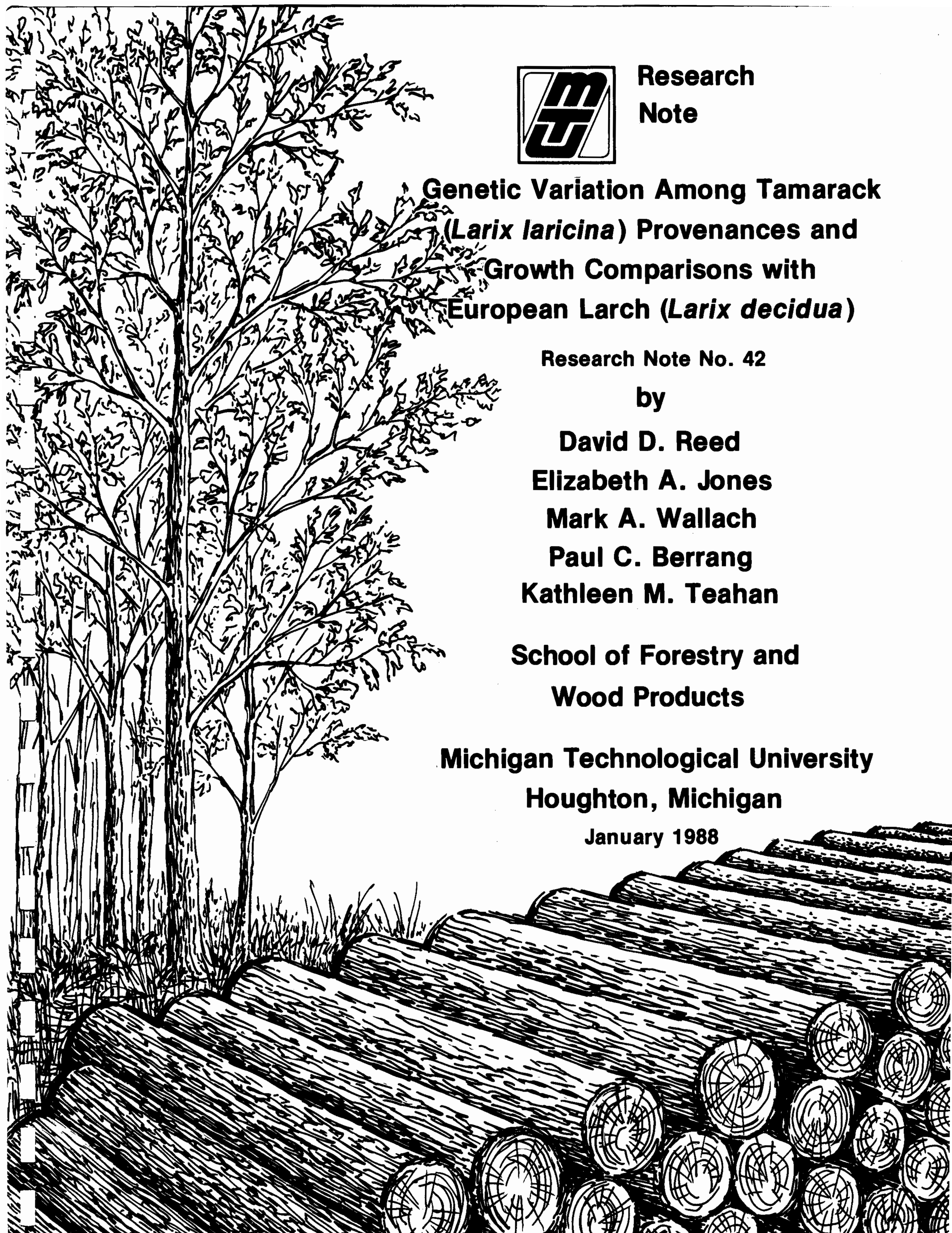

Research Note

Genetic Variation Among Tamarack (*Larix laricina*) Provenances and Growth Comparisons with European Larch (*Larix decidua*)

