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Variation in Habit Forms of Scots Pine (Pinus silvestris L.) on the Area of Poland

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The presented paper presents one of segments of the complex research in native forrns of Scots pine, carried out by the Forest Research Institute in Warsaw.

The main purpose of studies provided: 1) identification of characteristic types of habit forms in pine from selected seed producing stands, and 2) determination of their differentiating characters as criteria for preliminary evaluation of these forms for needs connected with the planned selection of native ecotypes of this species.

Such an approach determined the main direction of studies. It was expressed by the desire to know the population variations in the species on the background of identified geobotanical regions and plant associations, in which pine presents a fundamental or one of main forest-forming elements.

Studies were carried out during years 1961—1965 on the area of the whole country except of mountain and highland regions, where the Scots pine occurs in entirely different, when compared with lowlands, environmental conditions and where its quantitative share in specific composition of stands is rather low.

The distribution and quantity of study areas were conditioned by the previous selection of pine seed producing stands (TYSZKIEWICZ 1960). These areas are least numerous in central provinces, while more numerous in peripheral ones, what results from the higher forest area percentage in these regions.

Study method and area

Carrying out studies on so vast area brings about the necessity of the use of classification arranging changeable geographic and natural elements of the region with the consideration to their mutual relations.

In the present work there was accepted the division of Poland into geobotanical units proposed by Prof. W. SZAFER (1959).

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This division, considering relations existing between terrain sculpture, climate, and soil on the one hand, and plant associations on the other, is based on rather universal criteria for the evaluation of differentiation in vegetation conditions. Basing on the knowledge of natural geographical distribution of important trees and shrubs, natural variation of plant associations, and the history of plant cover development SZAFER identified on the area of Poland four geobotanical units of Ist order — "sections", and within "sections" units of lower order „subsections", "geographical regions", and, finally, "geobotanical districts".

The work included the area of two sections occupying the overwhelming portion of the country, namely: Baltic and Northern.

The Baltic Section occupies the whole lowland Poland and the major portion of highlands reaching Carpathians and Sudety. This area remains under the climatic influence of sea, which is less pronounced towards the east.

The Northern Section includes the eastern part of Mazurian Lake District and the north-eastern part of Mazowsze lowland. This section is distinguished by a more severe thermal climate, which contributed to the withdraw of few tree species from this area: beech, durmast oak, sycamore maple. Spruce is dominant in forest associations of this area.

Due to the unequal distribution of seed-producing stands on the area of country, the differentiation of habit characters in pine has been discussed for regions in order to avoid the excessive dispersion of experimental material. It is only within the Northern Section, where the analysis of differences within geobotanical districts was possible.

The seed-producing stands, in which measurements were taken, revealed optimal adaptation to local site conditions and, at the same time, distinguished themselves with a high quality of produced wood raw material. During measurement works they revealed a small differentiation in taxation features: tree cover and density was contained within limits of 07—08, site index was most frequently I and II, number of trees per 1 ha amounted to ca 150—200 pieces. So it could be accepted that individual objects were comparable with each other.

Experimental areas were established within homogeneous patches of vegetation, with consideration to their representativeness in relation to the whole stand. On each area 50 trees were subjected to measurements of features characterizing the habit in pine.

The present paper considered only external characters concerning the general appearance of tree, its size, shape of crown, branching, which permit to conclude about its utilitarian value and thus may provide a measure of usefulness of the selected stands in selection works, for which the present paper is aimed to provide an introductory outline.

Lines of papers by Vanselov (1933, 1934) and Steven and Carlisle (1959) were followed here. These papers aimed at the determination of the degree of variation in habit characters in pine on vast areas. On similar bases was founded the characteristics of Scots pine from the area of Tatra and Pieniny Mts. by Zajączkowski (1949).

Studies included following characters:

1) tree height in metres,

2) d.b.h. in cm,

3) determination of the range of cracked thick bark on stem in metres, denoted in tables with the symbol X_1,

4) identification of thick bark type. Three types were identified:

a) longitudinally cracked, upwardly shell-like; shell-like bark occupies 30% of cracked bark, in tables denoted by symbol X_2,

b) panel-like; panel-like thick bark comprises about 80% of the cracked bark, symbol X_3,

c) shell-like; shell-like thick bark comprises about 80% of the cracked bark.

Tables give the per cent proportion of individual types of thick bark on a study area.

5) crown length. Symbol X_4 — in % of tree height,

6) crown width. Symbol X_5 — in % of tree height,

7) classification to one of crown types. There were identified three types of crowns:

a) conical crown with triangular longitudinal section — type A, symbol X_6,

b) paraboloidal crown with rounded top — type B, symbol X_7,

c) crowns with irregular shape — type N.

Tables give the per cent proportion of individual crown types on study area.

8) thickness of branches of the Ist order. Symbol X_8. Index determined by the sum of product of the per cent proportion of definite branch thickness class multiplied by the value of conventional index /0.1/2.1/ of the given class has been accepted in tables as the value of this character.

9) unguinal angle in Ist order branches. Symbol X_9. The per cent proportion of branches set at right and acute angles is given in tables.

Tree heights and the range of cracked bark were measured with Blume-Lais's height gauge with a range-finder. In cases, when the cracked bark on one side of stem extended considerably higher, than on the other, there was measured the maximal range of cracked bark.

For the measurements of crown length and width there was used the folding strip constructed by S. Matusz (1963). This device enabled the measurement of crown length and width in relation to tree height. Unguinal angle of branches was estimated visually for the central part of crown. Observation point was always situated on the northern side of tree at the distance of 25—30 m. Thickness of branches has been also estimated visually identifying them as thick, medium, and thin. Age of each of measured trees has been examined with the aid of Moor's drill.

Simultaneously with measurement works plant sociological records after Braun-Blanquet's method were prepared for each area. Presented results are based on data from measurements taken on 115 study areas. Obtained arithmetic mean values for individual characters for each area provided the material for statistical analysis.

