures. The need for tree improvement in Manitoba has not diminished, but the organization has somehow faded away. The amount of work remaining is far beyond the capacity of small provincial organizations. If we are to hope to improve the quality of our product, we will have to continue to lean heavily on this body of scientists to show us the way.

TREE BREEDING AND SILVICULTURE NEEDS AND OBJECTIVES

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RÉSUMÉ

Le but de la production annuelle de semis nécessaires au reboisement se chiffre maintenant à 100,000,000 de plants, utilisant surtout les Épinettes noire et blanche, les Pins rouge, gris et blanc.

Ainsi, le programme de production de semis requiert une quantité approximative de 700,000,000 de bonnes semences. La responsabilité de la récolte en Ontario revient aux équipes qui existent dans les 21 districts de la province. Celle-ci a été divisée en 13 régions différentes quant à la station et les semences récoltées annuellement sont classées par espèce et par régions d'utilisations de semences.

Par contre, le programme annuel des coupes qui a atteint 400,000 acres en Ontario, en 1969 a détruit bon nombre de peuplements de qualité.

Ainsi, le besoin d'instaurer un programme susceptible de fournir le matériel nécessaire à la plantation annuelle de 100,000,000 de plants fut accepté et mis de l'avant. Un programme d'amélioration prit naissance en 1958.

Pour la production de semences, les superficies dans lesquelles les peuplements naturels ou issus de plantations dépassaient la moyenne ont été traitées afin de promouvoir cette production de semences (stage à court terme du programme). Par contre, les parcs à clones représentent le stage à long terme de ce programme: la sélection d'arbres "plus" est en cours et les greffons recueillis produisent 10,000 plants greffés par an. Nous avons actuellement 10 vergers totalisant 107 acres (43 ha.).

Nous sommes confiants qu'un tel programme d'amélioration produira une semence dont le gain génétique s'accroîtra à chaque décennie.

Si les principes de génétique forestière sont mis en pratique et reliés à l'aménagement des plantations, il semble certain que la qualité du produit augmentera de pair avec celle de la production de la forêt elle-même.

* * *

The tree-seed program carried out by the Timber Branch of the Ontario Department of Lands and Forests is concerned with two important objectives:

(1) to procure and maintain an adequate supply of forest tree seed of the highest possible quality necessary for the successful implementation of the reforestation program;

(2) to develop and maintain a forest tree improvement program to produce genetically improved seed on a scale sufficiently massive to meet the requirements of the reforestation program.

PRESENT REFORESTATION PROGRAM

The annual target for the production of planting stock for the reforestation program is now set at 100 million trees a year. This objective was first reached in our 10 Ontario forest-tree nurseries in the fall of 1968, and has continued to be attained each year since.

A large proportion (92%) of this total is made up of five major species, as follows:

White spruce	38,000,000
Black spruce	19,000,000
Red pine	16,000,000
Jack pine	13,000,000
White pine	6,000,000
Total	92,000,000

The remainder, 8 million trees, includes 19 additional species. Of these, Scots pine, red and Norway spruce, white cedar, silver maple, Carolina poplar and black walnut are grown in the largest quantities.

SEED COLLECTION

The planting stock production program, supplemented by the direct seeding program, requires the annual use of approximately 700 million viable seeds.

To meet this demand, the processing of 20,000 bushels of cones and rough seed is required annually at our tree-seed plant at Angus.

At this modern three-story plant, rebuilt in 1963, the extraction, treatment, testing and storage of seed are carried out under controlled conditions.

It is well known that seed produced in good crop years possesses good germinative capacity and stores well. The cost of collection in good crop years is thus proportionally lower. Seed storage bridges the gap between crop years for continuity of the reforestation program.

Responsibility for the collection of forest tree seed in Ontario is delegated to the field staff in the 21 administrative district offices across the province.

Ontario has been divided into 13 site regions. Nine of these are used as seed zones, which are separated in a north-south direction on the basis of effective temperature and in an east-west direction in accordance with effective humidity. The tree seed collected each year is identified as to species and seed zone. The identity of seed by zone source is maintained through all processing steps, so that nursery stock or seed may be returned to the zone of origin.

Most of the seed collected at present is obtained by controlled collection from quality stands that are being logged. This applies especially to jack pine and white and black spruce collections. Our field staff select the best-quality stands available at the time of collection and arrange controlled collections. The use of this good seed from the best stands is the most economical and feasible measure applicable in our immediate reforestation program.

However, with a large annual cutting program (400,000 acres in Ontario in 1969) these quality natural stands will not be available in the future. A forest tree improvement program is a necessity.

FOREST TREE IMPROVEMENT

With the advent of an expanding reforestation program in the mid 1950s, it became apparent that steps had to be taken to improve the availability and quality of tree seed. It was recognized that there was a need to emphasize the production aspect and to produce genetically improved seed on a scale sufficiently massive to meet the requirements of the planned 100-million-tree reforestation.

In 1958 a tree-improvement program was established, which took into account both the short-term and the long-term aspects. Because of our concern with production, it was necessary to consider the relative importance of species in the regeneration program. As previously shown, white and black spruce and white, red and jack pine together make up about 92% of the total seed requirement. The tree-improvement program is therefore concerned mainly with these species.

Seed-Production Areas

Areas in natural stands or plantations of better-than-average quality are managed for increased production of seed in the short-term phase of the program.

These stands are rogued to leave only the best trees at a desirable spacing for good cone production. Seed-production areas must be accessible and reasonably close for ease of management and cone collection. At present 29 seed-production areas consisting of 336 acres have been established.

Clonal Seed-Orchards

The long-term aspect of the tree-improvement program involves clonal seed-orchards. Plus trees are selected according to phenotypical characteristics. Scions are collected and veneer grafted to potted root stocks. The grafts are planted in the orchard which has a surround of ½ to 1 mile to prevent pollination from outside sources.

The present program objective is the production of some 10,000 grafts a year. At present, we have 10 orchards with a total area of 107 acres. The progeny testing of orchard material was started in 1969 and will be increased this year.

SPECIES SUMMARY

White Spruce

White spruce is our most widely planted species, the annual production being 38 million trees. The present seed requirement is obtained from controllec collections from natural stands and seed production areas. To date eight seed-production areas totalling 74 acres have been established and are now yielding seed. Two clonal seed-orchards with a total of 19 acres have been planted to produce improved seed and, wherein, progeny testing is being carried out. At age 2-0 it appears that seed from rogued seed-production areas is giving more uniform seedling growth in the nursery beds and that the result is a higher percentage of shippable trees per bed.

Black Spruce

Black spruce occurs in pure natural stands that are still available. We thus rely on controlled collections from these quality stands. To date we have established five seed-production areas covering 81 acres and two clonal seed-orchards on 19 acres.

Red Pine

Much of our early work in tree improvement was concerned with this species owing to the demand and low availability of seed. Twelve seed-production areas covering 129 acres and three clonal orchards on 36 acres have been established. Our tree improvement for this species is now concentrated on seed collections from managed seed-production areas.

Jack Pine

Jack pine occurs in pure even-aged stands. We rely at present on controlled collections from high-quality stands for improvement. Two seed-production areas totalling 26 acres have been established on a trial basis. We have not established clonal seed-orchards for this species.

White Pine

A considerable amount of basic research on rust resistance has been carried out with this species in Ontario. We have to date one seed-production area of 11 acres and three seed-orchards on 32 acres for the species. Two clonal seed-orchards on 26 acres have been established with resistant clonal material developed by Dr. C.C. Heimburger. It is expected that the progeny from these orchards will be at least 20% rust-resistant.

We are confident that a sound tree-improvement program will produce seed with successively more genetic gain each decade. If the principles of forest tree improvement are closely followed, in conjunction with intensified plantation management, there is no doubt that the productivity of the forest and the quality of forest products will be greatly increased.

LE REBOISEMENT AU QUÉBEC, RÉALISATIONS ET OBJECTIFS

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et

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SUMMARY

During the last decade reforestation has considerably increased in Quebec. In 1973, our forest tree nurseries will produce 50 million seedlings suitable for plantations.

Reforestation is a long-term and expensive investment and requires the application of the principles of forest genetics to ensure success. We have started the establishment of permanent forest seed stands in our seed collection zones. Seed orchards remain a long-term objective, but work on them will start in the near future. Meanwhile we still have to determine the best provenances of our main native species. At first we expect to improve by selection these native species before attempting to introduce a greater number of races of exotic species.

A close collaboration and a mutual understanding of the geneticist and the reforestation worker is needed to ensure the success of our present as well as our future reforestation programs.

* * *

INTRODUCTION

Les programmes nationaux de reboisement s'accroissent d'année en année, surtout depuis une décennie. Au Québec, un effort accru a porté notre production de plants d'environ 5 millions en 1966 à 27 millions en 1970. Pour 1973, nous prévoyons produire et planter un minimum de 50 millions de plants (figure 1).

Les essences que nous utilisons actuellement sont les épinettes (*Picea*), les pins (*Pinus*), les mélèzes (*Larix*) et le Sapin baumier (*Abies balsamea*). Nos stocks en pépinière sont actuellement équilibrés pour nous fournir, à partir de 1973, ces espèces dans les proportions indiquées au tableau 1.

Au cours de l'année 1969, environ 17 millions de plants ont servi à la revalorisation des propriétés privées impropres à l'agriculture.

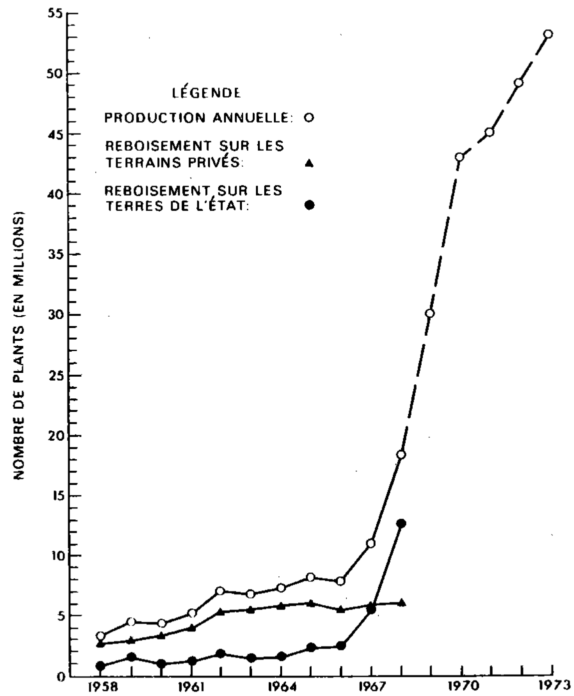

Figure 1. Reboisement et production annuelle des pépinières.

Tableau 1. Essences résineuses utilisées pour le reboisement et pourcentages comparatifs

Essence	(%)	Essence	(%)
Picea abies	15	*Pinus banksiana*	24
glauca	25	*resinosa*	5
mariana	10	*strobus*	1
rubens	5	*sylvestris*	5
Total	55	Total	35
Larix decidua	1.5	*Abies balsamea*	4
laricina	1.5		
leptolepis	3.0		
Total	6.0	Total	4

D'autre part, le ministère des Terres et Forêts, par l'entremise de ses districts forestiers, a fait planter plus de 9 millions de plants sur les terres publiques concédées et non concédées. Ces plants ont servi principalement à regarnir des brûlis et des "bûchés" non régénérés. La superficie ainsi couverte représente 12,600 acres (5090 ha).

Quoique ne disposant pas des compilations finales pour 1970, nous pouvons affirmer que nous atteindrons environ 30 millions de plants (figure 2).

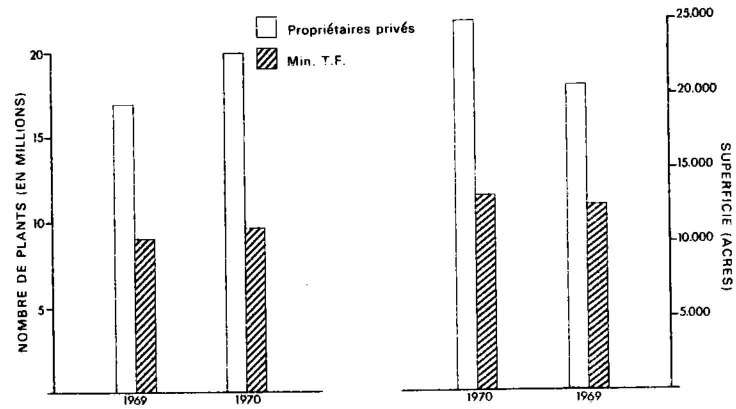

Figure 2. Quantités de plants mis en terre et superficies reboisées au cours de 1969 et 1970.

