The decrease in the utility of selection following testing is less drastic at high cost ratios, but there are limits in the cost ratio beyond which no testing is feasible for maximizing gain per unit cost. In actuality, sib testing costs are expected to be low and to be offset by seed production benefits; hence, the cost ratios will often be small.

If it becomes feasible to decrease the time to flowering significantly — as by cultivation, fertilization, or irrigation — the precision of the sibling tests may be affected. If no such speeding possibilities exist, the above calculations are sufficient for the situation. However, the breeder may well be faced with choosing between a quicker seed yield and a more precise second-stage selection. A new optimum level of selection will have to be found according to the relative decrease of h^2_1 by the ratio of time factors $\frac{t_2}{t_1}$ or other appropriate economic functions of time costs. Also, the variance ($\sigma^2_{x_2}$) of the progeny test may be increased by confounding interaction effects caused by the flowering treatments, in which case a heritability factor (h^2_2) would enter into the gain formulation (equation 2) and into the $\sigma_I i_2$ part of the optimizing equation (3). Both factors would therefore tend to increase the selection intensity of the first stage.

If the heritabilities listed by CAMPBELL (1964) for various growth traits are a guide, a reasonable heritability for such traits appropriate for woods selection might well be around 0.10. If the progeny test plantings can raise the heritability for family selection to 0.5, the following caculations can be made according to the formulas given previously on the basis of $\sigma^2_{x_1} = 1$:

$$\sigma_{x_i x_j} = \begin{pmatrix} 1.00 & 0.05 & 0.05 \\ 0.05 & 0.20 & 0.025 \\ 0.05 & 0.025 & 1.00 \end{pmatrix}$$

$$\sigma_{g x_i} = \begin{pmatrix} 0.05 \\ 0.025 \\ 0.100 \end{pmatrix}$$

where x_1 = mother tree phenothypic value
x_2 = half-sib family mean
x_3 = individual seedling value

The index $(w'x)$ would be:

$$0.040\,x_1 + 0.101\,x_2 + 0.083\,x_3$$

The value of σ_1 would be 0.1188. With these figures inserted into formula *(3)*, the optimum selection proportions for a cost ratio (C_2/C_1) of 1 would be approximately (0.06, 0.17) for first- and second-stage selections, respectively, for a final combined selection intensity of 0.01. If the selection is on the order of 20 out of 2,000, the per-unit gainlcost ratio is 177.

It is instructive to note that the gain/cost ratio for other allocations of selection intensity for these same parameters is not very bad within the neighborhood of the optimuni selection. In the breeding situation described above, selection proportions of 0.1, 0.1, respectively, give a gain/cost of 175. Allocations much different, say 0.02, 0.5, do however result in a significant loss in gain/cost, down to 165.

Summary

The allocation of selection intensities in a seedling seed orchard program can be optimized on the basis of gain per unit cost. Ordinary maximization procedures result in equations that can be solved for the proper selection intensities under given heritability and cost conditions for any desired final selection intensity. The solutions indicate that, as cost ratios rise, reliance should be increasingly placed on selection of suitable trees in the woods, rather than on selection following sib testing.

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Growth Patterns of Pinus sylvestris L. Provenances in Minnesota*)

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Introduction

Results of correlation analyses of the phenological data of *Pinus sylvestris* L. provenances grown in Minnesota with the object of determining the nature of variation in the species have been discussed in a separate paper (KHALIL, 1968). The conclusion was made that clinal variation exista from north to south with reference to (1) the number of days after April 15 to the time of the maximum rate of height growth, (2) the number of days after April 15 to the cessation of height growth, and (3) the total height in early age. The variation was non-clinal with respect to the remaining eight growth characteristics.

Clinal variation from west to east was found only for 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. The variation was found to be non-clinal with reference to the remaining nine growth characteristics studied.

Clinal variation with altitude was found to be absent for all the eleven characters studied.

These results show that a large part of the variation in the species is non-clinal, discontinuous or ecotypic, result-

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ing in the formation of varieties and ecotypes or geographic races.

Objectives

The present study covers 19 of the 21 varieties recognized by RUBY (1964). The primary objective of the 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 the 19 varieties recognized by RUBY were genetically homogeneous and which could be sub-divided into two or more sub-varieties or ecotypes.

