RANGEWIDE PROVENANCE STUDY OF BLACK SPRUCE IN NORTHERN MAINE

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ABSTRACT.--A rangewide provenance test of black spruce, including 100 provenances from the United States and Canada, was established in Maine in 1976. Height and root collar diameter were measured in 1981, and height for the previous two years was estimated from internodal distances. Growth rate differs significantly among provenances, with mean heights at age six ranging from 117.8 cm (Whiteshell Park, Manitoba) to 30.4 cm (Steamboat Mtn., British Columbia). Total height is negatively correlated with latitude of the seed source. In general, western Ontario and Lake States provenances have the greatest growth and survival.

Black spruce (*Picea mariana* (Mill.) B.S.P.) is one of the most abundant and widely distributed conifers of North America. It spans the entire continent, from Newfoundland and the Maritimes west and northward to central Alaska, with its southermost range extending into isolated pockets of central Pennsylvania (Heinselman 1957). In the United States, natural stands of black spruce are most common in the Lake States and northern New England.

In general, the climate over the botanical range of black spruce can be characterized as a cold sub-humid continental type. However, due to the extensive area covered, a wide range of climatic factors are encountered. Extremes in mean annual temperature, precipitation, and frost-free season are related to latitude, longitude, topography, and proximity to maritime influences.

Soils and topography play an important role in the growth and distribution of black spruce. Although it may occur on well-drained upland soils, it is frequently found under wet conditions; along streams, swamp borders, and sphagnum bogs. Black spruce grows in a variety of local climates and on both organic and mineral soils (Heinselman 1957). As a result of its wide spectrum of site conditions, black spruce is a preferred plantation species in eastern Canada. It is also becoming a popular species for planting in Maine because of its rapid juvenile growth rate and its relative resistance to the spruce budworm, *Choristoneura fumiferana* (Clem.).

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Black spruce is primarily a pulp and paper species and improvement of the fiber yield per unit area is the major objective of tree breeding programs. It has been estimated that the use of genetically improved seed could potentially increase total yields by at least 10 percent over those obtained from ordinary seed during the whole rotation period. (Morgenstern 1979).

Previous genetic studies of black spruce have indicated that a considerable geographic variation exists in growth rates and phonological characteristics. Morgenstern (1969 a; 1969 b) utilized a principal components analysis to demonstrate a definite clinal pattern of variation in germination, drought resistance, growth, and phenology of seedings from 148 trees in 24 stands located from Lake Erie to James Bay. In contrast, Khalil's (1975) limited-range provenance studies indicated that the pattern of variation in Newfoundland was ecotypic rather than clinal. A subsequent rangewide study by Morgenstern (1978) demonstrated that photoperiod and temperature had major effects on the phenology and growth rate of 1- and 3-year-old black spruce seedlings. Although the overall pattern of variation was clinal, there was also significant variation among geographic areas and among individual stands within areas.

Based upon the early indications of variation within black spruce, a rangewide provenance test was established in Maine in 1976 to examine the patterns of genetic variation under local conditions and to identify superior seed sources for reforestation in northern New England.

METHODS AND MATERIALS

Seeds used in this study were provided by the Petawawa Forest Experiment Station, Canadian Forestry Service, Chalk River, Ontario, and by the U.S.F.S North Central Forest Experiment Station, Rhinelander, Wisconsin. These seeds were collected from up to 20 trees in each of 100 stands coverin g the natural range of black spruce (Table 1). The seeds were sown in January, 1976, at the University of Maine greenhouse in size 608 Japanese paperpots using Promix B as the potting medium. The largest seedlings were approximately 15 cm tall at the time of planting in mid-July, 1976. The seedlings were planted with dibbles on a 2x2 meter spacing. The experimental design consists of a randomized complete block with four-tree row plots replicated nine times.

The Telos black spruce plantation is located in T4-R11 W.E.L.S. of north-central Piscataquis County at an approximate latitude of 46°01' north and a longitude of 69°10' west. The plantation was established on a level 1.1 hectare parcel of land owned by the Great Northern Paper Company. The elevation is approximately 460 meters above sea level. The area is located in the northern climatological zone of Maine and reflects interior weather patterns affected by broken topography. The mean annual temperature of 5.3°C, total precipitation of 1051.6 mm, and average freeze-free days of 128 recorded at Ripogenus Dam, approximately 30 kilometers southwest of the plantation, are not uncommon in the relatively severe northern zone (Lautzenheiser 1972).