Une étude faite en 1969 montre qu'il se coupe environ 10,000,000 de cordes de bois par année au Québec, ce qui peut couvrir une superficie approximative de 1600 milles carrés dont environ 25 p. 100 ne se régénèrent pas adéquatement. Il faudrait donc, pour garder notre territoire forestier en pleine production, reboiser 400 milles carrés (256,000 acres) par année dans les parterres de coupe. Ceci représente une plantation de quelque 200 millions de plants.

Si l'on considère en plus le retard dans le reboisement des terres privées non régénérées et certaines superficies détruites par le feu, un programme annuel de plantation de 200 millions de plants pourrait être un objectif minimum. Toutefois, étant donné les disponibilités budgétaires et le personnel, nous devons pour le moment limiter notre programme annuel à 50 millions.

RÉCOLTE DES SEMENCES

Pour produire les plants nécessaires à l'exécution d'un tel programme de reboisement, nous avons besoin annuellement d'un minimum de 1980 livres de semences de première qualité (tableau 2).

Tableau 2. Quantité de semences nécessaires pour ensemencement en pépinière

Essence	Nombre de semis (en milliers)	Semences nécessaires (en kilogrammes)	(en livres)	Cônes de 40 litres
Abies balsamea	2,000	54	120	80
Larix decidua	750	27	60	60
laricina	750	9	20	20
leptolepis	1,500	32	70	70
Picea abies	7,500	272	600	800
glauca	12,500	182	400	400
mariana	5,000	30	65	162
rubens	2,500	36	80	160
Pinus banksiana	12,000	136	300	1,000
resinosa	2,500	57	125	250
strobus	500	18	40	66
sylvestris	2,500	45	100	166
Total	50,000	898	1,980	3,234

Contrôle de la qualité

Devant l'ampleur du reboisement, il est primordial de porter une attention toute spéciale à la source même de celui-ci: la semence forestière. En effet, le résultat d'un reboisement est intimement lié à l'emploi de semences pleines, viables, adaptées au milieu à reboiser et possédant de bonnes qualités intrinsèques, si on veut obtenir des forêts cultivées capables de produire des bois de qualité.

Recueillir des semences forestières pour un tel reboisement est une tâche d'envergure et nous ne pouvons y parvenir qu'avec la collaboration de tous nos districts forestiers. Depuis quelques années, nous achetons et utilisons de moins en moins de semences dont l'origine nous est inconnue (moins de 5 p. 100 en 1969). Nous essayons au contraire de faire récolter la majeure partie des cônes dans des peuplements naturels ou dans des plantations de belle venue. Ces aires de récolte de cônes sont choisies par le personnel (ingénieurs ou agents forestiers) de nos districts. Ceux-ci complètent une fiche descriptive et c'est à eux également qu'incombe la surveillance de la récolte.

Les récoltes sont faites sur des arbres abattus ou des arbres sur pied. Nous devons aussi acheter certaines quantités de semences à l'étranger, par exemple le *Pinus sylvestris*, sélectionné pour la production d'arbres de Noël, le *Larix leptolepis*, etc.

Afin de faciliter l'identification de la provenance de nos semences, la province a été divisée en 13 zones de récolte. Ces zones ne sont que préliminaires et seront sans doute modifiées au cours des prochaines années.

L'extraction de la semence et la vérification de sa qualité (test de germination, pureté) sont faites à Berthierville. Les divers lots de semences sont identifiés selon l'espèce, la zone et l'année de la récolte. Des provenances spéciales sont gardées comme lots séparés afin de subvenir aux besoins futurs en recherches.

<u>Coût de la semence</u>

La cueillette des cônes, depuis quelques années, s'avère une opération assez dispendieuse (tableau 3) surtout si les ouvriers sont rémunérés sur une base journalière. La récolte à la pièce ou à forfait en réduit sensiblement le coût. Il devient donc nécessaire et très important de ne faire recueillir que les meilleures provenances et de procéder avec soin à l'extraction des semences afin d'en conserver toute la qualité.

Tableau 3. Coût de production des semences

Essence	Coût (par kilogramme)	Coût (par livre)
	$	$
Abies balsamea	17.60	8.00
Larix decidua	33.00	15.00
laricina	55.00	35.00
leptolepis	35.20	16.00
Picea abies	11.00	5.00
glauca	22.00	10.00
mariana	77.00	35.00
rubens	77.00	35.00
Pinus banksiana	77.00	35.00
resinosa	66.00	30.00
strobus	22.00	10.00
sylvestris	26.40	12.00

CULTURE EN PÉPINIÈRES

Quatre-vingts p. 100 des plants livrés pour le reboisement proviennent de nos 5 pépinières majeures ou principales. Il existe aussi 13 pépinières secondaires qui servent comme pépinières de repiquage ou d'acclimatation. Toutefois, le nombre de celles-ci peut être appelé à diminuer au cours des prochaines années car nous éliminons graduellement le repiquage pour ne produire que du 2-0 ou du 3-0 prêt pour le reboisement.

La culture artisanale en pépinières cède de plus en plus la place aux méthodes modernes de la grande culture. Avant l'ensemencement, nos sols sont fumigés afin d'enrayer les mauvaises herbes et les pertes dues à la fonte des semis. L'ensemencement mécanisé en sillons nous permet un cernage latéral et horizontal des racines. La fertilisation se fait avec des engrais simples selon des cédules définies. Les mauvaises herbes sont contrôlées chimiquement et nous effectuons aussi un désherbage manuel à l'occasion. Nos opérations ont pour objectif la production d'un plant de qualité à un coût compétitif. La majeure partie de nos plants est expédiée au printemps. Ils sont alors extraits, classés par catégorie, comptés et emballés par ballots de 500 ou 1000, selon leurs dimensions. Tous les plants sont distribués par l'intermédiaire de nos districts forestiers. Le transport est effectué généralement par camions légers, et à l'occasion par camions réfrigérés s'il s'effectue sur une longue distance. D'ici peu, nous ferons usage de chambres froides dans certaines régions afin de prolonger la période de plantation et augmenter le succès du reboisement.

LE REBOISEMENT

Un propriétaire privé qui veut faire du reboisement en fait la demande à un bureau de district. Un officier fait alors l'inspection du terrain et rencontre le propriétaire afin de recueillir l'information requise pour l'obtention des arbres. Ce n'est que par la suite que des plants lui sont accordés gratuitement selon les disponibilités des pépinières. La plantation chez ces propriétaires privés est manuelle ou mécanisée. Le Ministère met gratuitement des planteuses à la disposition des reboiseurs, si ces derniers plantent plus de 5000 arbres. Les reboisements effectués sous le contrôle direct de notre Ministère sont faits à la suite de projets soumis par les officiers de nos districts régionaux. Actuellement, les plans quinquennaux de reboisement sont déjà prêts, ou en voie de réalisation, pour chaque région. Ces plans nous permettront d'adapter la production de nos pépinières aux besoins réels.

La plantation effectuée sous le contrôle direct de notre Ministère est, à parts à peu près égales, manuelle ou mécanisée. Toutefois, nous prévoyons utiliser des planteuses partout où les conditions le permettront afin d'abaisser le coût de revient et d'assurer une meilleure survie.

Coût du reboisement

Le coût de production des semis en pépinière varie de \$15.00 (plants 3-0) à \$25.00 environ (plants 2-2) pour 1000 plants. A cela il faut ajouter les frais de plantation qui, en 1969, ont été d'environ $38.00 pour 1000 plants (coûts directs et indirects) pour une plantation manuelle, tandis que ce coût a été réduit à environ $21.00 pour 1000 plants lors de la plantation mécanisée. Toutefois, le coût de la plantation manuelle peut être abaissé si on base la rémunération sur le rendement, i.e. à forfait ($0.02 à $0.25 du plant). Nous avons aussi constaté, au cours des dernières années, une meilleure survie à la suite de plantation mécanisée (90 p. 100) que de plantation manuelle (70 p. 100). Chez les propriétaires privés, la survie varie habituellement de 85 à 100 pour 100 selon le soin apporté à la plantation et selon la qualité du stock.

Autres modes de reboisement

Des expériences de scarifiage avant reboisement ont débuté au cours des dernières années, mais nous en sommes encore au stade expérimental. Ces expériences sont faites en collaboration avec certaines compagnies forestières qui partagent le coût de l'équipement et de la main-d'oeuvre.

Nous avons fait quelques expériences d'ensemencement direct de certaines superficies par hélicoptère; nous prévoyons continuer les essais d'ensemencement direct en utilisant aussi d'autres méthodes.

La production de semis en tubes nous permettra de prolonger la période de plantation et sera un complément à la production de nos pépinières. Toutefois, nous n'en sommes qu'à une première approche en ce domaine.

Orientations sylvicoles

D'une façon générale, les reboisements effectués par notre Ministère sont surtout orientés vers la production de bois à pâte ou de grumes. Dans quelques régions, on tente de tenir compte des industries existantes. Toutefois, il est superflu de signaler qu'il est assez difficile de prévoir l'usage précis que l'on fera de nos forêts et plantations dans 50 ans ou plus.

Les concessionnaires forestiers et les propriétaires privés, sur les conseils de nos officiers, déterminent eux-mêmes l'orientation sylvicole de leur plantation.

AMÉLIORATIONS DE LA SEMENCE FORESTIÈRE

Nous essayons de retourner à une région donnée des plants issus de semences provenant de cette même région. Toutefois, cela n'est pas toujours possible et il y a certainement des études, tests de provenances ou plantations expérimentales de provenances à réaliser afin de connaître les limites en ce domaine. Nous avons encore à connaître les meilleures sources ou provenances pour les principales espèces indigènes de notre province. Actuellement, nous pratiquons une certaine sélection massale lors de la récolte des cônes, car les peuplements sont choisis et la récolte est faite sous surveillance. C'est un premier pas, mais la qualité de nos semences sera de beaucoup améliorée seulement lorsque nos peuplements semenciers commenceront à produire.

Peuplements semenciers

Quelques officiers de notre Ministère font actuellement un inventaire des plus beaux peuplements à l'intérieur des diverses zones de récolte, zones basées sur des facteurs climatiques et écologiques. Ces peuplements sont choisis selon des normes définies et on y pratique, à l'intérieur, des coupes de nettoyage, élagage, etc. Nous prévoyons même de la fertilisation pour y accroître la production de semences. Ces travaux, en vue de créer au Québec un réseau de peuplements semenciers, ont débuté lentement mais se poursuivront d'une façon accélérée au cours des prochaines années.

Vergers à graines

Nous prévoyons amorcer sous peu les premières étapes en vue de l'établissement de vergers à graines (sélection d'arbres-plus, greffes). Ceux-ci nous assureront l'obtention de semences de qualité génétique supérieure. Des tests de provenances et de descendances pourront être faits concurremment et aideront à déceler les meilleures provenances et les sujets d'élite.

Toutefois, nous n'ignorons pas que ce sont des travaux de longue haleine, et même si nous entrons tardivement dans ce champ d'action, pour de multiples raisons, nous essayons d'aborder les problèmes inhérents avec beaucoup de réalisme et de sens pratique, mettant à profit les travaux réalisés par les autres provinces et nos voisins du Sud.

