VARIATION IN HEIGHT OF WHITE SPRUCE PROVENANCES AFTER 10 AND 20 YEARS IN FIVE FIELD TESTS

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ABSTRACT.--Tree heights were measured at age 8 or 10 years and again at age 19 to 20 in five white spruce provenance tests belonging to a series planted in eastern and central Canada. There were statistically significant differences in mean height of provenances at each test site on both occasions, and ranking of provenances by mean height at age 8 or 10 was significantly correlated with ranking 10 years later. Performance of local, top-ranked, and bottom-ranked provenances in each test is compared with their performance in the other tests. Differences in growth of some of these provenances may reflect adaptation to calcareous or acidic soils.

Since the early 1950s much attention and effort has been devoted to research on the genetics and provenance variation of white spruce (Picea glauca (Moench) Voss) in Canada and in the United States (Nienstaedt 1969). Research initiated by scientists in the Canadian Forestry Service at Petawawa National Forestry Institute (PNFI, formerly Petawawa Forest Experiment Station) has led to the planting of three major series of white spruce provenance tests. Most of the early field tests were planted in central and eastern Canada with the cooperation of Provincial forestry agencies, but some were also planted by cooperators in the northeastern United States. Since they were planted the trees in those tests have been measured at intervals of one to five years. The data obtained from these tests show that there are highly significant differences in height growth among provenances and that it may be possible to increase the productivity of future forests by using the better seed sources so identified. However it is also recognized that relative growth of the different provenances may change with time, and that it is necessary to continue the evaluations (Teich, Skeates and Morgenstern 1975; Teich 1973; Khalil 1974).

The present paper will discuss and compare the results of measurements made 10 years apart in five field tests. These tests are located in the province of Ontario and belong to the 194 series of tests described by Teich, Skeates and Morgenstern (1975).

MATERIALS AND METHODS

Most of the white spruce seed used in the 194 series of provenance tests was collected between 1955 and 1957 in those parts of Ontario and Quebec falling within or close to the Great Lakes-St. Lawrence Forest Region (Rowe 1972). Additional seedlots were obtained from stands in New Brunswick, and the states of New York, Michigan, Wisconsin, and Minnesota. The distribution of provenances and the locations of the five Ontario tests described in this paper are shown in figure 1. All of these tests were field planted between 1963 and 1965 with four- or five-year old nursery stock. The tests differed from one another in site characteristics and in experimental design (Table 1).

Table 1. Location, design, and soil parent material in five white spruce provenance tests in Ontario.

Experiment number	Location name	lat.	long.	Seed sown in year	Number of provenances	replicates	trees per plot	Soil parent material
194-D-1	P.N.F.T.'	46.0	77.5	1959	25	3	144	Deep acidic till
I94-D-2	Lake Dore	45.6	77.1	1959	12	5	40	Shallow till over limestone
194-E	Owen Sound	44.2	80.8	1959	25	6	25	Calcareous till, 30-45 cm deep
194-M	P.N.F.T.	46.0	77.5	1961	54	12	10	Deep acidic till
194-N-1	Thunder Bay	48.2	89.7	1961	49	8	25	Deep clay loam

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Two experiments (194-D-1, and 194-M) were planted at Petawawa National Forestry Institute in different years (1963 and 1965) but are adjacent to each other so that site conditions are similar. The climate at these two test sites is also similar to that at Lake Dore (194-D-2), about 50 km from PNFI, but the soil at the Lake Dore plantation is calcareous and shallow. Supplementary geographic and climatic information about each provenance and test site is given by Teich, Skeates and Morgenstern (1975).

Survival and growth in these tests have been assessed many times since planting but, for the purposes of this paper, we are only concerned with heights of surviving trees measured in 1968 when the trees were 8 or 10 years old, and in 1977 to 1979 when they were 19 or 20 years old.

