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MARITIMES FOREST RESEARCH CENTRE

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ABSTRACT

The performance of red pine in two range-wide provenance trials is reported after 17 and 21 years from planting. Differences among provenances with respect to most growth characteristics, although statistically significant, are small and diminish as the trees mature. Height superiority of the best provenance over the plantation average was 5.8 to 6.1% (30 cm) in one trial after 17 years but only 4.7% (60 cm) in the other trial after 21 years. Differences among provenances with respect to survival, porcupine damage, and European pine shoot moth damage were not significant.

It is suggested that the differences among provenances result from non-genetic as well as genetic factors. In general, trees from the central part of the species range in the Lake States and Ontario grew slightly (3-4%) faster than trees originating from north of 47°N latitude. Trees of local origin were about average.

RESUME

Performance du pin rouge selon les résultats de deux tests de provenance à longue portée effectués 17 et 21 ans après la plantation. Les différences entre les provenances en ce qui concerne la plupart des paramètres de la croissance, bien que statistiquement significatives, sont faibles et diminuent avec le temps. La supériorité en hauteur de la meilleur provenance par rapport à la moyenne est de 5.8 à 6.1% (30 cm) dans celui des tests effectué après 17 ans, mais seulement de 4.7% (60 cm) dans l'autre effectué après 21 ans. Les différences entre les provenances quant à la survie et aux dégâts du porc-épic et du perce-pousse européen du pin ne sont pas significatives.

Les différences entre les provenances seraient attribuables à des facteurs tant génétiques que non génétiques. En général, la croissance a été un peu plus rapide (3 à 4%) pour les provenances de la partie centrale de l'aire (Etats des Grands lacs et Ontario) que pour celles échantillonnées au nord de 47°N. Les arbres d'origine locale se situaient autour de la moyenne.

INTRODUCTION

Red pine (Pinus resinosa Ait.) is an important reforestation species over much of its natural range in northeastern North America (Hough 1967; Morgenstern and Carlson 1979), but has not found wide acceptance outside its natural range (Hough 1952).

Red pine has been the subject of genetic investigations for over 50 years. From 1929 to 1937, a series of seed source trials was established in the eastern United States by the U.S. Forest Service (Hough 1952; Wright et al. 1963). Range-wide tests were established in eastern Canada by the Ontario Ministry of Natural Resources and the Canadian Forestry Service in the mid-1950's (Holst 1960). Other genetic studies using inbreeding as a tool to study genetic variation were started at about the same time (Fowler 1965). (For a detailed review of the genetics of red pine, see Fowler and Lester (1970).) In summary, red pine is a remarkably uniform species with respect to a wide array of characteristics including growth rate, morphology, phenology, response to photoperiod, and wood quality. The species is also unusually uniform with respect to genetic variation at lower levels of organization such as foliage polyphenols (Thieleges 1972) and isozymes (Fowler and Morris 1977).

Opinions differ on the feasibility of improving red pine genetically. Fowler (1964) considers that the possibility of improving the species is negligible whereas Rudolf (1964), Nienstaedt (1964) and Lester (1964) contend that efforts to improve red pine are warranted. Wright and Bull (1963) and Wright et al. (1979) predict that small, but worthwhile genetic gains are attainable through the use of open-pollinated progeny tests converted to seedling seed orchards.

Despite the lack of agreement, most authorities concur that any genetic improvement in red pine is dependent on incorporating small genetic gains in large numbers of seedlings (Fowler and Lester 1970). The precise amount of improvement attainable in red pine will continue to be a controversial subject until meaningful data become available from older studies.

Two series of cooperative red pine provenance tests were established by Petawawa National Forestry Institute (PNFI) in 1958 and 1962. The first series was established at 10 test locations including one in the Maritimes (Exp. 23) and the other was established at nine test locations including two in the Maritimes (Exp. 24). The purpose of this paper is to report on the performance of red pine in the experiments planted in the Maritimes and to re-examine the possibility of genetic improvement through provenance selection.

MATERIALS AND METHODS

Experiment 23

This experiment was carried out in cooperation with Petawawa National Forestry Institute and is one of 10 tests planted in central and eastern Canada. Maritimes Forest Research Centre (MFRC) experiment 23 corresponds to PNFI experiment 96-B.