Research Note No. 42

by

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GENETIC VARIATION AMONG TAMARACK (*Larix laricina*) PROVENANCES AND GROWTH COMPARISONS WITH EUROPEAN LARCH (*Larix decidua*)

ABSTRACT

Two tamarack plantations were established near South Range, Michigan in 1967 and 1968 using provenances from throughout the natural range of the species. Following the 1985 growing season, at ages 21 and 19, respectively, diameter at breast height, diameter at 2.5 m, clear bole length, total height, and mortality were measured on each tree. In addition to these factors indicating volume growth, a number of stem quality indicators were also observed: fork, sweep, crook, multiple crook, broken top, previously broken top, and heavy branches. Differences in volume growth variables were found between the provenances and these differences were still significant after accounting for climatic conditions at the original provenance locations. Most differences in stem quality measures were accounted for by using climatic conditions at the original provenance locations as covariates. Each plantation had been measured previously in 1970, 1974, and 1982. There were considerable differences in the relative rankings of the provenances between measurements. In 1970, a European larch plantation was established nearby. At 16 years of age, the first quartile (Q_{25}) of diameter and height in the European Larch were equal to or greater than the average diameter and height of the best growing 19 and 21 year old tamarack provenances. The proportions of stem quality defects in the European larch were within the ranges exhibited by the tamarack provenances. There were far fewer trees having seed cones (less than 2 percent) in the European larch than in the tamarack (over 90 percent).

GENETIC VARIATION AMONG TAMARACK (*Larix laricina*) PROVENANCES AND GROWTH COMPARISONS WITH EUROPEAN LARCH (*Larix decidua*)

Tamarack (*Larix laricina*) is one of the most widespread of the North American conifers and is adapted to a wide range of climatic conditions. This suggests a large degree of genetic variation within the species, a common characteristic for species in the genus *Larix*. This characteristic, along with a resistance to Scleroderris canker, typical good form, and rapid juvenile growth has led to renewed interest in members of the genus *Larix* as commercial fiber species in North America (Jeffers and Isebrands 1972).

Two tamarack plantations were established in 1967 and 1968 near South Range, Michigan. A European larch (*Larix decidua*) plantation was established nearby in 1970. This report presents the results following the 1985 growing season together with some previously published results from earlier measurements.

SITE DESCRIPTION

The site is located near South Range, Michigan (47° 05′ N latitude, 88° W longitude, 340 m above sea level). The area was an abandoned field which was treated with chlordane prior to planting. The soil is a spodic/alfic bisequeem type developed on lacustrine sands. The site is representative of the *Acer*-*Tsuga*-*Dryopteris* habitat type (Coffman and others 1983) which ranks on the low end of the productivity scale for hardwoods and on the high end for pines. The site receives heavy winter snow fall averaging about 575 cm.

GENETIC VARIATION AMONG TAMARACK PROVENANCES

Both tamarack plantations were planted at a 2.44 m x 2.44 m square spacing. The 1967 plantation was established using 2-1 stock from 22 sources while the 1968 plantation was established using 2-0 stock from 21 sources. Both were planted in a randomized block design with four replications in the 1967 plantation and 7 replications in the 1968 plantation. The tamarack plantations were 21 and 19 years old, respectively, at the time of the 1985 measurements. The replications consisted of four tree row plots of each source. The provenances were geographically dispersed representating most of the natural range of tamarack; the original locations of the provenances in the 1968 plantation show greater ranges in both latitude and longitude than those in the 1967 plantation (Table 1).

Height and diameter measurements were made in 1970, 1974, and 1982.[1/] Results from the 1970 and 1974 measurements are given by Wotton (1976). Reed and others (1983) described the results from the 1982 measurements. Following the 1985 growing season, total height, diameter at breast height, diameter at 2.5 m from the ground, and clear bole length were measured on the surviving trees. Presence or absence of broken tops, previously broken tops, fork, sweep, crook, multiple crook, heavy branches, and seed cones were recorded for each surviving individual.[2/] Representative climatic

[1/] The tamarack plantations are part of the NC 51 study initiated by the late Scott S. Pauley of the University of Minnesota. Seedlings were grown by Michigan State University and planted by Robert Sajdak of Michigan Technological University; the 1982 measurements were taken by S. G. Ernst of Michigan State University.