Nous ne croyons pas que d'ici quelques années notre Ministère mise tellement sur l'introduction de nouvelles essences exotiques. En effet, n'avons-nous pas beaucoup à gagner à tenter d'améliorer par la sélection nos espèces indigènes, ou les espèces exotiques bien établies *Pinus sylvestris* et *Picea abies*, qui ont une grande valeur commerciale. Ne sommes-nous pas assez riches en matériel biologique dont nous connaissons encore à peine le comportement et sur lequel nous pouvons travailler avant de dépenser énergie et efforts pour des espèces qui pourraient s'avérer partiellement ou totalement inadaptées à nos conditions climatiques. Ces espèces exotiques comportent autant sinon plus de risques entomologiques, pathologiques, etc., que nos espèces indigènes. Rarement, sauf quelques exceptions, une espèce exotique n'a été supérieure aux essences indigènes. Nous croyons que l'introduction d'espèces exotiques doit répondre à un besoin précis d'utilisation de matière ligneuse. Signalons des travaux d'introduction de nouvelles espèces de peupliers entrepris par le Service de la recherche de notre Ministère. Dans le même ordre de pensée, nous estimons que des travaux visant à la formation de nouvelles races et individus par hybridation doivent être le lot du généticien spécialisé en ce domaine, en vue de la création de races ou d'individus résistants à certaines maladies ou insectes.

Études des vieilles plantations

Nous n'avons pas encore réalisé d'étude sur la qualité supérieure des reboisements faits avec des semences améliorées, ou sur la résistance accrue aux insectes et aux maladies. Nous croyons que des recherches devraient être poursuivies en ce sens afin d'améliorer les garanties de succès des reboisements présents et futurs. Actuellement, des officiers du Service de la recherche font une étude de rendements de plantations réalisées il y a quelques décennies. Nous estimons que ces travaux seront très utiles comme guide de reboisement.

Notre Service de la recherche nous a soumis un programme sur l'amélioration des arbres forestiers dont nous tenons compte dans l'élaboration de notre programme. Les données recueillies par les spécialistes de l'Inventaire des terres du Canada pourront certainement nous être aussi d'un précieux apport dans le choix d'une ou plusieurs essences pour une région en regard d'un type de sol donné. Il ne s'agit pas seulement de planter des semis en grand nombre, mais de faire cette plantation avec des semis de qualité au bon endroit si nous voulons augmenter le rendement sur l'investissement qu'on doit consentir pour le reboisement.

CONCLUSIONS

Nous nous sommes attachés à vous montrer l'état actuel des travaux entrepris ou à réaliser par le Service de la restauration forestière qui, pour notre Ministère, a la responsabilité du reboisement et des travaux connexes. Nous croyons vous avoir révélé assez fidèlement nos réalisations, nos objectifs et nos besoins. Toutefois, il faut penser que nous ne pouvons réaliser tous ces objectifs seuls et ici, il convient de mentionner la collaboration des officiers des districts forestiers qui sont les principaux exécutants sur le terrain. Nous comptons aussi sur la collaboration du Service de la recherche, des autres services de notre Ministère et aussi des membres du ministère des Pêches et des Forêts du Canada, région de Québec.

Nous avons aussi essayé de vous faire connaître le point de vue du praticien, de ceux qui ont à réaliser le reboisement et résoudre ses problèmes inhérents. Nous sommes d'avis qu'il doit y avoir plus que jamais non seulement compréhension, mais aussi collaboration étroite entre le praticien et le chercheur. Nous croyons qu'actuellement, au Québec, toutes nos recherches en génétique, en reboisement et en sylviculture doivent avoir un sens éminemment pratique si l'on considère la tâche à accomplir.

A REVIEW OF SILVICULTURAL RESEARCH IN QUEBEC

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RÉSUMÉ

Un relevé des travaux de recherche sylvicole poursuivis au Québec depuis les années 30 jusqu'en 1970 a été effectué au cours des deux dernières années. L'étude a consisté à faire une revue de la littérature forestière pertinente, à interviewer les chargés de recherche auprès des gouvernements, de l'industrie et des universités et à visiter les lieux d'expériences en forêt. En tout, 148 projets de recherche ont été relevés. Ce compte rendu vise à passer en revue les travaux de recherche sylvicole effectués dans les forêts du Québec par ces divers organismes. Il raconte brièvement l'évolution des recherches en sylviculture et illustre les développements récents. Enfin, il suggère un certain nombre de recommandations destinées à assurer une meilleure coordination des programmes de recherche.

* * *

INTRODUCTION

From 1968 to 1970 inclusive, silvicultural research in Quebec has been comprehensively reviewed to determine what is being done and what is being planned. To make the survey, much correspondence and many phone calls and on-the-spot interviews were needed. This paper presents some of the results.

As a general reference, Table 1 shows the main divisions of the study. Under three headings -- "site preparation", "regeneration techniques", and "stand tending" -- appear 15 areas of study. It will be noted that these include virtually all silvicultural research, except that covering nursery techniques and silvics, which will be covered in a second report, to be written later.

All the agencies interested in silvicultural research in Quebec, and researchers belonging to any of these, were contacted. All in all, two governmental agencies -- namely, the Canadian Forestry Service, Quebec Region, and the Quebec Department of Lands and Forests -- eight industrial agencies, including Pulp and Paper Research Institute of Canada, Canadian Pulp and Paper Association and six major wood-using industries, and two universities (McGill and Laval) were visited on several occasions. A list

Table 1. Classification of Silvicultural Techniques and Number of Individual Projects by Study Areas

			Number of individual studies
I	Site preparation (for natural regeneration, seeding or planting)		12
	1 Slash disposal	1	
	2 Prescribed burning	2	
	3 Soil scarification	4	
	4 Fertilization	4	
	5 Drainage	1	
II	Regeneration techniques		68
	6 Nursery stock planting	46	
	7 Tubeling planting	4	
	8 Direct seeding	11	
	9 Cut modification systems (to aid natural regeneration)	7	
III	Stand-tending		68
	10 Release cutting	5	
	11 Thinning	45	
	12 Improvement cutting	6	
	13 Salvage cutting	1	
	14 Pruning	1	
	15 Fertilization	10	
	Total		148

of some 60 persons directly engaged in silvicultural research was drawn up. Lastly, some of 148 active individual research projects have been summarized.

STATE OF RESEARCH ACTIVITIES

Significant steps have been taken in Quebec since the establishment of the Valcartier Forest Experiment Station by the federal Forestry Department in the early 1930's. In fact, a few silvicultural activities can be traced back to the decade beginning with 1910. However, more than 60% of the 148 still-active research projects were initiated less than 10 years ago. The establishment of a Research Branch within the Quebec Department of Lands and Forests in 1967 is a recent significant step in the promotion of silvicultural research.

Of the 148 studies, 12 are concerned primarily with site-preparation techniques, 68 deal with the testing of various regeneration techniques, and 68 involve some kind of work on intermediate cuttings or stand-tending (Table 1). Not surprisingly, industrial agencies have put the accent on research activities involving stand-tending, for instance on studies of thinning methods and intensities and of mechanization of partial cutting operations, whereas governmental agencies have put the emphasis on regeneration techniques. Although the distinction between these two research areas is sometimes difficult to make, since the objectives of the individual studies are not always clearly defined or are multiple, it seems that this orientation is logical. In effect, industrial agencies normally prefer to improve residual-stand conditions, which represent a short-term objective, whereas governmental agencies can take a long-term goal and look at regeneration, whether established by natural or by artificial means.

Industrial agencies had 63 active research projects by the end of 1969, governments had 57, and the universities 16. A recent trend is toward the establishment of joint studies. Eleven such studies undertaken jointly by industries and governments have been surveyed, and one study involves the cooperation of industry, governments and universities (the project on forest fertilization in Canada). Cooperation among individual research agencies looks very promising and should yield excellent results.

A total of 90 unpublished manuscripts and publications, directly connected with the 148 studies, have been produced. It seems to us that this production is very low. There should be at least one establishment report, and occasionally some progress reports, for each of these projects.

Some of the interesting facts disclosed by this survey were as follows:

Most studies concern balsam fir and black spruce. Information on the management and silvics of the pines and on both tolerant and intolerant hardwoods under Quebec conditions is scanty.

Few studies have been initiated on site-preparation techniques for natural restocking and for planting or seeding.

The areas of investigation for the various research agencies are not clearly defined, so that there is some duplication.

On the whole, it is felt that silvicultural research in Quebec is inadequately developed and that, although significant progress has been made in the past few years, it cannot in its present state support an intensified forest management practice.

CONCLUSION

At present, some useful information is available on the silvicultural management of black spruce and balsam fir and, to a lesser extent, on that of jack pine and yellow birch, which are economically the most valuable native tree species in Quebec. However, our knowledge of species-habitat relations and of the performance of other tree species is scanty. There is an urgent need to define silvicultural research problems on a regional basis and to coordinate research activities in the province. Large-scale comprehensive research programs are needed now to secure the basic data required to manage forest stands to satisfy increasing demands for wood and fiber.

REGENERATION NEEDS AND OBJECTIVES OF THE PROVINCE OF NEW BRUNSWICK

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RÉSUMÉ

L'essor encore récent de l'industrie forestière au Nouveau-Brunswick a placé cette province dans une position telle que la demande en matière première se rapproche incessamment de la capacité naturelle des forêts.

L'importance d'une régénération artificielle s'est rapidement accrue sur des superficies-clés afin de venir en aide à la régénération naturelle même si cette dernière est généralement abondante. C'est là un moyen d'accroître la réserve en bois pour l'avenir.

Des régions d'utilisation des semences forestières ont été délimitées. D'autres travaux sont en cours afin de localiser et évaluer des peuplements naturels de grande valeur chez l'Épinette noire (*Picea mariana*) répondant ainsi aux demandes pressantes de récolte de semences.

La sélection individuelle d'arbres plus de cette espèce suivra ce programme de sorte que l'établissement de vergers à graines se concrétisera aussitôt que possible.

Il est à souhaiter que par l'amélioration des arbres forestiers on puisse parvenir à un accroissement concret dans le rendement des plantations de certaines espèces autochtones et exotiques dans cette région.

* * *

A discussion of the regeneration needs and objectives of the Province of New Brunswick requires a brief review of certain conditions affecting forestry in the province.

New Brunswick could well be called the forest province, having some 85% of its total area covered by forests. Its geography and climate favor forest growth, and its coastal location places it in a favored position for access to world markets.

After many years during which the total cut of forest products remained at a fairly constant level, only the products changing, recent expansion of the forest industry has caused a sharp upswing in the consumption of both softwood and hardwoods. It is generally agreed in economic forecasts that before the year 2000 the forest industry of New Brunswick will require more wood than will be naturally available.

Both government and industry recognize the need for conserving and increasing the wood supply, and for the last few years an operational reforestation effort has been in progress and is increasing yearly.

The province recognizes four main requirements for conserving and building up the wood supply. These are:

(1) improved utilization of individual trees and utilization of species that are not now merchantable;

(2) improvement of natural stands, particularly young stands resulting from natural reproduction following clear-cutting and fire, by such methods as thinning and fertilization;

(3) forest protection, including control of the spruce budworm; and

(4) artificial reforestation and afforestation.

Placed in perspective as to their relative potential effect on increasing the wood supply, these requirements would be ranked in the following order:

(1) forest protection, particularly the control of the spruce budworm;

(2) improved utilization of individual trees and utilization of species that are currently unmerchantable;

(3) improvement of natural stands; and

(4) reforestation and afforestation.

The relative importance of these requirements will change as forest development progresses and the value of wood increases.

We are concerned, at this meeting, only with reforestation and afforestation. The current attitude of the province with regard to artificial-regeneration methods takes into account that New Brunswick is favored by prolific natural reproduction in most forest types after clear-cutting and fire. It also takes into account that balsam fir, one of our chief species and a prolific natural reproducer, is an acceptable pulpwood species. Balsam fir grows under near optimum conditions in northern New Brunswick.

With this background in mind, we can now turn to a discussion of the regeneration needs and objectives of the Province of New Brunswick.

The amount of potential forest land currently out of production is probably less than 2% of the productive forest area of the province. This percentage amounts to some 300,000 acres, comprising clear-cuts and burns that are not reproducing naturally and abandoned farm lands.

At this time, and for the near future at least, spruce will be the main species required for reforestation. Other species requirements are for jack pine, red pine, Scots pine and balsam fir. The Scots pine and balsam fir are being used mainly as Christmas tree stock.

Planting in New Brunswick has increased from a few hundred thousand trees annually in the early 1960s to the current level of approximately 6 million trees a year. This is made up of conventional nursery stock, except for a few hundred thousand tubed seedlings in 1966.