Seed-producing stands under study revealed following differentiation:

1) spatial — they are distributed at various locations within the country, from Suwalki to the vicinity of Janów Lubelski and Zwierzyniec, and from Szczecin to Opole.

2) site — they represent association Vaccinio-Pinetum, Querco-Pinetum, and Carpino-Quercetum.

3) age — age differentiation is enclosed within limits of 70—180 years, the group of the youngest and oldest stands being not numerous. Most numerous stands were at the age of 91—130 years, what is illustrated by the table:

Age-class	number of areas
W_1 70— 90	13
W_2 91—110	36
W_3 111—130	40
W_4 131—180	27

In order to evaluate correctly the differentiation in habit characters of pine on the area of country one should determine to what extent above mentioned groups of factors affect the obtained results. Obviously they are not sole factors which could be important for the problem to be solved, but considering the fact that these works present only a fragment of complex research, they were restricted to a sketchy marking of these aspects of the problem, which seemed most important.

Method of statistical elaboration

For previously described habit characters of pine there were calculated four linear discriminant functions with Fisher's method for each of four age-class separately.

1a. In order to estimate the error covariance matrix B there were sampled 10 trees from each of ten areas representing all kinds of sites included within the studied area. For each area separately there was calculated the error covariance matrix according to the formula:

$$\{\text{cov}\, x_i\, x_j\}_l = \frac{1}{10} \{\Sigma_t (x_{it} - \bar{x}_i)(x_{jt} - \bar{x}_j)\}_l$$

where: $i = 1, 2 \ldots g$; presents an index of character; $p = 9$

$j = 1, 2 \ldots p$; presents also an index of character; $p = 9$

$t = 1, 2 \ldots n$; presents an index of tree number; $n = 10$

$l = 1, 2, 3 \ldots 10$; presents an index of area.

The total error covariance matrix B has been calculated as a mean of these four, above mentioned matrices.

$$B = \frac{1}{10} \Sigma_l \{\text{cov}\, x_i\, x_j\}_l$$

So calculated error covariance matrix has (n-1) l = 90 degrees of freedom.

1b. The treatment covariance matrix has been calculated on the basis of mean groups with 50 trees each taken from various sites within four age-classes according to the formula:

$$W_r = \frac{50}{Kr} \{\Sigma_l (\bar{x}_{il} - \bar{\bar{x}}_i)(\bar{x}_{jl} - \bar{\bar{x}}_j)\}_r$$

where: r = 1, 2, ... w presents an index of age-class; w = 4,
kr — is the number of sites in definite age-class,
l = 1, 2, ... Kr presents an index of site in the given r age-class,
i, j; are indices of examined characters.

2. On the base of the calculated matrix of error B there was found separately for each age-class the linear discriminant function in a form of:

$$Z_l = \Sigma \Theta_i \bar{x}_{il} + a$$

where $a = -\Sigma_p \Theta_i \bar{\bar{x}}_i$ and Θ_i are coefficients of discriminant function. With maximalizing the ratio

$$D^2 \text{ (treatment's z)} : D^2 \text{ (error's z)}$$

This ratio, as the quotient of two positive definite quadratic forms has a nontrivial solution which may be arrived at with Lagrange's method of multipliers while accepting the quantity of one of these forms and searching after the maximum quantity of the second quadratic form.

$$\text{Or } \hat{D}^2 \text{ (treatment's z)} = \max$$

with condition that $\hat{D}^2$ (error's z) = constant.

Thus differentiating we obtain:

$$\frac{\partial \hat{D}^2 \text{ (treatment's z)}}{\partial x_i} - \lambda \frac{\partial \hat{D}^2 \text{ (error's z)}}{\partial x_i} = 0$$

where λ presents Lagrange's multiplier.

Hence we obtain $\{Wr - \lambda B\} \{\Theta\} = 0$

$$\text{since } \left\{ \frac{\partial \hat{D}^2 \text{ (treatment's z)}}{\partial x_i} \right\} = 2 \{Wr\} \{\Theta\},$$

$$\text{and } \left\{ \frac{\partial \hat{D}^2 \text{ (error's z)}}{\partial x_i} \right\} = 2 \{B\} \{\Theta\}.$$

While multiplying the above pattern of equations by B^{-1} we obtain the equation of characteristic vector in a form of $\{B^{-1} Wr - \lambda I\} \{\Theta\} = 0$

where I presents the identy matrix. The latter equation was solved with the use of iterative method and the solution of Θ for λ max. was obtained.

It results from the above that

$$\hat{D}^2 \text{ (error's z)} = \Theta^T B \, \Theta;$$

hence the error mean square for variable z will be calculated as

$$s_z^2 = \frac{nl \, \Theta^T B \, \Theta}{(n-1) l - p + 1} = \frac{100}{82} \Theta^T B \, \Theta$$

and $\hat{D}^2$ (treatment's z) = $\Theta^T \, Wr \, \Theta$,

i. e. the treatment's mean square of variable z will be similarly obtained as

$$s^2_{tr.(z)} = \frac{k + p - 2}{k} \Theta^T \, Wr \, \Theta$$

Because $\{\Theta^T\} \{Wr - \lambda B\} \{\Theta\} = 0$

then $\lambda = \dfrac{\hat{D}^2 \text{ (treatment's z)}}{\hat{D}^2 \text{ (error's z)}}$; or the ratio of both mean squares amount to

$$F_{emp} = \frac{(k + p - 2) [(n - 1) l - p + 1]}{knl} \lambda = \frac{(k + p - 2) 82}{k \, 100} \lambda.$$

which may be tested from $F_{\alpha \, i(k + p - 2) \, (n - 1) \, l - p + 1}$.