Review of Literature

Variation in Scotch pine has been the subject of study in Europe for more than a century. Nineteen studies have been carried out from 1907 to 1964 on the taxonomy, ecology and genetics of *Pinus sylvestris* in Europe and the United States. These studies have resulted in ten taxonomic classifications of the species, which have been described by SCHOTT (1907), ELWES and HENRY (1908), BEISSNER (1909), BEISSNER and FITSCHEN (1930), REHDER (1949), SVOBODA (1953), CARLISLE (1958), GAUSSEN (1960), STASZKIEWICZ (1961, 1962) and RUBY (1964). RUBY based his conclusions on the study of cones and leaves collected in Europe and on the NC-51 nursery results reported by WRIGHT and BULL (1963).

RUBY (1964) recognized 21 varieties in the NC-51 outplantings in the North Central Region of the United States, which have been described in *Table 1*. The seed lot numbers refer to the Michigan State University acquisition numbers and are used in other literature on NC-51 plantations.

The Material

The experiments were conducted in the six Minnesota outplantings of *Pinus sylvestris* made by the School of Forestry, University of Minnesota a member of the North Central Cooperative Regional Research Committee. The research was conducted as part of the NC-51 project, entitled, "Tree Improvement through Selection and Breeding".

Seed Procurement

Range-wide samples of seed of Scotch pine, covering 19 countries in Europe and Asia, in the region between 40° and 68° N. latitude and 5° W. and 132° E. longitude were assembled at Michigan State University in 1958 and 1959. Sampling was most intensive in central and southern Europe, less intensive in northern Scandinavia and Siberia and nil in Switzerland. Each seed lot was collected from ten or more average trees located within a mile of each other. *Table 1* shows the varieties used, together with the seed lots in each, and their geographical distribution.

Nursery Work and Transplanting

The seedlings were grown to 2—0 size in East Lansing. They were exceptionally sturdy, being grown at a low density of about 50 per square foot. In 1961 they were shipped to Minnesota, where they were planted directly in the field (1961 Rice plantation) or were lined-out for an additional year to be planted as 2—1 transplants in 1962 at Blackberry, Cloquet and North Branch. Some stock was retained an additional year at Grand Rapids for replacement of first year losses. Some seedlots sown in 1961 were outplanted as 2—1 transplants in the spring of 1964 at the Blackberry and Cloquet plantations.

Location of Outplantings

The six outplantings were located at (1) Blackberry 1962 and (2) 1964 (latitude 47° — 9' N., longitude 93° — 15' W., number of provenances 30 and 16 respectively); (3) Cloquet 1962 and (4) 1964 (latitude 46° — 12' N., longitude 92° — 30' W., number of provenances 35 and 48 respectively); (5) North Branch (latitude 45° — 48' N., longitude 92° — 54' W., number of provenances 35); and Rice (latitude 47° — 43' N., longitude 94° — 15' W., number of provenances 96).

Table 1. — The varieties used.

Variety	Seed lot Nos.	Geographical Area
1. *altaica*	227, 234, 256, 573, 574, 578, 581, 583, 585, 587, 588.	Altai mountains in the U. S. S. R. south to Kirghiz and Sungaria.
2. *aquitana*	212, 238, 239, 249, 316, 320, 563, 567.	Massif Centrale of France.
3. *armena*	213, 220, 221, 262, 263, 621, 622, 623, 624, 625.	Northeastern Turkey, Rumania, Georgian S. S. R.
4. *borussica*	202, 209, 210, 506.	Northeastern German lowlands.
5. *carpatica*	314, 569, 572, 600, 601.	Northeastern and eastern Czechoslovakia.
6. *haguenensis*	206, 235, 236, 237, 241, 250, 251, 252, 253, 318, 513.	Western Germany, eastern France and Belgium.
7. *hercynica*	203, 204, 207, 208, 248, 305, 306, 307, 308, 309, 310, 311, 312, 319, 525, 526, 527, 528, 529, 571.	Southern and eastern Germany and central Austria.
8. *iberica*	218, 219, 245, 246, 247.	North central Spain.
9. *illyrica*	242.	Central mountains of Yugoslavia.
10. *lapponica*	229, 546, 548, 549.	Northern parts of Norway, Sweden, Finland and northwest Russia.
11. *mongolica*	234, 255.	Eastern Siberia and Manchuria.
12. *pannonica*	553.	Western highlands of Germany.
13. *polonica*	211, 317, 559, 560, 561, 562.	Poland.
14. *rhodopaea*	243, 244, 271, 272, 551, 606, 612, 613, 614.	Czechoslovakia, southern Bulgaria, mountains of northeastern Greece.
15. *rigensis*	223, 224, 541, 542, 550, 564, 3513.	Southern Sweden and Baltic provinces of Russia.
16. *scotica*	266, 267, 268, 269*), 270*).	Highlands of Scotland and in England.
17. *septentrionalis*	201, 222, 228, 230, 232, 233, 273, 274, 276, 521, 522, 523, 524, 543, 544, 545, 595, 596.	Central and southern Norway, central Sweden and southern Finland.
18. *uralensis*	257, 258, 259, 260, 574.	Ural mountains in the U. S. S. R. and the area immediately to their west.
19. *vindelica*	566.	Southeast central France, Switzerland, and western Austria.