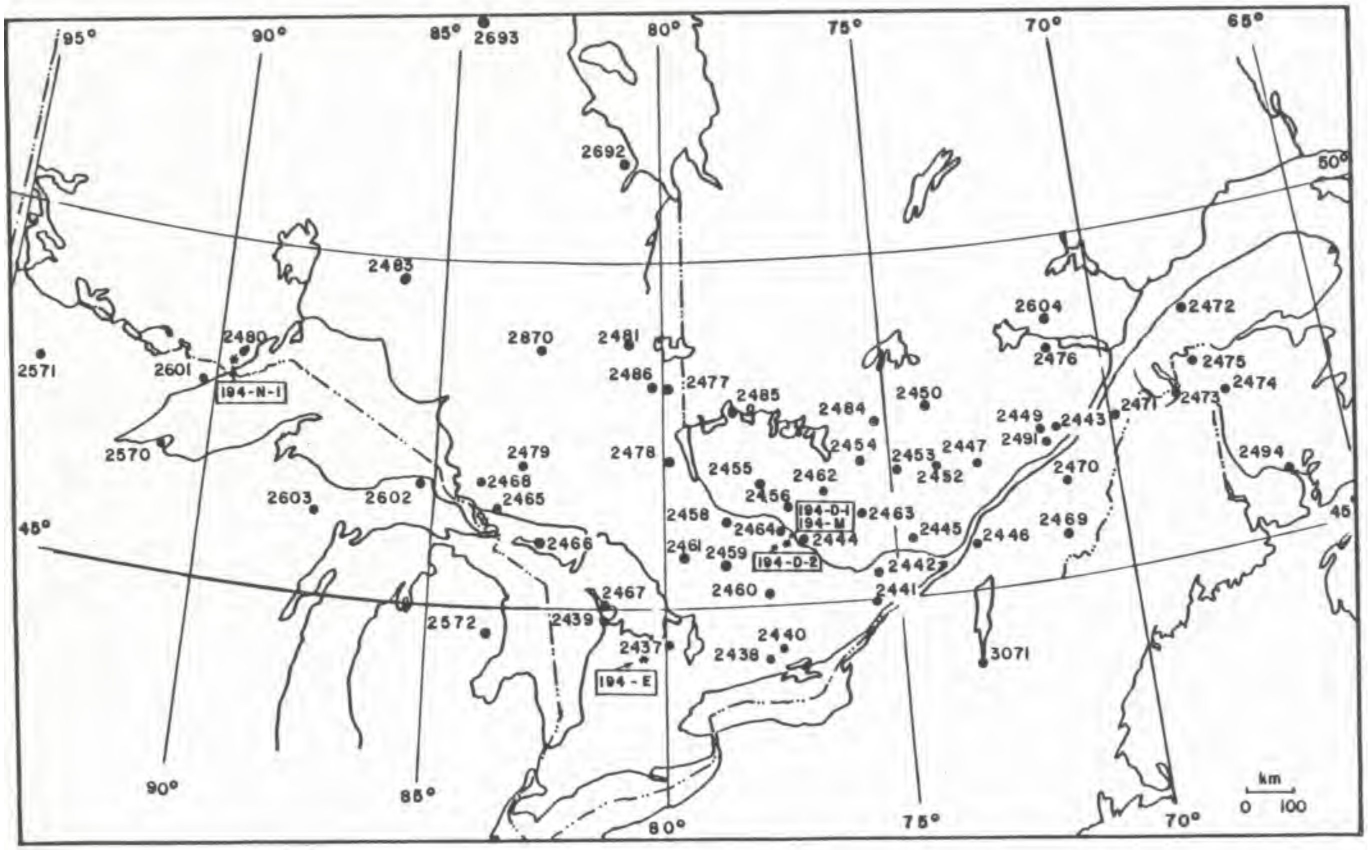

Figure 1. Distribution of provenances and locations of 5 Ontario tests.

RESULTS AND DISCUSSION

Analysis of the data collected showed that the effect of provenance on mean tree height was highly significant at all test sites on both occasions. In general, means based on measurements made in 1968 were well correlated with means determined about 10 years later, as shown by the highly significant values of Spearman's rank correlation coefficients (Table 2). The results also showed that there were large differences in average height between some of the experiments. For example, the mean heights of trees in 194-E and 194-N-1 were considerably lower than in the other three tests. These differences were attributed, in part, to the shallow impoverished soil in 194-E, and the shorter growing season in test 194-N-1 near Thunder Bay.