According to the above reasoning we may form the least significant difference for testing of differences between z_e (or discriminants), based on T^2 Hotelling's distribution, in a form of

$$NUR = \sqrt{\frac{1}{50} s_z^2 \cdot F_{\alpha i \, pi} \, 82} = \sqrt{\frac{1}{50} \frac{\Theta^T B \Theta \cdot 100}{82} F_{\alpha i \, pi} \, 82 \, i}$$

Discriminant functions obtained for individual age-classes are presented in *Table 1*. By putting means of characters for each studied area to the equation of discriminant function there were obtained discriminants given in *Tables 2, 3, 4*. On their basis there was carried out the classification of stands illustrated on *Figures 1, 2, 3*.

The paper gives also correlation coefficients in *Table 7*, on the base of which intercorrelationships between studied characters were studied.

All calculations of elements of matrix B, Wr, and following operations with matrices together with the solution of characteristic equations and calculation of discriminants were done on Polish electronic computer ZAMP based on the program especially designed for this purpose.

The influence of site conditions upon the differentiation of habit characters

The evaluation of site conditions has been based on plant sociological criteria, accepting as a foundation Emberger's statement that plant associations are, as a rule, repeated faithfully everywhere, where the environment is the same in such a way that patches occupied by a definite population, irrespectively to its geographical distribution have the same properties and identify the same site.

Plant sociological analysis permitted to determine the extent of differentiation in site conditions for studied stands and their arrangement according to increasing fertility.

The association Vaccinio-Pinetum was most numerously represented and 62% of acreage was classified to it, while 30% of acreage- to Pino-Quercetum. 8% of acreage was classified to Querco-Carpinetum.

Statistical analysis revealed that along with the betterment of trophic conditions there changed only the height and d.b.h. of tree. Habit characters on the other hand do not indicate any relation with site quality. At the same

Table 1. — Discriminant functions for individual age-classes.

W_1: $Z_1 = 0,2772\bar{X}_1 - 0,0017\bar{X}_2 - 0,0042\bar{X}_3 - 0,0108\bar{X}_4 - 0,1811\bar{X}_5 + 0,0030\bar{X}_6 + 0,0019\bar{X}_7 + 0,0079\bar{X}_8 - 0,0078\bar{X}_9 - 1,113$

W_2: $Z_1 = 0,0405\bar{X}_1 + 0,0176\bar{X}_2 + 0,0255\bar{X}_3 - 0,0260\bar{X}_4 - 0,1016\bar{X}_5 + 0,0461\bar{X}_6 + 0,0457\bar{X}_7 + 0,0094\bar{X}_8 + 0,0075\bar{X}_9 - 4,310$

W_3: $Z_1 = -0,0394\bar{X}_1 + 0,0086\bar{X}_2 + 0,0494\bar{X}_3 + 0,0516\bar{X}_4 - 0,1294\bar{X}_5 + 0,0172\bar{X}_6 + 0,0135\bar{X}_7 + 0,0066\bar{X}_8 + 0,0066\bar{X}_9 - 1,896$

W_4: $Z_1 = -0,0281\bar{X}_1 + 0,0048\bar{X}_2 + 0,0543\bar{X}_3 + 0,0299\bar{X}_4 - 0,0837\bar{X}_5 + 0,0074\bar{X}_6 + 0,0071\bar{X}_7 + 0,0059X_8 + 0,0056X_9 - 2,205$

Table 2.

