SEEDLING SEED ORCHARDS OF OTTAWA VALLEY WHITE SPRUCE FOR THE MARITIMES

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ABSTRACT

Southeastern Ontario provenances of white spruce (Picea glauca (Moench) Voss) have performed consistently well in tests established in the eastern part of the species range including three trials planted at Acadia Forest Experiment Station and one in northern New Brunswick. Because of this, the Maritimes Forest Research Centre decided to develop "local" sources of Ottawa Valley seed and at the same time improve it genetically through selection for Maritime use.

Approximately 120 open-pollinated seed collections from Ottawa Valley provenances have been obtained and these are being outplanted in three seedling seed orchards - two in Nova Scotia and one in New Brunswick. During the greenhouse and nursery stage the poorest families and poorest individuals in the better families will be culled. Through a series of thinnings favoring the best phenotypes, the seed orchards will be reduced to about 25% of their original stocking. The best individuals in these orchards will provide material for a one and a half generation clonal orchard.

RESUME

Des provenances d'Epinette blanche (Picea glauca (Moench) Voss) apportées du sud-est de l'Ontario se sont fort bien comportées au cours d'essais effectués dans la région est de l'aire de distribution de l'espèce, au cours de trois essais à la forêt expérimentale d'Acadia et un autre dans le nord du Nouveau-Brunswick. C'est pour cette raison que le Centre de recherches forestières des Maritimes décida de développer des sources "locales" de graines de la Vallée de l'Outaouais et de les améliorer génétiquement par la même occasion avec la méthode de sélection, pour les utiliser aux Maritimes.

Approximativement 120 collections de graines issues de pollinisation libre provenant de la Vallée de l'Outaouais furent obtenues et sont en train d'être plantées dans trois vergers (deux en Nouvelle-Ecosse et un au Nouveau-Brunswick). Durant leur stage en serre et en pépinière, les "familles" (semis issus de graines provenant d'un seul arbre) les plus pauvres et les sujets les plus pauvres venus des meilleures "familles" seront mis au rancart. Au moyen d'une série d'éclaircies favorisant les meilleurs phénotypes, on réduira les vergers jusqu'à 25% environ du nombre de semis originaire. Les meilleurs sujets parmi ces vergers fourniront des plants pour la durée d'une génération à une génération et demie à un verger "clonal".

INTRODUCTION

Genetically, white spruce, Picea glauca (Moench) Voss. is a highly variable species. Nienstaedt and Teich (1971) provide information on most aspects of improvement and genetics of the species. Provenance trials have shown that white spruce from different parts of the species range differs significantly in respect to height growth, wood density, edaphic response, threshold germination temperatures, DNA content, and nuclear volume (see Nienstaedt and Teich 1971 for specific references). The general pattern of variation appears to be clinal and has undoubtedly evolved in response to different climatic factors such as photoperiod, temperature, and precipitation. There is some evidence to suggest that localized ecotypes have developed in response to differences in edaphic features (Farrar and Nicholson 1966; Teich and Holst 1974).

Growth of white spruce has been evaluated in extensive provenance tests in the north-central and eastern United States and central and eastern Canada. The most outstanding finding from these tests has been the consistently good performance of seedlings originating from southeastern Ontario, especially from the Ottawa Valley region. The Ottawa Valley provenances have grown better than local seed sources over a wide range of climatic and edaphic conditions. In one of the earliest tests, planted in northern Wisconsin, seedlings from a Douglas, Ontario source were 22% taller than the plantation average and 16% taller than seedlings from the local source (Nienstaedt 1969). In a second trial involving 24 provenances from across the species range and planted in 14 locations, an Ottawa Valley provenance from Beachburg was tallest in seven plantations,

second tallest in three, and well above average in the remaining four locations. In two of these tests planted at the Acadia Forest Experiment Station (A.F.E.S.), seedlings from Beachburg were 4 and 27% taller than seedlings from northern New Brunswick and 44 and 28% taller than the plantation means after 15 years growth (Appendix A). The Beachburg provenance is considered to be highly stable in that it performs well on a wide range of planting sites. Figure 1, reproduced from Nienstaedt and Teich (1971), graphically presents the superiority of the Peterborough (31) and Beachburg (1663) provenances when planted in various locations.

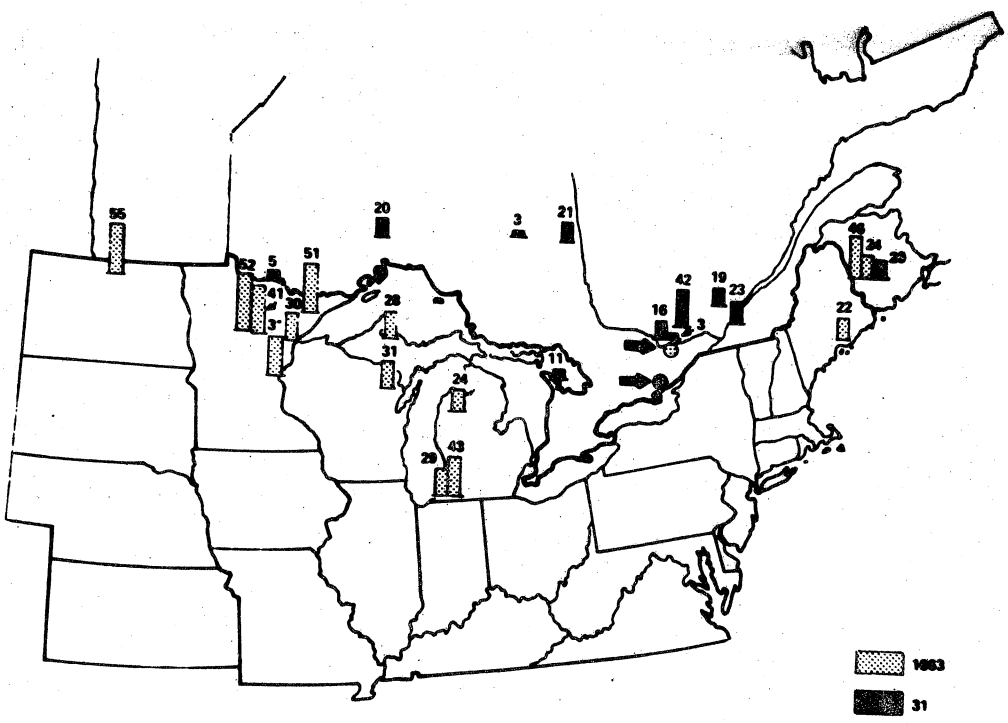

Figure 1.—Results with Beachburg and Peterborough provenances in 25 tests in the U.S.A. and Canada. The bars correspond to the approximate location of the test areas and show the percentage by which the respective sources exceed the plantation mean.

In a series of Ontario trials containing seedlings from 91 provenances, an Ottawa Valley source from Petawawa produced seedlings that were 17% taller and had 5% better survival than average in all 11 test locations (Teich 1970). The 11 test locations covered 30° of longitude (1200 miles) and 7° of latitude (350 miles) (Teich 1970). At 13-20 years of age, seedlings from eastern and southeastern Ontario averaged 21% taller than local provenances (Teich et al. 1975) in Ontario tests.

In a further trial, 53 provenances were compared in 13 locations in central and eastern Canada. In these trials, seedlings from the Cobourg, Ontario source grew exceptionally well. In a test of the materials at the A.F.E.S., the three tallest provenances at 11 years were from eastern Ontario and were 15, 14, and 14% taller than the local A.F.E.S. source (Appendix B).

In a trial of 25 sources from the Great Lakes - St. Lawrence Region planted at Plaster Rock, N.B. in 1964, four of the six tallest provenances were from the Ottawa Valley region while two of the six were local New Brunswick provenances (Appendix C).

It is evident, from the preceding brief review of available information on geographic variation in white spruce, that seed sources from southeastern Ontario perform well over a wide range of climatic and edaphic conditions. In most instances, these provenances have significantly surpassed the "local" provenances. It is tempting to recommend the direct use of these provenances for reforestation in the Maritimes Region. There are, however, reasons for not supporting such a recommendation at the present time:

a) Seeds from southeastern Ontario and the Ottawa Valley are already in high demand for reforestation efforts in Ontario and are not readily available to meet demands elsewhere. White spruce growing in that area of Ontario is usually confined to small stands, many of which are in private ownership, making the logistics of large-scale seed collection difficult.

b) The provenance tests of white spruce, described above, are generally less than half rotation age. It is possible, although not probable, that their superiority over "local" seedlings will not continue to rotation age.