*) Seed sources 269 and 270 have been designated as of presumed hybrid origin between variety *scotica* and a south European variety (WRIGHT *et al.*, 1966). It has been named "East Anglia".

Design of the Experiments

The randomized complete block design was used at all locations. Five replications were laid out at the two plantations at Blackberry and Cloquet 1964 and at North Branch. Ten replications were used at Cloquet 1962 and Rice plantations. Row plots of four trees were used at each location and a spacing of 8' × 8' was adopted throughout. One or two border rows were planted around each experiment.

Recording and Analysis of Data

Heights of all the surviving trees in each plot were measured in spring 1964 in the 1961 plantation at Rice and in the 1962 plantations at Blackberry, Cloquet and North

Branch. Similarly, the length of the 1965 shoot, the number of days after April 15 until the time of the maximum rate of height growth and to the cessation of height growth in 1965 were measured in the 1962 plantations at Cloquet and North Branch, in 1965. The data for both these years were grouped and averaged by five degree latitudinal classes as well as by the varieties recognized by RUBY (1964). Each set of data were subjected to analyses of variance and DUNCAN'S Multiple Range tests both between and within groups.

Detailed study was continued on the same material in the 1966 growing season. Stakes were tied to each tree and marks were scratched at weekly intervals to indicate height as of each measurement date. At the season's end the stakes were removed and taken to the laboratory for measurement.

Total height of each tree was also measured for the years 1961 to 1966 inclusive in the 1961 and 1962 plantations and for the years 1963 to 1966 inclusive in the 1964 plantations.

Both the periodic measurements of the current year's shoot and total heights were averaged for each provenance over the number of surviving trees. If all four trees of any particular provenance were missing the missing value was calculated by YATES' formula (YATES, 1930).

Preliminary calculations on a portion of the data showed that the length of the current year's shoot was best represented by a semi-logarithmic equation ($Y = a + b \log X$, Y = length at day X after April 15) and was, threrefore, used.

The data on each of the following 11 characters were analyzed for between as well as within varieties variance and by DUNCAN'S Multiple Range tests for each location:

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.
4. The intercept of Y and X in the semi-lagarithmic growth equation *(a)*.
5. The coefficient of regression of Y on X in the semi-logarithmic growth equation *(b)*.
6. Total height in 1961.
7. Total height in 1962.
8. Total height in 1963.
9. Total height in 1964.
10. Total height in 1965.
11. Total height in 1966.

Out of the 21 varieties recognized by RUBY for the seed sources in the NC-51 project only 19 were available in the six plantations of this project in Minnesota. Varieties *engadinensis* and *nevadensis* were absent. Four out of these 19 varieties, *viz. illyrica, mongolica, pannonica* and *vindelica* were represented by only one seed source in all plantations and their data could not be further analyzed for within variety variances.

Results and Discussion

Results of 1964

These results showed that the five degree latitudinal classes were significantly different from each other and were also heterogeneous. On the other hand, thought the varieties were significantly different from each other, they were homogeneous with respect to the total height in 1964.

Results of 1965

The results of 1965 showed that the varieties were significantly different from each other with respect to the length of the current year's shoot and the number of days after April 15 to the cessation of height growth. They were not significantly different from each other with respect to the number of days after April 15 to the time of the maximum rate of height growth. The varieties were homogeneous within themselves with respect to all the three characters.