Table 1.--Locations and mean heights in 1981 of black spruce provenances in the Telos plantation.

UMO Provenance Number	State or Province	Degrees North Latitude	Degrees West Longitude	Mean Height in 1981 (cm)
3015	Mich.	46:29	88:21	91.1
3016	Mich.	47:22	93:35	89.6
3018	Wisc.	46:07	90:56	103.3
3019	Wisc.	45:17	88:27	99.8
3020	Mich.	44:38	84:20	108.4
3021	Mich.	46:35	88:05	111.2
3022	Mich.	44:12	85:35	110.2
3023	Mich.	45:59	86:51	109.4
3025	Mich.	46:03	84:47	110.4
3026	Minn.	47:42	91:01	114.5
3028	Minn.	47:32	93:43	102.3
3029	Minn.	47:42	92:02	101.6
3030	Mich.	42:37	83:13	96.0
3031	Nfld.	47:20	53:07	92.4
3032	Nfld.	48:13	58:55	91.6
3033	Nfld.	49:01	55:26	78.9
3034	Nfld.	53:25	60:23	70.6
3035	Nfld.	50:54	56:06	59.9
3036	N.S.	43:50	65:11	82.5
3037	P.E.I.	46:03	62:51	110.7
3038	N.B.	47:29	66:52	89.9
3039	N.B.	45:35	66:29	103.8
3040	N.B.	47:55	67:49	87.1
3041	N.B.	46:49	65:09	97.2
3042	Que.	50:40	68:46	86.3
3043	Que.	50:27	73:38	96.2
3044	Que.	48:55	65:25	72.1
3045	Que.	46:55	73:26	103.8
3046	Que.	47:05	76:33	100.3
3047	Que.	48:36	76:41	105.9
3048	Que.	49:07	76:57	114.8
3049	Que.	49:37	77:45	93.2
3050	Que.	48:30	67:07	94.2
3051	Que.	46:55	71:31	86.6
3052	Que.	47:18	73:06	93.9
3053	Que.	46:50	74:25	90.6
3054	Ont.	45:10	77:10	96.7
3055	Ont.	44:50	78:05	105.4
3056	Ont.	45:58	77:25	104.9
3057	Ont.	46:25	79:26	106.9
3058	Ont.	46:55	79:42	100.5
3059	Ont.	48:12	82:23	99.8
3060	Ont.	48:32	81:25	91.6
3061	Ont.	48:59	80:38	97.5
3062	Ont.	49:45	85:05	96.7
3063	Ont.	49:40	87:50	101.0
3064	Ont.	46:20	82:50	111.2
3066	Ont.	46:43	84:23	106.1
3067	Ont.	48:38	85:20	90.9
3068	Ont.	49:08	85:47	104.3
3069	Ont.	50:18	89:11	96.5
3070	Ont.	49:00	90:27	102.6

Table 1 (Cont'd.)