Rather than recommend the direct use of the superior Ottawa Valley provenances, it was decided that the Canadian Forestry Service would develop a reliable "local" source of "Ottawa Valley" seeds to be available when a more confident recommendation can be made. In the process of developing this source of seeds, an attempt will also be made to improve it genetically for use in the Maritimes Region.

Briefly, the procedures to be used to develop a reliable source of genetically improved Ontario seed are as follows:

a) Obtain a reasonably large number (100-300) of half-sib (open pollinated) seed collections from average or above average trees growing in the southeastern Ontario - Ottawa Valley area.

b) Raise these families in greenhouse - nursery tests to eliminate obviously inferior families.

c) Use the better individual seedlings in the remaining families to establish progeny test - seedling seed orchards.

d) Remove, by thinning, below average families and individuals from the test-orchard, retaining only the best individuals from the best families for seed production.

METHODS

In July 1970, a standing request was placed with the Canadian Forestry Service, Petawawa Forest Experiment Station (P.F.E.S.) for the collection of white spruce seeds from the Ottawa Valley area of Ontario and Quebec. These collections were to be made from phenotypically average or above average trees and kept separate by trees. This request was subsequently expanded to include collections from other parts of southeastern Ontario. Mr. B.S.P. Wang, P.F.E.S. was responsible for the collection, extraction, cleaning, and preliminary testing of these seed.

During 1970-72, it was not possible to obtain seeds from the designated area because of poor cone crops, caused partly by high spruce budworm populations. In 1972, cones were collected from 22 trees near Beachburg and P.F.E.S. and the seeds were sent to the Maritimes Forest Research Centre. The location and pertinent data on these and subsequent collections are shown in Fig. 2 and Table D-1 of Appendix D. A portion of the seeds from each of these 22 families was used to establish a progeny test - seedling seed orchard in Nova Scotia - Orchard A. The remaining seeds were stored at - 18°C for future use. In the fall of 1973, cones were collected from an additional 56 trees and the cleaned seeds were sent to M.F.R.C. in March 1974 (Table D-1). Seeds from these 56 families plus seeds from 17 of the 22, 1972 families (total 73 families)

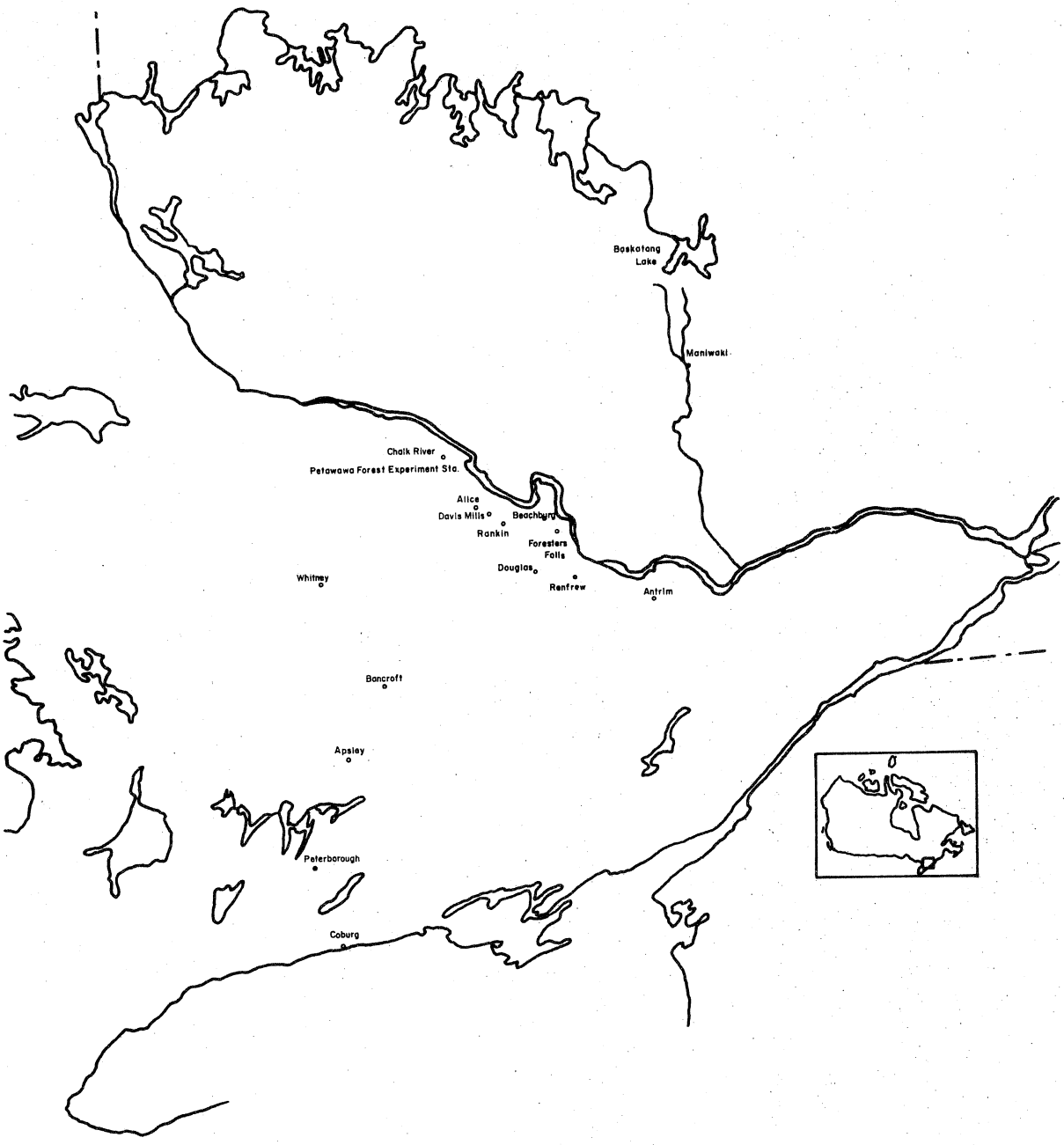

Figure 2. Location of some Ottawa Valley seed sources.

are being used to establish a production seedling seed orchard in cooperation with the Province of New Brunswick - Orchard B. In June 1976, the M.F.R.C. received seeds from an additional 44 families from P.F.E.S. These 44 families plus the 56, 1973 - families (total 100 families) are being used to develop a production orchard in cooperation with the Province of Nova Scotia - Orchard C.

Orchard A - Nova Scotia

Seeds of 22 families (single tree collections) of Ottawa Valley origin and seeds from five families of Acadia Forest Experiment Station origin were used for this test.

Greenhouse-nursery Five hundred seeds from each of the 27 families (except MS 2415 which had only 365 seeds) were sown on moist sand in petri dishes on February 26, 1973, stored for 2 weeks at 2°C, and then germinated at 27°C in a germination cabinet. The germinated seeds were transplanted, one per cavity, into multipot trays. Three trays (180 cavities) were planted per family and placed in a randomized three replicate block design in a greenhouse. Extra germinated seeds were planted in number 8 styroblock containers and were also placed in the greenhouse which was maintained at 21-27°C day and 15-19°C night and a 16 h photoperiod with supplemental incandescent (500 lux) light.

In July 1973, total height was recorded for 20 seedlings per replication for each of the 27 families (Table D-2 of Appendix D). The seedlings were then transplanted into nursery beds at 15x15 cm spacing and grown until May 1976. The nursery test was a randomized 30-seedling block design replicated six times. The "extra" seedlings were also

transplanted to the nursery at this time. In August 1975, total height was recorded for 10 seedlings per replication per family. Data are summarized in Table D-2.

On the basis of the 1975 measurements, the six shortest Ottawa Valley families were culled. The average seedling height of the five A.F.E.S. families was significantly shorter than the average for the Ottawa Valley families and therefore they were also eliminated. It should be noted, however, that one of the A.F.E.S. families (MS 2031) was close to the Ottawa Valley average, suggesting that important improvements in growth could be attained by selecting and testing families from within the region.

