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VARIATION IN SCOTCH PINE

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Scotch pine (Pinus sylvestris L.) is the most widely distributed pine species of the world and occupies extensive tracts in Europe and Asia between 40° and 70° N. latitude and 10° W. and 140° E. longitude. It is used as lumber and pulpwood in northern Europe and as an ornamental and Christmas tree in the United States where it is extensively planted for this purpose. As a result of such wide distribution, the species exhibits considerable morphological and physiological variation. This was recognized as early as 1865 when De Vilmorin first published the results of provenance trials of this species conducted at his forest at Des Barres in France.

The present research was conducted to study the nature of variation in Scotch pine with respect to physiological processes exhibited in phenology of height growth shown by the different provenances of the species. Specifically the objective was to determine whether this variation was continuous, i.e., clinal or discontinuous, i. e., ecotypic.

Controversy about the nature of variation started with the publication by Wright and Baldwin (1957) of the results of one of the I.U.F.R.O. provenance studies outplanted in 1938 in the Vincent State Forest in New Hampshire. These results were based on the analysis of variance of seven qualitative and three quantitative traits studied in June 1955 when the trees were 17 years old. Wright and Baldwin (1957) concluded from these results the presence of discontinuous variation in Scotch pine, giving rise to geographic races or ecotypes, the dividing lines between which ran approximately east-west. This suggests that selection pressures exerted by temperature, day length and other factors that normally vary from north to south have resulted in more genetic differentiation than have rainfall, soil and other factors which vary most from east to west.

Langlet (1959) disputed the conclusions of Wright and Baldwin (1957) contending that variation in Scotch pine was clinal. He based his conclusions on the study of the dry weight of 2-0 and 2-2 seedlings and 17-year height and their statistically significant correlation with the length of the first day of the year with an average 24-hour temperature of +6° C. or more and the number of days with an average temperature of +6° C. Correlation analyses of the data of Wright and Baldwin (1957) and of those of Schreiner et. al. (1962) showed that variation in the percentage of trees with large crooks, cones and lean was discontinuous or ecotypic (Khalil, 1967). On the other hand Langlet's results on the percentage of dry matter in needles, average height and diameter at the

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age of 18 years show clinal variation with latitude. Hence, the species exhibits clinal variation with respect to some characters and ecotypic variation with respect to others.

The present studies were conducted on six outplantings of Pinus sylvestris raised by the School of Forestry, University of Minnesota from a range-wide seed collection at Blackberry (1962 and 1964), Cloquet (1962 and 1964), North Branch (1962) and Rice (1961). These plantations have different numbers of provenances, five or ten replications, are arranged in randomized complete block design and have four-tree plots and one or two border rows around each plantation.

The first measurements were recorded in April 1964 in the 1961 plantation at Rice and the other three 1962 plantations. They consisted of total heights of all trees. The data were grouped and averaged by five degree latitudinal classes of the seed sources. The results are presented in Table 1.

Table 1. Mean height in 1964

Latitudinal Class	Mean Heights							
	Blackberry		Cloquet		North Branch		Rice	
	cm.	ft.	cm.	ft.	cm.	ft.	cm.	ft.
40° - 45° N.	32	1.1	30	1.0	43	1.4	42	1.4
45° - 50° N.	65	2.1	64	2.1	56	1.8	55	1.8
50° - 55° N.	66	2.2	67	2.2	58	1.9	55	1.8
55° - 60° N.	52	1.7	47	1.5	45	1.5	44	1.4
60° - over N.	44	1.4	39	1.3	36	1.2	31	1.0

Analysis of variance and orthogonal comparisons showed that the component of variance due to the five-degree latitudinal classes was highly significant at all locations.

Coefficients of correlation and the corresponding "t" values were calculated by location for the relationship between total height in the spring of 1964 and latitude, longitude and altitude. The results are summarized in Table 2.

Table 2. Results of correlation analyses between total height in spring 1964 and latitude, longitude and altitude of the origin of the provenances

Location	Latitude		Longitude		Altitude	
	r	t	r	t	r	t
Blackberry	-0.4662	2.7382*	-0.2142	1.1395 NS	-0.1079	0.5639 NS
Cloquet	-0.6435	4.6807**	-0.2602	1.5016 NS	-0.0676	0.3773 NS
North Branch	-0.5467	3.6352**	-0.1276	0.7163 NS	-0.0628	0.3503 NS
Rice	-0.3472	3.5122**	-0.2386	2.3309 *	-0.1328	1.2711 NS

r = Coefficient of correlation
t = Student's "t"
NS = Non-significant at the 0.05 level
* = Significant at the 0.05 level
** = Significant at the 0.01 level

These results show that there is a significant correlation between total height in spring 1964 and latitude, indicating the presence of clinal variation from north to south. There is no such correlation between total height and longitude or altitude.

Length of the current year's shoot of each tree was measured at approximately weekly intervals during the spring and summer of 1965 from which the following statistics were computed for each tree: (1) total length of the current year's shoot; (2) the number of days after April 15 to the time of the maximum rate of height growth; (3) the number of days after April 15 to the cessation of height growth.

The data for the first measurement were grouped and averaged by five degree latitudinal classes and analyzed for variance and by orthogonal comparisons. The results showed that all the orthogonal comparisons were highly significant at both locations.