Within a few years planting requirements should rise to 10 million trees a year, although it is difficult at this time to make an accurate assessment of future needs.

There are two tree nurseries in the province, one operated by J.D. Irving Company Limited and the other, formerly known as Valley Tree Nursery Limited, by the New Brunswick Department of Natural Resources. Each of these nurseries has the capacity to produce approximately 10 million trees annually, an output that should be adequate to meet the demand for nursery stock for several years.

Direct seeding, currently being done at an experimental level of a few hundred acres annually, promises to be an effective regeneration technique in combination with site preparation.

The basis of any reforestation program is tree seed. Seed requirements are currently being met partly by local collections and partly from out-of-province sources. Plans call for meeting all or nearly all seed requirements by using local seed. The first-priority, large-scale requirements are black spruce and jack pine seed.

For the past 2 years jack pine seed has been collected from some of the better stands of jack pine being cut. The case is similar for black spruce. This summer (1970) the Province is cooperating with the Canadian Forestry Service to find the best black spruce stands in the province for seed production areas. Seed collections will be made from some of these areas this fall (1970).

To get as early a start as possible in establishing seed orchards for black spruce, seed from the selected seed-production areas will be sown in the nursery, and from the resulting seedlings, the best will be chosen for establishment of a seed orchard. It is realized that this is a rather primitive method of establishing a seed orchard, but it should give us producing seed orchards by the early 1980s, on the assumption that cone production will start when the trees are about 10 years old. In the meantime black spruce seed for the reforestation program will have to come from the selected natural stands.

Following selection of natural stands of black spruce for seed production will come the finding of superior individual black spruce trees from which seed will be obtained for seed-orchard establishment.

Each of the two nurseries in the province has set up minimal seed-handling facilities to serve present needs. However, it would be desirable to have one central facility for seed extraction and storage, and this is now being considered by the Canadian Forestry Service.

Seed zones were established for the Maritime Provinces by the Canadian Forestry Service in 1967. These are tentative and are based on climatic data, forest classification, topographic maps and phenological data. It is expected that these seed zones will be altered as better information is acquired. Meanwhile they should prove adequate for use in the early stages of our developing reforestation program.

Although first priority will be given to improvement of black spruce, other native species such as white spruce, red pine, jack pine and perhaps balsam fir should receive attention as soon as possible. Hardwoods are becoming increasingly important and should be considered in a tree-improvement program. Exotics such as Norway spruce and the larches show promise of being important fiber producers.

A planted stand of Norway spruce on the Fundy Coast of New Brunswick has produced an average of 1.7 cords per acre per year over a 51-year period. It may be possible to obtain similar or greater growth rates on other sites with this or other species.

Matching of genetically improved species with site, followed by application of silvicultural methods such as thinning and fertilization, could greatly reduce rotation periods in plantations.

We are only at the beginning of a tree-improvement program in New Brunswick. Problems associated with the finding of genetically superior black spruce stands have already appeared, such as the problem of determining whether or not obviously superior growth rate and form of trees in a certain stand is due to genetic qualities or to site.

Other questions we will soon need answers to are:

What are the problems associated with the selection of superior individual trees?

What are the problems associated with the establishment of seed orchards?

Exactly where should they be situated and why?

What exotic species and hybrids will be the best producers of fast-growing high-quality wood fiber?

There will be many other questions, including that of the economics associated with tree improvement.

We are looking to the experts, yourselves, for answers to our questions.

The importance of using genetically superior tree seed has been demonstrated in several regions of North America. We hope that somewhat similar results can be obtained in our region.

In New Brunswick we are fortunate in having the Maritimes regional office of the Canadian Forestry Service in Fredericton. They are pursuing an active role in tree improvement and tree-breeding. We have already received guidance from Don Fowler, George MacGillivray and Steve Manley of the Canadian Forestry Service on our approach to tree improvement, and we look to them for future guidance.

REGENERATION - PROBLEMS AND OBJECTIVES IN NOVA SCOTIA

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RÉSUMÉ

Les facteurs climatiques et pédologiques responsables des conditions qui influencent la régénération et la croissance des arbres sont passés en revue.

On rapporte une comparaison historique entre la pratique de la foresterie en Nouvelle-Écosse et les problèmes théoriques tels qu'avancés par Duerr (1960).

On indique également de quelles façons et pour quelles raisons une reproduction dégénérée peut avoir lieu sous l'influence de la sélection naturelle.

Si les forêts de la Nouvelle-Écosse sont appelées encore à fournir une matière première suffisante pour répondre à la demande d'une industrie en plein essor, il est à souhaiter que le sylviculteur unisse ses efforts à ceux du généticien qui pourra lui donner réponse à une partie des problèmes qui surgissent relativement "à l'origine ou à la connaissance d'espèces ou de races d'arbres supérieures à celles actuellement employées".

Un travail a été amorcé en ce sens sur l'Épinette noire (*Picea mariana* (Mill.) B.S.P.) et on encourage fortement la permanence de tels travaux sur plusieurs espèces introduites intéressantes.

Un système de régions d'utilisation de semences forestières est en cours et se poursuit en pépinière où les graines subissent une classification suivie.

On mentionne aussi le besoin d'avoir un programme de reboisement à grande échelle qui démontre les objectifs du sylviculteur basés suivant un point de vue économique se rattachant à l'industrie des pâtes et papiers.

Un défi est lancé aux généticiens, sylviculteurs et aménagistes. Ils auront à localiser et améliorer espèces ou races capables de surpasser non seulement celles actuellement retenues pour les fins du reboisement, mais susceptibles de fournir à l'industrie un rendement de 40 cordes à l'acre suivant une révolution de 40 ans.

* * *

Nova Scotia has much in common with many of the other provinces, not the least of which is the need for, and the problems associated with, a tree-improvement program. Our province, however, is a peninsula jutting into the

Atlantic, and our cutting history is somewhat longer than that of other provinces. These facts perhaps suggest the reasons for some of the problems associated with regeneration, which are peculiar to Nova Scotia.

Our province has a humid, cool, modified maritime climate, with a mean annual precipitation of 36 to 55 inches fairly evenly distributed over the year.

Most forest soils have developed from glacial materials that, for the most part, have given rise to coarse-textured, acid soils inherently low in nutrients. These soils, podzolized, shallow and stony and mostly unfit for agriculture, are only fair for forest growth even under favorable climatic conditions and when not impoverished by frequent fires and dense ericaceous vegetation.

When the high acidity and low fertility and the restriction of the rooting zone or drainage due to a shallow soil or impermeable layer are combined with the "exposure" (wind and freezing rain or snow) to which most of peninsular Nova Scotia is subjected, some of the problems that must be faced in a provincial tree-improvement program can be appreciated.

Historically, the practice of forestry in Nova Scotia has followed the theoretical models presented by Duerr (1960).

Thus, we passed through a period of physical abundance of forest land and timber, when land-clearing and wood utilization were accompanied by extensive physical waste. Next came exploitation by the mother country, when high-grading was common and physical waste was still moderate. The following period saw the establishment of sawmills and pulp mills to take advantage of the remaining old-growth timber. Operations were then based on resource exploitation in a period that coincided with some of the worst fires in the province's history.

The next period, the Aftermath, is characterized by reduced timber resources and a stocking of existing stands of relatively small trees. A high proportion of the inventory is of species of undesirable quality or characteristics. Timber procurement almost becomes a scavenging operation, especially for the export buyers.

The sawmilling industry in Nova Scotia is still, more or less, in this period. The pulpwood industry, however, through technological advance, has increased utilization to take advantage of the smaller sizes, poorer quality, and less desirable species, and has thus passed to the next period.

In that period, which Duerr termed Hiatus, a period of preparation for intensive forest management, growing stocks should be accumulating. The land market is active, and the general public, and federal, provincial and municipal governments are buying up land for use as watershed and wilderness areas, for recreational and wildlife purposes, for prestige and the socio-economic benefits that may accrue, and for aesthetic reasons.

Large companies are setting aside newly acquired land to restock and are meanwhile obtaining wood from the private woodlot owners. Owners of these small holdings tend toward exploitive management, thereby making possible conservative programs on the larger company-owned lands.

This is where we are today. So now is the time to think conservation. To do this we must think, among other things, reforestation.

Nova Scotia was one of the earliest settled provinces and logging has been going on there for more than 335 years. As I have intimated in my outline, the logging pattern left a great deal to be desired. The trend was to take only the best and leave the rest. These residuals, if some of today's practices are any indication, were of poor genetic quality, but these were the trees left to propagate the next stand. Compound this by three to five rotations following the same pattern of high-grading (or, as some like to call it, selective logging), and I am sure that we can show you the results of degenerative breeding.

With a rising demand for wood fiber, and ever increasing competition in world markets, Nova Scotia is going to be hard put to continue to supply its forest industries with their raw-material needs on a sustained or increasing-yield basis. To meet this end the province may have to look to the use of exotics or the development of "super" trees for our variable conditions.

Natural regeneration is generally considered prolific, but it is not always that of a desirable species. When the species is desirable, the genetic quality is usually poor. The combination of poor soils, excessive exposure and degenerative breeding leaves much to be desired if we are to produce wood fiber competitively. Hence the need for a concentrated tree-improvement program.

Because the Nova Scotia Department of Lands and Forests has no research organization, we rely on the Canada Department of Fisheries and Forestry to do research for us. The task of tree improvement is at present in the competent hands of D.P. Fowler and H.G. MacGillivray of the Maritimes regional office of the Canadian Forestry Service, Canada Department of Fisheries and Forestry, Fredericton, New Brunswick.

It has been stated that the purpose of the tree-improvement work is to locate or produce species or strains of trees that are better than those now being used for reforestation in the region.

The consensus of a recent tree-improvement meeting, which included personnel from industry, the Nova Scotia Department of Lands and Forests and the Canadian Forestry Service, was that work on the native species was more important than work on exotics. A minority, however, felt that work should continue with such species as *Larix*, Norway spruce and Scots pine, claiming that the increased risks could be offset by increased yields.

Our present plans are to proceed with tree-improvement work on native black spruce. A proposal was presented for the immediate and future seed requirements of this species and received the general approval of all parties concerned.

We expect that similar procedures will be followed for other species when success with black spruce has been demonstrated.

Since the publication of "Seed Zones for the Maritime Provinces" (Fowler and MacGillivray, 1967), our Reforestation Section, with the cooperation of other departmental personnel and pulp companies, has coordinated seed collections, following the seed zones as delineated in the report.

Seed-lot classification simply consists of the species, seed zone and year of collection. Because Nova Scotia has only six seed zones and two subzones for the coastal areas, our classification can remain simple, for the time being at least.

Our province, with a total area of 13.3 million acres, had in 1958 approximately 1.3 million acres (10%) that were classed as depleted forest, bushland, or not regenerating old burn. Of course, much of this acreage is affected by inaccessibility, extreme boulder coverage, the presence of rock outcrop or very shallow soils - conditions that preclude planting or make planting uneconomical.

The present plan is to have a small group of specially trained personnel assess many of these areas. This group will decide whether the sites are plantable and will prescribe what site preparation is needed, if any, and which species and age class or type of planting stock are to be used.

At our present nursery production in Nova Scotia (3 million trees annually), our seed requirements are relatively small. This gives us an opportunity to develop seed-production areas and seed orchards in an orderly fashion, to prepare for future demands.

As I said, we still have a sawmilling industry, but we appear to be headed for a pulpwood economy. The goal of our silviculturists for a pulpwood economy is 40 cords of merchantable wood per acre on a 40-year rotation.

This is the challenge to tree geneticists, silviculturists and resource managers in our province. Can we locate or produce species or strains of trees that not only are better than those being used at present for reforestation in Nova Scotia but can be expected to provide our industries with a cord of usable wood fiber per acre per year?

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ECONOMIC CONSIDERATIONS IN TREE BREEDING

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RÉSUMÉ

Les programmes d'amélioration des arbres forestiers prennent toute leur signification du moment qu'ils peuvent améliorer le bien-être général de la société. Par conséquent, lors de l'élaboration de ces programmes on doit rechercher les "bénéfices additionnels aux consommateurs" en provenance des produits forestiers, ces derniers étant plus importants que le seul accroissement net dans la quantité de tels produits.