Red pine seeds from 16 provenances (Table 1) representing much of the east-west range of the species were obtained by Mr. Mark Holst (PNFI, retired) and sown in unreplicated plots at the PNFI nursery in the spring of 1954. The seedlings were raised as 2 + 2 stock. In the spring of 1958 the seedlings were shipped to Mr. H.G. MacGillivray (MFRC, retired) who supervised their planting in a test on the Chignecto Game Sanctuary, Cumberland County, Nova Scotia.

The test site was a recent burn which had regenerated to intolerant

Table 1. Provenance data for Experiment 23, Chignecto, Nova Scotia

Accession number PNFI	Accession number MFRC	Origin	Long. °W	Lat. °N	Elev. m
S 1712	MS 410	Raco, MI	84.7	46.4	244
S 1713	MS 411	Trout Lake, WI	89.6	46.0	496
S 1714	MS 412	Petawawa, Ont.	77.4	45.8	168
S 1715	MS 413	Thessalon, Ont.	83.6	46.3	244
S 1716	MS 414	Sault St. Marie, Ont.	84.0	46.5	244
S 1717	MS 415	Regina Bay, Ont.	94.0	49.4	410
S 1718	MS 416	Sturgeon Falls, Ont.	79.9	46.3	227
S 2044	MS 417	Upper Jay, NY	75.0	44.3	568
S 2045	MS 418	Stanley, N.S.	63.8	45.1	183
S 2046	MS 71	Grand Lake, N.B.	66.0	46.0	11
S 2047	MS 419	Cass Lake, MN	94.6	47.3	397
S 2112	MS 420	Sorel, P.Q.	73.0	46.0	15
S 2113	MS 421	Mattawin River, P.Q.	73.5	46.8	366
S 2114	MS 422	Kenogami, P.Q.	71.5	48.3	163
S 2130	MS 423	St. Charles de Mandeville, P.Q.	73.4	46.4	152
S 2131	MS 424	St. Alphonse, P.Q.	73.8	46.3	305

hardwood. The hardwoods were removed from the site in 1957 and the stumps were sprayed with 2,4,5-T. The experimental design was randomized 49-tree square plots planted at 1.2 x 1.2 m spacing and replicated five times. A single row of surround trees was planted around each plot with an extra row planted around the boundary of the whole experiment.

Survival, tree condition, and damaging factors were recorded in 1959, 1960, and 1962. Tree height was measured in 1963 and 1968 and diameter at 1.3 m and total height were measured in 1970. In 1972, trees growing in rows 1, 3, 5, and 7 were removed leaving a maximum of 21 trees per plot at a spacing of 1.2 x 2.4 m. Total height and diameter at 1.3 m (DBH) were recorded and stem form was rated in October 1978 when the trees were 21 years from planting (25 years from seed).

Experiment 24

Experiment 24 was also carried out in cooperation with PNFI and corresponds to PNFI experiment 216E and 216F.

Red pine seeds from 24 provenances (Table 2) were obtained by Mr. Mark Holst, sown in PNFI nursery in the spring of 1958 and raised to 2 + 2 stock. In May 1962, the seedlings were shipped to Mr. H.G. MacGillivray who supervised their planting. One test, representing all 24 provenances, was planted at the Garden of Eden, Pictou County, Nova Scotia. The other test which included seedlings from only 16 of the 24 provenances was established at Iris, Queens County, Prince Edward Island.

The Garden of Eden test was planted in May, shortly after the seedlings were received from PNFI. The planting site once supported a mature stand of eastern white pine (Pinus strobus L.) but had been cut and repeatedly burned to encourage blueberry production. The experimental design was randomized 25-tree square plots planted at 1.8 x 1.8 m spacing and replicated three times. An extra plot of seedlings from seed lot MS

418 was included in each replication to fill out the design.

Seedlings for the other test were transplanted into the Acadia Forest Experiment Nursery near Fredericton, N.B. where they remained until October of the same year when they were lifted and field planted at Iris. The planting site was abandoned farmland supporting a light cover of grass sod. The experimental design was randomized 25-tree square plots planted at 1.8 x 1.8 m spacing and replicated five times.