[2/] Sweep is defined as a longitudinal deviation of twice the upper stem diameter in 2.5 m, crook is a longitudinal deviation of twice the upper stem diameter in 1.25 m, and heavy branching is indicated by a branch with a basal diameter greater than one quarter of the main stem diameter at the point of branching.

Table 1. Original locations of the provenances in the tamarack plantations.

Provenance Number	State/ Province	County	Latitude (North)	Longitude (West)	Elevation (m)
1967 Plantation					
11	WI	Washington	43°10′	88°-	299
12	WI	Washburn	46°-	91°45′	335
13	MN	Carver	45°-	93°45′	229
17	WI	Waukesha	43°-	88°15′	250
19	IL	McHenry	42°27′	88°02′	244
20	MN	St. Louis	47°53′	91°51′	128
21	MN	Anoka	45°05′	93°05′	244
22	MN	Itaska	47°10′	93°20′	427
24	WI	Richland	43°15′	90°20′	335
26	MI	Livingston	42°30′	83°50′	213
27	WI	Eau Clare	44°45′	91°-	
41	MI	Schoolcraft	46°21′	86°20′	244
47	WI	Sawyer	46°-	91°30′	381
48	ME	Somerset	45°40′	70°15′	361
50	MI	VanBuren	42°10′	86°08′	236
52	MI	Cass	41°52′	85°57′	256
53	MI	Clare	44°-	85°-	
55	MI	Clare	44°-	85°-	
56	MI	Shiawasee	42°29′	84°21′	
63	ONT		53°45′	89°50′	235
64	ONT		49°28′	82°16′	229
65	MI	Kalamazoo	42°23′	85°22′	256
1968 Plantation					
100	MN	Anoka	45°10′	93°05′	244
101	MN	St. Louis	47°-	93°-	387
102	MN	Carlton	46°42′	92°31′	335
105	MD	Garrett	39°42′	78°56′	820
106	MD	Garrett	39°42′	78°56′	820
109	MAN		53°55′	101°15′	261
110	ALTA		56°39′	111°14′	335
115	MI	Kalamazoo	42°23′	85°22′	256
117	MAN		50°05′	95°25′	229
118	NWT		58°58′	111°40′	229
120	MI	Alger	46°21′	86°20′	244
122	MI	Chippewa	46°19′	84°14′	183
124	ONT		46°-	77°26′	146
127	ME	Somerset	45°38′	70°16′	244
128	MI	Houghton	47°01′	88°25′	201
129	ONT		43°13′	80°35′	297
131	N.S.		44°48′	65°03′	229
153	MI	Alger	46°21′	86°20′	244
157	WI	LaCrosse	43°51′	91°08′	261
159	MN	Itaska	47°22′	93°35′	411
160	MI	Gogebic	46°15′	89°10′	488

variables (average January temperature, average July temperature, length of the frost free period, total annual precipitation, and total annual snowfall) were obtained for the original location of each provenance from regional maps (Canadian Ministry of Mines and Technical Surveys (1958), U.S. Department of Commerce (1968)). There were no significant ($\alpha = 0.05$) correlations between diameter or height with climatic variables in the 1967 plantation, but in the 1968 plantation, which had a greater geographical range in its provenances, there were highly significant ($\alpha = 0.01$) relationships between diameter at breast height and diameter at 2.5 m with longitude (negative) and annual snowfall (positive) (Table 2). There was also a highly significant negative correlation between total height and longitude. In the 1968 plantation there were less significant ($\alpha = 0.05$) correlations between diameter at breast height with total annual precipitation (positive), diameter at 2.5 m with latitude (negative) and total annual precipitation (positive), and height with annual snowfall (positive). These results seem to indicate physiological adaptations across the range of tamarack with more easterly sources and those from localities with high snowfall leading to the greatest growth at the study site. The possibility of climatic adaptation also seems to be indicated by the results of the tree quality measures.