Table 2. Experiment mean height, range of provenance mean heights, and F ratio for two measurements of five provenance tests, and Spearman's coefficients of rank correlation between provenance mean heights in the first and second measurement.

Experiment Number	Tree Age (years)	Expt. Mean Height (cm)	Provenance Mean Ht. Max	Provenance Mean Ht. Min	F Ratio'	Spearman's Coefficient'
First measurement						
194-0-1	10	117	133	99	4.9	
194-0-2	10	74	93	63	5.6	
194-E	10	51	64	42	2.4	
I94-M	8	73	86	60	7.1	
194-N-1	8	38	46	31	3.9	
Second measurement						
194-0-1	19	479	539	418	5.9	0.852
194-0-2	19	402	491	362	5.6	0.727
194-E	20	246	312	189	2.0	0.913
194-M	19	544	612	475	6.3	0.819
194-N-I	18	261	322	210	2.3	0.796

All F-ratios and correlation coefficients are significant at P • 0.01

Other provenance effects can be seen by comparing the performance of local, top-ranked, and bottom-ranked provenances in each of the five tests. The term "local" describes the provenance closest to the test site, when provenance refers to the population of trees growing at a specific location (Callaham 1964). Table 3 shows the local and the six top-ranked provenances in each test along with the ranks they achieved in the other four tests at age 19 or 20. Mean heights of each provenance, expressed as percent of the experiment mean, are also given. Rank and mean height (as percent of experiment mean) of the five poorest provenances are given in table 4.

Table 3. Ranks and mean heights (as percent of experiment mean) of the local and the best six provenances in a given experiment.

Provenance Number	194-D-I	I94-D-2	194-E	194-M	194-N-1
2437		----	----	5 (107)	13 (106)
2438	1 (113)	I (122)	2 (125)	6 (107)	3 (106)
2439		6 (98)	7 (107)*	45 (95)	39 (93)
2440		----	3 (116)	17 (103)	44 (86)
2441		3 (104)	5 (111)	31 (99)	----
2442	----	2 (111)	4 (113)	14 (104)	34 (97)
2444	----	4 (103)*	----	1 (113)	----
2445	5 (108)	----	9 (104)	----	----
2446	----		----	2 (110)	25 (102)
2447	2 (111)	----	19 (94)	8 (106)	----
2454	3 (108)	----	6 (111)	41 (96)	26 (101)
2459	----	5 (99)	----	9 (106)	20 (103)
2460	----	----	----	4 (108)	8 (110)
2464	4 (108)*		14 (98)	3 (110)*	2 (117)
2473	6 (107)		1 (127)	27 (100)	23 (102)
2475	----		----	40 (97)	6 (110)
2476	----		----	11 (105)	1 (123)
2480	21 (92)		17 (95)	39 (97)	47 (82)*
2603	20 (94)	11 (90)	11 (101)	29 (100)	4 (111)
3071	----		----	32 (99)	5 (110)

* Local provenance

Table 4. Ranksl and mean height (as percent of experiment mean) of the five poorest provenances in a given experiment.

Provenance Number	I 94-D-I	I 94-D-2	I 94-E	I 94-M	I 94-N-I
245R	14 (100)	4 (96)	13 (99)	1 (87)	36 (105)
2466	10 (96)	1 (90)	----	9 (94)	4 (84)
2467	2 (92)	3 (94)	3 (84)	5 (92)	2 (RI)
2470	----	----	----	22 (98)	5 (84)
2480	5 (92)		9 (95)	16 (97)	3 (82)
2483	1 (87)		15 (104)	----	----
2570	16 (103)	----	5 (88)	----	----
2571	15 (102)	----	4 (84)	36 (103)	18 (99)
2572	13 (Ino)	5 (97)	1 (77)	43 (105)	13 (95)
2601	3 (92)	----	10 (95)	6 (93)	9 (90)
2602	9 (96)		2 (RO)	4 (91)	31 (103)
2603	6 (94)	2 (90)	15 (101)	26 (100)	46 (III)
2604	4 (92)		----	2 (90)	8 (89)
2692	----			3 (91)	I (80)

The lowest rank is given as the numeral I.