From 1962 to 1964, the two tests were visited regularly and observations were made on survival, tree conditions, and damaging factors. Total height was recorded at the end of the 1967, 1972, and 1978 growing seasons. Diameter at 1.3 m was recorded in 1972 and 1978 and stem straightness and damage were assessed in 1978.

Table 2. Provenance data for Experiment 24

Accession number		Origin	Long. (°W)	Lat. (°N)	Elev. (m)	Provenances in PEI
PNFI	MFRC					
S 1713	MS 411	Trout Lake, WI	89.7	46.0	488	x
S 2045	MS 418[1]	Stanley, N.S.	63.9	45.1	61	x
S 2046	MS 71	Grand Lake, N.B.	66.1	46.0	11	x
S 2132	MS 675	Rawdon, P.Q.	73.7	46.1	130	x
S 2356	MS 676	Sturgeon Falls, Ont.	79.9	46.4	213	x
S 2530	MS 677	Thistledew Lake, MN	93.3	47.8	457	x
S 2531	MS 678	Clubhouse Lake, MN	93.5	47.6	366	
S 2532	MS 679	Itasca Park, MN	95.3	47.3	457	x
S 2533	MS 680	Cass Lake, MN	94.7	47.4	402	
S 2559	MS 681	Dryden, Ont.	92.9	49.8	381	x
S 2560	MS 682	Fort Frances, Ont.	93.4	48.6	343	x
S 2561	MS 683	Douglas, Ont.	76.9	45.1	152	x
S 2567	MS 684	Lake States, USA	90.7	45.6	304	
S 2578	MS 686	Schoolcraft Co., MI	86.2	46.2	213	x
S 2579	MS 687	Grand Traverse Co., MI	85.5	44.7	259	x
S 2580	MS 688	Presque Isle Co., MI	84.2	45.4	198	x
S 2581	MS 689	Superior Natl. Forest, MN	91.3	47.6	487	x
S 2582	MS 690	Chippewa Natl. Forest, MN	93.5	47.4	305	x
S 3136	MS 691	Boulder Junction, WI	89.7	46.0	488	
S 3137	MS 692	Oneida Co., WI	89.5	45.9	503	
S 3138	MS 693	Six Mile Lake, MN	94.1	47.3	402	
S 3139	MS 694	Lake Thirteen, MN	94.5	47.3	402	
S 3140	MS 695	Grand Bend, Ont.	81.8	43.3	183	x
-	MS 279	Zone 3, Pembroke, Ont.	-	-	-	

[1] Used twice and treated as separate plots, MS 418A and MS 418B.

RESULTS

Experiment 23

Percent survival up to 1970 (12 years from planting) ranged from 92.4 to 100% with a mean of 96.1% (Table 3). However, between 1970 and 1978 porcupines (Erethizon dorsatum L.) caused considerable damage to plantation trees. Survival after 21 years in the field ranged from 36.2 to 61.0% with a mean of 49.2%. Survival was not related to growth variables or to geographic variables such as latitude, longitude, or elevation of the provenances.

Analysis of variance indicated that differences among provenances were significant for all growth variables except for DBH at 21 years. However, the actual differences among provenance means were small. For example, the difference in mean height between the best and poorest provenances was only 30 cm after 5 years and 60 cm after 21 years. Percent superiority in height for the best provenance over the plantation mean decreased from 11.5 to 4.7% over the same period. The better provenances were from the central part of the species range in the Lake States, Ontario, and Quebec. The local provenances i.e., those from Nova Scotia and New Brunswick were about average with respect to most growth characteristics. The most northern provenances i.e., those from north of 47°N latitude were among the slowest growing. All correlations among growth characteristics were highly significant (Table 4). However, growth was not correlated with latitude, longitude, or elevation of the provenances. Differences among provenances with respect to damage by porcupines were not significant.

Experiment 24

In general, trees growing in the Iris, P.E.I. plantation were taller and had larger diameters than those in the Garden of Eden, N.S. plantation. Survival after 17 years averaged 95.8% in Prince Edward Island and 97.3% in Nova Scotia (Table 5). Differences among provenances with respect to survival were not significant. Effects of European pine shoot moth [Rhyacionia buoliana (Schiff.)] damage, although still evident at age 17 years, were no longer important and were independent of provenance.