In April 1976, seedlings which had produced terminal forks during the 1975 growing season were culled. The eight tallest seedlings per replication from each of the remaining 16 families were selected and tagged with the appropriate MS numbers. In addition, the next tallest 16 seedlings from each family were selected and tagged, totalling 64 selected seedling per family. Sixty-four bundles containing one seedling per family were formed. The next tallest 96 seedlings per family were selected from the "extra" and remaining test seedlings and were lifted and bundled as before. The 64 tagged bundles and 96 untagged bundles were packed in peat moss and stored in a cold room at 2-3°C until the time of transportation to the planting site.

Orchard establishment A planting site for the progeny test - seedling seed orchard was selected with the assistance of the Nova Scotia Department of Lands and Forests and Scott Paper Company Ltd. The selected site was an old field located along the main road to the Scott Paper Company Ltd.

mill on Abercrombie Point, N.S. The field had previously been planted to red pine which had done poorly, primarily because of serious rodent damage and a heavy clay soil.

The orchard was laid-out at 2.4 x 2.4 m spacing with four center blocks (center core) and a surround area. Each of the four center core blocks consisted of 16 rows with 16 seedlings per row. One bundle of tagged seedlings was used to plant each of the 64 center core rows. This part of the orchard was then mapped, recording the location of each tagged seedling. The remaining 96 bundles of untagged seedlings were used to plant the surround area. The orchard was cultivated during the summer of 1976 to control competing vegetation and to reduce the suitability of the habitat for rodents.

Future plans The progeny test - seedling seed orchard will be allowed to develop as a normal plantation over the next few years. Vegetation control will be carried out and fertilizers applied as deemed necessary.

Prior to plantation closure, probably 5-8 years, all the seedlings in the center core of the orchard will be measured for height, stem form, and possibly other attributes. The plantation will then undergo a 50% thinning. Based on the data available after the measurement, the poorest families (probably 5) and the poorest individuals in the better families will be removed. In the surround area the best phenotypes will be retained.

A further 50% thinning, possibly removing one or two additional families, but primarily to favor the phenotypically best trees in the remaining families will be carried out when competition between trees

become evident again. Similarly, the surround area will receive a second 50% thinning, favoring the best phenotypes at this time.

It is anticipated that the final orchard will consist of the best 10 families (45% of the original 22 families) and each family will be represented by about 50% of the original number of seedlings planted. Considering all seedlings, including those culled at the nursery stage, within family selection will range from 1:6.4 to 1:11.7.

Orchard B - New Brunswick

In the fall of 1975, the M.F.R.C. and the Department of Natural Resources (D.N.R.), Province of New Brunswick undertook a cooperative project to establish a production scale progeny test - seedling seed orchard of southeastern Ontario and Ottawa Valley white spruce. The 74 families used for this project are listed in Table D-1 (Orchard B). The seedlings were grown at the D.N.R. greenhouse and nursery Kingsclear, N.B.

On January 28, 1976, three 608 paper pot trays, each containing 136 "pots" of peat planting medium were sown, two seeds per pot, with seeds from each of the 74 families. The trays were placed in a randomized block, three replicate design in an unheated greenhouse where they were held for 10 days. The greenhouse temperature was gradually raised over a four day period to 27°C on February 10, to initiate germination. During the second week in March, the resulting seedlings were thinned to one seedling per pot and the extra seedlings from the thinned pots were transplanted. The seedlings were raised in the greenhouse, maintained at 15-21°C and a 16 h, photoperiod (supplemental light of 500 lux) until the end of June 1976.

On June 16, all seedling trays were rated subjectively according to general appearance, on a scale of 1 (exceptional) to 3 (poor). During the third week in June, total height was recorded for 20 seedlings per block per replication for each of the 74 families (Table D-3 of Appendix D). The seedlings were transplanted to nursery beds at 15x15 cm spacing. The experimental design used in the greenhouse was maintained in the nursery. At the time of planting, inferior seedlings were culled. The numbers of seedling planted and culled are listed in Table D-3. The seedlings will be grown in their present location at Kingsclear until the spring of 1978.

Future plans Nursery survival will be recorded and seedling height will be measured on 20 seedlings per family per replication at the end of the 1977 growing season. The resulting data will be used to determine which families should be culled before field planting. It is estimated that 25-30% of the families will be eliminated at this time. In April 1978, the 60 best seedlings (20 per replication) will be selected and tagged and the 90 second best (30 per replication) will then be selected. Selection, tagging, and bundling procedures will be similar to those used for Orchard A.

An appropriate planting site, about 4 ha (10 acres), will be chosen in 1977 and prepared for planting in the spring of 1978. The orchard should be located on a typical white spruce planting site in a part of the province where white spruce is an important reforestation species. If possible, the orchard should be isolated from other major white spruce pollen sources.

Selection and culling procedures to be practiced after field planting will be the same as those outlined for Orchard A. It is estimated that the center core of the final orchard will be composed of trees representing 20-25 families of which 50% of the individuals from each family have been removed. This will provide a 1:3 selection intensity among families and will range from 1:8 to 1:10 within families (MS 2419 excluded). Among-family selection for the surround area of the orchard will be 2:3 (determined by the number of families culled prior to field planting) while mass selection favoring the best phenotypes will approximate 1:10.

Orchard C - Nova Scotia

During the summer of 1976, Scott Paper Co. of New Glasgow and the Nova Scotia Department of Lands and Forests, (N.S.D.L.F.), selected 28 plus white spruce trees from Pictou, Antigonish, Guysborough, Colchester, Digby, and Halifax counties. These seed lots, collected in the fall, were combined with the 17 plus trees selected in 1973 by N.S.D.L.F. for a total of 45 single plus tree collections.

The M.F.R.C. included these 45 selected families with 100 Ottawa Valley individual tree sources to establish a large seedling seed orchard-progeny test at A.F.E.S. in November 1976.

The 145 families were seeded into "608" paper pot trays with peat growing medium so that each family occupied one third of each of three trays. Each pot was seeded with either two or three seeds depending on the original number in the lot (Table D-1). The 145 trays were stratified in a cold room at 0°C for 3 weeks then randomly placed in three blocks

in a plastic greenhouse. The greenhouse was maintained at 27°C for 8 days until germination began and then lowered to 21-27°C daytime and 16-18°C nighttime. Photoperiod was extended from 4 a.m. to 8 p.m. through the use of incandescent lamps (500 lux). Germination was tallied during the transplanting and thinning operation in the first week of January 1977.

Future plans The seedlings will be measured and evaluated before outplanting in May or June of 1977. Because of the initial affect of seed weight on seedling height only a light family and within family selection will be applied at this time. The seedlings will be planted at two locations:-

a) Abercrombie Point adjacent to Orchard A on Scott Paper Co. land. This large seedling seed orchard-progeny test will be planted on a 3 ha plowed site. The orchard will provide an excellent unrelated pollen source for the smaller Orchard A. Orchard C will be established at close spacing and designed so that the Nova Scotia families can be removed without damaging the continuity of the orchard, should they prove inferior.

b) A good site will be chosen on the 1976 Trafalgar burn and a small progeny test established. This will provide additional information on which to base subsequent family selections in the Abercrombie Point seed orchard.

Selection and culling procedures in the orchard will be similar to that described for Orchard A. The second location will not be thinned but will be used to provide statistical information. Genotype X site interaction may occur and only those families which grow well at both sites will be favored.

Opportunities For Improvement

There is some risk involved when selection is conducted in the nursery. Potentially useful material may be removed because of poor juvenile-mature correlations or because of interaction with the final planting site. Presumably, however, "early starters" will have greater ability to survive competing vegetation and thus will excel. Mohn et al. (1975) found that nursery-field correlations were strong enough to indicate that culling in the nursery could improve cost/gain ratios in white spruce improvement programs.

Selections in Orchard A were made at two levels before outplanting in the field.

1) The New Brunswick families and the shortest six Ottawa Valley families were removed leaving the 16 tallest Ottawa Valley families.
2) Within the 16 remaining families, the tallest 8 seedlings of the 30 in each of the 6 replication were tagged for inclusion in the central core of the orchard.

Table 1 is a summary of the improvement attained by these two selections.