La culture d'arbres à croissance rapide peut facilement neutraliser les gains obtenus à la suite d'une forte production en volume si les tiges en cause sont alors caractérisées par une densité moindre et une résistance affaiblie.

Cet état de choses n'est pas impossible parce qu'un produit de pauvre qualité peut entraîner un prix inférieur dû à un changement dans la demande de ce produit. Ainsi le changement simultané de l'offre et de la demande rend très difficile l'évaluation des bénéfices additionnels revenant à la société par suite d'un programme d'amélioration des arbres.

La tâche d'évaluer de tels programmes s'avère alors en retour, très embarrassante.

* * *

INTRODUCTION

When the economics of forest tree improvement is discussed, it often happens that the possible increase in quantity of wood, due to the development of better strains of a species, is the main improvement taken into consideration (see, for example, Perry and Wang, 1958; Lundgren and King, 1965; Davis, 1967). This is so perhaps because quantitative improvement is usually the most spectacular one to be noticed and also the easiest to measure. This paper points out that for planning future plantations (Cayford and Bickerstaff, 1968) what we should be focusing our attention on is not quantitative improvement of yield as such. It is not simply the qualitative improvement either. The objective to be sought is the additional benefit accruing to society from the products of forestry operations, which depends on both the quantitative and the qualitative improvements. Without keeping in mind this objective of the tree-development programs, we cannot evaluate their success or failure from the overall viewpoint of society.

BENEFITS OF TREE BREEDING

Besides a possible increase in volume yield, the changes due to tree-breeding may affect the density of wood, its strength, pulp yields, disease resistance, frost resistance, size of clear bole, suitability for making veneers, timber quality, etc. It will be seen that some of these changes have a tendency to neutralize the beneficial effects of others. For example, fast-grown red pine (*Pinus resinosa* Ait.) yields a greater volume of wood in a given period, but the strength of the wood is poorer and its pulp yield is lower (Love and Williams, 1968). Therefore, it may not be safe to assume that a simple increase in volume of, say, 5% would be sufficient to cover the costs of production of genetically superior seed. An example may help explain the point.

Let a seed-improvement program increase by 5% the yield of a species from the existing 100 units. Let the price of wood from unimproved seed be $2 per unit. If the improved seed causing fast growth reduces the quality of timber so that the price is reduced to $1.90 per unit, the net benefit from new seed is 105 x $1.90 - 100 x $2.00 = -$0.50 and no expenditure on such improvement is justifiable. On the other hand, a reduction in physical yield accompanied by an improvement in quality can be economically justified if the quality improvement is large enough.

When seed improvement has more than one effect working in opposite directions, it becomes essential to understand how such effects neutralize each other. Let the quantity and quality (measured by price per unit) produced before breeding be given by x and y in the case of a certain species. Let the relative change in the two because of breeding be denoted by p and q where by relative change is meant the absolute change in quantity or price divided by the quantity or price before breeding. The market value of the product before breeding would then be xy and after breeding $x(1 + q) \cdot y(1 + p)$. The change in market value due to the breeding program will be:

$$xy(1 + q)(1 + p) - xy$$

$$= xy(p + pq + q)$$

When an improvement in quantity produced is accompanied by a lowering of quality and so of the price of the product, or a lower quantity produced has higher quality and therefore higher price, the signs of q and p will always be opposite. Therefore, when p and q are equal in magnitude, the expression $(p + pq + q)$ will be negative and the change in market value of production will invariably be a deterioration. Thus, a 10% improvement in yield and a 10% lowering of the price of the product do not result in just "no improvement", but will reduce the market value of the production below what it was. For the program to be financially feasible, the parameter that increases must increase more in relative terms than the one that decreases.

The change in market value due to breeding will be zero when

$$p + pq + q = 0$$

$$\text{or when } q = -\frac{p}{1+p}$$

From this relationship, the following combinations of *p* and *q* can be obtained:

p = Relative change in price	*q* = Relative change in quantity
-.1	.111
-.2	.250
-.3	.430
-.4	.666
-.5	1.000

It will be seen now that a lowering of quality such as to reduce the price by 10% must be accompanied by an increase in yield of at least 11.1% before the program that brings about such changes can approach financial feasibility. The corresponding percent increases in yield that are the minimum required to go along with percent price reductions of 20, 30, 40 and 50 are 25, 43, 66.6 and 100, respectively. It must also be remembered that financial feasibility does not mean that a program is necessarily desirable. To qualify as the most desirable investment opportunity available to a society, a tree-improvement program must show increases in yield well in excess of the foregoing figures if there is any lowering of quality that accompanies any yield improvements.

It thus appears that we ought to be very careful about the side effects of tree-breeding. Breeding may result in handsome improvements in quantity or quality, but the accompanying deteriorations in the quality or quantity have the capacity to neutralize these benefits with relative ease.

Unfortunately, that is not all. Among other things, we have assumed so far that a change in price reflects only the change in quality of the produce. This obviously is not the case. Price is subject to change not only owing to quality differences but also owing to the quantity available in the market and the interaction of supply and demand. These changes are very important, and to understand the combined effects of quality and quantity on price, one must first have a look at changes due to quantity only. For this purpose, the theory of benefit-cost analysis[1] is given in brief as applicable to tree-improvement programs.

[1]For a review of benefit-cost analysis and its application to forestry, see Prest and Turvey (1965), Sewell *et al.* (1965), Webster (1965) and Chappelle (1969).

PURE THEORY OF BENEFIT-COST ANALYSIS

The principles that govern the decision whether an investment in a tree-breeding program should be made are of interest to most people who are confronted with such decision-making. Investment of one dollar in a program at any time is economically feasible if it results in a return (to whomsoever it may accrue) the present worth of which, at the time when investment is made, is more than one dollar. But feasibility alone does not determine the desirability of an investment. An outlay is desirable only if it returns more than what an equal amount of investment somewhere else in the economy would yield. The size of the desirable outlay should be increased to the level at which each extra dollar put in returns more than that a dollar would earn in the best available alternative.

Now let us assume that the demand schedule for the timber of a certain species is as shown by DD_1 in Fig. 1. Let it also be assumed that the schedule will remain more or less the same between now and a time "*t*" years hence, when an improved breed is ready for harvest. If the only effect of tree-breeding is higher yield and if land input remains constant, the investment in such a program has only the effect of pushing the supply curve from S_1 to S_2.

With the supply curve S_1 the ruling price of stumpage is OA and the quantity transacted is OH. The total benefit going to the consumers is, therefore, expressed by the area of the figure OHFD. When the supply curve shifts to S_2, the total benefit becomes OEGD. A shift in the supply curve

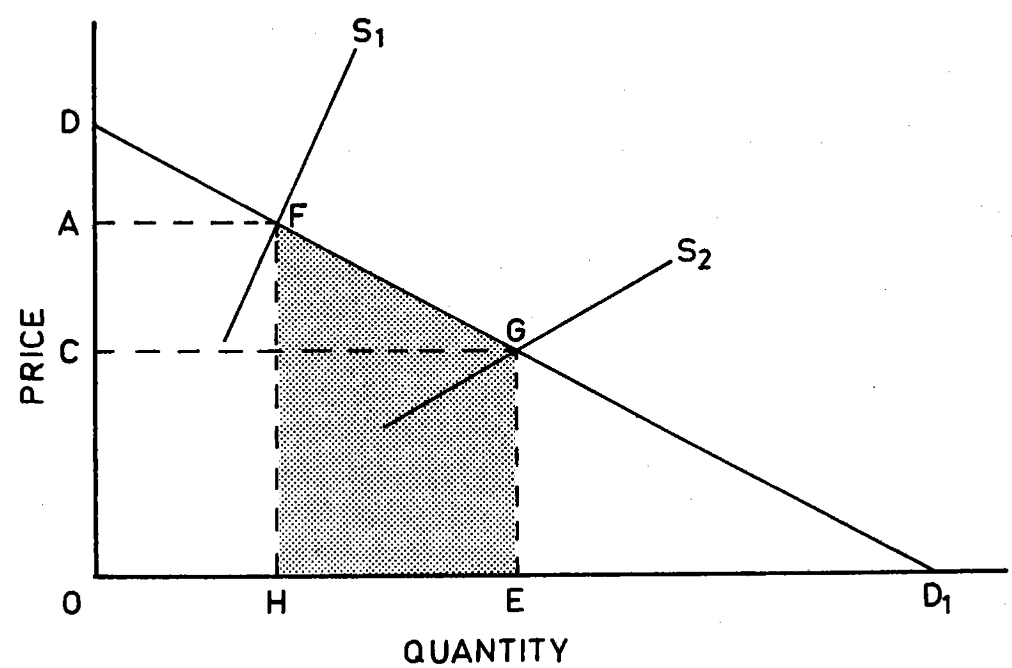

Figure 1. Benefits of a tree-improvement program when quality is not affected.

thus definitely increases the welfare of society by an amount represented by the area HEGF. This is the social value of the tree-improvement program in 1 year. Because the shift in the supply curve comes about only at a cost to society, it is necessary to investigate whether the additional benefit HEGF is worth the cost of having it. We must not forget, however, that HEGF (=B) is the extra benefit to society in one time period or year. Presumably, the benefit will accrue each year in perpetuity if the stumpage in question is demanded in the market *ad infinitum* and the supply also continues. Therefore, the total extra benefit resulting from the tree-improvement program is an infinite series of B's every year. The worth of this series in the first year when benefit occurs is:

$$B + \frac{B}{(1 + i)} + \frac{B}{(1 + i)^2} + \ldots = \frac{B}{i}$$

The worth of $\frac{B}{i}$ in the year when investment is made can be obtained by discounting this value to "t" years, which is the time that elapses between investment and the first benefit "B". Such a discounted value is $\frac{B}{i(1 + i)^t}$ and it is this that must be compared with the present worth of the costs of the tree-breeding, i.e. "C". The comparison can be made in two ways.

One method is to calculate the net benefit $\frac{B}{i(1 + i)^t} - C$ of the program and the other is to calculate the benefit-cost ratio $\frac{B}{Ci\ (1 + i)^t}$. The desirability of the program is indicated by the ranking among alternatives that the project gets on the basis of the net benefits or benefit-cost ratios. It can be shown that for a public financed program, the more desirable criterion for ranking is the benefit-cost ratio and that the project with the highest ratio should be selected for execution. If there is an opportunity to increase the scale of the project, it should be made use of and the scale increased to the level where the incremental benefit-cost ratio is equal to the ratio of the next best alternative (Sewell *et al.*, 1965).

When seed improvement results not only in increasing yield but also in affecting the quality of the produce, the supply schedule, as well as the demand schedule, move simultaneously. In Fig. 2, if the demand and supply functions were DD_1 and S_1 before improvement, the total benefit earned by consumers is OHFD. After improvement, the supply function is pushed down to S_2 and due to quality deterioration, the demand schedule also moves to $D'D_2$. The total benefit earned by consumers is now OEGD' and, therefore, the additional benefit derived in 1 year (=B) is measured by the difference OEGD' - OHFD.

