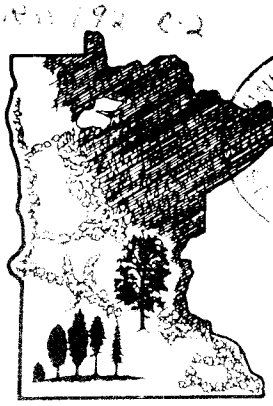

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HEIGHT GROWTH PATTERNS OF SCOTCH PINE PROVENANCES IN MINNESOTA AND THEIR VARIETAL CLASSIFICATION

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Results of correlation analyses of growth data for Pinus sylvestris L. provenances grown in Minnesota with the object of determining the nature of variation in the species have been discussed in a previous paper (Khalil, 1968). These results have shown that a large part of the variation in Scotch pine is non-clinal, i.e., discontinuous or ecotypic, resulting in the formation of ecotypes or varieties.

Taxonomists have attempted to sub-divide the species into varieties and geneticists have tried to assign the various provenances to these taxonomic varieties. This has resulted in ten taxonomic systems of classification, the latest of which has been proposed by Ruby (1964). Ruby has recognized 21 varieties in the NC-51 project outplantings in the United States. Nineteen of these have been planted in Minnesota and form the subject of the present study.

The primary objective of this study was to determine if significant differences existed between as well as within the varieties with respect to total height and the pattern of annual height growth. The results would determine which of these 19 varieties were genetically homogeneous and which could be further sub-divided into sub-varieties or ecotypes.

Six outplantings of Scotch pine in Minnesota constituted the material for the present research. These plantings were raised by the School of Forestry, University of Minnesota from a range-wide seed collection outplanted at Blackberry (1962 and 1964), Cloquet (1962 and 1964), North Branch (1962) and Rice (1961). Different numbers of provenances have been planted in these plantations, but all of them have four tree row-plots, five or ten replications, arranged in the randomized, complete block design with one or two border rows around the plantation.

The first measurements were recorded in April 1964 in the 1961 plantation at Rice and the 1962 plantations at Blackberry, Cloquet and North Branch and comprised the total height of all or surviving trees in each plot. The data were first grouped and averaged by the varieties recognized by Ruby (1964) and were subjected to analyses of variance between as well as within varieties, followed by Duncan's multiple range tests in each case. The results are summarized in Tables 1 and 2.

These results showed that the between variety variance was significant at the 0.01 level at all four locations, always with a high percentage of significantly different

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pairs of varieties at the 0.05 level. Of 32 cases analyzed, the within variety variance was non-significant in 21, was significant only in four cases, and highly significant only in seven. The percentage of significantly different pairs of provenances was always low, even if the variance was significant. These results indicated that the varieties were significantly different from each other but fairly homogeneous within themselves.

Table 1. Results of the analyses of variance and Duncan's multiple range tests between varieties for total height in spring 1964 in the four plantations measured in 1964

Location	Snedecor's F for varieties	Percentage of significantly different pairs of varieties at 0.05 level
Blackberry 1962 plantation	22.64 **	71
Cloquet 1962 plantation	44.35 **	69
North Branch plantation	27.88 **	80
Rice plantation	13.72 **	54

** = Significant at the 0.01 level

Table 2. Results of analyses of variance and Duncan's multiple range tests within varieties for total height in spring 1964 in the four plantations measured in 1964

Variety	Blackberry		Cloquet		North Branch		Rice	
	F	P	F	P	F	P	F	P
altaica	-	-	-	-	-	-	1.25NS	0
aquitana	-	-	-	-	0.18NS	0	1.76NS	0
armena	-	-	-	-	-	-	1.75NS	0
borussica	-	-	0.04NS	0	6.52NS	0	3.36NS	33
haguenensis	18.00**	100	1.08NS	0	0.06NS	0	2.50*	15
hercynica	5.82**	25	11.80**	54	2.88*	24	1.05NS	4
iberica	-	-	1.20NS	0	-	-	0.72NS	0
lapponica	-	-	-	-	-	-	1.17NS	0
polonica	2.15NS	0	-	-	0.02NS	0	0.15NS	0
rhodopaea	-	-	-	-	-	-	1.29NS	0
rigensis	5.45*	17	6.10*	66	3.18NS	0	2.70NS	10
scotica	-	-	-	-	-	-	2.73NS	20
septentrionalis	9.57**	42	3.13**	26	7.26**	57	3.09**	19
uralensis	-	-	-	-	-	-	0.42NS	0

- = Variety absent
F = Snedecor's F ratio for provenances within variety
P = Percentage of significantly different pairs of provenances
NS = Non-significant at the 0.05 level
* = Significant at the 0.05 level
** = Significant at the 0.01 level

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

The data for each of these characters at each location were grouped and averaged by varieties. They were subjected to between variety as well as within variety analyses of variance and Duncan's multiple range tests. The results are summarized in Tables 3 and 4.