Analyses of Variance and Duncan's Multiple Range Tests between Varieties based on the Results of 1966

The results of the tests of the 11 characters listed above are summarized in *Table 2*. Since two of the 11 characters, *viz.* total heights in 1961 and 1962 were not available for measurement in both the 1964 plantations the total number of measurements was reduced from 66 to 62. Out of the 62 cases analyzed the variance due to seed sources was significant at the 0.01 level in 55 cases, significant at the 0.05 level in four cases and non-significant at the latter level in only three cases. These results support the variety designation used by RUBY.

Table 2. — Results of Analysis of Variance and DUNCAN'S Multiple Range Tests Between Varieties.

Character	Blackberry 1962		Blackberry 1964		Cloquet 1962		Cloquet 1964		North Branch		Rice	
	F	P	F	P	F	P	F	P	F	P	F	P
1. Number of days after April 15 to the time of commencement of height growth.	**	50	**	44	**	49	**	44	**	28	**	63
2. Number of days after April 15 to the time of maximum rate of height growth.	**	31	NS	15	*	15	*	10	NS	48	**	23
3. Number of days after April 15 to the time of cessation of height growth.	*	28	*	8	NS	8	**	25	**	42	**	47
4. The intercept *(a)*.	**	68	**	44	**	64	**	62	**	82	**	68
5. The coefficient of regression *(b)*.	**	71	**	42	**	64	**	65	**	73	**	63
6. Total height in 1961.	**	42	absent		**	41	absent		**	62	**	55
7. Total height in 1962.	**	43	absent		**	80	absent		**	67	**	59
8. Total height in 1963.	**	70	**	51	**	61	**	74	**	69	**	56
9. Total height in 1964.	**	71	**	60	**	69	**	81	**	80	**	54
10. Total height in 1965.	**	71	**	60	**	69	**	67	**	80	**	45
11. Total height in 1966.	**	75	**	60	**	69	**	62	**	82	**	46

P = Percentage of significantly different pairs at 0.05 level.
NS = Non-significant at 0.05 level.
* = Significant at 0.05 level.
** = Significant at 0.01 level.
a = The intercept of Y on X in the semi-logarithmic equation $Y = a + b \log X$.
b = The coefficient of regression of Y on X in the semi-logarithmic equation $Y = a + b \log X$.

Table 3. — Results of Analysis of Variance and DUNCAN'S Multiple Range Tests Within Varieties.

Blackberry 1962 Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. aquitana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. armena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. borussica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. carpatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. haguenensis	NS	0	NS	0	NS	0	NS	0	NS	0	*	100	**	100	**	100	*	100	**	100	NS	0
7. hercynica	NS	0	NS	0	NS	0	NS	0	NS	0	**	32	*	35	NS	28	**	25	*	24	*	24
8. iberica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. lappnonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. polonica	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	*	100	NS	0	NS	0	NS	0	NS	0
11. rhodopaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. rigensis	NS	0	**	75	NS	0	NS	0	NS	0	**	50	**	50	*	50	*	17	**	60	*	17
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. septentrionalis	NS	0	NS	0	NS	4	**	17	**	17	**	45	**	48	**	49	**	42	**	48	**	46
15. uralensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Blackberry 1964 Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. aquitana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. armena	-	NS	0	NS	0	**	30	**	40	A	A	A	A	**	40	**	60	**	20	**	70	-
4. borussica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
5. carpatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. haguenensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
7. hercynica	one	seed	source	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
8. iberica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
9. lappnonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. polonica	NS	0	NS	0	NS	0	NS	0	NS	0	A	A	A	A	NS	0	NS	0	NS	0	Only	one
11. rhodopaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. rigensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. septentrionalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
15. uralensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cloquet 1962 Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. aquitana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. armena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. borussica	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
5. carpatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. haguenensis	NS	66	NS	0	NS	0	NS	0	NS	0	*	33	**	33	NS	0	NS	0	NS	0	NS	0
7. hercynica	NS	0	NS	0	NS	0	**	29	**	25	**	44	**	62	**	56	**	54	**	61	**	61
8. iberica	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
9. lappnonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. polonica	Only	one	seed	source	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. rhodopaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. rigensis	NS	0	NS	0	**	66	NS	0	NS	0	NS	66	*	66	*	66	*	66	*	66	NS	66
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. septentrionalis	*	9	NS	0	NS	0	NS	11	*	14	**	42	**	46	**	26	**	26	*	12	*	19
15. uralensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Cloquet 1964 Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	NS	0	NS	0	NS	5	NS	19	NS	20	A	A	A	A	NS	6	*	16	NS	0	NS	17
2. aquitana	NS	0	NS	0	NS	0	**	66	**	66	A	A	A	A	**	66	**	66	**	66	**	66
3. armena	**	41	NS	0	*	16	*	17	*	19	A	A	A	A	**	34	**	55	**	40	**	58
4. borussica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. carpatica	NS	0	NS	0	NS	0	NS	0	NS	0	A	A	A	A	A	NS	17	NS	0	NS	0	NS
6. haguenensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. hercynica	NS	0	NS	0	NS	0	NS	7	NS	7	A	A	A	A	A	NS	7	NS	13	NS	13	*
8. iberica	NS	0	NS	0	NS	0	NS	0	NS	0	A	A	A	A	A	NS	0	NS	0	NS	0	NS
9. lapponica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. polonica	NS	17	NS	0	NS	0	NS	17	NS	0	A	A	A	A	A	NS	0	NS	0	NS	0	NS
11. rhodopaea	NS	0	NS	0	NS	0	NS	0	NS	0	A	A	A	A	A	NS	0	**	66	*	33	NS
12. rigensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. septentrionalis	NS	0	NS	0	NS	0	NS	0	NS	0	A	A	A	A	A	NS	0	NS	0	NS	0	NS
15. uralensis	Only	one	seed	source	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