Region	Area	Site	H	d.b.h.	H_1 X_1	Bark type: Long X_2	Bark type: Panel-Like X_3	Bark type: Shell-Like	Crown dimensions: Length X_4	Crown dimensions: width X_5	Crown type: A X_6	Crown type: B X_7	Crown type: N	thickness of branches X_8	acute angle of branching X_9	right angle of branching	Discriminant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
W_1																	
Okręg Kurp. Piski	1	P.	22	29	6	98	2	0	30	18	64	30	6	3	84	16	—1.364
Poj. Mazurskie	2	P. V.	21	26	5	68	0	32	27	15	92	6	2	0	82	18	—0.978
Półn. Podlaska	3	P. Q.	28	34	11	97	0	3	25	13	59	31	10	2	86	14	—0.954
Okręg Augustowski	4	P. V.	23	30	6	94	1	5	30	15	97	3	0	1	88	12	—0.810
Poj. Mazurskie	5	P. V.	24	30	8	100	0	0	28	13	50	44	6	13	40	60	—0.530
Mazowiecka	6	P. Q.	24	30	8	100	0	0	27	17	62	18	10	0	66	34	—0.503
Poj. Mazurskie	7	Q. C.	27	32	8	100	0	0	24	16	86	14	0	0	78	22	—0.319
Płask. Łuk. Siedleckie	8	S. P.	26	33	8	100	0	0	26	15	78	14	8	5	78	22	—0.144
Zach. Pom. Pas Przejściowy	9	P. Q.	23	28	7	82	0	18	22	14	78	14	8	2	44	56	—0.075
Łomżyńska	10	P. V.	24	29	8	98	2	0	24	14	78	16	6	2	76	24	—0.049
Poj. Mazurskie	11	P. Q.	26	31	8	100	0	0	25	14	96	4	0	0	88	12	—0.036
Poj. Mazurskie	12	Q. C.	28	35	10	96	2	2	28	12	78	22	0	4	42	58	1.219
Mazowiecka	13	Q. C.	29	34	10	82	2	16	23	11	80	16	4	0	54	46	1.346
W_2																	
Zach. Pom. Pas Przejściowy	14	P. V.	24	30	8	62	0	38	31	18	16	92	62	12	48	52	—3.326
Zach. Pom. Pas Przejściowy	15	P. V.	26	33	8	42	0	58	26	16	54	24	78	9	52	48	—1.500
Wzg. Trzebnicko-Ostrzeszowskie	16	P. V.	27	38	12	56	0	44	26	20	46	46	8	2	30	70	—1.094
Wyżyna Śląska	17	P. Q.	26	36	11	48	0	52	24	16	74	10	16	1	42	58	—1.089
Zach. Pom. Pas Przejściowy	18	P. V.	27	33	7	66	0	34	26	16	66	12	22	1	76	24	—1.007
Zach. Pom. Pas Przejściowy	19	P. V.	25	33	9	52	0	48	24	15	54	32	14	4	28	72	—0.992
Zach. Pom. Pas Przejściowy	20	P. V.	26	35	9	46	0	54	22	17	56	36	8	4	26	74	—0.989
Zach. Pom. Pas Przejściowy	21	P. V.	21	28	6	66	0	34	26	18	82	6	12	1	54	46	—0.954
Poj. Mazurskie	22	P. V.	27	34	7	60	8	40	26	15	64	18	18	2	62	38	—0.721
Wkp. Kujawska	23	P. V.	21	26	8	38	0	62	23	18	64	34	2	0	74	26	—0.696
Poj. Mazurskie	24	P. V.	27	37	8	40	0	60	26	13	84	16	0	2	58	42	—0.233
Poj. Mazurskie	25	Q. C.	31	44	12	100	0	0	30	25	46	52	2	34	70	30	—0.056
Poj. Mazurskie	26	P. Q.	28	37	9	44	14	42	25	13	56	38	6	10	54	46	0.020
Poj. Mazurskie	27	P. Q.	28	28	8	68	14	18	30	15	86	12	2	0	42	58	0.079
Zach. Pom. Pas Przejśc.	28	P. Q.	28	36	9	92	4	4	25	13	70	18	12	1	36	64	0.120
Świętokrzyska	29	P. V.	24	37	9	72	12	16	24	17	16	76	8	36	56	44	0.232
Poj. Mazurskie	30	P. V.	27	36	8	46	24	30	25	15	68	30	2	4	60	40	0.244
Poj. Mazurskie	31	P. Q.	27	36	8	84	6	10	30	16	62	36	2	12	54	46	0.248
Poj. Mazurskie	32	P. Q.	28	40	8	100	0	0	26	18	66	32	2	1	64	36	0.250
Poj. Mazurskie	33	P. V.	27	38	10	96	4	0	32	17	94	6	0	0	48	52	0.281
Poj. Mazurskie	34	P. V.	25	34	7	100	0	0	26	16	70	28	2	0	48	52	0.285
Świętokrzyska	35	P. V.	26	37	10	88	0	12	26	16	54	38	8	24	78	22	0.377
Okr. Kurp. Piski	36	P. V.	26	34	10	96	4	10	27	15	86	6	8	11	60	40	0.440
Półn. Podlaska	37	P. V.	27	40	8	96	4	0	30	16	48	50	2	37	30	70	0.455
Poj. Mazurskie	38	P. V.	28	41	9	94	6	0	29	16	74	26	0	3	48	52	0.457
Poj. Mazurskie	39	Q. C.	29	40	10	100	0	0	26	15	86	8	6	4	64	36	0.490
Świętokrzyska	40	P. V.	30	41	10	100	0	0	26	16	66	26	8	21	72	28	0.509
Okr. Kurp. Piski	41	P. V.	31	38	12	92	8	0	24	14	66	26	8	2	44	56	0.519
Poj. Mazurskie	42	P. Q.	28	40	11	52	30	18	30	15	60	40	0	6	60	40	0.601
Poj. Mazurskie	43	P. V.	27	33	9	74	8	18	26	13	84	16	0	0	60	40	0.605
Okr. Kurp. Piski	44	P.	25	34	8	94	6	0	30	16	68	28	4	23	80	20	0.634
Świętokrzyska	45	P. V.	25	32	8	100	0	0	30	15	82	16	2	18	70	30	0.663
Poj. Mazurskie	46	P. V.	31	39	9	54	26	20	26	13	78	20	2	0	80	20	0.771
Świętokrzyska	47	P. V.	29	40	10	98	0	2	21	15	40	56	4	14	80	20	0.872
Poj. Mazurskie	48	P. V.	31	42	10	74	22	4	28	12	48	50	2	13	40	60	1.021

Table 3.