UMO Provenance Number	State or Province	Degrees North Latitude	Degrees West Longitude	Mean Height in 1981 (cm)
3071	Ont.	49:25	91:31	115.5
3072	Ont.	50:19	90:41	108.2
3073	Ont.	50:44	90:34	98.2
3074	Ont.	51:28	90:11	99.5
3075	Ont.	50:13	91:40	94.4
3076	Ont.	50:24	93:20	104.9
3077	Ont.	50:53	93:44	109.7
3078	Ont.	49:50	93:30	107.9
3079	Ont.	50:03	94:52	105.4
3080	Ont.	50:50	94:17	100.3
3082	Ont.	48:44	93:40	99.8
3083	Ont.	48:48	93:40	110.9
3084	Ont.	48:44	91:40	99.0
3085	Ont.	48:40	90:11	95.5
3086	Mich.	44:38	84:20	102.6
3087	Mich.	44:12	85:35	102.8
3088	Mich.	46:03	84:47	101.3
3089	Mich.	45:59	86:51	88.6
3090	Wisc.	45:17	88:27	92.9
3091	Wisc.	45:44	88:59	102.6
3094	Wisc.	46:07	90:56	101.3
3096	Minn.	47:42	92:28	105.1
3097	Minn.	47:37	90:52	107.1
3098	Minn.	47:42	91:18	112.7
3099	Manit.	50:45	99:58	107.6
3101	Manit.	51:38	100:47	79.2
3102	Manit.	51:48	100:12	88.3
3103	Manit.	52:29	101:26	83.0
3105	Manit.	55:30	98:04	73.1
3106	Manit.	54:35	101:00	87.6
3107	Sask.	54:52	102:48	84.8
3108	Sask.	56:03	108:42	85.3
3110	Sask.	53:14	105:46	82.5
3111	Manit.	49:17	95:18	106.4
3112	Manit.	51:00	96:14	108.2
3113	Manit.	50:04	96:27	117.8
3114	Manit.	57:00	97:52	51.0
3116	Alberta	52:23	15:02	67.3
3117	Alberta	52:22	15:15	72.8
3118	Alberta	52:30	15:53	60.1
3120	Alberta	55:16	14:47	76.4
3121	Alberta	55:03	15:16	69.5
3123	B.C.	56:35	21:22	48.7
3124	B.C.	56:36	21:23	49.2
3125	B.C.	56:37	21:28	68.5
3126	B.C.	58:47	23:36	50.2
3127	B.C.	58:44	23:38	44.7
3128	B.C.	58:42	23:45	30.4

The planting site was a spruce-fir clearcut that had been prepared with sharkfin drums the season before planting. Moderately well-drained soils of the Ridgebury and Peru series are uniformly distributed throughout the site. The plantation has a natural spruce-fir stand on the south end and is bordered on the east and west sides by a five-year-old white spruce (*Picea glauca* Moench.) plantation. Hardwood sprouts and brush, most notably pin cherry (*Prunus pensylvanica* L.), red raspberry (*Rubus idaeus* L.) red-berried elder (*Sambucus pubens* (Michx.), and fireweed (*Epilobium angustifolium* L.) are the primary competing vegetation on the site. Severity of brush competition decreases rapidly in all directions from a concentration on the north end of the plantation. Proximity to a former landing and small slash burn may account for this distribution.

Three height measurements were made on each black spruce seedling. Total height at the end of the 1981 growing season was measured directly. Height for the previous two years was determined from internodal distances. All measurements were made to the nearest 0.5 inch using a range pole placed next to the stem of each tree. In addition, records of tree height in 1977 were available from previous measurements. The data were recorded and analyzed in English units and then converted to metric units. Stem diameter measurements were made using conventional micrometer at 5 to 8 centimeters above the root collar and recorded to the closest hundredth of an inch.

Precocious cone formation was not encountered on any specimens in the planting. White pine weevil (*Pissodes strobi* Peck) damage was visible throughout the area and constituted the most serious problem on the site. Trees with damaged or dead terminals were tallied as weevil damaged trees for subsequent statistical analysis.

Statistical analyses were based on the mean values of four-tree plots (families) within each replication. Computerized analysis of variance and Duncan's multiple range test were conducted for each variable that was measured. Pearson product-moment correlations were computed among a number of provenance variables, including total height 1981 (Ht81), total height 1980 (Ht80), total height 1979 (Ht79), total height 1977 (Ht77) and total stem diameter 1981 (Diam81). Total height 1981, percent mortality and percent weevil damage were also correlated with environmental and geographic variables such as latitude, longitude, elevation, mean annual temperature, and mean annual precipitation at the seed origin.

RESULTS

Survival

Overall plantation survival at the Telos site was 84.9%. The mortality rates ranged from zero mortality for six sources (3020, 3026, 3043, 3062, 3067, and 3113) to a maximum of 69.4% mortality for source 3128. Percent mortality was correlated (P = .05) with environmental and geographic variables (Table 2). The highest correlation was between mortality and latitude of the seed source (r = 0.48), with the highest mortality occurring in provenances from northwestern Canada.

Table 2.--Pearson correlation coefficients for geographic and environmental variables with 1981 height, mortality, and frequency of weevil damage.