Analyses of variance followed by Duncan's multiple range tests were conducted between the seed sources within each five degree latitudinal class. The results showed that in eight cases out of the ten analyzed the within class variance was significant or highly significant with a large percentage of significantly different pairs of seed sources.

Coefficients of correlation and the corresponding "t" values were then calculated for the relationship between each of the above three characters and the latitude, longitude and altitude of the origin of the provenances. The results are summarized in Tables 3 and 4 for Cloquet and North Branch, respectively.

Table 3. Summary of the correlation analyses of growth characters and latitude, longitude and altitude of the places of origin of the provenances planted at Cloquet

Character	Latitude		Longitude		Altitude	
	r	t	r	t	r	t
1. Length of current year's shoot	-0.0908	0.5077 NS	0.0487	0.2715 NS	-0.0310	0.1726 NS
2. Number of days after April 15 to the time of maximum rate of height growth	-0.2136	1.2174 NS	-0.2924	1.7024 NS	0.0026	0.0145 NS
3. Number of days after April 15 to cessation of height growth	-0.5983	4.1573 **	-0.0686	0.3828 NS	0.1921	1.0900 NS

Table 4. Summary of the correlation analyses of growth characters and latitude, longitude and altitude of the place of origin of the provenances planted at North Branch

Character	Latitude		Longitude		Altitude	
	r	t	r	t	r	t
1. Length of current year's shoot	-0.1988	1.1294 NS	0.1110	0.6219 NS	-0.3396	2.0103 NS
2. Number of days after April 15 to the time of maximum rate of height growth	-0.3216	1.8910 NS	0.2506	1.4413 NS	-0.2147	1.2239 NS
3. Number of days after April 15 to cessation of height growth	-0.5771	3.9344 **	-0.0755	0.4216 NS	-0.0921	0.5150 NS

r = Coefficient of correlation
t = Student's "t"
NS = Non-significant at the 0.05 level
** = Significant at the 0.01 level

Character 3 shows the presence of clinal variation with latitude.

Length of the current year's shoot of each tree in all the six plantations was again measured at approximately weekly intervals during the growing season of 1966 from which the following statistics were computed: (1) the number of days after April 15 to the commencement of height growth; (2) the number of days after April 15 to the time of the maximum rate of height growth; (3) the number of days after April 15 to the cessation of height growth. A regression equation was established for each tree, showing the relationship between the number of days after April 15 (X) and the length of the shoot (Y). The following statistics were computed for each tree from these equations: (4) the intercept of Y on X (a); (5) the coefficient of regression of Y on X (b); (6-11) total heights in 1961 through 1966 were also measured, correct to the nearest centimeter.

The data were analyzed by correlation analysis. Coefficients of correlation were calculated for each of the above mentioned eleven characters and the geographical factors of latitude, longitude and latitude for each replication at each location. The results are summarized in Table 5.

Table 5. Results of correlation analyses

Character	Value of Student's t																	
	Latitude						Longitude						Altitude					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1. Number of days after April 15 to commencement of height growth	NS	NS	NS	**	NS	**	NS	**	*	**	NS	**	NS	NS	**	*	NS	NS
2. Number of days after April 15 to the time of maximum rate of height growth	**	NS	**	NS	*	**	NS	*	NS	**	NS	*	NS	NS	NS	NS	NS	NS
3. Number of days after April 15 to cessation of height growth	NS	NS	**	NS	**	**	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
4. Intercept of Y on X (a)	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS
5. Coefficient of regression of Y on X (b)	**	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS
6. Total height in 1961	**	A	**	A	**	**	NS	A	NS	A	NS	NS	NS	A	NS	A	NS	NS
7. Total height in 1962	**	A	**	A	**	**	NS	A	NS	A	NS	NS	NS	A	NS	A	NS	NS
8. Total height in 1963	**	NS	*	**	**	*	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	*
9. Total height in 1964	*	NS	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	*
10. Total height in 1965	*	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	**
11. Total height in 1966	*	NS	NS	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	**

A = Plantation absent
NS = Non-significant at the 0.05 level
* = Significant at the 0.05 level
** = Significant at the 0.01 level

1 = Blackberry 1962 plantation
2 = Blackberry 1964 plantation
3 = Cloquet 1962 plantation
4 = Cloquet 1964 plantation
5 = North Branch plantation
6 = Rice plantation

These results support the following conclusions: (1) there is clinal variation from north to south with respect to the number of days after April 15 to the time of the maximum rate of height growth. With respect to height growth the clinal variation disappears as the trees grow older. Correlation analysis between latitude and 17-year height based on the data of Wright and Baldwin (1957) has shown that there is clinal variation in height with latitude. Similar conclusions are available from the correlation analysis of the data of Schreiner, et. al. (1962). This suggests that the clinal variation reappears on or about the age of 17 years. The results also agree with the preliminary studies in 1964 and 1965. (2) There is clinal variation from west to east only with respect to two characters, viz. the number of days after April 15 to the commencement of height growth and to the time of the maximum rate of height growth. There is no clinal variation with respect to any of the other characters. (3) There is no clinal variation with respect to the altitude for any character.

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