North Branch Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. aquitana	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
3. armena	NS	0	NS	6	NS	0	NS	3	NS	14	**	29	**	24	*	24	*	17	*	22	*	12
4. borussica	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
5. carpatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. haguenensis	NS	0	NS	0	*	66	NS	33	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
7. hercynica	NS	0	NS	6	NS	0	NS	3	NS	14	**	29	**	24	*	24	*	17	*	22	*	12
8. iberica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
9. lapponica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS
10. polonica	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0	NS	0
11. rhodopaea	NS	0	NS	0	NS	0	NS	0	NS	0	*	33	*	0	NS	0	**	66	NS	33	NS	0
12. rigensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
14. septentrionalis	NS	0	NS	10	**	29	**	29	*	16	**	56	**	56	**	57	**	51	**	45	**	36
15. uralensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NS

Rice Plantation

Variety	1		2		3		4		5		6		7		8		9		10		11	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
1. altaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. aquitana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. armena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. borussica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. carpatica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. haguenensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. hercynica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. iberica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. lapponica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10. polonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. rhodopaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. rigensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13. scotica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14. septentrionalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. uralensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1. Number of days after April 15 to the time of commencement of height growth.
2. Number of days after April 15 to the time of maximum rate of height growth.
3. Number of days after April 15 to the cessation of height growth.
4. The intercept of Y on X in the equation Y = a + b log X (a).
5. The coefficient of regression of Y on X in the equation Y = a + b log X (b).
6. Total height in 1961.
7. Total height in 1962.
8. Total height in 1963.
9. Total height in 1964.
10. Total height in 1965.
11. Total height in 1966.

F = Snedecor's F ratio.
P = Percentage of pairs of seed sources significantly different from each other 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, date not available.
A = Planting absent.

Analyses of Variance and Duncan's Multiple Range Tests within Varieties based on the Results of 1966

The criteria used for determining homogeneity of a variety with respect to a given character were: (1) the statistical non-significance, at the 0.05 level, of SNEDECOR's F-ratio for variance due to seed sources; and (2) the low percentage of the pairs of seed sources significantly different from each other at the 0.05 level. A variety was classified as homogeneous if SNEDECOR's F-ratio was non-significant at the 0.05 level for a majority of characters. In the case of heterogeneous varieties the ecotypes or geographical races were distinguished as geographically separated groups on the basis of ranking under DUNCAN's Multiple Range tests, using 0.05 level of significance. These results are summarized in *Table 3* and their important features are discussed below.

1. Variety *altaica:*

The results are based on two seed sources in the Cloquet 1964 and three in the Rice plantations. These seed sources can be divided into two, largely overlapping groups. The variety is shown to be homogeneous.