Region	Area	Site	H	d.b.h.	H_1 X_1	Bark type: Long X_2	Bark type: Panel-Like X_3	Bark type: Shell-Like	Crown dimensions: Length X_4	Crown dimensions: width X_5	Crown type: A X_6	Crown type: B X_7	Crown type: N	thickness of branches X_8	acute angle of branching X_9	right angle of branching	Discriminant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Zach. Pom. Pas Przejśc.	49	V. P.	26	38	9	42	0	58	22	20	8	58	34	7	30	70	—2.176
Wzgórz. Trzebn. Ostr.	50	P. V.	22	30	8	50	0	50	22	20	12	78	10	4	28	72	—1.762
Wzgórz. Trzebn. Ostr.	51	P. Q	26	34	10	40	0	60	22	18	32	60	8	5	18	82	—1.626
Wkp. Kujawska	52	P. Q.	24	35	8	40	0	60	28	20	46	34	20	3	22	78	—1.594
Wkp. Kujawska	53	Q. C.	29	43	13	56	0	44	27	20	36	52	12	7	24	76	—1.594
Wkp. Kujawska	54	P. V.	26	41	12	54	0	46	28	21	24	68	8	15	30	70	—1.548
Wyżyna Śląska	55	P. V.	27	37	13	52	0	48	22	17	8	78	14	3	54	46	—1.457
Niz. Szczecińska	56	Q. C.	28	37	11	78	4	18	26	20	28	32	40	9	50	50	—1.402
Zach. Pom. Pas Przejśc.	57	V. P.	25	32	9	48	0	52	28	21	72	8	20	1	54	46	—1.400
Zach. Pom. Pas	58	P. Q.	32	40	11	60	0	40	25	18	52	18	30	23	32	68	—1.350
Zach. Pom. Pas	59	V. P.	29	39	12	48	0	52	22	15	18	62	20	7	44	56	—1.277
Wkp. Kujawska	60	P. V	22	29	8	52	0	48	24	19	30	58	12	0	74	26	—1.195
Zach. Pom. Pas Przejść.	61	P. Q.	30	41	11	50	2	48	25	16	36	36	28	20	28	62	—1.092
Pn. Podlaska	62	P. Q.	30	45	12	94	0	6	22	19	32	68	0	17	60	40	—0.904
Zach. Pom. Pas Przejść.	63	Q. C.	26	42	9	74	0	26	27	18	20	62	18	20	60	40	—0.839
Łomżyńska	64	P. Q.	30	41	11	64	14	22	95	20	56	22	22	4	62	38	—0.688
Roztocze	65	P. V.	26	41	10	86	2	12	27	20	28	68	4	50	56	44	—0.545
Polesie Tyśm.	66	P. Q.	30	42	12	70	0	30	28	16	84	16	0	12	78	22	—0.135
Łomżyńska	67	P. Q.	30	43	13	76	22	2	25	18	38	50	12	7	38	62	—0.079
Pn. Podlaska	68	P. V.	27	37	9	94	4	2	27	18	76	22	2	32	60	40	0.034
Polesie Tyśm.	69	Q. C.	31	54	16	70	30	0	26	19	20	46	34	52	56	44	0.118
Pn. Podlaska	70	Q. C.	30	40	12	51	12	37	25	13	62	28	10	8	65	35	0.119
Łomżyńska	71	P. Q.	30	44	12	46	24	30	24	16	42	52	6	4	48	52	0.149
Pn. Podlaska	72	P. V.	29	38	10	98	2	0	27	14	66	32	2	5	54	46	0.194
Roztocze	73	P. V.	29	42	9	96	4	0	24	15	24	72	4	46	68	32	0.209
Okręg Augustowski	74	P. V.	27	35	7	96	4	0	27	17	70	30	0	45	54	46	0.310
Okręg Augustowski	75	P. V.	27	35	7	96	0	4	30	15	90	10	0	5	52	48	0.324
Łomżyńska	76	P. V.	28	38	10	50	20	70	25	15	48	42	10	6	72	28	0.389
Okręg Augustowski	77	P. V.	25	32	8	100	0	0	32	15	96	4	0	1	72	28	0.547
Łomżyńska	78	P. Q.	28	41	11	62	30	8	24	14	32	50	18	8	58	42	0.775
Poj. Mazurskie	79	P. V.	28	37	11	46	32	22	25	15	50	44	6	0	52	48	0.794
Okręg Augustowski	80	P. V.	23	30	7	100	0	0	35	15	94	6	0	0	86	14	0.822
Poj. Mazurskie	81	P. V.	31	48	12	70	28	2	28	13	56	40	4	16	36	64	1.227
Poj. Mazurskie	82	P. V.	28	38	9	38	46	16	23	15	50	36	14	9	56	44	1.369
Okręg Augustowski	83	P. V.	30	40	10	76	24	0	28	12	96	4	0	12	56	44	1.597
Okręg Augustowski	84	P. V.	29	41	9	56	44	0	31	16	84	14	2	22	60	40	2.109
Okręg Augustowski	85	P. V.	29	39	9	62	36	2	30	12	92	8	0	17	62	38	2.269
Okr. Kurp. Piski	86	P.	23	33	6	14	70	16	30	19	72	22	6	15	48	52	2.484
Okr. Kurp. Piski	87	P. Q.	29	44	10	12	86	2	25	17	46	38	16	17	56	44	2.935
Okr. Augustowski	88	P. V.	29	39	10	20	80	0	31	13	82	16	2	19	70	30	3.963

time height and d.b.h. classify an area according to site index and mask the differentiating effect of remaining characters. In following considerations we decided, therefore, to exclude these both characters from the construction of discriminant functions.

The influence of age upon the differentiation of habit characters

There was found the relationship between the age of stand and habit characters *(Tab. 5)*. Along with age there:
1) increases the number of crowns in B and N type,
2) increases the width of crowns,
3) decreases the proportion of branches with acute anguinal angle,
4) increases the proportion of thick branches,
5) decreases the proportion of longitudinally cracked bark and increases the per cent of trees with panel-like bark.

Considering this the variation of habit characters of individual stands was discussed with respect to division into age-classes. Various characters, depending upon age-classes, revealed highest discriminate values, what is presented in *Table 6*. At the same time, while comparing discriminant functions inserted in *Tab. 1*, one can note the concordance in coefficients Θ_i of discriminant function for W_3 and W_4.

In this connection the spatial classification of areas from age-classes W_3 and W_4 was treated jointly in the preparation of *Figure 3*.

In youngest stands most obviously differentiating characters provide the range of cracked bark and acute angle of branching. The significance influence of bark type upon differentiation of stands is marked beginning with W_2 until W_4. And so for W_2 longitudinal cracking is significant, while for older stands, W_3 and W_4 — the bark of panel-

Table 4.