All sources of variation in growth characteristics tested in the analysis, i.e., blocks, provenances, and provenance x block interactions, were significant at both test locations. In the analysis for the combined tests using data on the 16 provenances common to both tests, locations x provenance interactions were significant for all growth variables except diameter at age 17.

Growth differences among provenances, although significant, were small. The tallest provenance in the Nova Scotia test (MS 688) had only a 30 cm (5.8%) height advantage over the plantation average at age 17. Similarly, in the Prince Edward Island test the best provenance (MS 695) was 30 cm (6.1%) taller than the plantation mean. Percent superiority of the best provenance declined as the plantations matured (Table 5).

About one-half of all the possible correlations tested were significant (Table 6). All correlations for growth characters within each test location were significant ranging from 0.77 to 0.95 in Nova Scotia and from 0.86 to 0.97 in Prince Edward Island. Although considerably weaker, correlations of growth characteristics between locations were evident, especially those involving 17-year DBH in the Nova Scotia test. Except for a weak but significant correlation between latitude and 17-year height and DBH in the Nova Scotia test, growth characteristics were not correlated with geographic features of the provenances, i.e., latitude, longitude or elevation.

Table 3. Mean performances of provenances at Chignecto, Nova Scotia (Experiment 23)

Accession Number	Survival at age[1]			Height at age[1]				DBH at age[1]		
	1 year	12 years	21 years	5 years	10 years	12 years	21 years	12 years	21 years	
MS	(%)	(%)[2]	(%)[2]	(m)	(m)	(m)	(m)	(cm)	(cm)	Rank[3]
422	87.1	96.2	57.1	1.16 A[4]	3.38 A[4]	4.33 A[4]	8.1 A[4]	6.6 A[4]	12.1	16
419	99.6	96.2	36.2	1.22 A	3.57 B	4.48 A	8.3 A	6.6 A	12.3	15
423	91.0	92.4	45.7	1.16 A	3.38 A	4.36 A	8.2 A	6.6 A	12.4	14
71	99.6	100.0	53.3	1.28 B	3.54 B	4.51 A	8.4 A	6.7 A	12.3	12
415	97.1	96.2	58.1	1.28 B	3.51 B	4.45 A	8.4 A	6.6 A	12.3	12
418	93.1	97.1	38.1	1.31 B	3.69 C	4.66 B	8.2 A	7.1 B	12.8	11
410	100.0	99.0	56.2	1.28 B	3.54 B	4.51 A	8.4 A	6.7 A	12.7	10
417	100.0	93.3	41.9	1.28 B	3.41 A	4.45 A	8.7 B	6.6 A	12.5	9
411	99.6	95.2	48.6	1.43 D	3.90 D	4.91 C	8.7 B	7.4 B	12.8	7
416	98.0	96.2	41.9	1.34 C	3.72 C	4.66 B	8.7 B	7.1 B	12.8	7
412	98.7	95.2	44.8	1.34 C	3.69 C	4.63 B	8.8 B	7.1 B	12.8	6
421	96.7	97.1	56.2	1.46 D	3.90 D	4.91 C	8.7 B	7.4 B	12.9	5
424	89.0	95.2	49.5	1.31 B	3.69 C	4.66 B	8.5 A	7.1 B	13.1	4
413	98.8	95.2	53.3	1.40 D	3.78 C	4.79 C	8.6 B	7.1 B	13.2	3
414	95.5	95.2	61.0	1.37 C	3.81 D	4.82 C	8.9 B	7.4 B	13.0	2
420	93.5	96.2	44.8	1.31 B	3.78 C	4.79 C	8.7 B	7.1 B	13.2	1
Mean	96.1	96.0	49.2	1.31	3.64	4.62	8.5	6.9	12.7	
Superiority[5] (%)				11.5	7.1	6.3	4.7	7.2	2.4	

[1] Age from planting.
[2] Based on 105 trees sampled, and includes all types of mortality.
[3] Ranking based on a crude estimate of volume $\frac{\pi r^2 h}{3}$ at age 21.
[4] Mean separation by cluster analysis [Gates and Bilbro (1978)]; means with different letter belong to the different cluster.
[5] Percent superiority of the best provenance over plantation mean.

