VARIATION IN WHITE SPRUCE FROM 24 DIFFERENT PROVENANCES STUDIED IN MARYLAND'S PIEDMONT PLATEAU[1]

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ABSTRACT -- Twenty-four white spruce populations representing the entire range of the species were tested in Maryland at 39023'N. It is the most southerly plantation of this widely distributed white spruce material. The measured response patterns, particularly in height growth, are very similar to patterns described for tests further north. Some of the pattern were: (1) A general decline in growth potential of white spruce populations from the southeast to the northwest over the range of the species. This pattern corresponds to a temperature and a precipitation gradient. (2) *Growth potentials of the populations are already well differentiated at age 9 from seed; only minor shifting in ranking occurred between the 9th and the 20th growing season. (3) Genotype x environment interaction is of little consequence in the white spruce test. (4) The Beachburg, Ontario provenance grew best in this Maryland test; it is recommended for Piedmont Plateau conditions.*

White spruce (Picea glauca (Moench) Voss.) is an important tree of Canada and northeastern United States, with a large range extending from the Pacific to the Atlantic Oceans. It is widely planted particularly in Canada (Sutton 1969). The species is not native to Maryland, but is the second most planted spruce after Norway spruce (P. abies L. (Karst.)). Studies are under way in both these species to select the best seed sources (Genys 1965, 1969).

The white spruce range extends from Kotzebue Sound on Seward Peninsula, Alaska to Newfoundland, and from 68°N

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on the Artic Ocean to about 43°-44°N in the Great Lakes Region and New York (Fowells 1965). It grows at elevations ranging from a few feet above the sea level to 2100 m. The species is adapted to great climatic diversity; some populations in Alaska tolerate temperatures as low as -70°F; others are tolerant to temperatures as high as +110°F in southern Manitoba (Fowells 1965; Nienstaedt and Teich 1972). Past investigators have described three distinct geographic varieties, P. E. var. densata (Bailey) in the Black Hills, P. g. var. pursildii (Raup) in Alaska and Yukon, and P. g var. albertiana (S. Brown) Sarg.) in Alberta. Several horticultural forms and interspecific hybrids have also been described.

Provenance studies in Canada and northern regions of the U.S.A. have shown that white spruce varies in growth rate, branching habits, stem and wood properties, and many other characteristics (Gent's 1965; Holst 1955; 1963; Jeffers 1969; Jones 1958; King and Rudolf 1969; Nienstaedt 1969; Revel 1969; Wilkinson, Hanover, Wright, and Flake 1971; Wright, Nienstaedt, Lemmien, Bright, Day, and Sajdak 1977). Here we compare variation observed further south in Maryland with the results in the northern tests.

MATERIALS AND METHODS

This study is part of a large experiment which was started by the Lake States Forest Experiment Station (North Central Forest Experiment Station) Forest Service in 1956. Seedlings were grown at Rhinelander, Wisconsin and were distributed in April 1962 for planting at 16 locations in Canada and the United States (Nienstaedt 1969). Twenty-four different populations were assigned for studies in Maryland (Figure 1), and 2-2 seedlings were planted in April 1962 at two locations. Only the Piedmont Plateau plantation is described here. It is located in Carroll County in north central Maryland near Liberty Lake at 39°23'N, 76°54'W and approximately 150 m (490'). The site has been farmed before and has deep fertile soil. The original design was 4-tree square plots in a randomized block design with 4 replications. Spacing was approximately 2 x 2 meters (7' x 7'). Unfavorable warm weather and dry soil prevailed during planting and caused a high mortality. Seedlings from one block were therefore used for replacements; only three blocks of trees were left for measurements.