Table 3. Results of analyses of variance and Duncan's multiple range tests between varieties for the three characters measured in 1965

Location	Character 1		Character 2		Character 3	
	F	P	F	P	F	P
Cloquet	13.63**	72	0.65NS	0	5.53**	41
North Branch	20.19**	64	1.43NS	0	2.85*	32

F = Snedecor's F ratio for varieties
P = Percentage of significantly different pairs of varieties at the 0.05 level
NS= Non-significant at the 0.05 level
* = Significant at the 0.05 level
**= Significant at the 0.01 level
Character 1 - Total length of the current year's shoot
Character 2 - Number of days after April 15 to the time of the maximum rate of height growth
Character 3 - Number of days after April 15 to the cessation of height growth

Table 4. Results of analyses of variance and Duncan's multiple range tests within varieties for the three characters measured in 1965

Variety	Character 1				Character 2				Character 3			
	Cloquet		North Branch		Cloquet		North Branch		Cloquet		North Branch	
	F	P	F	P	F	P	F	P	F	P	F	P
aquitana	Absent		0.53NS	0	Absent		0.92NS	0	Absent		2.27NS	0
borussica	1.64NS	0	0.47NS	0	1.67NS	0	0.31NS	0	1.67NS	0	0.25NS	0
haguenensis	1.01NS	0	4.05NS	33	1.08NS	0	0.26NS	0	5.98*	33	0.99NS	0
hercynica	8.85**	29	1.36NS	0	1.07NS	0	0.37NS	0	3.05*	36	1.50NS	12
iberica	0.39NS	0	Only one provenance		1.05NS	0	Only one provenance		0.66NS	0	Only one provenance	
polonica	Only one provenance		1.34NS	0	Only one provenance		0.00NS	0	Only one provenance		0.80NS	0
rigensis	5.59*	67	2.27NS	0	0.99NS	0	0.56NS	0	1.88NS	0	0.68NS	0
septentrionalis	2.66*	14	5.88**	52	0.62NS	0	0.77NS	0	1.79NS	13	1.08NS	0

F = Snedecor's F ratio for provenances within varieties
P = Percentage of significantly different pairs of provenances at the 0.05 level
NS = Non-significant at the 0.05 level
* = Significant at the 0.05 level
** = Significant at the 0.01 level

Character 1 = Total length of the current year's shoot
Character 2 = Number of days after April 15 to the time of the maximum rate of height growth
Character 3 = Number of days after April 15 to the cessation of height growth

These results showed that the between variety variance was significant or highly significant for characters 1 and 3 and non-signficant for character 2. Similarly, the percentage of significantly different pairs of provenances was high for character 1, medium for character 3 and nil for character 2. Thus, the varieties were found to be distinct and significantly different from each other for characters 1 and 3 but not for character 2. The within variety variance is significant at the 0.01 level in one case, at the 0.05 level in five cases and non-significant in 33 cases out of 39 analyzed.

The percentage of significantly different pairs of seed sources is usually nil or very low, except in two cases where it is 67 and 52 percent, respectively. These results show that the varieties studied are homogeneous with respect to these three characters.

The field work in the growing season of 1966 consisted of the measurement of the length of the current year's shoot of each tree in all six plantations at approximately weekly intervals. The following statistics were computed from these data: (1) number of days after April 15 to the commencement of height growth; (2) number of days after April 15 to the time of the maximum rate of height growth; and (3) 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 current year's shoot (Y). The best fitting equation was found to be $Y = a + b \log X$.

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).

Total heights in 1961 through 1966 were also measured.

These data were then analyzed in the same way as the data for 1964 and 1965, i.e., by the analyses of variance, followed by Duncan's multiple range tests for both the between varieties and within variety variances.

Out of the 19 varieties based on Ruby's (1964) classification planted in Minnesota only 15 could be further analyzed for determining the within variety variances. These varieties were valid on the basis of their physiological responses to the environment.

Twelve of the 15 varieties appear to be uniform in growth characters and cannot be further sub-divided into sub-varieties or ecotypes on the basis of the information available from the seed sources tested. Eight of these are homogeneous, usually with non-significant differences between seed sources within varieties. These are borussica, carpatica, iberica, lapponica, polonica, rhodopaea, scotica and uralensis. One variety, viz. haguenensis possibly has a Belgian ecotype significantly different from the German ecotype. Three, viz. altaica, hercynica and septentrionalis have a large, randomly distributed within variety component of variance. These varieties have a considerably higher proportion of significantly different pairs of provenances, which cannot be grouped in any distinct geographic pattern.

The remaining three varieties, viz. aquitana, armena and rigensis appear to be divisible into geographically distinct ecotypes as shown below:

Variety aquitana - Two ecotypes, viz. the one in the Massif Centrale of France and the other in southwestern Germany.

Variety armena - Two ecotypes, viz. one covering northeastern Turkey, Georgian S.S.R. and Bulgaria; and the other occupying Rumania.

Variety rigensis - Three ecotypes, occupying different latitudinal zones, viz. about 55° N., 57° N., and 58° N. latitudes.

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