Table 4. Correlation coefficients for Experiment 23, Chignecto, Nova Scotia

Characters	1	2	3	4	5	6	7	8	9	10	11	12
1. Longitude	1	.47	.56	.46	-.13	.13	.14	.12	.07	.20	-.08	-.07
2. Latitude		1	.01	-.25	.16	.50	-.26	-.20	-.28	-.36	-.32	-.43
3. Elevation			1	.35	-.37	-.07	.26	.05	.08	.21	-.06	-.14
4. 1-year survival				1	.25	-.11	.43	.22	.22	.45	.10	.07
5. 12-year survival					1	.26	.12	.12	.07	-.17	.12	-.12
6. 21-year survival						1	.19	.07	.10	.11	.16	-.03
7. 5-year height							1	.91*	.93*	.75*	.89*	.69*
8. 10-year height								1	.99*	.67*	.95*	.76*
9. 12-year height									1	.70*	.95*	.78*
10. 21-year height										1	.67*	.69*
11. 12-year DBH											1	.79*
12. 21-year DBH												1

* Significant at P = 0.01.

Table 5. Mean performances of provenances at Nova Scotia and Prince Edward Island (Experiment 24)

Accession number MS	Garden of Eden, Nova Scotia							Iris, Prince Edward Island						
	17 years survival (%)	Height at age[1] 5 years (cm)	Height at age[1] 10 years (m)	Height at age[1] 17 years (m)	DBH at age[1] 10 years (cm)	DBH at age[1] 17 years (cm)	2 rank	17 year survival (%)	Height at age[1] 5 years (cm)	Height at age[1] 10 years (m)	Height at age[1] 17 years (m)	DBH at age[1] 10 years (cm)	DBH at age[1] 17 years (cm)	2 rank
297	97.8[3]	73.2 A[4]	2.10 A[4]	4.9 A[4]	1.78 A[4]	7.9 A[4]	25	–	–	–	–	–	–	
681	95.6	83.9 B	2.32 B	4.8 A	2.29 B	8.4 A	24	100.0[5]	132.2 A	2.71 A	5.8 A	3.30 A	10.3 A	15
677	95.6	81.6 B	2.35 B	5.0 A	2.29 B	8.4 A	23	100.0	132.0 B	2.68 A	5.9 A	3.30 A	10.7 A	12
678	97.8	88.9 C	2.50 B	5.1 A	2.54 B	8.4 A	22	–	–	–	–	–	–	–
675	93.3	87.1 C	2.35 B	5.0 A	2.29 B	8.5 A	20	96.0	148.6 D	2.93 B	6.0 B	3.81 B	11.0 A	9
679	97.8	91.6 C	2.44 B	5.0 A	2.54 B	8.5 A	20	96.0	135.3 B	2.83 B	5.8 A	3.56 B	10.5 A	14
680	100.0	91.9 C	2.44 B	5.0 A	2.54 B	8.6 A	18	–	–	–	–	–	–	–
682	97.8	93.0 C	2.44 B	5.0 A	2.54 B	8.6 A	18	100.0	130.9 B	2.74 A	5.7 A	3.05 A	10.6 A	13
418 A	93.3	84.8 B	2.38 B	4.9 A	2.54 B	8.7 A	17	94.7	120.2 A	2.74 A	5.7 A	3.30 A	10.3 A	16
692	100.0	98.0 D	2.53 C	5.1 A	3.05 C	8.6 A	16	–	–	–	–	–	–	–
684	95.6	93.8 C	2.50 B	5.1 A	2.54 B	8.8 A	15	–	–	–	–	–	–	–
694	95.6	102.3 D	2.62 C	5.1 A	2.79 C	8.9 B	14	–	–	–	–	–	–	–
689	88.9	95.0 D	2.53 C	5.4 C	3.05 C	8.7 A	13	94.7	140.5 C	2.74 B	6.1 C	3.56 B	10.9 A	8
683	95.6	99.0 D	2.59 C	5.2 B	3.05 C	8.9 B	12	97.3	145.3 C	2.87 B	6.2 C	3.56 B	11.0 a	6
418 B	95.6	96.7 D	2.56 C	5.2 B	2.54 B	9.0 B	10	–	–	–	–	–	–	–
691	97.8	101.4 D	2.56 C	5.2 B	2.79 C	9.0 B	10	–	–	–	–	–	–	–