Table 1. Gains achieved through selection of families and individuals prior to establishment of Orchard A

	Mean Height cm		Percent
	Before selection	After selection	Increase
27 families	49.6		
16 of 27 families		52.2	5.2
64 of 253 individuals in 16 families		60.4	16.5
		Total	21.7

The seedlings planted in the central core were 21.7% taller than the nursery average. This improvement is not an indication of the genetic gain we can expect from orchard produced progeny. A brief description of the estimated heritability and the predicted genetic gain from the orchard is contained in Appendix E. The estimated heritability of two year height in this experiment is .52 and the predicted genetic gain is 13.0% i.e. seedlings produced by this orchard are expected to be 13.0% taller than those produced by the original unselected population.

Future Improvement

Additional genetic gain can be expected from the orchards and from one and a half generation orchards when the seed orchard-progeny test materials have developed to a stage where evaluation becomes more meaningful. Through a series of thinnings, favoring the best phenotypes, Orchards A + C will be reduced to about 25% of the original stocking (6x6 m spacing) which should produce a further gain of 5 to 10%. At about 20 years, the single phenotypically-best individual tree will be selected from each of the best families remaining in the orchard. These selected individuals will be propagated vegetatively, either by rooting cuttings or by grafting, and will be used to establish one and a half generation clonal seed orchards. Selections from Orchards A and C will be combined to establish a clonal orchard in Nova Scotia and similarily selections from Orchard B will be used in New Brunswick.

Assuming that 10 families remain in Orchard A and 50 families in Orchard C, a total of 60 best clones will be available for the Nova Scotia orchard. Family selection for these clones will be approximately 1:2 and within family selection will range from 1:200 to 1:375 for the

10 "Orchard A" clones, and 1:130 for those from Orchard C. The best individuals in each of 20 to 25 families will be available from Orchard B and will represent a family selection of 1:3 and within family selection of approximately 1:300.

The genetic gain attainable in one and a half generation orchards is difficult to predict because of the dearth of available data on within family variability and heritability. However, we can confidently predict an additional gain of 5-10% in height over seedlings derived from the seedling orchard.

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APPENDIX A

White Spruce Provenance Trial - A.F.E.S. Expt. #17

Establishment

In 1957, seed was collected from 24 seed sources throughout the range of white spruce in Canada and the United States (Table A-1). These were raised at the Institute of Forest Genetics, Rhinelander, Wisconsin and sent to the 13 cooperators as 2 + 2 stock, in May 1962. Two plantations were established at A.F.E.S.:- Plantation A is located on a fairly flat, moist, rich site nearly optimal for white spruce; Plantation B is on a fresh moderately rich site with a 8% NW slope. Each plantation consists of four tree plots in five randomized blocks with four rows of surrounding trees. Post-planting treatment consisted of cutting weed species in 1964 and 1970. Total height has been measured every five years since planting (Table A-2).

Results

Plantation A: The Beachburg Ontario source (1663) is 44% taller than the plantation average after 15 years but just 4% taller than Green River, New Brunswick (1659) which ranks second. Both have similar and above average survival. The mean plantation height after 15 years is 3.44 m and the mean survival is 78.5%.

Plantation B: The Beachburg provenance is again tallest (28% above mean) after 15 years. A Bangor, Maine (1655) provenance ranks second but the New Brunswick provenance has dropped to 13th position - about the plantation mean.

There has been surprising little change in ranking of the 24 provenances over the three measurement periods within each plantation indicating relative stability and the possibility for early selection of well adapted provenances.

Table A-1 Seed source material: Identification numbers and original sources

Seed source numbers	Location			Number of mother trees
	Name	Lat.[a] °N	Long.[a] °W	
1631	Spruce Woods Reserve, Manitoba	49° 51'	99° 30'	S[b]
1628	Black Hills, S. Dakota	44° 10'	103° 55'	13
1630	Lewis & Clark National Forest, Mont.	46° 48'	109° 31'	5
1644	Adirondack Mountains, New York	44° 23'	74° 6'	10
1645	Monico, Wisconsin	45° 41'	89° 7'	10
1647	Chippewa National Forest, Minnesota	47° 33'	94° 10'	2
1649	Coos County, New Hampshire	44° 51'	71° 26'	10
1653	Gerstle, Alaska	63° 45'	144° 53'	S
1654	Fort Yukon, Alaska	66° 35'	145° 11'	1
1655	Bangor, Maine	44° 50'	68° 38'	15
1657	Port Hope Simpson, Labrador	52° 36'	56° 26'	S
1658	Lake Melville, Labrador	53° 46'	60° 05'	S
1659	Green River, N.B.	47° 50'	68° 21'	S
1660	Maniwaki, Quebec	46° 32'	76° 30'	S
1661	South of Lake Kenogami, Quebec	(48° 18'	71° 22'	S
		(48° 13'	71° 38'	S
1662	Ashley Mines, Bannockburn, Ontario	48°	81°	S
1663	Beachburg, Ontario	45° 44'	76° 51'	S
1664	Flin Flon, Manitoba	54° 39'	101° 36'	S
1665	Stony Rapids, Saskatchewan	59° 19'	105° 59'	S
1669	Grand Rapids, Minnesota	47° 33'	94° 8'	6
1676	Huron National Forest, Michigan	44° 30'	83° 45'	17
1677	Summit Lake Region, Fort McLeod, B.C.	54°	123°	S
1686	Fort Albany, Ontario	52° 15'	81° 40'	25
1687	Kakabeke Falls, Ontario	48° 30'	89° 30'	S

a. From Neinstaedt (1969).

b. S indicates stand collection.

Table A-2. Height as percent of mean and rank of white spruce provenances after 6, 11 and 15 years growth

	Plantation A Site 2 (13)						Plantation B Site 4 (14)					
	Height 6 years	Rank	Height 11 years	Rank	Height 15 years	Rank	Height 6 years	Rank	Height 11 years	Rank	Height 15 years	Rank
1628	97	15-16	86	17	86	17	99	15	106	11-12	105	11
1630	57	22	49	23	50	24	84	19	68	22	71	23
1631	97	15-16	104	13	106	13	102	12	92	16	92	16
1644	115	10	115	9-10	111	9-10	100	14	100	14-15	107	9-10
1645	116	9	114	11-12	111	9-10	103	11	100	14-15	100	15
1647	131	4	125	5-7	116	7	126	1-3	109	8-9	107	9-10
1649	126	6	136	3	132	4	121	6-7	115	7	115	6
1653	53	23	51	22	62	22	53	24	56	24	58	24
1654	43	24	46	24	57	23	74	20-21	61	23	74	22
1655	117	7-8	125	5-7	122	6	122	5	123	3-4	124	2
1657	67	20	69	19	72	18	74	20-21	81	20	78	21
1658	72	18	72	18	68	20	73	22	89	18-19	91	17-18
1659	127	5	125	5-7	139	2	101	13	107	10	101	13-14
1660	132	3	135	4	131	5	121	6-7	123	3-4	120	3
1661	111	11-12	114	11-12	108	11	126	1-3	131	1-2	119	4
1662	133	2	143	2	136	3	117	8	117	6	117	5
1663	146	1	144	1	144	1	124	4	131	1-2	128	1
1664	86	17	89	16	90	16	88	18	90	17	91	17-18
1665	68	19	63	20	69	19	56	23	76	21	87	19
1669	117	7-8	116	8	107	12	96	16	89	18-19	86	20
1676	105	14	105	14	98	15	126	1-3	121	5	112	7
1677	63	21	59	21	67	21	95	17	109	8-9	101	13-14
1686	109	13	115	9-10	115	8	110	9	106	11-12	109	8
1687	111	11-12	101	15	99	14	107	10	101	13	104	12
Mean	82.3 cm		2.51 m		3.44 m		71.6 cm		1.96 m		2.78 m	

APPENDIX B

White Spruce Provenance Trial - A.F.E.S. Expt. #19

Establishment

In 1958-59, seed was collected from 54 sources across the eastern and central part of the range of white spruce (Table B-1). The seeds were sown in 1961 at the P.F.E.S. and sent to 13 cooperators in 1965 as 2 + 2 stock. At the A.F.E.S., the 54 provenances were planted at 2 x 2 m spacing in 10 blocks with 12 trees (3 x 4)/plot. Survival and height were measured at 10 and 15 years from seed (6 and 11 years from outplanting) (Table B-2).