2. Variety *aquitana:*

This variety is represented by two seed sources each in the Cloquet 1964 and North Branch plantations and by five seed sources at Rice. The results indicate that the 11 growth characters used are apparently valid criteria for distinguishing this taxon and that the variety is homogeneous in Massif Centrale of France.

3. Variety *armena:*

Eight seed sources in each of the Blackberry and Cloquet 1964 and Rice plantations represent this variety. The results show that the variety is heterogeneous in the 1964 plantation at Blackberry and Cloquet and is homogeneous at Rice. The Blackberry and Cloquet 1964 plantations have seed sources from southeastern Turkey and Rumania, which are homogeneous within themselves and form two significantly different groups. Rice has seed sources from northeastern Turkey and Georgian S. S. R., which form one homogeneous group. The variety is, thus, divisible into two ecotypes, *viz.* one native to northeastern Turkey and Georgian S. S. R. and the other occurring in Rumania.

4. Variety *borussica:*

The results on this variety are based on two seed sources in the Cloquet 1962 and North Branch plantations and three at Rice. The variety is homogeneous in the Cloquet 1962 and North Branch plantations, with seed sources from northeastern German lowlands. Rice also has three seed sources from the same region. Two of them, *viz.* 209 and 210 are non-significantly different from each other and both are significantly different from 202. These results are difficult to reconcile and call for more data before reaching a meaningful conclusion.

5. Variety *carpatica:*

This variety is represented by only four provenances in the Cloquet 1964 plantation. The results indicate that the four seed sources, obtained from the Unkrainian S. S. R. and Czechoslovakia, are representative of the variety and cannot be further grouped into ecotyes.

6. Variety *haguenensis:*

The following discussion is based on two seed sources in the Blackberry 1962 plantation, three each in the Cloquet 1962 plantation and North Branch and 11 at Rice. Both the seed sources in Blackberry 1962 plantation were obtained from the same locality in West Germany. *Table 3* shows that the variety is homogeneous and the seed sources are non-significantly different from each other. The provenances in the remaining three locations were obtained from the three regions, *viz.* West Germany, the adjoining portion of eastern France and Belgium. DUNCAN's Multiple Range tests for characters for which SNEDECOR's F-ratio was significant showed that the seed sources may be divided into the following overlapping groups:

Group 1 — Seed sources 206, 235, 237, 250, 251, 252, and 253 from western Germany and eastern France.

Group 2 — Seed sources 235, 241, 251, 252, 253, 318, and 530 from western Germany, eastern France and Belgium.

Group 3 — Seed sources 235, 236, 241, 251, 252, 318, and 530 from western Germany, eastern France and Belgium.

These results show that the variety is homogeneous, with the possible exception that a Belgian ecotype may be designated.

7. Variety *hercynica:*

This variety is represented by seven seed sources in the Blackberry 1962 plantation, eight and six in the Cloquet 1962 and 1964 plantations respectively, nine seed sources in the North Branch plantation and 17 at Rice. As *Table 3* shows SNEDECOR's F-ratio is statistically significant for different characters at different locations. The seed sources were obtained from six regions, *viz.* southern Germany, Czechoslovakia, Bayerwald Germany, southeastern Germany, central Germany and central Austria. DUNCAN's Multiple Range tests for these characters show that these groups are different for different characters and locations and they do not conform to any geographical zones. Hence the variety cannot be sub-divided into ecotypes.

8. Variety *iberica:*

Two seed sources in the Cloquet 1962 and 1964 plantations and five at Rice represent this variety. As SNEDECOR's F-ratio is non-significant with reference to all the 11 characters at the three locations, the variety can be taken as homogeneous and not divisible into ecotypes.

9. Variety *lapponica:*

This variety is represented by only four provenances at Rice. The results support the conclusion that on the basis of the seed sources tested the variety is homogeneous and cannot be further sub-divided into ecotypes.

10. Variety *polonica:*

The results for this variety are based on two seed sources in each of the Blackberry 1962, North Branch and Rice plantations, three seed sources in the Blackberry 1964 plantation and four in the Cloquet 1964 plantation.

The results support the conclusion that the seed sources studied constitute a genetically homogeneous variety, which cannot be sub-divided into ecotypes.

11. Variety *rhodopaea:*

Four seed sources in the Cloquet 1964 plantation and five seed sources at Rice represent this variety. The four seed sources planted in the Cloquet 1964 plantation were obtained from Czechoslovakia and southern Bulgaria. The results in *Table 3* show that these seed sources are non-significantly different from each other with respect to phenology as well as total height.