Table 5. Cont'd

Accession number	Garden of Eden, Nova Scotia							Iris, Prince Edward Island						
	17 years survival	Height at age[1]			DBH at age[1]			17 year survival	Height at age[1]			DBH at age[1]		
		5 years	10 years	17 years	10 years	17 years			5 years	10 years	17 years	10 years	17 years	
MS	(%)	(cm)	(m)	(m)	(cm)	(cm)	rank[2]	(%)	(cm)	(m)	(m)	(cm)	(cm)	rank[2]
411	97.8	103.8 D	2.65 D	5.3 B	3.05 C	9.0 B	8	100.0	135.6 B	2.90 B	6.2 C	3.81 B	11.4 B	5
693	95.6	100.5 D	2.68 D	5.3 B	3.05 C	9.0 B	8	-	-	-	-	-	-	-
695	97.8	102.5 D	2.71 D	5.5 C	3.05 C	8.9 B	7	90.7	164.9 E	3.20 C	6.5 D	4.57 C	11.6 B	3
690	97.8	107.4 D	2.68 D	5.3 B	3.05 C	9.1 B	6	98.7	151.7 D	3.20 C	6.4 D	4.57 C	11.8 B	2
676	95.6	96.8 D	2.62 C	5.4 C	3.05 C	9.1 B	5	97.3	160.0 E	3.11 C	6.3 D	4.57 C	11.7 B	4
686	97.8	105.1 D	2.74 D	5.4 C	3.30 C	9.2 B	4	100.0	143.8 C	2.87 B	6.1 C	3.81 B	10.9 A	10
71	91.1	104.4 D	2.68 D	5.2 B	3.05 C	9.4 B	3	98.7	130.5 B	2.71 A	5.8 A	3.30 A	10.8 A	11
687	97.8	100.2 D	2.74 D	5.4 C	3.30 C	9.4 B	2	96.0	138.4 C	2.87 B	6.0 B	3.81 B	11.1 A	7
688	84.4	108.6 D	2.83 D	5.5 C	3.30 C	9.7 B	1	96.0	164.2 E	3.11 C	6.4 D	4.57 C	11.9 B	1
Mean	95.8	95.7	2.54	5.2	2.78	8.9		97.3	142.1	2.89	6.1	3.78	11.0	
Superiority[6] (%)		13.5	11.4	5.8	18.7	9.0			15.6	10.1	6.6	20.9	8.2	

[1] Age from planting.
[2] Ranking based on a crude estimate of volume $\frac{\pi r^2 h}{3}$ at age 17.
[3] Based on 45 trees sampled and includes all types of mortality.
[4] Mean separation by cluster analysis [Gates and Bilbro(1978)]; means with different letter belong to different clusters.
[5] Based on 75 trees sampled and includes all types of mortality.
[6] Percent superiority of the best provenance over plantation mean.

Table 6. Correlation coefficients for Experiment 24

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Latitude	1	.59*	.53*	-.42	-.50	-.46	-.53*	-.51*	-.41	-.47	-.46	-.48	-.44
2. Longitude		1	.88*	-.02	-.07	-.04	-.06	-.31	.06	.02	.03	.10	.05
3. Elevation			1	-.12	-.21	-.10	-.14	-.42	-.16	-.20	-.15	-.04	-.10
4. 5-year height, N.S.				1	.95*	.90*	.79*	.88*	.54	.60	.61	.66*	.73*
5. 10-year height, N.S.					1	.94*	.87*	.92*	.58	.59	.65*	.68*	.74*
6. 10-year DBH, N.S.						1	.85*	.85*	.49	.48	.56	.63*	.65*
7. 17-year height, N.S.							1	.77*	.72*	.64*	.73*	.80*	.81*
8. 17-year DBH, N.S.								1	.44	.46	.54	.50	.64*
9. 5-year height, P.E.I.									1	.89*	.91*	.90*	.86*
10. 10-year height, P.E.I.										1	.97*	.88*	.89*
11. 10-year DBH, P.E.I.											1	.91*	.92*
12. 17-year height, P.E.I.												1	.92*
13. 17-year DBH, P.E.I.													1

* Significant at P = 0.01 level.