Results

The three tallest provenances after 11 years (Chalk River-2462, Peterborough-2438, Beachburg-2444) are from the Ottawa Valley and southeastern Ontario and are 17%, 16%, and 15% taller than the mean. All are of average survival. Three of the New Brunswick provenances were about average in height growth after 11 years and one was well below average. In this plantation, the rankings have changed considerable between the 6 years and the 11 year height measurements and cannot be considered stable as yet.

Table B-1. Location and climatic data of seed sources

Seedlot Provenance No.	Province or State	Lat. N. degrees	Long. W. degrees	Elev ft	Mean Ann precip ins	Frost-free days/ year	Average Jan. Temp °F
2437	Ont.	44.2	75.9	725	36	150	20
2438	Ont.	44.1	78.0	850	32	150	20
2439	Ont.	44.5	81.3	600	36	140	21
2440	Ont.	44.1	77.0	300	34	150	20
2442	Ont.	45.1	75.3	250	36	135	15
2443	Que.	46.2	76.7	800	31	100	9
2444	Ont.	45.7	76.8	410	30	130	10
2446	Que.	45.6	73.3	100	38	140	14
2449	Que.	47.0	71.7	900	44	105	7
2450	Que.	47.8	74.2	1,450	34	90	4
2452	Que.	46.8	74.2	1,000	34	100	6
2453	Que.	46.8	74.8	1,500	34	105	7
2454	Que.	47.0	75.6	800	34	100	6
2455	Que.	46.8	77.8	1,000	32	95	7
2456	Que.	46.3	77.3	1,000	30	110	9
2458	Ont.	46.2	78.1	1,400	30	115	11
2459	Ont.	45.6	78.6	1,400	31	100	12
2460	Ont.	45.2	77.9	1,300	30	110	12
2461	Ont.	45.7	79.5	1,150	36	110	13
2462	Que.	46.5	76.5	800	32	100	8
2463	Que.	46.0	75.4	1,050	36	115	10
2464	Ont.	45.9	77.4	525	30	120	10
2465	Ont.	46.3	83.3	650	32	120	15
2466	Ont.	45.8	82.9	675	32	130	16
2467	Ont.	45.0	81.4	600	32	145	22
2468	Ont.	46.8	84.1	1,100	32	105	14
2469	Que.	47.0	71.4	1,000	46	110	8
2470	Que.	46.3	71.2	1,500	42	110	11
2471	Que.	47.1	69.8	1,500	38	105	10

Table B-1. Location and climatic data of seed sources (cont'd)

Seedlot Provenance No.	Province or State	Lat N degrees	Long W. degrees	Elev ft	Mean Ann precip ins	Frost-free days/ year	Average Jan Temp °F
2472	Que.	48.2	67.8	1,000	38	90	5
2473	N.B.	47.4	68.2	650	38	110	8
2474	N.B.	47.3	67.4	1,100	40	90	5
2475	N.B.	47.8	68.3	1,000	38	90	5
2476	Que.	48.3	71.4	500	38	100	4
2477	Ont.	48.0	81.0	1,120	29	80	2
2478	Ont.	46.7	79.8	964	33	100	8
2479	Ont.	46.8	83.2	1,250	32	95	10
2480	Ont.	48.5	89.5	900	28	90	5
2481	Ont.	49.4	80.7	950	29	80	-1
2484	Que.	47.4	75.1	1,300	34	90	5
2485	Que.	47.5	78.6	900	32	95	5
2486	Ont.	48.1	80.1	1,000	31	80	3
2491	Que.	46.9	71.5	1,000	46	110	8
2571	Minn.	47.5	94.0	1,350	24	120	5
2572	Mich.	44.5	83.7	700	28	95	19
2601	Minn.	47.7	90.1	650	30	125	14
2602	Mich.	46.7	85.3	700	30	140	16
2603	Mich.	46.1	87.6	900	31	90	12
2604	Que.	48.7	71.1	970	40	100	3
2692	Ont.	51.3	80.6	50	29	80	-6
2694	N.B.	46.0	66.3	250	39	120	14
2870	Ont.	48.9	82.8	715	28	80	0
3071	N.Y.	43.9	73.6	960	38	130	26

Table B-2. Height as a percent of mean rank and survival as a percent of mean of white spruce provenances after 6 and 11 years growth

	6 years			11 years		
	Height Percent of Mean	Rank	Survival Percent of Mean	Height Percent of Mean	Rank	Survival Percent of Mean
2437	117	4-5	100	106	10	101
2438	120	1-2	105	116	2	100
2439	104	19	79	95	41	102
2440	102	24-25	97	98	28-33	102
2442	103	20-23	99	97	34-35	102
2443	105	17-18	102	100	24-26	99
2444	120	1-2	110	115	3	103
2446	113	6	89	112	4-6	94
2449	100	27-28	99	101	22-23	92
2450	94	37-40	93	102	18-21	92
2452	94	37-40	93	101	22-23	96
2453	99	29-30	102	104	13-16	104
2454	106	15-16	105	105	11-12	101
2455	93	41	106	98	28-33	100
2456	96	33-36	100	96	36-40	101
2458	97	31-32	104	98	28-33	100
2459	108	12	109	107	9	105
2460	103	20-23	103	98	28-33	102
2461	109	9-11	102	105	11-12	101
2462	118	3	109	112	4-6	104
2463	80	51	105	96	36-40	100
2464	117	4-5	103	117	1	100
2465	100	27-28	99	96	36-40	98
2466	87	48-44	83	83	52	97
2467	90	43	87	90	48-50	94
2468	87	48-49	101	92	45-46	96
2469	96	33-36	99	100	24-26	100

Table B-2. Height as a percent of mean rank and survival as a percent of mean of white spruce provenances after 6 and 11 years growth (cont'd)

	6 years			11 years		
	Height Percent of Mean	Rank	Survival Percent of Mean	Height Percent of Mean	Rank	Survival Percent of Mean
2470	94	37-40	102	98	28-33	100
2471	89	44-45	103	97	34-35	100
2472	89	44-45	96	93	43-44	101
2473	94	37-40	106	103	17	105
2474	91	42	104	96	36-40	100
2475	101	26	104	104	13-16	101
2476	112	7	109	112	4-6	107
2477	103	20-23	107	104	13-16	105
2478	96	33-36	98	90	48-50	96
2479	105	17-18	94	104	13-16	97
2480	86	50	93	90	48-50	99
2481	88	46-47	95	93	43-44	92
2484	99	29-30	102	102	18-21	100
2485	97	31-32	102	100	24-26	96
2486	103	20-23	109	109	7-8	102
2491	109	9-11	103	98	28-33	99
2571	102	24-25	99	99	27	100
2572	109	9-11	97	102	18-21	100
2601	76	52-53	91	84	51	99
2602	88	46-47	102	91	47	96
2603	110	8	100	96	36-40	100
2604	96	33-36	103	92	45-46	100
2692	76	52-53	76	79	53	91
2694	107	13-14	106	102	18-21	104
2870	106	15-16	106	109	7-8	107
3071	107	13-14	103	94	42	100
Mean	70cm		90%	216.7 cm		92%

APPENDIX C

White Spruce Provenance Trial - Plaster Rock, N.B. Project 194-J

Establishment

Between 1957 and 1959 seed was collected from 25 sources in the Great Lake - St. Lawrence Forest Region. The seed was sown in nursery beds in the fall of 1959 at P.F.E.S. In the spring of 1962 the 2 + 0 seedlings were transplanted to the A.F.E.S. nursery and in 1964 were outplanted as 2 + 2 stock near Fraser Co. sawmill at Plaster Rock, N.B. Six blocks were established at 2 x 2 m spacing. Each block contained 25 randomly distributed plots of 25 trees (5 x 5). Each plot was separated by a row of an Edmundston source of similar age and the block was surrounded by two rows of the same source. Replacement plantings were completed in the spring of 1965 and 1966. Survival and height were measured by Fraser Co. staff in the spring of 1976, 12 years after planting.

Results

Four of the six tallest provenances were from the Ottawa Valley Region and two were from northeast New Brunswick (Upper Green River, Edmundston) (Table C-1). Both these New Brunswick sources had excellent survival as did the third ranked sources from North Bashatong Lake, P.Q. The Peterborough, Ontario source had the most rapid height growth but less than average survival. The other New Brunswick provenance (Jardine Brook) ranked 17th in height growth and had average survival.