There were highly significant ($\alpha = 0.01$) correlations between the presence of sweep and the presence of crook with climatic variables in the 1967 plantation. There were less significant ($\alpha = 0.05$) negative correlations between the presence of sweep and crook with latitude, and between the presence of crook and climatic

Table 2. Linear correlations between tree measurements and climatic variables.

Measurement	Latitude	Longitude	Elevation	Temperature		Frost Free Period	Precipitation	
				Jan.	July		Total	Snowfall
1967 Plantation								
Diameter:								
Breast Height	-.24	-.40	.21	.26	.01	-.27	.30	.19
2.5 m	-.11	-.29	.09	.16	-.04	-.25	.15	.18
Height:								
Total	-.13	-.04	-.03	.19	-.06	-.19	.09	.05
Proportion:								
Previous Broken								
Top	.16	-.20	-.06	-.18	-.22	-.13	.09	.25
Forked	.28	.19	.19	-.30	-.16	-.21	-.24	.05
Sweep	-.47*	.30	-.06	.35	.59**	.50**	.15	-.69**
Crook	-.48*	.11	-.00	.43*	.53*	.27	.24	-.61**
Multiple Crook	-.32	.12	.26	.30	.36	.05	.22	-.37
Seed Cones	-.54**	-.24	.15	.45*	.34	.04	.50*	-.20
1968 Plantation								
Diameter:								
Breast Height	-.41	-.72**	-.19	.43	-.06	.35	.52*	.68**
2.5 m	-.44*	-.72**	-.27	.42	-.12	.20	.45*	.76**

Table 2. (continued)

Measurement	Latitude	Longitude	Elevation	Temperature Jan.	Temperature July	Frost Free Period	Precipitation Total	Precipitation Snowfall
1968 Plantation (continued)								
Height:								
Total	-.38	-.61**	-.15	.40	-.09	.30	.37	.55*
Proportion:								
Previous Broken								
Top	-.49*	-.21	.45*	.48*	.50*	.50*	.40	-.32
Forked	.00	.05	-.46*	-.02	-.10	.04	-.19	-.20
Sweep	-.36	-.11	.48*	.29	.35	.28	.32	-.32
Crook	-.36	-.35	-.45*	.38	.20	.52*	.19	-.10
Multiple Crook	-.21	-.50*	-.40	.31	-.07	.24	.36	.13
Seed Cones	-.40	-.38	.11	.40	.29	.40	.34	-.02

Significance: * $\alpha = .05$

** $\alpha = .01$

variables. There were highly significant ($\alpha = 0.01$) correlations between the presence of seed cones and latitude and less significant correlations between the presence of seed cones and climatic variables. There were no highly significant ($\alpha = 0.01$) correlations between the tree quality measures and climatic variables in the 1968 plantation, but there were a number of less significant ($\alpha = 0.05$) relationships. These less significant relationships were found between several tree quality variables and climatic variables, latitude, longitude, and elevation. From the correlations found, the results indicate that sources from cooler climates with heavier snowfall have less defect in individuals. This is not surprising given the heavy snowfall at the study site.

The significant relationships between elevation and stem quality variables in the 1968 plantation is less perplexing when it is realized that there were significant relationships between elevation and climatic variables as well as latitude. No such relationships exist in the provenances in the 1967 plantation and elevation was not significantly correlated with any tree quality variable.

Following the correlation analysis, a randomized block analysis of variance was performed on each plantation to determine the extent of differences in growth and stem quality between provenances (Table 3). If the measured tree variables were significantly correlated with one or more of the climatic variables at the original provenance location then an analysis of covariance was performed for the measured tree variable incorporating the two most highly correlated climatic variables

Table 3. Results of the analysis of variance and covariance for detecting differences between provenances.