As in experiment 23, the better provenances tended to be from the central part of the species range in the Lake States and Ontario. The slower-growing provenances tended to be from the most northern latitudes. Local provenances, MS 71 from New Brunswick and MS 418 from Nova Scotia, performed about average. MS 71 ranked 3 (out of 25) in Nova Scotia but ranked only 11 out of 16 in Prince Edward Island. Overall, MS 418 ranked below average. The two samples of this provenance included in the Nova Scotia test, and treated as separate provenances in the analysis, fell into different clusters with respect to essentially all growth characteristics.

DISCUSSION

Statistically significant differences among provenance means of red pine have been demonstrated for several growth characteristics. However, the actual differences are small and of questionable practical value. The significance tests used are highly sensitive with small error mean squares involving large degrees of freedom. Such small error variances are indicative of genetic uniformity among the individual trees in the test. Fowler and Lester (1970) suggest that the narrow range of genetic variation in red pine increases the uncertainty of correct genetic interpretation of the data.

It has been demonstrated in red pine, that seed size is correlated with seedling size (Hough 1952) and seedling gross weight is correlated with tree height at least to age 10 years (Hough 1957). Experiments 23 and 24 were established with stock raised in unreplicated nursery beds at PNFI. There is no information available on seed size or seedling sizes. Other non-genetic factors such as variation in seedbed density (Wright et al. 1963) and variation in soil fertility (Youngberg 1952) can also affect seedling development.

In both tests, superiority of the best provenance over the plantation average is of the same magnitude at all test sites for comparable characteristics and declines as the plantations become older. When provenance means are grouped into discrete, non-overlapping classes (Gates and Bilbro 1978) the number of classes decreases with age. The plantations tend to become even more uniform as they mature. These findings suggest that early differences among provenances may, at least in part, result from non-genetic influences. Further support for a non-genetic interpretation of the data stems from the fact that provenance MS 418, which was included twice in one test and treated statistically as separate entities, differed significantly in several growth characteristics.

Despite the fact that a genetic interpretation of the differences among provenances is somewhat tenuous, it is evident that at least some of the differences are of genetic origin. The correlation of latitude of origin and growth characteristics, although significant only for 17-year height and diameter in the Nova Scotia planting of experiment 24, did exhibit the same pattern in the other tests. In general, trees from the central part of the species range in the Lake States and Ontario grew somewhat faster (3.5-4.0%) than trees from more northern latitudes, i.e., higher than 47°N. Trees of local (Maritimes) origin were about average in performance.

Highly significant correlations of all growth variables within each location indicate a strong juvenile-mature correlation and suggest that early evaluation of provenances could be effective. The provenance x location interaction evident (experiment 24) at the earliest measurement dates (5 - 10 years) diminished as the

plantation matured. After 17 years, growth in the Nova Scotia test was significantly correlated with growth of trees of the same provenance in Prince Edward Island.

Fowler and Lester (1970), in summarizing the results of earlier provenance studies with red pine, concluded that, in general, the differences between the overall mean and the mean of the best provenance is about 10% for height growth up to 20 years. The results of these experiments generally support this conclusion. The best provenance in these experiments exceeded the plantation mean by only 4.7% at age 21 and by 5.8 to 6.1% at age 17.

Genetically red pine is an unusually uniform species in which early growth characteristics may be strongly influenced by non-genetic effects. These non-genetic or environmental effects diminish as the trees mature.

From a practical point of view, there is little to be gained by attempting to identify "best provenance" for use in reforestation in the Maritimes Region. Seeds of northern provenance, i.e., north of latitude 47°N, should not be used. Seeds of local provenances or from the central part of the species range are fully satisfactory for use in the Region.

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