It will be seen that the measurement of benefits or social value as the additional area below the demand schedules in Fig. 1 or 2 is a difficult task, and so a more simplistic approach of considering only market value is likely to be taken. According to this, the value of the products supplied before the improvement program was OHFA and the value after improvement is OEGC in both figures. The difference between the two rectangles is then the

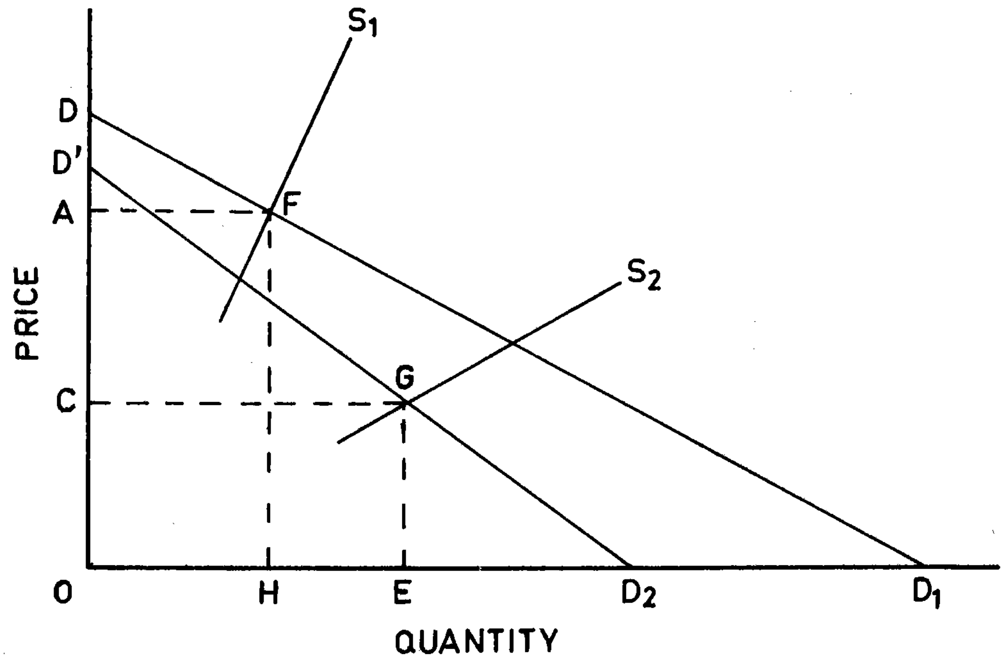

Figure 2. Benefits of a tree-improvement program when quality is affected.

additional benefit accruing to the agency that owns the forest. All the benefits to society due to improvement are not being taken into account in this system, but only the part of the benefits that are appropriated by the agency that initiates the program and sells the resulting product. From the point of view of the agency, these benefits alone figure in any benefit-cost analysis, and this was the approach that was discussed in the beginning of this paper.

DISCUSSION

A closer look at the benefits from tree-breeding shows that the advantages of such programs cannot be considered in isolation from their side effects. Such effects change the quality of wood and so the demand schedule, which, in turn, affects price. Also, the full benefit of a program is the addition in the "area under the demand schedule" that results from the program and not simply the addition to market value of the product. Owing to the difficulties involved in the measurement of full benefits or social value of a project, especially when demand and supply schedules change simultaneously, the market value is likely to be taken as a guide to the evaluation of the benefits of a program and may, therefore, lead to wrong results. As recognized by Carlisle and Teich (1970), it is difficult to get a clear picture of the economics of such programs in terms of hard cash. The usual error made is to underestimate the benefits. An interesting and useful outcome can be recognized from these observations. Tree-breeding enthusiasts who choose to see only one aspect of breeding and ignore others are likely to push too many projects, at least some of which would be economically unfeasible. On the other hand, those who can recognize only the market value of production are apt to use a kind of benefit-cost analysis that, by its very nature, tends to underestimate the benefits and so disqualifies many a socially desirable project. An understanding of the benefit-cost analysis and intimate knowledge of any tree-breeding program is, therefore, essential if scarce resources are not to be misallocated in such programs. This is by no means easy.

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THE ECONOMICS OF THE GENETIC IMPROVEMENT OF WHITE SPRUCE

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RÉSUMÉ

Le présent rapport décrit et discute les bénéfices encourus à la suite de programmes d'amélioration de l'Épinette blanche (*Picea glauca*).

Il rend également compte des résultats d'une analyse coût-bénéfice à partir d'un modèle de neuf paramètres ("input") et de quatre autres ("output") utilisés pour évaluer l'augmentation du rendement (15%) que l'on s'attend obtenir par l'emploi de semences génétiquement supérieures chez l'Épinette blanche.

On estime à près de 3,400 par année le nombre de livres de semences nécessaire pour équilibrer le programme d'ensemencement et de plantation au Canada pour les 15 prochaines années.

De telles semences améliorées peuvent être produites au taux de 43 sous l'acre suivant un espacement de 8 x 8 pieds (2.5m x 2.5m).

Si l'utilisation d'une meilleure semence entraîne une augmentation de 15% à la récolte, la valeur nette actuelle de ce rendement accrû se chiffre entre $5 à $12 l'acre selon le lieu d'utilisation. Le projet s'avère fort intéressant comparativement au coût de production de la semence. A cet emploi d'une semence améliorée peut également s'ajouter une sécurité et une qualité accrues du produit ligneux; cette dernière pouvant influencer les profits du moulin à papier.

La corrélation entre l'espacement des arbres et la valeur nette actuelle fut positive et curviligne. Il n'est pas impossible que des essais sur l'amélioration des arbres forestiers puissent aboutir à des conclusions plus réalistes si ces derniers étaient installés suivant des espacements plus larges que les valeurs conventionnelles de 4' x 4' (1.2 x 1.2m) ou 6' x 6' (1.8 x 1.8m). La valeur nette actuelle était fortement influencée par les facteurs suivants: taux d'intérêt, hausse des prix, coût d'établissement et de gestion.

De plus amples informations sont encore requises sur les coûts d'opérations forestières, d'aménagement des vergers à graines, du rendement des plantations d'arbres économiquement importants et poussant en des stations variées, suivant divers espacements, de même que sur l'hérédité des caractéristiques ligneuses dont dépend la qualité de la pâte à papier.

* * *

INTRODUCTION

The purpose of this report is to describe and discuss some of the benefits that can be achieved by tree-improvement programs and how much such programs cost. The paper will briefly describe a cost-benefit model for white spruce (*Picea glauca* (Moench) Voss) plantations grown mainly for pulp. The model was constructed to assess the value (in terms of present net worth and internal rates of return) of different percent increases in yield; the model applies whether these increases are achieved by silvicultural or genetic means or by both. The overall aim is to provide the forest manager with a foundation upon which he can base management decisions.

Throughout the paper "tree improvement" will refer to production of trees with superior, genetically controlled attributes; used in this sense the expression covers the whole research and development spectrum.

THE DEMAND FOR WHITE SPRUCE SEED

Tree-improvement programs make their main impact in planting and seeding programs; in some cases they are of benefit to natural-regeneration programs in that parents with superior attributes can be left as seed trees. These improvement programs are of economic value only if they meet a real need for better seed. In the case of white spruce, there is no doubt that such a need exists on a national scale. By 1965 about 50,000 acres of white spruce were being planted annually, equivalent to 28% of the total area seeded or planted annually throughout Canada. It has been predicted (Cayford and Bickerstaff, 1968) that by 1985, 10 million acres will have been planted or seeded in Canada; if the same proportion of white spruce is planted as at present, the area of white spruce planted or seeded in the next 15 years will average 147,000 acres per annum. To meet this demand, we shall need a minimum of 3,400 pounds per annum of good white spruce seed, preferably seed from populations of known superiority in growth and other attributes of economic importance.

THE TYPE OF TREE THE FORESTER WANTS

The forester wants to establish trees for pulp that will

(1) produce a high volume or weight of stem wood per acre in the minimum time,

(2) respond well to silvicultural practices aimed at increasing yield,

(3) survive the extremes of air and soil climate and attacks by pathogens, and

(4) produce a uniform, high-quality stem-wood product that is cheap to harvest, gives a high yield of paper per unit quantity of wood and is relatively cheap to process.

In brief he wants high yield, crop security and high quality.

These can all be achieved to varying extents by silviculture or tree improvement or by both. To make a decision about how far he should rely upon silviculture and to what extent he should utilize genetically superior trees, the forester needs to know what increases in yield, security and quality he can get by either method, how much it will cost, and how long the benefits will persist.

GAINS FROM USING IMPROVED WHITE SPRUCE

White spruce is an extremely variable species. There is evidence that appreciable gains can be made both by selecting the right natural white spruce population as a seed source and by breeding from selected individual trees. Nienstaedt (1969) reported results from trials of white spruce from 29 sources in the United States and Canada, field-planted from 1960 to 1962 at 14 locations across these countries. Trees from some locations in Ontario had 35% more height growth than the average; in New Brunswick trees from these locations grew 25% better than the average and 23% better than the local population. These trials are still young, but older (29 years) tests of white spruce from a similar source had 22% better height growth than the average and 16% better growth than the local white spruce in a test in Wisconsin (Nienstaedt, 1969). In these proceedings Teich (p. 95-100) reports results from trials of 8- to 15-year-old white spruce in Canada; the best provenances had 22% better height growth than the average, and (on average) 19% better growth than local populations. These trials are still young, but together with Nienstaedt's results, they indicate that considerable increases in height growth can be achieved by using selected white spruce populations rather than general or local collections as seed sources. The increases in volume will be even more.

Jeffers (1969) tested progeny from 32 selected white spruce parents growing at various locations in Michigan; the parents were selected on the basis of vigor, height growth, form, needle length and branch characteristics. After four growing seasons the progenies from the two fastest-growing parents had 63% more height growth in one year (1967) than the average; progeny from the five fastest-growing parents grew 21% better than the average in the year studied. Teich (p. 95-100) reports that the tallest 19-year-old progeny from 12 selected white spruce plus trees were 16% taller than the average. Again, these trials are young, but they illustrate the gain that can be achieved by breeding with this variable species, quite apart from gains from selecting the right populations. Heritability of height growth in white spruce is known to be high - e.g. 91% (Holst and Teich, 1969).

We can, therefore, embark upon a program of genetic improvement of white spruce yield with a very good chance of success. For most tree-improvement programs it is reasonably safe to predict a 10% increase in yield; for white spruce we can expect a much greater gain. For the purpose of the present report, however, we shall assume that the use of improved white spruce will result in a 15% increase in yield of merchantable timber.

So far we have dealt mainly with yield, but adaptive characteristics such as flushing and dormancy are also genetically controlled in white spruce.

If trees could be selected for both late flushing and rapid growth rate, as suggested by Nienstaedt and King (1969), it would be possible to increase both crop security and yield simultaneously.

We know very little about the heritability of the timber characteristics of white spruce. Some work has been done on the wood density of different white spruce provenances (Jones, 1958). It has, however, been demonstrated for other coniferous tree species that wood characteristics such as specific gravity, tracheid length, fiber and tracheid cell-wall thickness and proportion of summer wood (which influence pulp quality) are genetically controlled, with relatively high narrow- and broad-sense heritabilities - e.g. 80% (Harris, 1969; McElwee, 1963; Dadswell and Wardrop, 1959; Goggans, 1962). There is every reason to believe that further research will show that such a variable species as white spruce will respond to selection and breeding for these characteristics.

The available evidence, therefore, strongly suggests that white spruce will respond well to selection and breeding.

THE VALUE OF A 15% INCREASE IN YIELD

Tree improvement, like any other technique for increasing yield, costs a great deal of money. It is fair to ask whether the value of the increases in yield, security and quality is commensurate with the investment; also it is fair to ask whether these gains can be achieved more economically by other means.

The authors constructed a model with a view to answering the question, "Is the value of the increase in yield we can expect from using genetically improved white spruce in plantations more or less than the investment in the production of improved seed in seed-production areas?" The results of this analysis have been described in more detail in an earlier report (Carlisle and Teich, 1970). Since the writing of that report, the model and program have been revised and refined, and the new results (which differ only slightly from those from the earlier model) are given in this report. The model was designed throughout to minimize estimates of benefits. It involves the assumption that most of the trees will be sold as pulp, but that some of the larger trees may provide sawlogs.

The model consists essentially of a series of equations for computing total costs, total value of the crop at time of harvest, profit, and increase in profit due to increases in increment. In computations of costs and values, the interest rate and inflation were taken into account. All profits were backdated to planting time (i.e. were expressed as present net worth), and the percent returns on investment were calculated with the present net worth at zero (i.e. were expressed as internal rate of return). Present net worth and internal rate of return were computed for different site index classes. The mensuration data were taken from the Petawawa, Ont., white spruce plantation yield tables by Stiell and Berry (1967). The nine input parameters for computing costs and values of timber and the four outputs are given in Table 1.