Variable	1967 Plantation ANOVA	1967 Plantation ANACOVA	1968 Plantation ANOVA	1968 Plantation ANACOVA
Diameter:				
Breast Height	***	NA	***	***
2.5 m	**	NA	***	-
Height:				
Total	-	NA	***	**
Clear Bole	***	NA	***	NA
Proportion:				
Broken Top	-	NA	-	NA
Previous Broken Top	-	NA	-	-
Mortality	-	NA	-	NA
Forked	**	NA	-	-
Sweep	**	-	**	-
Crook	**	-	*	-
Multiple Crook	-	NA	***	**
Heavy Branching	-	NA	**	NA
Seed Cones	***	***	-	NA

Significance:
- \- $\alpha > 0.10$
- * $\alpha = 0.10$
- ** $\alpha = 0.05$
- *** $\alpha = 0.01$
- NA No covariates used

as covariates. If only one climatic variable was significantly correlated with the measured tree variable then only that variable was used as a covariate. If no significant correlations between the measured tree variable and the climatic variables existed then no analysis of covariance was performed.

In the analysis of variance for the 1967 plantation there were highly significant (α = 0.01) differences between provenances in diameter at breast height, clear bole length, and the presence of seed cones. There were also significant (α = 0.05) differences in the frequency of forked individuals, individuals with sweep, and the presence of crook. In the analysis of covariance the presence of seed cones still showed significant (α = 0.05) differences between provenances, but the differences in sweep and crook were accounted for by the climatic variables which were used as covariates. In the 1968 plantation there were highly significant (α = 0.01) differences in diameter at breast height and diameter 2.5 m, total height, clear bole length, and presence of multiple crook. There were significant (α = 0.05) differences in the frequencies of sweep and heavy branching and a less significant (α = 0.10) difference in the frequency of crook. In the anlysis of covariance there was still a highly significant (α = 0.01) difference in diameter at breast height. The differences in total height and frequency of multiple crooks were reduced in significance (α = 0.05 with p-levels of .0494 and .0490 respectively), and there were no significant differences in diameter at 2.5 m or the frequency of sweep or crook.

These results, and those from the correlation analysis, indicate that stem quality is largely related to climatic variables and not just latitude and longitude of the original provenance location. There are significant differences in diameter at breast height beyond that accounted for by climatic variables. The same is true of height in the 1968 plantation while, due to a large error variance, there were no significant differences in height in the 1967 plantation.

The Newman-Keuls procedure (Zar 1974) was used to examine differences between provenances for the measured tree variables where differences were indicated by ANOVA or ANACOVA. The results for total height and diameter at breast height (Table 4) were typical of previous studies in only showing a low degree of separation between provenances. Diameter at breast height, which had the most significant differences in the ANOVA for both plantations, showed only one provenance different from all others in the 1968 plantation while in the 1967 plantation three groups were indicated with a high degree of overlap.

The plantation averages and interquartile ranges for all measured tree variables are given in Table 5. In general, there was about a 30 percent mortality rate over the life of the study. There was also a large proportion of trees possessing defects indicative of snow damage. Twenty to thirty percent of the individuals showed evidence of previously broken tops, 30 to 40 percent had excessive sweep, and around 45 percent were crooked with twenty percent of those considered multiply crooked. There was considerable variation among provenances for these characteristics, but most of this variation was accounted for by the climatic conditions at the original provenance location.

Table 4. Multiple range comparisons of diameter at breast height and total height using Newman-Keuls procedure.