Region	Area	Site	H	d.b.h.	H_1 X_1	Bark type: Long X_2	Bark type: Panel-Like X_3	Bark type: Shell-Like	Crown dimensions: Length X_4	Crown dimensions: width X_5	Crown type: A X_6	Crown type: B X_7	Crown type: N	thickness of branches X_8	acute angle of branching X_9	right angle of branching	Discriminant
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Zach. Pom. Pas Przejściowy	89	P. V.	26	36	8	48	0	52	24	21	32	56	12	11	42	58	—2.306
Przejściowy	90	P. V.	30	41	12	36	0	64	26	17	24	58	18	37	6	94	—2.176
Wkp. Kujawska	91	P. V.	28	35	12	40	12	48	22	21	12	76	12	1	18	82	—2.064
Łomżyńska	92	P. Q.	30	42	12	48	2	50	26	16	74	12	14	6	38	62	—1.883
Kołl. Śląska	93	P. V.	26	42	12	80	4	16	26	20	2	94	4	21	46	54	—1.777
Zach. Pom. Pas Przejściowy	94	P.	25	35	9	50	8	42	27	20	32	40	28	28	34	66	—1.775
Wkp. Kujawska	95	P. V.	23	35	10	70	14	16	22	21	0	90	10	8	14	86	—1.727
Zach. Pom. Pas Przejściowy	96	P. Q.	30	45	12	68	14	18	30	19	34	34	32	26	14	86	—1.425
Okr. Augustowski	97	P. V.	31	42	11	90	10	0	28	20	30	66	4	46	48	52	—1.148
Łomżyńska	98	P. V.	30	42	10	46	20	34	22	16	32	46	22	10	44	56	—1.992
Okr. Augustowski	99	P. Q.	30	44	10	92	8	0	28	17	44	48	8	49	56	44	—1.929
Pn. Podlaska	100	P. V.	28	39	9	84	42	4	24	17	44	56	0	41	50	50	—0.865
Zach. Pom. Pas Przejściowy	101	Q. C.	25	47	10	64	28	8	23	22	0	86	14	35	32	68	—0.818
Wkp. Kujawska	102	P. V.	30	44	15	46	40	4	22	22	0	84	16	13	20	80	—0.633
Mazowiecka	103	P. A.	31	51	14	80	20	0	29	19	20	62	18	60	74	26	—0.499
Nizina Szczecińska	104	P. V.	24	38	9	68	28	4	25	20	0	82	18	55	30	70	—0.466
Okr. Augustowski	105	P. V.	30	40	9	66	34	0	30	13	30	8	2	8	66	34	0.657
Łomżyńska	106	P. V.	25	37	9	42	56	2	23	20	32	60	8	40	50	50	0.977
Okr. Kurp. Piski	107	P. V.	28	37	9	32	56	12	24	15	68	26	6	9	74	26	1.357
Pn. Podlaska	108	P. V.	30	44	12	36	62	2	24	15	34	41	22	15	62	38	1.478
Okr. Kurp. Piski	109	P. V.	29	39	11	32	66	2	27	18	52	40	8	19	60	40	1.643
Łomżyńska	110	P. V.	24	37	8	20	88	0	23	20	10	74	16	32	46	54	2.070
Pn. Podlaska	111	P. Q.	34	55	15	28	72	0	25	11	26	68	6	67	16	84	2.153
Okr. Kurp. Piski	112	P. V.	26	33	8	14	74	12	31	17	68	20	12	11	68	32	2.254
Poj. Mazurskie	113	P. Q.	32	58	15	12	88	0	30	20	20	74	6	52	38	62	2.626
Poj. Mazurskie	114	P. V.	29	43	8	4	94	2	24	16	0	86	14	36	30	70	3.064
Okr. Kurp. Piski	115	P. Q.	30	42	11	2	98	0	25	16	70	18	12	24	46	54	3.275

like type is characteristic. Moreover the type and width of crown introduces significant differentiation in each age-class.

Spatial variation of habit characters

Using the prepared discriminant functions there was obtained within individual age-classes the division of stands into groups (vide the arrangement of discriminants in *Tab. 2, 3, 4).*

Generally, in each age-class there is marked a clear division of stands into two classes — western and eastern. The line of division runs in north-south direction, from Vistula delta to Kraków. Within this main division there was obtained further differentiation of stands illustrated by enclosed figures, prepared for most numerously represented age-classes W_2 and W_3, and additionally, with regard to previous considerations, for W_3 and W_4 jointly.

In the characteristics of individual, identified groups resulting from ranking of discriminants, calculated correlation coefficients describing interrelationships between examined characters *(Tab. 7)* were used.

From the above table it results that crown type provides a strongly discriminate character within each age-class. It will be thus purposeful to describe a set of characters accompanying crown types A and B as ones most numerously represented.

Crown type A:

1) is negatively correlated with H_1; the range of cracked bark,
2) is negatively correlated with thickness of branches,
3) is positively correlated with the per cent of acute angles in branching,
4) is negatively correlated with panel-like appearance of bark,
5) is positively correlated with crown length (what is particularly evident in W_3 and W_4 age-groups),
6) is negatively correlated with crown width in W_3 and W_4 age-groups,
7) reveals a trend towards negative correlation of type A with d.b.h. (at every age),
8) reveals a trend towards positive correlation of type A with tree height (increase with age).

Crown type B:

1) is positively correlated with H_1, the range of cracked bark,
2) is positively correlated with thickness of branches,
3) is negatively correlated with the per cent occurrence of acute angles in branching,
4) is positively correlated with panel-like appearance of bark,

Table 5. — Arithmetic means for characters X_{ir} for individual age-classes and standard deviations of the error S_{X_i}

Age-classes	H m	d.b.b. cm	H_1 m	Type of bark: Longitudinally cracked bark %	Type of bark: panel Like %	Type of bark: shell Like	Crown dimensions: crown Length %	Crown dimensions: crown width %	Crown types: A %	Crown types: B %	Crown types: N %	Thickness of branches 0; 1/2; 1	angle of branching: <90° %	angle of branching: >90° %
			X_1	X_2	X_3	—	X_4	X_5	X_6	X_7	—	X_8	X_9	—
70 to 90 years W_1	25.00	30.8	7.92	93	0.7	6.3	26.1	14.4	76.8	17.8	5.4	0.02	69.7	30.3
91 to 110 years W_2	26.94	36.3	9.00	74	5.7	20.3	26.6	15.8	63.8	28.3	8.9	0.09	56.8	43.2
111 to 130 years W_3	27.70	38.7	10.15	62	15.5	22.5	26.2	16.8	50.2	38.6	11.2	0.14	52.3	47.7
131 to 180 years W_4	28.30	41.6	10.74	48	37.0	15.0	25.5	18.2	31.5	55.8	12.7	0.28	41.6	58.4
standard deviation S_{X_i}	2.54	5.97	2.84	35	18	—	5.53	3.74	36	34	—	26	45	—

5) is negatively correlated with crown length, the relationship increasing with age,
6) is positively correlated with the % of crown width,
7) reveals a trend towards positive correlation of type B with d.b.h. (at every age),
8) reveals a trend towards positive correlation of type A with tree height (increase with age).