Table C-1 White Spruce Provenance Trial at Plaster Rock N.B. Ranked by Height Growth

Provenance	Race No.	Mean Height Feet	Mean Mortality Percent
Peterborough, Ontario	2438	9.0	14.2
Cushing, P.Q.	2445	8.7	7.0
N. Baskatong Lake, P.Q.	2454	8.7	3.2
Upper Green River, N.B.	2475	8.6	4.8
Chalk River, Ontario	2464	8.5	8.7
Edmundston, N.B.	2473	8.5	4.3
St. Sylvestre, P.Q.	2470	8.4	8.3
Grand Piles, P.Q.	2447	8.4	4.8
Valcartier, P.Q.	2491	8.2	5.5
Napanee, Ontario	2440	8.2	6.6
Usborne Lake, P.Q.	2443	8.2	4.3
Swastika, Ontario	2486	8.0	5.6
Aylmer Lake, Ontario	2469	7.8	13.5
South Hampton, Ontario	2439	7.8	17.8
Mitchinamekus Lake, P.Q.	2484	7.6	9.2
Luce Co., Mich.	2602	7.3	9.2
Jardine Brook, N.B.	2474	7.3	10.8
Marquette Co., Mich.	2603	7.2	5.2
Casey, P.Q.	2450	7.2	4.8
Monk, P.Q.	2471	7.2	15.3
Price, P.Q.	2472	7.0	14.0
Miller Lake, Ontario	2467	6.8	24.7
Shipshaw River, P.Q.	2604	6.7	17.3
Beloeil, P.Q.	2446	6.7	28.2
Kakabeka, Ontario	2480	6.7	15.2
Overall Mean		7.8	10.5
Edmundston Surrounds		8.2	

APPENDIX D

Table D-1 Provenance and seed data

MS Number	P.F.E.S. Number	Provenance	Seed Data			Orchard		
			Approx. no. received	Wt/1000 g	% Germ.	Number of seed used for A	B	C
2410 (2564)	70055	Beachburg	3900	2.4	98	500	1000	
2411 (2565)	70056	Beachburg	4100	2.4	92	500	1000	
2412	70058	Beachburg	2000	2.5	83	500		
2413	70059	Beachburg	2000	2.4	75	500	903	
2414	70060	Beachburg	2000	2.4	59	500	732	
2415	70061	Beachburg	365			365		
2416	70062	Beachburg	2000	2.5	59	500		
2417	70063	Beachburg	1200	2.6	82	500		
2418	70066	Beachburg	2000	2.4	84	500	711	
2419	70068	Beachburg	1000	1.9	70	500	219	
2420 (2568)	70069	Alice	4050	2.4	99	500	1000	
2421 (2569)	70070	Alice	4000	2.0	97	500	1000	
2422 (2570)	70071	Alice	4100	2.5	70	500	1000	
2423	70072	Alice	1000	2.4	55	500	360	
2424 (2573)	72072	Petawawa F.E.S.	3900	2.6		500	1000	
2425 (2574)	72073	Petawawa F.E.S.	3900	2.4	95	500	1000	
2426 (2575)	72074	Petawawa F.E.S.	3800	2.5	95	500	1000	
2427	72075	Petawawa F.E.S.	2000	2.5	79	500		
2428 (2576)	72076	Petawawa F.E.S.	4000	2.5	99	500	1000	
2441 (2565)	70064	Beachburg	4300	2.3	92	500	1000	
2442	70065	Beachburg	1000	2.4	92	500	542	
2443 (2567)	70067	Alice	4000	2.5		500	1000	
2546	66001	Petawawa F.E.S.	(3000)		85		1000	405
2547	66002	Petawawa F.E.S.	(3000)		91		1000	405
2548	67066	Petawawa F.E.S.	2700	1.7	92		1000	405

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data			Orchard		
			Approx. number received	Wt/1000 g	% Germ.	Number of seed used for A	B	C
2549	67067	Petawawa F.E.S.	2000	2.0	80		1000	405
2550	67068	Petawawa F.E.S.	2700	1.7	99		1000	405
2551	67069	Highview	2000	2.0	98		1000	405
2552	67070	Highview	1900	2.4	96		1000	405
2553	67071	Highview	1800	2.2	90		1000	405
2554	67072	Highview	1700	2.4	91		1000	405
2555	67073	Chalk River (A.E.C.)	2100	2.2	75		1000	405
2556	67074	Petawawa F.E.S.	1900	2.2	93		1000	405
2557	67075	Petawawa F.E.S.	2800	1.6	88		1000	405
2558	67076	Petawawa F.E.D.	2100	1.9	93		1000	405
2559	67077	Petawawa F.E.D.	2200	2.3	76		1000	405
2560	67079	Petawawa F.E.S.	2200	1.8	91		1000	405
2561	67080	Petawawa F.E.S.	2000	2.0	86		1000	405
2562	67081	Petawawa F.E.S.	2000	2.0	85		1000	405
2563	67082	Petawawa F.E.S.	2200	1.8	98		1000	405
2571	70073	Alice	1600	3.1	94		1000	405
2572	72071	Petawawa F.E.S.	1600	2.8			1000	405
2577	72077	Sand Lake	1900	2.6			1000	405
2578	72079	Sand Lake	1900	2.4			1000	405
2579	72083	Beachburg	1600	2.9	99		1000	405
2580	72084	Beachburg	1800	2.8	89		1000	270
2581	72085	Beachburg	1700	3.0	87		1000	405
2582	72086	Beachburg	2100	2.4	85		1000	405
2583	72087	Petawawa F.E.S.	1500	3.0	95		1000	405
2584	72088	Petawawa F.E.S.	1600	2.8	97		1000	405
2585	72089	Davis Mills Rd.	1800	2.8	78		1000	405
2586	72090	Davis Mills Rd.	2000	215	97		1000	405
2587	72091	Davis Mills Rd.	1520	3.0	96		1000	405

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data			Orchard		
			Approx. number received	Wt/1000 g	% Germ.	Number of seed used for A	B	C
2588	72092	Davis Mills Rd.	1500	3.0	93		1000	405
2589	72093	Davis Mills Rd.	1400	3.3	98		1000	405
2590	72095	Davis Mills Rd.	1600	2.7	95		1000	405
2591	72097	Petawawa River	1700	2.7			1000	405
2592	72101	Rankin	1500	4.0	92		1000	405
2593	72102	Rankin	1600	2.6	88		1000	
2594	72105	Rankin	1400	3.2	96		1000	405
2595	72106	Rankin	1500	3.1	97		1000	405
2596	72107	Rankin	1500	2.9	93		1000	405
2597	72108	Rankin	1600	3.1	98		1000	405
2598	72109	Rankin	1750	2.9	90		1000	405
2599	72110	Rankin	1400	3.3	45		1000	405
2600	72113	Irving Creek	1800	2.8	95		1000	405
2601	72114	Irving Creek	1900	2.7	96		1000	405
2602	72115	Irving Creek	1900	2.7	91		1000	405
2603	72116	Irving Creek	1600	3.1	98		1000	405
2604	72117	Irving Creek	1400	3.2	90		1000	405
2605	72118	Irving Creek	1300	3.5	95		1000	405
2606	72119	Irving Creek	1700	2.6			1000	405
2607	72120	Irving Creek	1600	2.9	98		1000	405
2608	72121	Irving Creek	1200	3.8	95		1000	405
2609	72122	Irving Creek	1800	2.7	95		1000	405
2610	72123	Irving Creek	2200	2.8	77		1000	405
2611	72124	Douglas	1800	2.5	93		1000	405
2612	72127	Apsley	2400	1.9	97		1000	405
2792	743041	Petawawa F.E.S.	420	2.4	98			270
2793	743042	Petawawa F.E.S.	520	1.9	92			270
2794	743043	Petawawa F.E.S.	550	1.8	98			270