The five seed sources planted at Rice were obtained from the mountains of northeastern Greece. The results show that they are non-significantly different from each other and constitute a single variety, which is not further divisible into ecotypes.

On the basis of these results the variety may be regarded as composed of two ecotypes, *viz.* one from Czechoslovakia and southern Bulgaria and the other from the mountains of northeastern Greece.

12. Variety *rigensis:*

This variety is represented by three seed sources in the Cloquet 1962 and North Branch plantations, by four seed sources in the Blackberry 1962 plantation and by five seed sources at Rice.

Table 3 shows that SNEDECOR's F-ratio is significant or highly significant with respect to more than fifty percent of the characters at all four locations. Grouping under DUNCAN's Multiple Range tests shows different groupings under different characters at different locations. The conclusions drawn from these results are that the variety may be divided into the following three significantly different groups:

1. The group occurring at latitude 55° N. in Southern Sweden.
2. The group occurring at latitude 57° N. in Latvia and southern Sweden.
3. The group occurring at latitude 58°N. in southern Sweden.

13. Variety *scotica:*

Only five seed sources of this variety have been planted at Rice. The results in *Table 3* show that SNEDECOR's F-ratio is significant only with respect to two characters, *viz.* 1 and 3. On the basis of ranking of seed sources under DUNCAN's Multiple Range tests the variety may be divided into two groups or ecotypes, *viz.* that from Scotland, represented by seed sources 266, 267, and 268 and that from England, represented by the seed sources 269 and 270. The latter have been designated as "East Anglia" of presumed hybrid origin between variety *scotica* and a south European variety (WRIGHT *et al.* 1966).

14. Variety *septentrionalis:*

This variety has 12 seed sources in the Blackberry and Cloquet 1962 plantations, three in the Cloquet 1964 plantation, 10 at North Branch and five at Rice. The provenances were obtained from southern Norway, central and southern Sweden and southern Finland, the region being between 59° — 30' and 60° — 30' N. latitude and 3° to 26° E. longitude, with altitudes varying from sea level to 900 feet.

DUNCAN's Multiple Range tests show that the seed sources may be classified into two to four, usually overlapping, groups which are significantly different from each other at the 0.05 level but within which the seed sources are non-significantly different from each other at that level. These groups vary considerably with respect to different characters and locations. None of the groups, however, follow a pattern conforming to the geographic origin of the seed sources. The most probable explanation for this anomaly seems to be the fact that the seed sources have been collected from a wide longitudinal range, between the seed sources of which there is significant variation.

15. Variety *uralensis:*

The results on this variety are based on the Rice plantation only, which has four seed sources. These four sources were obtained from the Ural Mountains of Russia and appear to constitute a genetically distinct and homogeneous variety.

Conclusions

The results give useful information on the status of the varieties into which RUBY (1964) divided the 162 seed sources used in the NC-51 Scotch pine project. Of the 21 varieties recognized by him only 19 were available for the present study and only 15 could be further analyzed for determining the within variety variance in growth characteristics. It was found that the varieties as recognized by him on the basis of morphological characteristics are valid, on the basis of their physiological responses to the environment also.

Nine of the 15 varieties analyzed appear to be uniform in growth characters and cannot be further sub-divided into sub-varieties or ecotypes. These are *altaica, aquitana, borussica, carpatica, hercynica, iberica, lapponica, polonica,* and *uralensis.* One, *viz. haguenensis* possibly has a Belgian ecotype, significantly different from the German ecotype. The eleventh variety, *viz. septentrionalis* has a large, randomly distributed within variety component of variance. This variety has a high proportion of significantly different pairs of seed sources, which cannot be grouped in any distinct geographic pattern.

Four varieties, *viz. armena, rhodopaea, rigensis and scotica* appear to be divisible into geographically distinct ecotypes as shown below:

Variety *armena* — Two ecotypes, *viz.* (1) from northeastern Turkey and Georgian S. S. R. and (2) from Rumania.

Variety *rhodopaea* — Two ecotypes, *viz.* (1) from Czechoslovakia and southern Bulgaria and (2) from the mountains of northeastern Greece.

Variety *rigensis* — Three ecotypes, occupying three different latitudinal regions, *viz.* 55° N., 57° N. and 58° N. latitudes.