These data show that, in four of the five tests, a local provenance was among the best 7 performers. In fact, there was no statistically significant difference between the mean height of the local and the best provenance in these four tests. In contrast, the single local provenance was one of the poorest in the plantation near Thunder Bay (194-N-1). It is possible that this particular provenance does not truly reflect the character of the white spruce populations in the surrounding area. More information on white spruce in this geographic region should shortly be available from a more recent series of tests which incorporate seedlots from more provenances in the area (Ying 1979). The results from the five tests considered in this paper confirm the general rule that local seed sources should be used for reforestation until the suitability and possible advantages of non-local sources have been unequivocally demonstrated (Zobel and Talbert 1984). However, the results also show that there are exceptions to this general rule which can only be detected by an adequate testing program.

Another effect illustrated by the data is that some provenances consistently grow very well, or very poorly, in several tests, although soil and climate at each test site may be quite different. The best example of a provenance with superior growth in each of the five tests is number 2438. The seed of this provenance were collected from trees growing in calcareous soil to the south of Peterborough, Ontario, but even in the acidic soil of the most northerly plantation near Thunder Bay this provenance ranked third out of forty-nine. Although provenance 2444, from the Beachburg area of the Upper Ottawa Valley, was only planted in two of the tests, its superior growth was consistent with reports in the literature that white spruce from this area grows exceptionally well at many different locations (Nienstaedt and Teich 1972). Provenance 2466, from Manitoulin Island, is one example of a provenance that grew poorly in all the tests in which it was planted (Table 3). However, the best example of consistently poor growth is seen in provenance 2467, from Miller Lake, Ontario, which ranked no higher than fifth from the bottom in any of the five tests, even in 194-E where it could almost have been considered a local provenance. One item of particular interest is that this was considered to be a suitable source of seed for reforestation before the results of this research became known.

Some provenances show a certain degree of provenance by experiment interaction. For example, provenance 2441, from Cardinal on the St. Lawrence, ranked third and fifth, respectively, in tests 194-D-2 and 194-E, but was only 31st in 194-M. Provenance 2442, from the same general area of Ontario, ranked second, fourth, and fourteenth in the same three tests, and in test 194-N-1 its rank fell to 34. Some of these apparent interactions are undoubtedly due to differences among provenances in their response to changes in test site environment. One question of interest in this study was whether the variation among provenances might be related to their origin on calcareous or acidic soil. Both provenances 2441 and 2442 originated on calcareous soils, and their best growth occurred in the calcareous soils of tests 194-D-2 and 194-E. In contrast, provenance 2464, from acidic soils near Chalk River, ranked fourth, third, and second in the acidic soils of 194-D-1, 194-M, and 194-N-1, but was only 14th on the calcareous soils of experiment 194-E. These results suggest that these provenances may exhibit ecotypic variation in their adaptation to calcareous or acidic soils as described by Teich and Hoist (1974). On the other hand, provenance 2438, from a calcareous soil, grew well in all soils, while provenances 2466 and 2467, also from calcareous soils, grew poorly on both calcareous and acidic soils.

The results from these five tests provide additional evidence confirming that white spruce exhibits large amounts of provenance variation, and that there are opportunities to make gains in productivity by the identification and use of superior, well-adapted seed sources. The consistently poor growth of some provenances, even some that could be considered local, tends to emphasize the value of field tests to evaluate the material. Foresters may be understandably reluctant to plant such tests in view of their high cost and the possiblity of a long delay before useful results are available. However, the high degree of correlation between measurements made when the trees were about ten and twenty years old adds to the confidence with which data from young tests can be used to guide selection of suitable seed sources. Although adaptation to acidic or calcareous soils was not equally apparent in each provenance, it would be prudent to give some weight to this soil characteristic during the selection of suitable seed sources.

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