Diameter at Breast Height (cm)			Total Height (m)		
Provenance Number	D	Comparison[A/]	Provenance Number	H	Comparison[A/]
1967 Plantation					
26	12.97	a	20	8.83	
48	12.78	a	53	7.86	
53	12.16	a b	21	7.84	
55	11.73	a b	12	6.90	
20	11.30	a b	56	6.76	
56	11.20	a b	47	6.57	
21	10.96	a b	48	6.29	
22	10.85	a b	17	6.26	
11	10.49	a b	22	6.21	
12	10.16	a b c	64	6.14	
64	10.02	a b c	24	6.11	
47	9.82	a b c	50	6.06	
17	9.35	a b c	55	6.00	
27	9.19	a b c	11	5.83	
41	8.46	a b c	52	5.83	
52	8.34	a b c	41	5.80	
24	8.21	a b c	26	5.67	
19	7.66	a b c	65	5.27	
65	7.54	a b c	19	5.02	
50	7.40	b c	27	4.35	
13	4.15	c	13	3.90	
63	3.77	c	63	3.48	

Table 4 (continued).

Diameter at Breast Height (cm)			Total Height (m)		
Provenance Number	D	Comparison[A/]	Provenance Number	H	Comparison[A/]
1968 Plantation					
127	13.92	a	124	7.80	a
153	11.08	b	122	7.41	a b
129	10.85	b	129	7.31	a b
124	10.62	b	120	7.19	a b
131	10.17	b	127	7.17	a b
128	9.95	b	109	6.33	a b
122	9.76	b	102	6.28	a b
120	9.66	b	131	6.12	a b
109	8.94	b	106	5.98	a b
106	8.93	b	153	5.75	a b
102	8.60	b	115	5.56	a b
105	8.29	b	105	5.46	a b
115	8.29	b	101	5.36	a b
100	8.16	b	100	5.34	a b
157	7.93	b	128	5.33	a b
110	7.89	b	110	5.22	a b
160	7.67	b	160	4.99	a b
159	7.57	b	159	4.74	a b
101	7.49	b	157	4.70	a b
117	6.53	b	117	3.99	b
118	4.93	b	118	3.35	b

A/ Provenance values followed by the same letter were not significantly different ($\alpha = 0.05$) using the Newman-Keuls procedure. Heights are given for the 1967 plantation for comparison purposes only since no significant differences ($\alpha = 0.10$) were found in the ANOVA.

Table 5. Plantation average and interquartile ranges of provenance averages for the measured tree variables in the tamarack plantations.

Variable	1967 Plantation			1968 Plantation		
	First Quartile	Overall Average	Third Quartile	First Quartile	Overall Average	Third Quartile
Diameter (cm)						
Breast Height	8.34	9.75	11.20	7.89	9.09	9.95
2.5 m	6.86	7.67	8.81	5.61	6.66	7.73
Height (m)						
Total	5.80	6.14	6.57	5.22	5.93	6.33
Clear Bole	0.65	0.77	0.88	0.47	0.67	0.75
Proportion						
Mortality	0.12	0.26	0.33	0.21	0.34	0.43
Broken Top	0.00	0.03	0.08	0.00	0.06	0.08
Previous Broken Top	0.14	0.21	0.30	0.23	0.31	0.39
Forked	0.00	0.10	0.14	0.06	0.14	0.18
Sweep	0.30	0.40	0.50	0.16	0.28	0.41
Crook	0.33	0.46	0.55	0.29	0.43	0.53
Multiple Crook	0.09	0.20	0.27	0.08	0.22	0.30
Heavy Branching	0.08	0.15	0.20	0.12	0.23	0.36
Seed Cones	0.92	0.94	1.00	0.95	0.96	1.00

In an effort to rank and compare the overall performance of the provenances, a ranking scheme was developed which groups the measured tree variables into two groups: those related to volume and those related to stem quality. The provenances were ranked (rank one being the most desirable) for each measured tree variable and the average rank was calculated for each group of characteristics (Table 6). An overall rank was assigned by averaging the two average group ranks for a provenance with the volume characteristics given twice the weight of the stem quality characteristics. The average rank of volume characteristics (diameter at breast height and 2.5 m, total height, and percent mortality) showed a much greater difference between provenances than did the average rank of stem quality characteristics (clear bole length, frequencies of broken tops, previously broken tops, fork, sweep, crook, multiple crook, and heavy branches). The combined ranking in Table 6 considers volume production to be twice as important as stem quality, but considers both in evaluating the provenances.