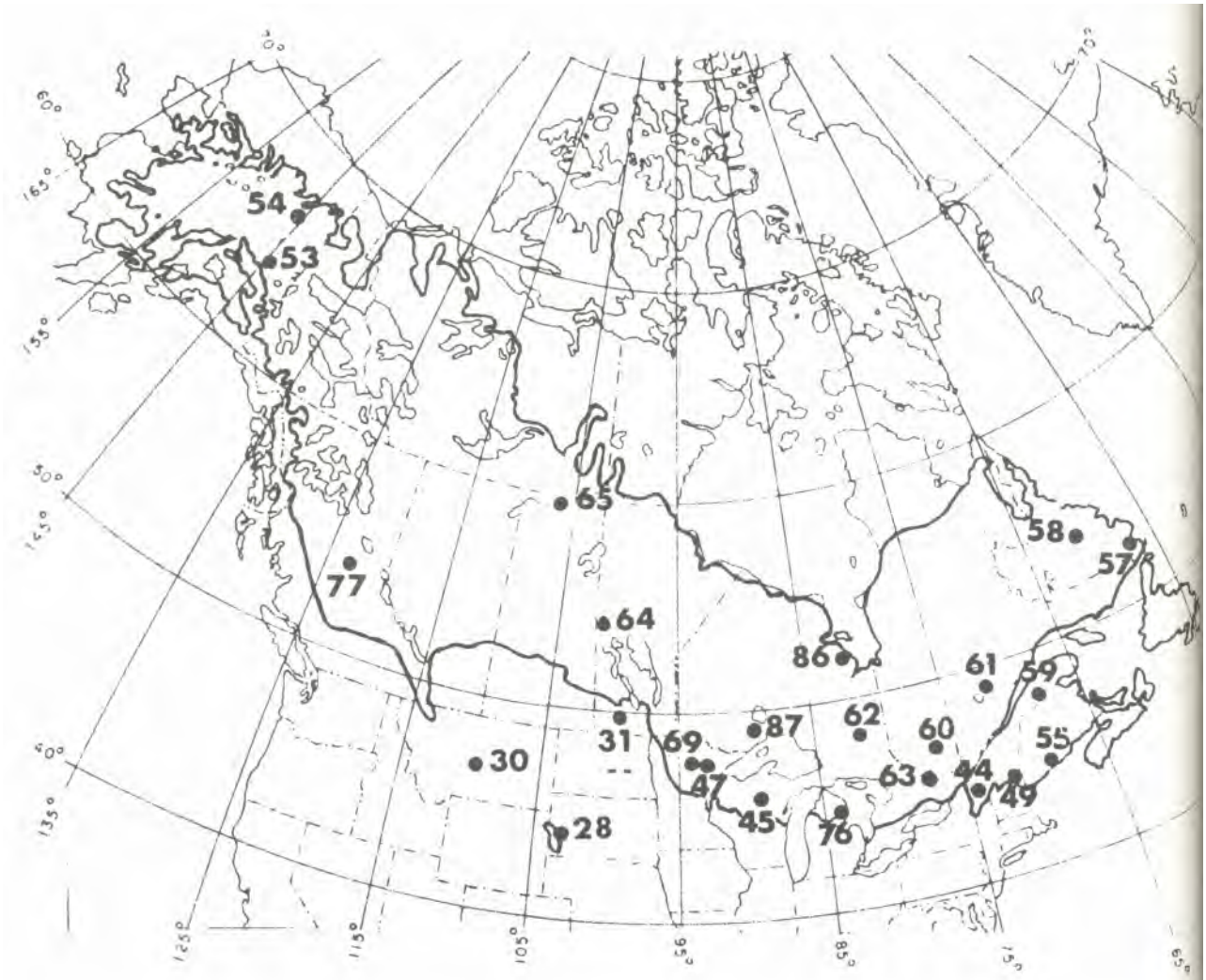

Figure 1. Range of white spruce. Dots show the locations of seed sources used in this study, identified by the Lake States seedlot numbers without prefix "16".

Heights were measured at various ages. The most current measurements were made in April 1978, 16 years after planting when trees were 20 years old from seed. Foliage color, needle length, cone production, and losses due to trespassing were studied in July 1978.

Analysis of variance and Duncan's multiple range test using plot averages were used in comparing provenances. The degrees of freedom were distributed as follows: populations 23, blocks - 2, interaction - 45, total - 72. Origin, character and juvenile-mature correlations were also determined using simple correlation analysis.

RESULTS

Variation in survival.--After the initial replacements overall survival was good (79 percent). It was as low as 17 percent for one of the slower growing populations, but 5 populations still survived with 100 percent at the age of twenty years from seed (Table 1)

Although the variation among populations is not statistically significant, the simple correlation analyses (Table 2) suggest that the variation is not random, but that rapidly growing populations survive better than those growing at a slower rate. The correlation between survival and 20 year heights - r = .44*, precipitation r = .42* and longitude r = .50* all suggest non-random variation.

Variation in height growth.--At 16 years after planting, the mean height of all populations was 2.87 m (9.4 feet). The populations from northern or high elevation provenances from Alaska, Saskatchewan, Labrador, British Columbia, Montana, and South Dakota grew slowest; their heights ranged from 50 to 78 percent of the plantation mean. The fastest growing populations originated in the Lake States, southeastern Ontario and in New York and Maine. Some of the better sources from these areas exceeded plantation mean height by 23 to 50 percent.