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data			Orchard		
			Approx. number received	Wt/1000 g	% Germ.	Number of seed used for A	B	C
2795	743045	Petawawa F.E.S.	460	2.2	97			270
2796	743046	Petawawa F.E.S.	390	2.6	95			270
2797	743054	Douglas	390	2.6	85			270
2798	743055	Douglas	450	2.2	82			270
2799	743059	Douglas	380	2.7	72			270
2800	743060	Douglas	520	1.9	93			270
2801	743065	Douglas	410	2.5	72			270
2802	743071	Renfrew	430	2.3	72			270
2803	743072	Renfrew	400	2.5	95			270
2804	743075	Renfrew	420	2.4	97			270
2805	743076	Renfrew	480	2.1	88			270
2806	743077	Renfrew	460	2.2	91			270
2807	743083	Antrim	460	2.2	97			270
2808	743085	Antrim	470	2.1	90			270
2809	743088	Antrim	400	2.5	95			270
2810	743091	Antrim	520	1.9				270
2811	743092	Antrim	290	3.5				270
w2812	743096	Bancroft	460	2.2	92			270
2813	743097	Bancroft	550	1.8	92			270
2814	743098	Bancroft	510	2.0	99			270
2815	743100	Bancroft	530	1.9	94			270
2816	743101	Bancroft	560	1.8				270
2817	743104	Apsley	360	2.8	94			270
2818	743104	Apsley	420	2.4	80			270
2819	743107	Apsley	440	2.3	93			270
2820	743108	Apsley	430	2.3				270
2821	743113	Apsley	380	2.6	87			270
2822	743114	Silver Lake	450	2.2	95			270

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data: Approx. number received	Seed Data: Wt/1000 g	Seed Data: % Germ.	Orchard: Number of seed used for A	Orchard: B	Orchard: C
2823	743116	Silver Lake	490	2.1	81			270
2824	743116	Silver Lake	440	2.3	75			270
2825	743123	Silver Lake	440	2.3				270
2826	743123	Silver Lake	390	2.6				270
2827	743127	Whitney	469	2.2	94			270
2828	743129	Whitney	440 -	2.3	99			270
2830	743130	Whitney	450	2.2	93			270
2831	743131	Whitney	520	1.9	99			270
2832	743174	Foresters Falls	410	2.4	99			270
2833	743175	Foresters Falls	(400)	2.9				270
2834	743177	Foresters Falls	(400)	2.4				270
2835	743178	Foresters Falls	(400)	2.2				270
2836	743188	Beachburg	(400)	2.2				270
		Acadia Forest Experiment Station Sources in Orchard A						
2033			800		73	500		
2024			1700		79	500		
2026			2200		79	500		
2029			1600		73	500		
2031			1000		70	500		
		Province of Nova Scotia Sources in Orchard C						
Block 39		Millsville, Pictou		2.2				405
Block 207		Dunmaglass, Antigonish		2.4				405
Block 271		Gunn Lake, Pictou		2.3				405

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data: Approx. number received	Seed Data: Wt/1000 g	Seed Data: % Germ.	Orchard: Number of seed used for A	Orchard: B	Orchard: C
Block 48		S. Loganville #1		2.2				405
Block 48		S. Loganville #2, Pictou		2.3				405
Block 153		Rossfield #1, Pictou		3.1				405
Block 153		Rossfield #2, Pictou		2.5				405
Block 71		Blue Mtn., Pictou		2.8				405
Block 76		Bailey's Brook, Pictou		1.9				405
Block 89		Black Brook, Pictou		2.4				405
Block 141		Glencoe, Pictou		2.0				405
Block 201		Piedmont, Pictou		2.0				405
Block 253		Laggan, Pictou		3.5				405
Town Lot,		Forbes Lake, Pictou		2.1				405
Private Lot,		Locharbor, Guysborough		2.4				405
Mgmt Lot,		McPherson Lake, Pictou		2.3				405
76-1		E. Stewiacke, Colchester		2.5				405
76-4		Lake Egmont, Halifax		2.2				405
76-5		Lake Egmont, Halifax		2.6				405
76-7		Lake Egmont, Halifax		1.8				405
76-8		Monastery, Antigonish		3.1				405
76-9		West River, Antigonish		2.6				405
76-11		West River, Antigonish		2.6				405
76-54		Meteghan, Digby		2.6				405
76-55		Meteghan, Digby		2.4				405
76-58		Wentworth Centre, Colchester		2.3				405
76-59		Wentworth Centre, Colchester		2.2				405
7-1		New Glen, Victoria		1.8				405
7-3		New Glen, Victoria		2.6				405
7-4		New Glen, Victoria		2.8				405
8-1		Steel's Cross, Victoria		2.2				405

Table D-1. Provenance and seed data (Cont'd)

MS number	P.F.E.S. number	Provenance	Seed Data: Approx. number received	Seed Data: Wt/1000 g	Seed Data: % Germ.	Orchard: Number of seed used for A	Orchard: B	Orchard: C
Nova Scotia Provenance (Cont'd)								
8-2		Steel's Cross, Victoria		2.4				405
8-3		Steel's Cross, Victoria		2.4				405
10-1		Baddeck Forks, Victoria		2.3				405
10-2		Baddeck Forks, Victoria		3.9				405
10-3		Baddeck Forks, Victoria		2.2				405
11-1		Fairmount, Antigonish		2.4				405
11-2		Fairmount, Antigonish		3.2				405
11-3		Fairmount, Antigonish		2.7				405
14-2		French River, Pictou		3.6				405
14-5		French River, Pictou		2.7				405
52-1		Hunter's Mtn., Victoria		2.0				405
52-2		Hunter's Mtn., Victoria		2.8				405
52-3		Hunter's Mtn., Victoria		3.2				405

Table D-2. Orchard A. Germination, greenhouse and nursery data

MS No.	Germination percent	Survival to July '73 percent	Total height, cm July 1973	Number planted Nursery	Survival to Aug.'75 percent	Mean height, cm August 1975
2410	86	87	6.2	367	99	46.6
2411	88	90	7.3	375	97	52.0
2412	83	84	6.0	341	93	49.0
2413	75	83	6.0	300	97	52.4
2414	59	78	7.0	211	86	50.9
2415	85	84	7.9	249	95	54.7
2416	59	77	5.7	205	93	50.4
2417	82	83	5.5	346	97	50.4
2418	84	80	6.5	336	96	58.4
2419	69	93	6.6	326	94	54.4
2420	68	79	5.2	245	95	52.3
2421	86	81	4.4	324	95	44.9
2422	59	86	4.6	242	93	51.4
2423	55	84	6.0	242	93	54.9
2424	79	80	4.6	304	91	44.3
2425	79	83	5.4	313	95	45.0
2426	79	82	6.3	318	95	52.1
2427	79	94	5.8	357	96	46.1
2428	60	92	5.7	278	97	49.0
2441	73	84	5.0	281	94	49.0
2442	94	79	5.5	342	95	44.1
2443	79	81	6.2	322	92	53.1
2022	73	67	5.7	230	95	46.7
2024	79	76	5.4	280	94	48.3
2026	79	88	5.4	333	94	44.1
2029	73	67	5.1	240	90	41.7
2031	70	86	6.4	287	92	51.7

Table D-3. Orchard B. - First year seed and seedling data

MS No.	Number seeds to germinate	Germination percent	Number seedlings after thinning	Survival June 1976 percent	Number seedlings culled	Number planted Nursery	Subjective rating by reps.	Total height, cm June 1976
2413	816	81	408	100	6	402	1,1,2	10.3
2414	732	62	408	100	4	367	3,3,3	6.9
2418	711	57	408	100	12	396	1,1,1	11.1
2419	219	84	183	100	6	177	3,3,3	8.2
2423	360	92	330	100	3	327	3,1,1	10.3
2442	542	75+	408	99	41	357	3,3,3	6.5
2546	816	57	408	98	4	401	2,2,1[1]	9.8
2547	816	86	408	100	5	402	2,2,1	8.6
2548	816	51	408	100	24	384	3,3,3	7.0
2549	816	77	408	99	4	402	3,3,3	6.6
2550	816	81	408	99	6	398	3,2,2	8.2
2551	816	53	408	100	10	397	2,2,2	8.2
2552	816	90	408	99	1	404	2,2,2	9.0
2553	816	55	408	100	1	396	3,2,3	7.4
2554	816	58	408[2]	97	38	357	3,3,3	7.8
2555	816	74	408	100	6	402	3,2,2	9.6
2556	816	62	408	100	7	400	3,2,3	7.6
2557	816	55	408	100	5	401	3,2,2	8.0
2558	816	74	408	100	14	393	3,2,2	8.3

Table D-3. Orchard B. - First year seed and seedling data (Cont'd)