	Long.	Elev.	Prec.	Temp.	Height	% Weevil	% Mortality
Latitude	0.66**	0.46**	-0.65**	-0.77**	-0.72**	-0.65**	0.48**
Longitude		0.73**	-0.91**	-0.42**	-0.42**	-0.46**	0.37**
Elevation			-0.62**	-0.23*	-0.45**	-0.36**	0.26*
Precipitation				0.41**	0.36**	0.43**	-0.28*
Temperature					0.41**	0.50**	-0.31**
Height (1981)						0.58**	-0.61**
% Weevil Damage							-0.38**

* P <0.05
** P <0.01

Height and diameter growth

The tallest single tree in the Telos plantation in 1981 was 181.6 cm (source 3041). The plantation mean height and the average heights of the ten tallest provenances for each year are given in Table 3. Most of these fast-growing seed sources are from the Great Lakes region in Canada and the U.S. The mean diameter for all provenances was 5.5 cm and ranged from a minimum of 1.7 cm (source 3128) to a maximum of 7.9 cm (source 3021).

Significant differences were found among provenances in height for each year and in diameter. Results from the analyses of variance for 1981 are presented in Table 4. Differences among replications were also significant for all years.

Table 3.--Location of the ten tallest sources for each year of measurement.

Year	Rank	Source	Location	Height (cm)
1981	1	3113	Whiteshell, Prov. Park, Manitoba	117.9
	2	3071	Ignace, Ontario	115.6
	3	3048	Abitibi Est., Quebec	114.8
	4	3098	Isabella, Minnesota	112.8
	5	3021	Houghton, Michigan	111.3
	6	3064	Massey, Ontario	111.3
	7	3083	Rainy Lake, Ontario	111.0
	8	3037	Garfield, P.E.I.	110.7
	9	3025	Mackinac, Michigan	110.5
	10	3022	Wexford, Michigan	110.3
			Plantation mean	93.3
1980	1	3071	Ignace, Ontario	89.7
	2	3064	Massey, Ontario	89.2
	3	3113	Whiteshell Prov. Park, Manitoba	89.0
	4	3048	Abitibi Est., Quebec	87.9
	5	3098	Isabella, Minnesota	86.6
	6	3025	Mackinac, Michigan	85.6
	7	3021	Houghton, Michigan	84.6
	8	3083	Rainy Lake, Ontario	83.1
	9	3112	Manitogan, Manitoba	82.8
	10	3077	Redlake, Ontario	82.6
			Plantation Mean	69.9
1979	1	3071	Ignace, Ontario	66.3
	2	3113	Whiteshell Prov. Park, Manitoba	66.0
	3	3064	Massey, Ontario	64.F
	4	3048	Abitibi Est., Quebec	64.3
	5	3098	Isabella, Minnesota	63.0
	6	3097	Tofte, Minnesota	62.0
	7	3077	Red Lake, Ontario	61.7
	8	3068	Manitouwadge, Ontario	60.8
	9	3066	Fenwich, Ontario	60.2
	10	3072	Boucher, Ontario	60.0
			Plantation mean	51.0
1977	1	3071	Ignace, Ontario	36.7
	2	3111	N.W. Angle, Manitoba	35.3
	3	3077	Red Lake, Ontario	35.1
	4	3098	Isabella, Minnesota	34.8
	5	3047	Augier, Quebec	34.8
	6	3072	Boucher, Ontario	34.5
	7	3048	Abitibi Est., Quebec	34.0
	8	3070	Upsala, Ontario	33.4
	9	3066	Fenwich, Ontario	33.3
	10	3045	St. Maurice, Ontario	33.0
			Plantation mean	27.1

Table 4.--Analyses of variance for height and diameter in 1981.

Source of Variation	Height			Diameter	
	DF	SS	F	SS	F
Provenance	99	34465.67	9.60**	159.49	5.83**
Replication	9	1000.58	3.45**	14.26	6.45**
Error	696	25251.05		192.37	

** P < 0.01

Pearson correlation coefficients between the total height for each year and the stem diameter in 1981 were significant at the .01 level for each variable (Table 5). The correlation between height in 1980 and 1981 was extremely high (r = .99) as could be expected and the correlation between total height 1981 and diameter in the same year was also very high (r = 0.91). Total height in 1977 was highly correlated with height four years later in 1981 (r = 0.93).