Reed and others (1983) demonstrated that the relative rankings of total height had been very dynamic from 1970 to 1982. This changing of relative ranks continued in the 1985 measurements (Table 7). When comparing ranks it is important to remember that this is a relative and not an absolute measure of performance. This is especially important in the middle ranks where a 0.26 m difference exists in average height between the eighth and thirteenth ranked provenances in the 1967 plantation (Table 4). The death of a small number of individuals or the incidence of broken tops can, in a short time span, considerably alter the

Table 6. Overall rankings of provenances in the tamarack plantations.

Volume Measures		Quality Measures		Combined Ranking	
Provenance Number	Average Rank[A/]	Provenance Number	Average Rank[B/]	Provenance Number	Combined Ranking[C/]
1967 Plantation					
53	3.50	64	6.62	48	6.13
48	3.75	20	8.75	20	7.08
21	4.00	12	8.94	53	7.10
20	6.25	47	9.12	21	7.56
22	6.25	19	9.25	22	8.02
26	7.88	41	9.50	64	8.37
64	9.25	13	10.62	26	9.40
55	9.50	55	10.69	12	9.65
56	9.50	56	10.75	55	9.90
11	10.00	48	10.88	56	9.92
12	10.00	17	11.00	47	10.12
47	10.62	11	11.19	11	10.40
41	11.50	22	11.56	41	10.83
17	12.75	63	11.75	17	12.17
24	12.75	52	11.81	19	12.92
50	14.00	26	12.44	24	13.31
19	14.75	50	12.56	50	13.52
52	15.50	65	13.44	52	14.27
27	17.50	53	14.31	65	16.81
65	18.50	24	14.44	13	17.54
13	21.00	21	14.69	27	18.08
63	21.75	27	19.25	63	18.42
1968 Plantation					
124	2.00	117	8.06	124	5.50
122	4.00	109	8.12	122	6.08

Table 6 (continued).

Volume Measures		Quality Measures		Combined Ranking	
Provenance Number	Average Rank[A/]	Provenance Number	Average Rank[B/]	Provenance Number	Combined Ranking[C/]
1968 Plantation (continued)					
129	5.62	128	8.62	129	6.91
120	6.00	160	8.94	127	7.29
127	6.00	159	9.06	128	7.54
128	7.00	118	9.31	109	8.45
131	7.38	110	9.38	120	8.71
153	8.50	129	9.50	131	9.36
109	8.62	105	9.56	153	9.98
115	10.50	127	9.88	160	10.65
160	11.50	122	10.25	105	11.60
101	12.50	102	10.62	106	12.15
105	12.62	106	10.94	115	12.17
106	12.75	124	12.50	101	12.83
100	13.12	153	12.94	102	12.87
102	14.00	131	13.31	100	13.21
157	16.12	100	13.38	159	14.02
110	16.50	101	13.50	110	14.13
159	16.50	120	14.12	117	15.19
117	18.75	157	14.44	157	15.56
118	21.00	115	15.50	118	17.10

A/ Average of ranks for four volume characteristics: diameter at breast height and 2.5 m, total height, and percent motality.

B/ Average of ranks for eight stem quality characteristics: clear bole length and frequencies of broken top, previously broken top, fork, sweep, crook, multiple crook, and heavy branching.

C/ Combined ranking with the average rank of volume characteristics given twice the weight of the average rank of stem quality characteristics.

Table 7. Relative rankings of total height at previous measurements for selected provenances.