Variety *scotica* — Two ecotypes, *viz.* (1) from Scotland and (2) from England, designated by some authors as "East Anglia".

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Summary

Scotch pine *(Pinus sylvestris* L.) has been the subject of taxonomic and ecological study for more than a century. The most extensive and the latest such study was initiated in 1961 by the North Central Cooperative Regional Research Committee, known as the NC-51 Regional Project. Seed samples from 162 stands in 19 European and Asian countries were propagated and outplanted throughout the North Central region. On the basis of preliminary results in Michigan RUBY (1964) recognized 21 taxonomic varieties, 19 of which have been planted in Minnesota under the above project.

The present research is a continuation of the work of RUBY. Patterns of height growth and total heights from the year of planting in Minnesota through the 1966 growing season were studied to determine whether these 19 varieties were genetically homogeneous or if they could be further sub-divided into ecotypes. The experiments were established in six plantations at four places in Minnesota, *viz.* Blackberry, Cloquet, North Branch and Rice.

Total heights were measured in the 1961 and three 1962 plantations in the spring of 1964. The data were grouped and analyzed by five degree latitudinal classes, and subjected to analysis of variance, and DUNCAN's Multiple Range tests. The results showed that the five degree latitudinal classes were heterogeneous, while the varieties were homogeneous with respect to total height in 1964.

Three measurements were recorded in the Cloquet 1962 and North Branch plantations in the growing season of 1965, *viz.* (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, and (3) the number of days after April 15 to the cessation of height growth.

The data were grouped and averaged by five degree latitudinal classes as well as by varieties. Analyses of variance and DUNCAN's Multiple Range tests were conducted between zones and between varieties as well as within zones and within varieties. The varieties were found to be homogeneous with respect to the three characters.

In the 1966 growing season measurements were recorded in the six plantations on the following 11 characters:

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.
4. & 5. The periodic growth of the current year's shoot for each seed source and for each variety. The best fitting regression equation was found to be $Y = a + b \log X$ (where Y is the length of the current year's shoot after X days from April 15). The values of *a* and b for each seed source and each variety were calculated from these equations.

6 — 10. Total height in 1961 through 1966.

The data were grouped and averaged by varieties for each of these 11 characters. Analyses of variance and DUNCAN's Multiple Range tests were performed separately for each location, both between varieties and within each variety. The following results were obtained.

Only 15 of the 19 varieties available for analysis could be analyzed. It was found that the varieties as recognized by RUBY on the basis of morphological characters are also valid on the basis of their physiological responses to the environment.

Nine of the 15 varieties analyzed appear to be uniform in growth characters and cannot be further sub-divided into sub-varieties or ecotypes. These are *altaica, aquitana, borussica, carpatica, hercynica, iberica, lapponica, polonica* and *uralensis*. One, *viz., haguenensis* possibly has a Belgian ecotype significantly different from the German ecotype. The eleventh, *viz. septentrionalis* has a large randomly distributed within variety component of variance. This variety has a high proportion of significantly different pairs of seed sources, which cannot be grouped in any distinct geographic pattern.

Four varieties, *viz., armena, rhodopaea, rigensis* and *scotica* appear to be divisible into geographically distinct ecotypes as shown below:

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Variety *rigensis:* — Three ecotypes, occupying three different latitudinal regions, *viz.,* 55° N., 57° N. and 58° N. latitudes.

Variety *scotica:* — Two ecotypes, *viz.,* (1) from Scotland and (2) from England, designated by some authors as "East Anglia".

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The Influence of Meteorological Factors on the Cone Crop of Douglas-fir in the Netherlands

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Introduction

Douglas-fir was introduced around 1860 and has since become a successful exotic forest tree species in the Netherlands. Douglas-fir plantations now occupy more than 12,000 hectares, or almost 8 percent of the coniferous forest area of the country.

Provenance trials started in 1923 have shown that the coastal Douglas-fir seed sources from lower altitudes are best suited for the Netherlands because of their height growth, volume production, susceptibility to late frosts and resistance to needle cast disease (VEEN, 1951). Many imported provenances have nevertheless been serious failures in spite of careful attention to seed origins. The enormous extent of the seed procurement areas and the fact that large genetic differences may occur over small distances are the main reasons for these failures. Local provenances from registered seed stands are consequently in great

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