Table 5.--Pearson correlation coefficients for geographic variables with diameter and height in several years.

	Latitude	Longitude	Height 1981	Height 1980	Height 1979	Height 1977	Diameter 1981
Elevation	00.46**	0.73**	-0.45**	-0.44**	-0.42**	-0.43**	-0.48**
Latitude		0.66**	-0.72**	-0.72**	-0.68**	-0.76**	-0.73**
Longitude			-0.42**	-0.42**	-0.43**	-0.49**	-0.51**
Height 1981				0.99**	0.97**	0.91**	0.92**
Height 1980					0.98**	0.93**	0.92**
Height 1979						0.94**	0.90**
Height 1977							0.89**

** P < 0.01

Of all the environmental and geographic variables examined (Table 2), latitude of seed origin was most strongly correlated with total height in 1981 (r = -0.72). Latitude was also negatively correlated with height in the previous three years, and with diameter (Table 5). Mean annual temperature was moderately well correlated with height in 1981 (r = 0.50). Height and mortality were negatively correlated.

Weevil damage

Overall, 18% of the trees at Telos had damaged leaders attributable to white pine weevil attack. Eight far western provenances showed no evidence of weevil damage, while the highest frequency of weevilling was 44% for source 3020 from Michigan. The frequency of weevil damage was correlated with geographic variables, most notably with latitude of the seed source (Table 2). There was a moderate correlation between weevil damage and height in 1981 (r = 0.58). Overall, provenances from the Great Lakes region suffered an average of 21% weevil-damaged terminals, but within this region the frequency of attack ranged from 6% to 44%. The frequency of weevilling was also high (30%) for provenances from New Brunswick and Nova Scotia.

DISCUSSION

Survival was high for all provenances, with the exception of those from locations above 55° north latitude. Trees from those areas are presumably adapted to different climates and photoperiods from those found at Telos. Provenances from the Maritimes region of Canada, which is similar to Maine in climate, had survival rates above 90%. The six seed sources having 100% survival were all from the Great Lakes area.

The negative correlation between latitude and sixth-year height which was observed in this plantation is in agreement with Morgenstern's (1969A, 1978) earlier observations of 2- and 3-year-old seedlings and supports the assertion that clinal variation in height is evident over the range of black spruce. However, at Telos this correlation is due in large part to the rapid decline in height for provenances located north of 50° N latitude. The seed sources which are in the upper third for height are generally from a region between 44° and 51° N latitude, and 75° to 96° W longitude, an area which corresponds roughly to Rowe's (1972) Canadian Great Lakes region and the Lake States of the U.S. Within this area, variation is random with respect to latitude and longitude. Seed sources from New Brunswick, Nova Scotia, and eastern Quebec, the locations which are closest to the Maine planting site, were not among the faster-growing sources.

Although there has been some change in the ranking of individual provenances for each year of measurement, the high correlation between height in 1977 and in 1981 may indicate a potential for early selection for growth rate in black spruce. Rapid juvenile growth is of special value when the seedlings must compete with hardwood stump sprouts and other weed species, a situation which is commonly found on cutover forest sites in northern New England.

The correlation between height and frequency of white pine weevil attack in black spruce is similar to the pattern observed in white pine (*Pinus strobus* L.)(Connola 1973; Gerhold and Soles 1967). When considering only provenances from the Great Lakes region, however, the correlation between provenance mean height and percent weevil damage is not significant. While no genetic basis for weevil resistance is known in black spruce, the great variation in frequency of attack among provenances suggests that some genetic influence may exist.

The patterns of variation in height, survival, and white pine weevil damage in this plantation indicate that gains in juvenile growth rate of black spruce in Maine can be attained through the selection of fast-growing seed sources. In general, provenances from the Great Lakes region were taller than those of local origin and had excellent survival rates. Two provenances from eastern Canada (3037 and 3039) were also among the tallest one-third of all provenances. In eastern Canada, as well as in the Great Lakes region, there are large variations in height and in frequency of weevil damage among provenances within the region. These stand-to-stand differences should also be considered when selecting planting or breeding stock.

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