Provenance Number	Date of Measurement[A/] 1970	1974	1982	1985
1967 Plantation (22 Provenances)				
20	7	5	7	1
47	16	13	16	6
24	4	10	18	11
41	2	8	5	16
63	22	22	21	22
1968 Plantation (21 Provenances)				
124	1	12	2	1
109	16	18	13	6
115	14	9	19	11
110	18	19	20	16
118	21	21	21	21

A/ The details of the 1970 and 1974 measurements are given by Wotton (1976) and the 1982 measurements are described by Reed and others (1983).

relative rankings of the provenances. This raises serious concerns about the ability to evaluate future (rotation age) performance based on young tree measurements and emphasizes the need to consider a multitude of characteristics when evaluating performance.

GROWTH COMPARISONS WITH EUROPEAN LARCH

The European larch plantation was established in 1970 using 1-0 stock from a common (Austrian) source at a 2.44 m x 2.44 m spacing. The trees were 16 years old at the time of this measurement. The European larch were planted less than 50 m from the tamarack on the same site. The same variables measured on the tamarack were measured on the European larch. Four five row by five tree plots giving a total of 100 individual planting locations were measured for comparison with the tamarack.

When the European larch were 12 years old their average diameter and height were essentially the same as the best growing 16 and 18 year old tamarack provenances (Reed and others 1983). In 1985 the first quartile of the diameter at breast height measurements for European larch was 12.7 cm compared to averages of 12.97 and 13.92 cm for the largest tamarack provenances in each plantation. The third quartile of diameter at breast height was 19.76 cm for European larch with the largest individual measuring 29.97 cm. The results are similar for diameter at 2.5 m with the first quartile of the European larch roughly equal to the average for the largest tamarack provenances. When considering total height the European larch far exceeded the largest tamarack provenances (7.80 and 8.83 m) with a first quartile of 10.06 m and a third quartile of 12.61 m. The tallest European larch individual was 14.33 m in height. There also was less mortality in the European larch (16 percent as compared to 25-35 percent in the tamarack), but the differences by provenance in the tamarack make it difficult to conclude that any real difference in mortality rate exists. The European larch showed very little seed cone production while almost every tamarack had cones. Though border trees in the European larch were observed to have cones, few were found on interior trees.

In terms of stem quality, the European larch showed greater clear bole lengths and a greater incidence of heavy branches. There were little differences in frequencies of broken tops, previous broken tops, and forked individuals. The European larch showed slightly less sweep, crook, and multiple crook than the tamarack plantation averages, but 25 percent of the European larch had excessive sweep and 32 percent had crook, well within the ranges for the tamarack provenances. Some of these differences are due to stand conditions. The European larch show much more crown closure, and the greater clear bole length is probably due to self pruning and a different response to spacing between the two species. If under intensive forest management, the European larch would probably be ready for a thinning operation now at age 16. All of the above information is summarized in Table 8.

Table 8. Plantation average and interquartile ranges for the measured tree variables in the European larch plantation.

Variable	First Quartile	Overall Average	Third Quartile
Diameter (cm)			
Breast Height	12.78	15.91	19.76
2.5 m	10.92	13.80	17.27
Height (m)			
Total	10.06	11.02	12.61
Clear Bole	1.52	1.88	2.44
Proportion			
Mortality	-	.16	-
Broken Top	-	.06	-
Previous Broken Top	-	.25	-
Forked	-	.10	-
Sweep	-	.25	-
Crook	-	.32	-
Multiple Crook	-	.16	-
Heavy Branching	-	.38	-
Seed Cones	-	.02	-

CONCLUSIONS

1. In tamarack individual tree dimensional growth is largely genetically controlled with only limited evidence supporting its dependence on the climate of the original provenance location.

2. In tamarack individual tree stem quality is more dependent on the climate of the original provenance location and conditions at the planting site. A complex of climate factors affect stem quality and more than latitude and longitude should be considered when selecting planting stock. Annual snowfall and average July temperature were important in this study as were a complex of factors represented by elevation.

3. This study suggests that early selection of tamarack provenances is difficult, and any selection should be based on a complex of tree characteristics.

4. European larch is outgrowing the best tamarack provenances at the study site. There is less difference between tamarack and European larch in terms of stem quality characteristics.

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