So the *type A* characterizes itself with a low range of cracked bark and thin branches set at acute angles. Its crown is long and narrow. This is particularly pronounced

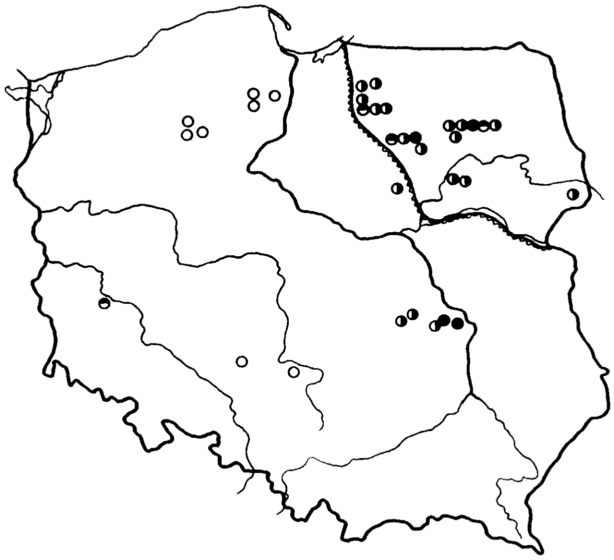

Figure 1. — The differentiation of stands within W_2 age-class (91—110 years) by means of groups discriminants = 3 NUR.
Groups of discriminants:
○ from —1.500 to —0.954
◒ —0.721 —0.056
◑ 0.020 0.634
● 0.663 1.012
Border of Northern Section

Figure 2. — The differentiation of stands within W_3 age-class (110—130 years) by means of groups discriminants = 3 NUR.
Groups of discriminants:
○ from —1.762 to —1.092
◐ —0.904 —0.135
◑ —0.079 0.775
◒ 0.794 1.369
◒ 1.597 2.269
● 2.484 2.935

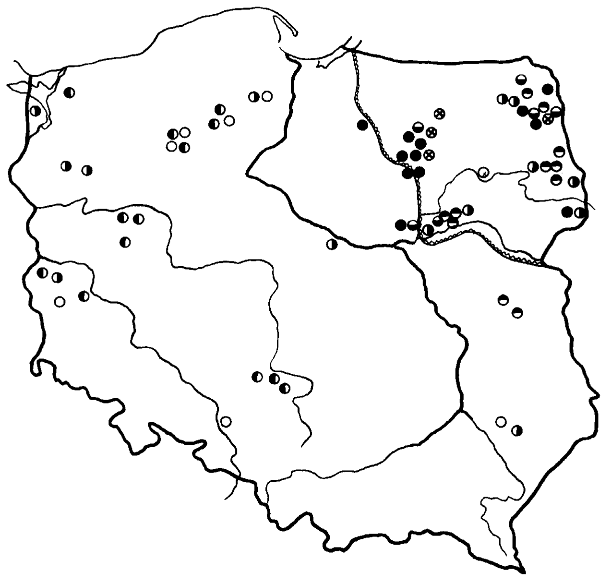

Figure 3. — The differentiation of stands within W_3 and W_4 age-class jointly, by means of groups discriminants.

Groups of discriminants:

○	from —2.306	to —1.775
◐	—1.762	—1.195
◑	—1.148	—0.466
⊖	—0.135	0.385
⊖	0.597	0.977
⊗	1.227	1.597
●	1.643	3.963

in higher age-classes. Trees classified to this type are higher and thinner.

Type B is connected with higher reaching thick bark, has thicker branches and higher percentage of branches set at right angle. It has also higher proportion of trees with panel-like bark. Its crowns are shorter and broader. In older age-classes these two characters become ever more obvious. Trees classified to this type are lower and have greater d.b.h.

Both habit types occur parallely, but in the north-eastern part of Poland equivalent with boundaries of the Northern Section predominates type A, while in the central and western part, within boundaries of the Baltic Section, the number of trees classified to this type decreases on the favour of type B, these changes occurring gradually.

The enclosed *Figure 4* illustrates the spatial distribution of identified habit types.

In the north-eastern part of the studied region in 110—130 years old stands the number of crowns in type A is enclosed within limits of 50—88%. On the remaining area the proportion of this type drops to 34—21%.

The number of crowns narrower than mean is almost by twice lower in the western and southern part, when compared with the northern east. Crown length reveals a similar character of variation.

Bark types are intermingled, but the high proportion of shell-like bark in the western and south-western part of the studied region and panel-like bark in northern and south-western part is regular.

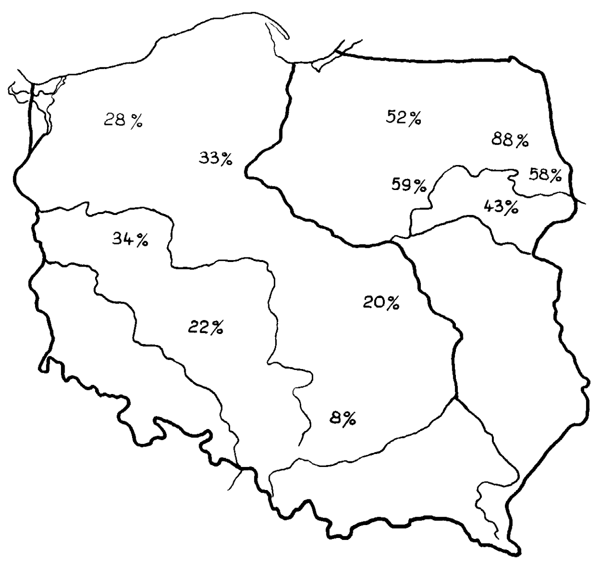

Figure 4. — The distribution of habit type A (in %) in age-class W_3 (110—130 years).