With only two exceptions all the populations that exceeded plantation mean height at 20 years from seed originated south of 490N latitude and heights were in fact significantly correlated with latitude (r = -.71** d.f. 22) (Table 2)

Table 1.--Variation among 24 populations of white spruce (Picea glauca) studied in Maryland

L.S. seed Nos. 1600 +NW	Geographic origin: State, Province, County, or nearest location	North Latitude	West Longitude	Climates: Growing season days without frost	Precipitation	July temp.	Maryland plantation characteristics at 20 years: Survival	Height in % of plantation mean	Needle length	Needle color*
				Days	Inches	°F	%	%	mm	Grades 1-7
	Northwestern range									
54	Alaska (Ft. Yukon)	66°35'	145°11'	81	7	61.3	33	58	14	3.3
53	" (Gerstle)	63°45'	144°53'	63	15	54.9	75	50	11	2.3
65	Saskatchewan (Stony Rapids)	59°15'	105°59'	60	11	60	92	77	14	2.7
77	Brit. Columbia (Summit Lake)	54°00'	123°00'	68	20	60	58	71	14	4.0
	Mid-continent									
64	Manitoba (Channing)	53°39'	101°36'	100	17	66	50	106	12	4.0
31	" (Brandon)	49°51'	99°30'	96	16	65	83	91	13	3.7
30	Montana, Fergus	46°48'	109°31'	96	17	63	17	63	15	4.7
28	South Dakota, Lawrence	44°10'	103°55'	129	23	69.5	83	78	13	3.7
	Eastern Canada									
58	Labrador (Lake Melville)	53°47'	60°05'	96	29	61	92	69	12	4.0
57	" (Port Hope Simpson)	52°36'	56°36'	88	42	52	83	64	13	4.3
61	Quebec, Chicoutimi & St.Joan	48°15'	71°30'	124	33	65	75	112	16	3.0
60	" Pontiac	46°32'	76°30'	101	30	66	75	114	15	3.0
59	New Brunswick(Restigouche)	47°50'	68°21'	100	35	64	100	116	13	2.7
	Ontario, Canada									
86	Ontario (Akimiski Island)	52°15'	81°40'	87	20	60	100	111	14	4.7
62	" (Ashley Mines)	48°30'	81°00'	81	31	62	92	114	15	2.7
63	" (Beachburg)	45°44'	76°51'	132	33	69	83	150	17	3.3
87	" (Kakabeka Falls)	48°30'	89°30'	94	26	64	83	104	13	2.7
	Lake States, U.S.A.									
69	Minnesota, Itasca	47°30'	94°00'	115	23	68.9	92	110	14	3.3
47	" "	47°20'	93°30'	115	23	68.9	100	130	15	3.3
45	Wisconsin, Oneida	45°40'	89°30'	112	32	68.3	100	131	16	3.0
76	Michigan, Iosco	44°30'	83°45'	127	29	67.5	92	123	16	3.0
	Northeastern U.S.A									
49	New Hampshire, Coos	44°51'	71°26'	95	45	63.4	100	113	14	3.3
55	Maine, Penobscot	44°50'	68°38'	142	39	69.1	58	135	17	3.0
44	New York, Essex	44°23'	74°06'	99	36	65.1	83	133	15	2.3
	Means ($\bar{x}$)						79	2.87	14.3	3.3
	The least significant difference at 0.05 level						n.d.	56	4	2.3
	F-value **						1.1	4.6	3.6	2.3

* Foliage color was scored in July 1978, grades: 7 = extreme dark blue-green; 1 = yellow green

** Data on populations which included less than seven trees were not included in the analysis of variance.

Table 2.--Correlations among heights of white spruce populations tested in Maryland, Michigan and elsewhere[a] -- Correlations among growth characteristics and climatic conditions at the geographic origin of the populations

	Latitude	Longitude	Growing season	July temp.	Precipitation	Maryland characteristics at age 20: Heights	Survival	Needle color
Heights age 14								
Michigan	-.75[b]	-.64				.90		
Other sides	-.77	-.64				.92		
Maryland characteristics at age 20								
Heights	-.71	-.56	.65	.70	.54			
Survival	-.31	-.50	.10	.10	.42	.44		
Needle color	-.02	-.03	-.02	-.18	-.13	-.33	-.32	
Needle length	-.54	-.24	.59	.54	.37	.63	-.02	-.11

[a]Average heights in 6 plantations in Michigan; and in 9 plantations in North Dakota, Minnesota, Wisconsin, Maine and New Brunswick (from Wright et al. 1977).

[b]D.F. 22 = Significance levels: 5% = .40; 1% = .52.

The correlation between heights and west longitude is less marked but significant (r = .56** d.f. 22). Combined, the latitudinal and longitudinal relationships indicate a general trend of declining growth potential of white spruce populations from the southeast to the northwest over the range.

Across North America latitude is reflected in climates as a general decline in the temperature regimes from south to north. Longitude, on the other hand, reflects an east-west decline in precipitation. As expected therefore, heights after 20 years from seed were significantly correlated with the length of the frost-free period, r = .65**, mean July temperature r = .70** and precipitation r = .54**.