Table 1. Input and output parameters used in the white spruce cost-benefit model

Input		
1.	Site index class	40 - 70 (height in feet at 40 years)
2.	Tree spacing	4 x 4 to 8 x 8 feet
3.	Volume of merchantable wood in increment and standing crop	From yield tables by Stiell and Berry (1967)
4.	Interest rate	6% per annum
5.	Stumpage value	8.2 cents per cubic foot
6.	Inflation rate	2% per annum
7.	Establishment costs	6.15 cents per plant + $11 an acre
8.	Management costs	$1 per acre per annum
9.	Improvement in yield	0, 15% (to 25%)
Output		
10.	Economic rotation	Age in years at which the cost of waiting one more year is equal to or greater than the increase in value in the next year
11.	Present net worth of the forest enterprise	Profit or loss ($ per acre) at harvest discounted to planting time
12.	Change in present net worth due to increase in yield	Increase in profit or decrease in loss ($ per acre) at harvest discounted to the time of planting
13.	Internal rate of return	Interest rate (%) that makes the present net worth zero

In this table certain base-line values for individual parameters are given; these were based on the literature and values suggested by practicing foresters. Some people will disagree with the levels used for individual parameters. It should be remembered, however, that these values can be varied in the model. The program for the model was written in Fortran and was designed for use on a PDP-8L computer.

A summary of the results is given in Table 2. As one would expect the most profit came from trees grown on the best site; on all but the best site there was a net loss for the particular interest rate (6%) used. For site classes 40 to 70, with no increase in yield the present net worth ranged from +$8.42 to -$40.42 per acre. For the same site classes with a yield increase of 15%, the present net worth ranged from +$20.32 to -$35.68 per acre. The additional 15% of yield increased profit or reduced loss by +$11.90 to +$4.74 per acre, depending upon site class; the last-mentioned figures are the value of the yield increase at harvest discounted to planting time. A decrease in loss is as valuable as an increase in profit when the former is inevitable; both represent a gain. The fact that the forest operation from seed purchase to sale at the stump operates at a loss does not mean that plantation forestry is uneconomic: losses in this aspect of forestry may well be offset by later profits in the sale of pulp, lumber and consumer goods. The cost of the raw material may well still be small in relation to ultimate benefit from the full cycle of seed collection, culture, harvest, conversion and sale of products.

COSTS OF PRODUCTION OF GENETICALLY IMPROVED SEED IN RELATION TO THE VALUE OF THE YIELD INCREASE

Unfortunately the authors have not been able to find a detailed analysis of seed-production costs for white spruce seed orchards. There is, however, some information about the costs incurred in seed-production areas of this species. Pitcher (1966) found that improved white spruce seed produced in such areas cost $43 a pound, i.e. $27 a pound more than the current price for white spruce seed (up to $16 a pound). One pound of white spruce seed produces at least 43,000 transplants; if these trees are planted at 8 x 8 feet, the additional cost of producing the improved seed is about 43 cents per acre planted. The increase in height growth to be expected from using this seed is 15%; the increase in volume will be more. The value (present net worth) of a 15% increase in yield is from about $5 to $12 per acre depending upon site index class; from any point of view this is a good return on an investment of 43 cents an acre. It would be hard to find a cultural practice that costs so little and yet increases yield by 15%. These costs do not include the cost of research leading to the prescription as to which seed source to use. It has been estimated that for a total research investment of $1,500,000 over a period of 15 years (including interest) and an additional annual expenditure of $23,310 on seed production leading to a 15% increase in yield, the approximate potential economic benefit generated in a 100,000-acre-per-annum white spruce planting program would be $832,000 per annum (Carlisle and Teich, 1970). In this broader context tree improvement is still a good investment.

Table 2. The present net worth and internal rate of return for white spruce plantations at different tree spacings on different sites for 0 and 15% increases in yield

Site class (height in ft at 40 years)	Spacing (ft)	Current annual increment (ft^3/acre)	Economic rotation age (years)	Improvement in yield (%)	Present net worth ($/acre)	Change in present net worth ($/acre)	Internal rate of return (%)
70	8 x 8	199	42	0	+ 8.42	-	6.3
				15	+20.32	+11.90	6.7
60	8 x 8	164	43	0	- 8.97	-	5.6
				15	+ 0.35	+ 9.32	6.0
50	8 x 8	132	45	0	-25.20	-	4.8
				15	-18.26	+ 6.94	5.2
40	8 x 8	104	48	0	-40.42	-	3.9
				15	-35.68	+ 4.74	4.2

THE VALUE OF INCREASES IN WOOD QUALITY

No information on the value of increasing white spruce wood quality has been found in the literature, but some information is available for the pine-improvement programs of the United States. Davis (1969) pointed out that in the paper industry raw-material quality influences both yield of product per unit quantity of wood input and the time required to process a certain quantity of wood. He calculated that if, in the case of a paper mill producing 500 metric tons of paper a day, the yield of paper per unit quantity of wood were increased by 5% and the processing time reduced by 5%, mill costs would be reduced by 2.4% to 7% and daily profits increased from 15% to 41%. Small improvements in raw-material quality greatly affect mill profits. Many of the factors affecting raw-material quality are genetically controlled in other tree species (Harris, 1969), and the same is probably true for white spruce. We need to know much more about the potential for breeding for wood quality in white spruce and which characteristics to breed for.

THE EFFECT OF VARYING TREE SPACING, ESTABLISHMENT COSTS AND MANAGEMENT COSTS ON PROFIT

The model was also used to assess the effects upon the present net worth of varying tree spacing, establishment costs, management costs and stumpage, factors over which the forest industry and government agencies have some control. The effects of varying interest and inflation rates were also studied, but they are less amenable to control.

Some preliminary results for site class 70 are given in Fig. 1 to 4.

Only the effect of spacing is of direct relevance to the economics of tree improvement (Figure 1); other relationships (Fig. 2 to 4) illustrate how the model can be used by forest managers to assess changes in profits associated with changes in stumpage and costs.

Tree spacing influences establishment cost; the latter is essentially the product of the number of trees per acre and the cost of establishment per tree, plus site-preparation costs. Tree spacing also influences yield, which in time affects profit. The relation between tree spacing and present net worth is positive and curvilinear (Figure 1); at 8 x 8 feet the present net worth had still not quite reached its maximum. The decision about which spacing to use is influenced by other factors - e.g. whether or not a tree develops heavy branches with poor self-pruning at wider spacings. The economic data, however, clearly illustrate the greater profits associated with wider spacing in the present context. In provenance trials and progeny tests, the tendency is to plant closely at 4 x 4 to 6 x 6 feet. Results would be more realistic if these trials were carried out at wider spacings.

Figures 2 to 4 illustrate the sensitivity of present net worth to changes in stumpage, establishment costs and management costs. At stumpage rates below about 8 cents per cubic foot there is a net loss in the limited

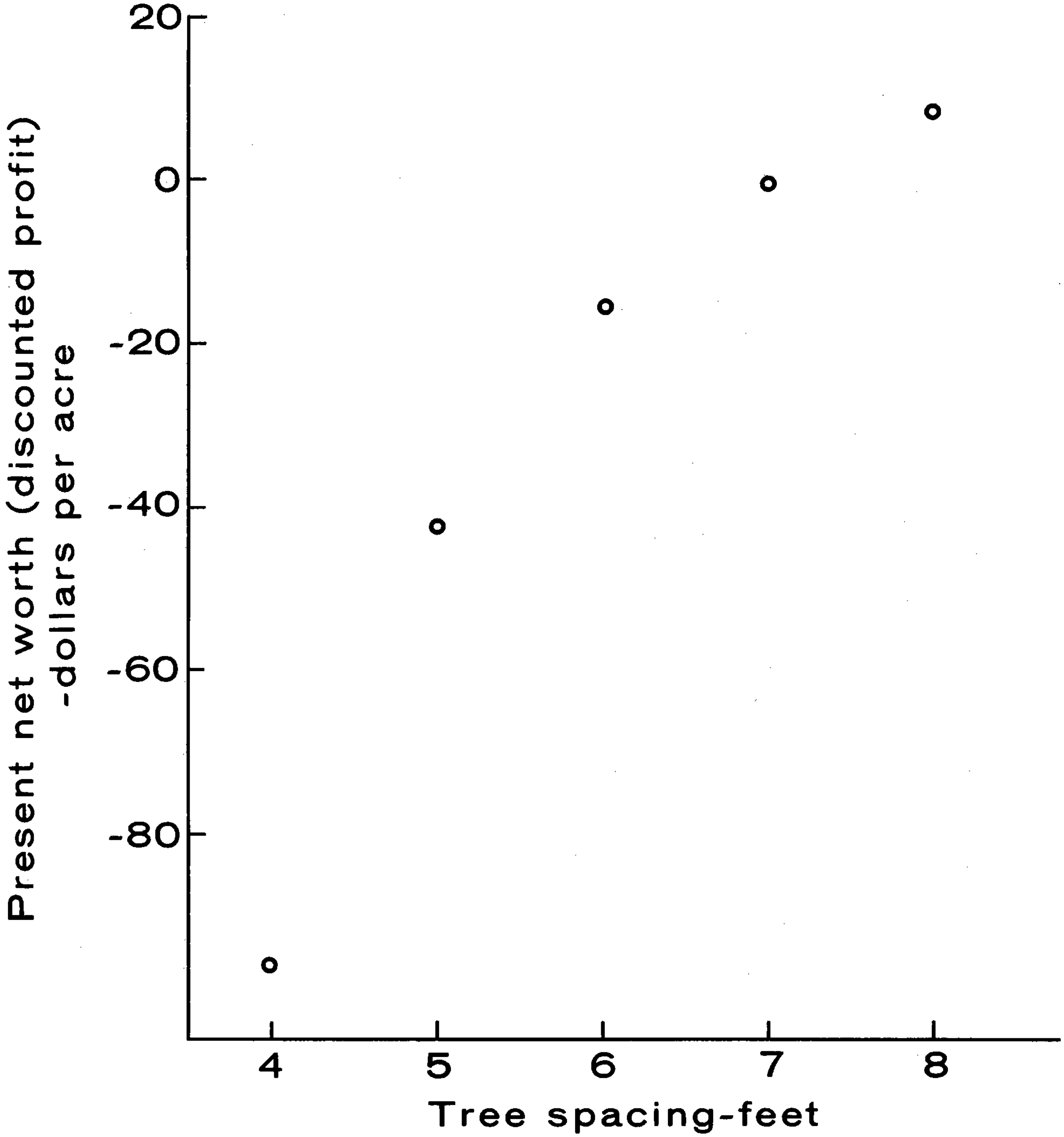

Figure 1. The relation between tree spacing and present net worth (at planting time) of a white spruce plantation, site class index 70.