MS No.	Number seeds to germinate	Germination percent	Number seedlings after thinning	Survival June 1976 percent	Number seedlings culled	Number planted Nursery	Subjective rating by reps.	Total height, cm June 1976
2559	816	84	408	99	13	392	3,2,2	7.4
2560	816	50	408	100	27	380	3,2,3	7.7
2561	816	55	408	100	5	403	3,1,2	7.8
2562	816	77	408	100	4	403	2,2,1	8.6
2563	816	64	408	100	16	380	3,2,2	8.1
2564	816	57	408	100	10	397	3,2,2	7.8
2565	816	77	408	100	4	403	1,2,2	9.2
2566	816	71	408	100	13	394	3,2,3	7.6
2567	816	50+	408	99	8	395	3,2,2	7.9
2568	816	54	408	100	0	408	2,1,2	9.4
2569	816	87	408[3]	100	22	384	3,3,2	7.8
2570	816	58	408	100	16	392	3,2,3	6.3
2571	816	78	408	100	2	405	2,2,1	8.2
2572	816	86	408	100	16	390	3,2,2	6.7
2573	816	89	408	100	19	389	3,2,2	8.6
2574	816	82	408	100	2	406	2,1,2	9.6
2575	816	66	408	100	5	401	2,1,1	9.7
2576	816	52	408	100	9	197	3,2,3	8.0

Table D-3. Orchard B. - First year seed and seedling data (Cont'd)

MS No.	Number seeds to germinate	Germination percent	Number seedlings after thinning	Survival June 1976 percent	Number seedlings culled	Number planted Nursery	Subjective rating by reps.	Total height, cm June 1976
2577	816	70	408[3]	100	15	393	3,1,3	9.9
2578	816	50+	408	98	17	384	3,3,2	7.8
2579	816	91	408	99	3	402	2,1,1	10.8
2580	816	93	408	100	7	401	2,2,2	8.6
2581	816	79	408	100	2	406	2,1,1	10.4
2582	816	50+	408	100	9	399	3,2,2	8.6
2583	816	83	408	100	0	408	2,1,1	9.6
2584	816	84	408	100	21	385	3,2,2	8.6
2585	816	52	408	100	8	400	3,2,1	9.3
2586	816	51	408	97	5	391	2,1,2	8.8
2587	816	50	408	100	4	402	2,1,1	9.8
2588	816	72	408	100	16	390	3,2,2[4]	8.1
2589	816	86	408	100	1	407	2,1,1	9.3
2590	816	81	408	100	7	400	3,1,2	8.2
2591	816	75	408	99	23	378	3,2,2	6.7
2592	816	89	408	99	4	401	2,1,1	10.6
2593	816	75	408	99	7	396	2,1,2	10.2
2594	816	85	408	100	1	407	2,1,1	9.8
2595	816	94	408	99	2	403	1,1,1	11.0

Table D-3. Orchard B. - First year seed and seedling data (Cont'd)

MS No.	Number seeds to germinate	Germination percent	Number seedlings after thinning	Survival June 1976 percent	Number seedlings culled	Number planted Nursery	Subjective rating by reps.	Total height, cm June 1976
2596	816	88	408	99	3	402	1,1,1	10.3
2597	816	79	408	100	6	402	2,1,2	7.7
2598	816	76	408	100	5	401	3,1,2	7.9
2599	816	81	408	100	1	407	3,1,2	9.5
2600	816	91	408	100	6	401	2,2,2	8.6
2601	816	53	408	100	11	397	3,1,2	7.6
2602	816	51	408	99	1	403	3,2,1	8.6
2603	816	54	408	100	3	404	2,1,1	8.1
2604	816	91	408	100	2	406	1,1,2	10.7
2605	816	89	408	100	3	405	2,1,2	9.3
2606	816	84	408	100	3	403	3,2,2	7.8
2607	816	54	408	99	1	403	2,2,2	9.5
2608	816	88	408	100	7	401	3,1,3	8.0
2609	816	51	408	100	0	408	2,1,1	11.0
2610	816	81	408	99	2	402	2,2,2	8.7
2611	816	79	408	99	1	402	2,1,1	9.5
2612	816	97	408	100	2	404	2,2,1	8.9

[1] MS 2546 and MS 2547 - secondary needles on many of the seedlings in these families thicker than normal and frequently fused together.

[2] MS 2554 - retarded germination in all replications.

[3] MS 2569 and MS 2577 - damping off well above average for experiment in all replications.

[4] MS 2588 - 8% (49/593) of seedlings exhibited chlorophyl deficiency at 4 weeks. Most of these removed at first thinning. Maternal parent probably heterozygous for deficience.

Appendix E

Heritability and Genetic Gain of Two Year Nursery Grown White Spruce

Calculation of Heritability

Heritability is the degree to which a character, in this case height growth, is influenced by heredity as compared to environment. Without heritability estimates neither an efficient selection procedure nor genetic gain can be accurately determined. The reader is referred to Morgenstern (1973) for a detailed discussion of heritability and genetic gain. The nursery planting of Ottawa Valley and New Brunswick sources of white spruce for inclusion in Orchard A was not designed to determine heritabilities and genetic gain. However, since data are available the estimates were obtained, using the Ottawa Valley sources.

The mean height growth of the 22 families after two years nursery growth is contained in Table D-2. Table E-1 contains the analysis of variance and expected mean squares from which the following variance components are obtained:

Within plot variance

$$\sigma_w^2 = 74.34$$

Family x replication variance

$$\sigma_p^2 = \frac{148.11-74.34}{10} = 7.38$$

Family variance

$$\sigma_f^2 = \frac{886.69-148.11}{6x10} = 12.31$$

$$\text{Heritability (narrow sense)} = h_{ns}^2 = \frac{4\,\sigma_f^2}{\sigma_f^2 + \sigma_p^2 + \sigma_w^2} = .52$$

The heritability estimate for height growth after 2 years in the nursery is 52% which is unrealistically high. The family variance component contains the variation due to genotype x environment interactions and the variation due to stand differences although Dhir (1975) found that differences attributable to stand origin were not important and suggested a lack of genetic differentiation among local Ottawa Valley white spruce populations. The heritability estimate is biased upward because of this and is applicable under these conditions and can be expected to drop considerably when field tested. The exercise does point to the need for properly designed experiments to estimate heritability.

Calculations of Genetic Gain

Genetic gain is the average improvement in a progeny over the mean of parents and is achieved by selecting within the parental generation. The amount of genetic gain depends on selection intensity, parental variation and heritability (Snyder 1972).

The selection intensity for family selection (i_1) in the nursery was 16 in 22 or 73% and the within family selection (i_2) was 64 in 253 or 25%. Expressed in standard deviations i_1 is 0.43 and i_2 is 1.24 (Falconer 1960, p 193). Namkoong et al. (1966) suggest that the formula for genetic gain (ΔG) from family selection followed by selection of individual trees within families is

$$\Delta G = i_1 \frac{1/4\ \sigma_A^2}{\sigma_1} + i_2 \frac{3/4\ \sigma_A^2}{\sigma_2}$$

where $\sigma_A^2 = 4\ \sigma_f^2$ and $\sigma_1^2 = \frac{\sigma_w^2}{nr} + \frac{\sigma_p^2}{r} + 1/4\ \sigma_A^2$ and $\sigma_2^2 = \sigma_w^2 + \sigma_p^2$

The calculation of gain relative to the mean height in the unselected population (49.6 cm) is

$$\Delta G = \frac{0.43 \times 12.31}{3.84} \times \frac{1}{49.6} + \frac{1.24 \times (3 \times 12.31)}{9.04} \times \frac{1}{49.6} = 13.0\%$$

The estimate of gain, like that of heritability, was higher than can be reasonably expected for the same reasons. A larger number of families would improve the selection intensity.

Table E-1. Analysis of variance of two year nursery grown white spruce

Source of variation	df	Mean squares	F-ratio	Expected mean squares
Replicates	5	1772.67	23.84	$\delta_w^2 + N_f N_w \delta_r^2$
Families	21	886.69	5.99	$\delta_w^2 + N_w \delta_{rf}^2 + N_r N_w \delta f^2$
Families x Replicates	105	148.11	1.99	$\delta_w^2 + N_w \delta_{rf}^2$
Within plot	1188	74.34		δ_w^2
Total	1319			

$N_w = 10$ $N_f = 22$ $N_r = 6$