Growth of the same populations studied at 4, 9, 11, 16, and 20 years from seed, were highly correlated:

Height at age	Height at 20 yrs r	r^2
4	.73	.53
9	.88	.77
11	.93	.86
16	.94	.88

The growth potentials of the populations are already well differentiated at age 9 from seed; only minor shifting in ranking occurred between the 9th and the 20th growing season,

Similarly, the heights of the populations in Maryland at age 20 from seed were highly correlated with mean heights at age 14 in 6 tests in Michigan, r = .90** d.f. 22, and 9 tests in North Dakota, Minnesota, Wisconsin, Maine and New Brunswick, r = .92** d.f. 22. This indicates that genotype x environment interaction is of little consequence in this white spruce test.

The fastest growing population in Maryland is of the Beachburg Ontario provenance originating about 50 miles northwest of Ottawa Ontario. This provenance has been widely tested and has consistently been among the most productive.

Variation in needle lengths,--The mean needle length of all populations was 14.3 mm. Average lengths for different populations ranged from 11 to 17 mm. The trees with the shortest needles came from Gerstle, Alaska (No. 53) and those with the longest from Beachburg, Ontario (No. 86) and from Penobscott County in Maine (No. 55) (Table 1).

The correlation between needle length and height at age 20, r = .63** d.f. 22 and latitude, r -.54* d.f. 22 were significant at the .01 level. As was the case for heights, needle lengths were correlated with growing season and average July temperature, but it was not related to precipitation (Table 2).

Variation in foliage color.--Foliage color was scored when trees were in active growth in July, The darkest blue green color was found among trees from Akiminski Island, Ontario (No. 86). A similar dark color was observed on two trees from Fergus, Montana (No. 30). The population from Gerstle, Alaska (No. 53) had the most yellowish needles. Yellowish needles were also observed in individual populations from Saskatchewan, New Brunswick and southern Ontario. Needle color showed no significant correlation to either the growth rates or the geographic and climatic factors.

Other characteristics.--At 20 years, the cone production of white spruce in Maryland was very low. Only 4 trees out of 228 (2%) had any number of cones. These belonged to four populations: No. 76 from Michigan (20 cones), No. 49 from New Hampshire (10 cones), No. 44 from New York (10 cones), and No. 86 from Ontario (5 cones). Although these are inadequate data for general conclusions to be drawn, it is interesting to observe that with the exception of the Ontario tree the other trees all represent some of the most southerly populations in the test.

In Maryland's Piedmont Plateau white spruce suffered no injury from either insects or disease. However, 22% of the trees were injured by white-tailed deer (Odocoileus virginianus) rubbing their antlers against tree trunks. When such injury exceeded half of the circumference of stem, the top of the injured tree usually died. Some strains were not injured while others had 50% or more injured trees. This variation among individual populations was not statistically significant, but strains from eastern

Canada, as a group, were all injured, while some strains from other regions escaped. Also, deer preferred white spruce over Scotch pine (Pinus sylvestris L.), loblolly pine (Pinus taeda L.) and white pine (Pinus strobus L.) planted on the same site.

Trespassers stole 13 white spruce during the past three years. From some populations two or three trees were cut, while from others none. Most preferred trees were from Labrador (No. 53) and Wisconsin (No. 45). The basis for this preference is obscure, since the Labrador trees have relatively dark foliage, short needles and slow growth, while the Wisconsin trees grew relatively rapidly and had nondescript foliage characteristics.

DISCUSSION

Direct increase in yields through provenance selection is a simple low cost approach to tree improvement and economically sound plantation management. Past reports (Nienstaedt 1969; Wright et al. 1977) have selected Beachburg No. 63 as an outstanding, broadly adapted white spruce population and has recommended it for use in the Lake States and adjacent Canada. With these results from Maryland we also recommend the use of Beachburg white spruce in the Maryland Piedmont and adjacent regions with similar climatic conditions. Other more detailed studies of the populations in the Ottawa River Valley may identify other superior stands or individual trees. And for those beginning a more intensive white spruce breeding program the search for superior genotypes should extend into adjacent regions to the east and west. Use of more northern (46°N) seed sources is not indicated.

The Maryland test could not include a local control; white spruce is not native in the state. The Northeastern and the Lake *States* seed sources probably represent the seed sources most likely to be used in Maryland white spruce planting programs. On the average they exceed the mean height of the plantation by 25%. If this assumption regarding sources of seeds is correct, our results indicate that the use of the Beachburg source of seed could add 25% to the height growth potential of white spruce in Maryland plantations. This increase is comparable to the increases demonstrated in other tests (Wright et al. 1977; King and Rudolf 1969).

Color of needles varied significantly in the Maryland test. However, Wright et al. (1977) have pointed out that color varies from one plantation to another. For that reason recommendations for Christmas tree growers cannot be made on the basis of this isolated Maryland test.

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