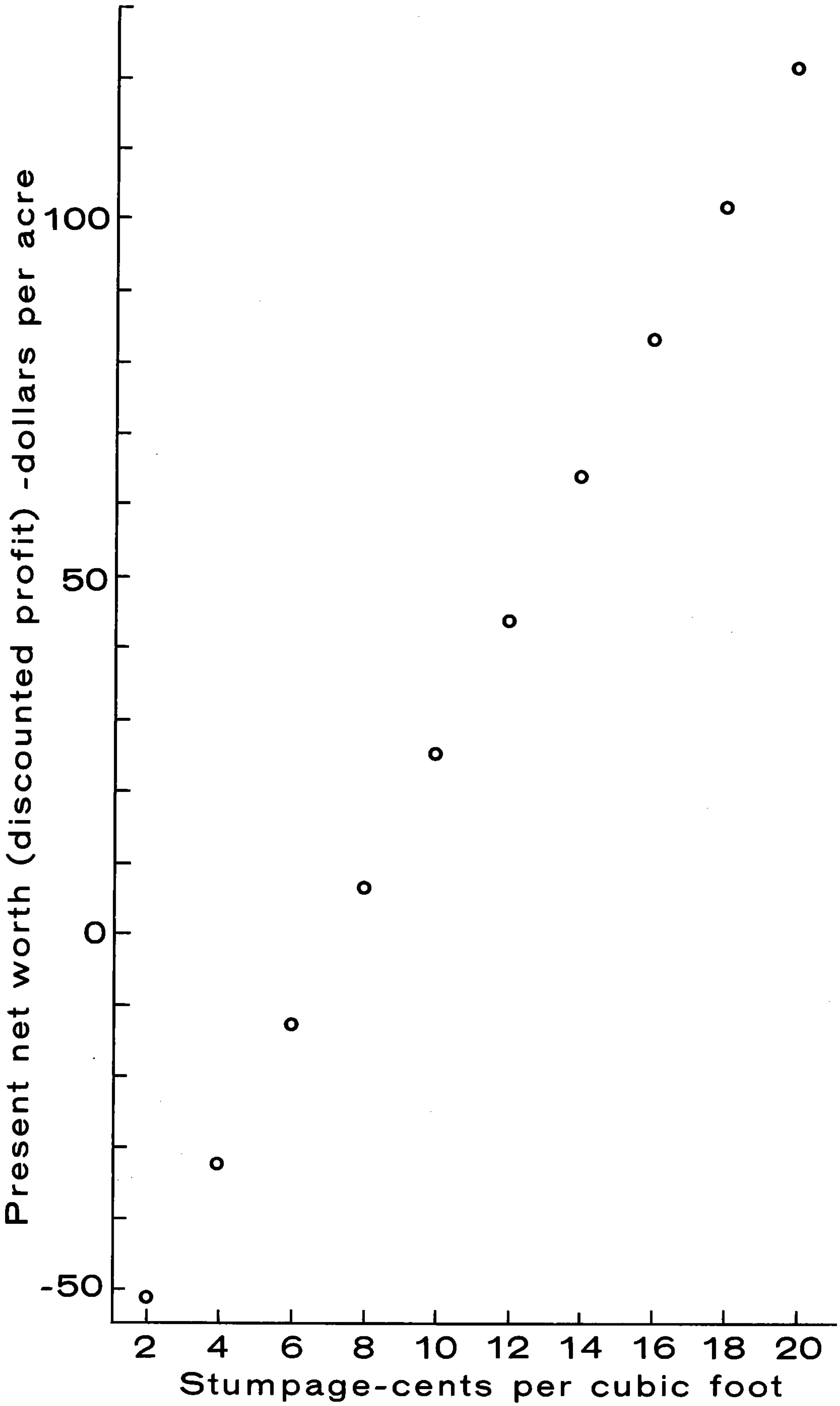

Figure 2. *The relation between stumpage value and present net worth (at planting time) of a white spruce plantation, site class index 70, spacing 8 X 8 feet.*

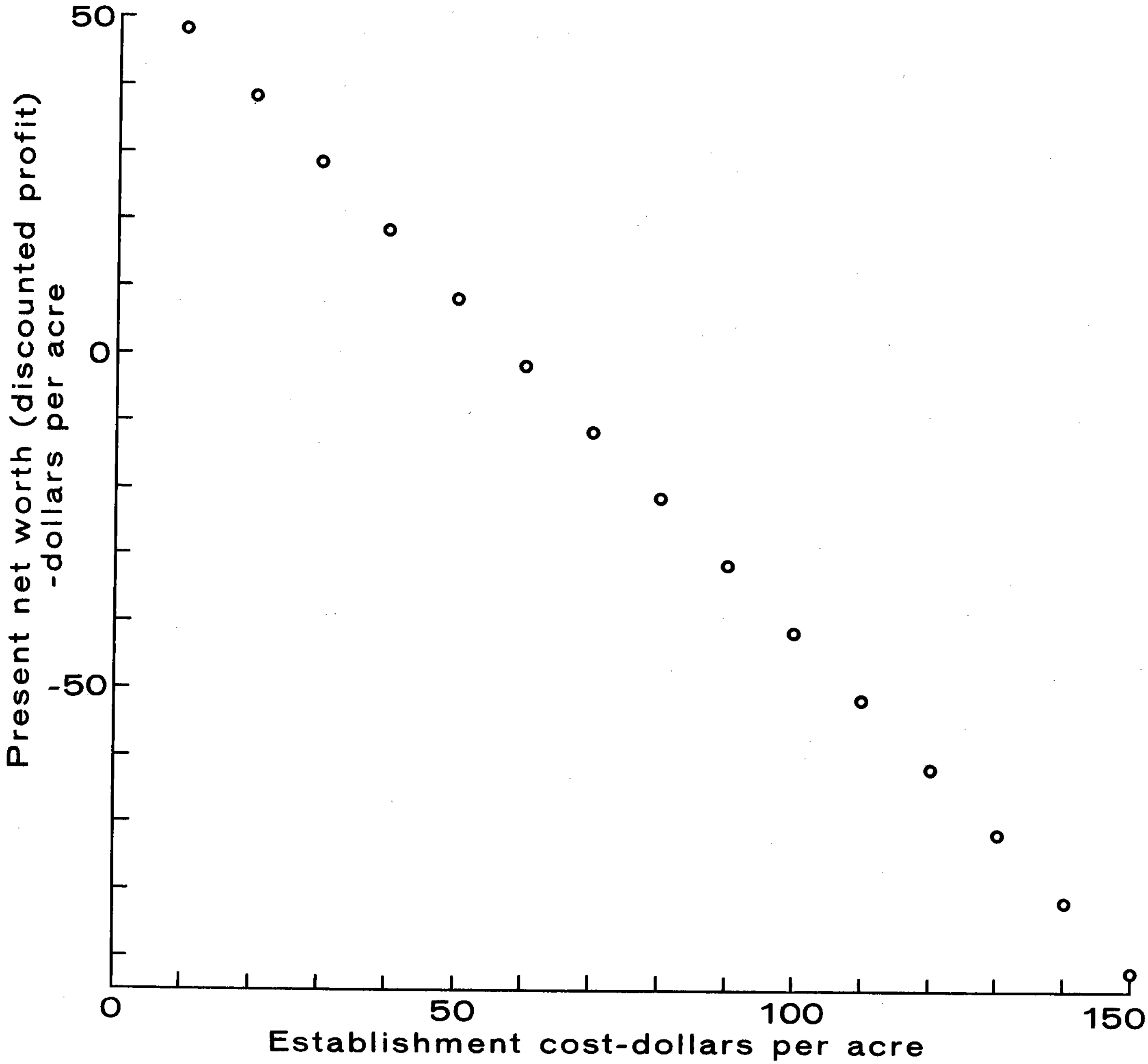

Figure 3. The relation between establishment costs and present net worth (at planting time) of a white spruce plantation, site class index 70, spacing 8 X 8 feet.

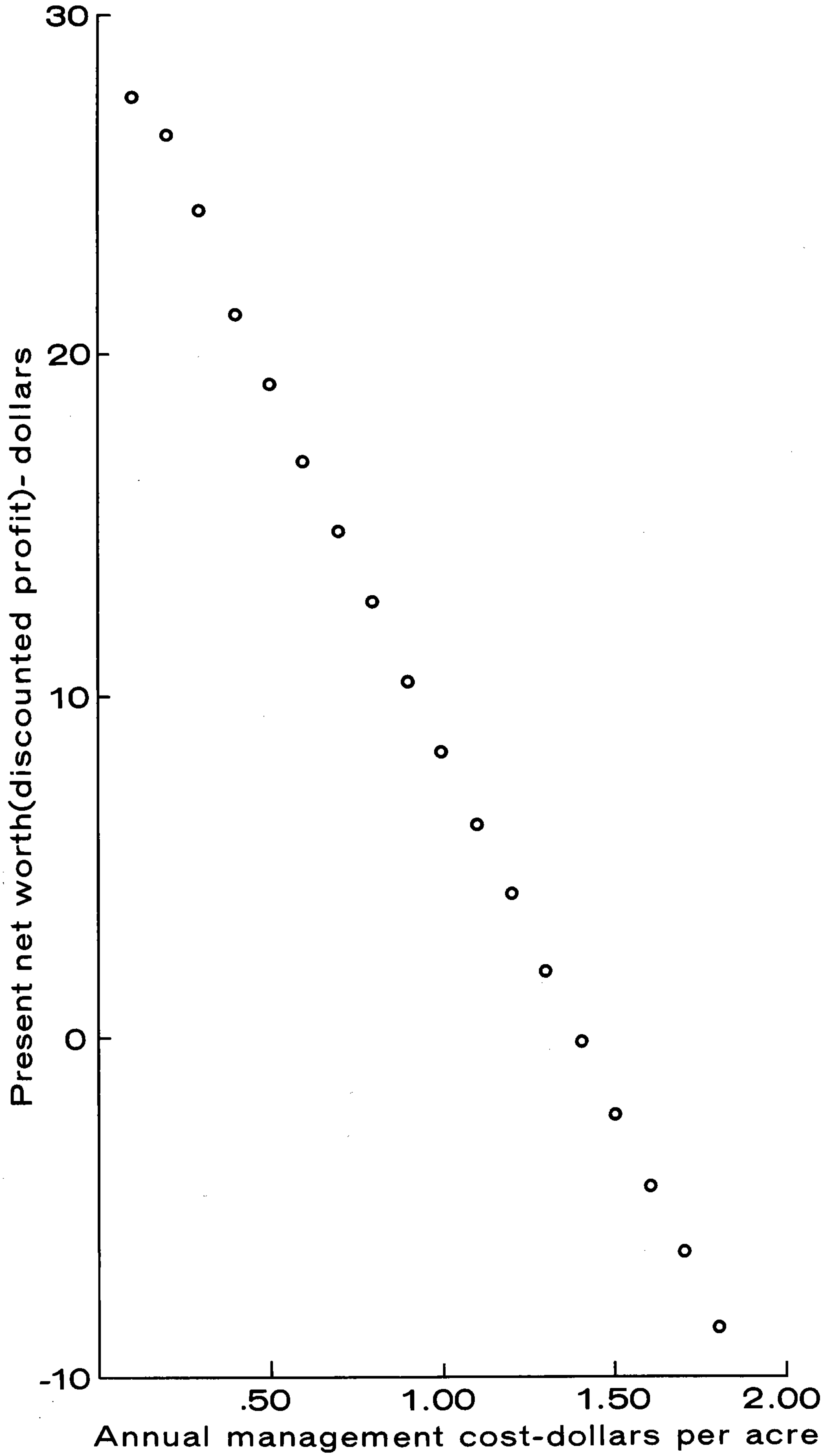

Figure 4. The relation between management costs and present net worth (at planting time) of a white spruce plantation, site class index 70, spacing 8 X 8 feet.

context of the present model. The forest manager can help to maximize profits by influencing management and establishment costs so that the full economic potential of using genetically superior seed can be realized.

Profit is very sensitive to changes in interest and inflation rates. Preliminary results suggest that if stumpage value and management costs are affected by inflation, present net worth is positively correlated with inflation, because inflation affects crop value to a greater extent than the costs.

The model is a simplification of a complex system. It involves the assumption that, for the increases in yield considered, pulping characteristics are not adversely affected to an extent sufficient to reduce stumpage; in it no account is taken of variations in management costs on sites with different indices; it also involves the assumption that inflation affects stumpage value and that (in the context of pulp) tree size does not affect stumpage. All these assumptions will not be valid in all situations, but the program can be modified so that this is taken into account.

DISCUSSION

There is good evidence that the production of genetically superior white spruce seed is a good investment; potential benefits greatly exceed the costs.

The use of the model has made it possible to observe the effects of the nine input parameters on profit. It has also indicated certain gaps in our knowledge. It was surprisingly difficult to obtain estimates of costs of management (the latter ranged from 40 cents to $2.20 an acre), seed production in orchards and seed-production areas, and research. If practicing foresters would keep records of the costs of some of these operations, such records would be most valuable for future calculations of the costs and benefits of yield increases. We should also like to know much more about the wood characteristics affecting pulp quality and their heritability. Increasing yield should be given highest priority in view of increasing demands for cellulose, but the quality factor cannot be ignored. The authors also encountered a scarcity of yield data for plantations on different sites and at different spacings, although a great deal of information is available for natural woodlands. More information on plantation yield, particularly for faster-growing genotypes, would be most valuable. We know a little about how trees from different sources behave in small test plots, but we should very much like to know how apparently superior genotypes behave in operational plantings.

The choice of seed is a management decision. It should not be thought that, since increasing yield by genetic improvement of white spruce is relatively cheap to achieve, it is an alternative to increasing yield by silvicultural methods. Neither tree improvement nor silviculture can achieve optimum yields on their own: they must work in conjunction. The full growth potential of superior genotypes can be achieved only by good cultural practices, and the full benefit of costly cultural practices such as fertilisation can be achieved only if the trees have a high inherent growth potential.

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