Table 6. — The habit characters especially discriminating within individual age-classes.

W_1	W_2	W_3 and W_4
1) height of cracked bark (x_1)	1) crown types A and B (x_6 and x_7)	1) bark type (panel like) x_3
2) crown width (x_5)	2) bark type (longitudinally cracked) x_2	2) crown types A and B, x_6 and x_7
3) angle of branching (x_9)	3) crown width x_5	3) crown width x_5
4) crown type A (x_6)	4) bark type (panel — like) x_3	

Table 7. — Matrices of correlation coefficients for all studied characters determined from individual variation of trees (error) (above diagonal) r = 0,205 and from arithmetic means for 10 trees, determined for each of 10 experimental areas (below diagonal) r = 0,63.
0,95; 98 0,95; 98

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Range of cracked thick bark H_1	X_1		0.02	0.21*	0.05	0.21*	—0.42*	0.41*	0.16	—0.04
longitudinally cracked bark	X_2	—0.15		—0.34*	0.24	—0.25*	0.18	—0.17	0.06	0.05
panel — like bark	X_3	0.65*	—0.17		—0.14	0.15	—0.20	0.22	0.07	0.22*
crown length	X_4	—0.36	0.28	—0.26		0.23*	0.37*	—0.36*	—0.09	0.16
crown width	X_5	0.09	—0.77*	0.35	0.08		0.13	0.10	0.15	0.003
crown type A	X_6	—0.78*	0.44	—0.73*	0.54	—0.35		—0.94*	—0.15	0.12
crown type B	X_7	0.75*	—0.36	0.72*	—0.54	0.25	—0.99*		0.11	—0.18
thickness of branches	X_8	0.50	0.23	0.51	—0.25	—0.01	—0.51	0.47		0.05
angle of branching	X_9	—0.59	0.24	—0.42	0.26	—0.12	0.61	—0.56	0.36	

* correlation is significant with confidence coefficient P = 0,95

The direction of changes in habit characters in pine is coincident with the direction of intensification of continental features in the climate of Poland, what may suggest a mutual relationship between these phenomena.

Summary

The paper contains results of studies on the variation in habit characters in Scots pine *(Pinus silvestris* L.) on the area of Poland.

For studies were used seed producing stands of pine with the following pattern of taxation characters: tree cover and density within limits of 07—08, site index — most frequently I and II, number of trees per 1 ha — amounting to 150—200 pieces.

Study areas have been established within homogeneous vegetation stands considering their representative appearance for the whole stand. On each area 50 trees were subjected to measurements of characters describing the habit in pine (crown type, length and width of crown, thickness of Ist order branches, angle of branching, range of cracked bark). Arithmetic mean values for individual characters within each area yielded the material for statistical processing, in which the spatial, site, and age variation in study objects were taken into consideration. The existence of correlation between crown type and remaining characters was found. This made possible the identification of two habit types in pine: 1) crown type A, with thin branches, arising at acute angle, with long and narrow crown, with low reaching thick bark. Trees classified to this type are higher and thinner; 2) crown type B, with thicker branches, with crown shorter and broader when compared with the previous one, with higher proportion of branches set at right angle. This type has a higher proportion of trees with panel — like bark. Trees classified to this type are lower and thicker in d.b.h. It was found that within limits of differentiation from Vaccinio-Pinetum to Querco-Carpinetum habit characters failed to reveal any relation with site quality.

Age had an obviously differentiating effect upon habit characters in pine. At the same time, within even-aged groups of stands there was marked a spatial variation which leads to the division of study objects into two main groups: western and eastern. The boundary runs along Vistula River.

In the north-eastern part of Poland, in the region corresponding with the Northern Section distinguished by Szafer, in stands exceeding 111 years of age the number of trees classified to the type A is contained within limits of 50—88%. On the remaining area, belonging to Baltic Section, the proportion of trees in this type decreases to 21—34%.

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Control-Pollination Seeds from Cuttings of Coast Redwood[1])

By W. J. Libby, Y. T. Kiang and Y. B. Linhart[2])

Introduction

In 1964, we observed the maturation of viable seeds on cuttings detached from Coast redwoods *(Sequoia sempervirens* D. Don [Endl.]) shortly after pollination. In 1965, further investigation showed that the cuttings could be taken before the male and female strobili opened, and controlled pollinations could be performed successfully in the glasshouse. Seedlings from seeds matured on cuttings were smaller at germination than seedlings from seeds matured on the tree but these differences disappeared after 12 weeks' growth. Success varied with pollination technique, and with the clones used as females. Most of the viable seeds were produced by one pollination technique and were from females of a single clone. Thus, the 1964—66 observations and experiments established that normal healthy seedlings can be obtained from controlled crosses on detached redwood cuttings, but the technique needed further development to be practical (Linhart and Libby, 1967).

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During 1966—68, we conducted a more extensive series of experiments to investigate the effects of several variables on yield of viable seed: position of the cutting in the crown; storage of both cuttings and pollen; number of female strobili per cutting; levels of contamination with unbagged strobili; and differences between clones.

Materials and Methods

All the cuttings were collected on 23 December 1966 from six planted trees (20 to 30 years old) growing on the Russell Reservation 15 km east of Berkeley. Approximately half were placed in cold storage (4^0 C) in moist partly-opened polyethylene bags. The rest were placed in rooting benches in the glasshouse, in a perlite rooting medium with bottom heat (22^0 C), at ambient temperatures from about 7^0 C to 33^0 C and averaging about 20^0 C, with the photoperiod extended to 16 hours by incandescent lights, and intermittent mist irrigation during the day. The occasional male strobilus occurring on a cutting with female strobili was removed, and the cuttings with male and female strobili were placed in separate rooting benches 15 meters apart.

Of the six trees used in 1966—68, clones 8 and 10 had been used as females and clones A, B, 8 and 10 had been used as males in the 1965 experiments (Linhart and Libby, 1967).