VARIABILITY OF EIGHT POLISH POPULATIONS OF *PINUS SYLVESTRIS* L. EXPRESSED IN TRAITS OF CONES

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ABSTRACT

Two-year old cones were collected from 257 standing *Pinus sylvestris* L. trees, representing 8 Polish populations of the species. The cones were analyzed in respect to 11 morphological traits. The obtained data were subjected to multivariate statistical analysis to determine interpopulation variability. Multivariate analysis of variance was performed with testing of statistical hypothesis, Mahalanobis distances for each pair of populations were calculated and their significance was estimated using Hotelling T_2 statistics. Using the shortest Mahalanobis distances a dendrite was constructed while Euklidean distances provided grounds for hierarchy grouping. Most of the populations were found to differ significantly from the remaining ones. The population from Ruciane proved to be most distinct. Cone setting angle was the trait of the highest discriminating power in interpopulational comparisons. Using the Bryant's test, the discussed populations were found to form two geographic groups: the north-eastern population group and the south-western one.

KEY WORDS: *Pinus sylvestris* L., populations, cones, varability, multivariate analysis

INTRODUCTION

The present study presents results of testing variability in eight Polish populations of *Pinus sylvestris* L. (described earlier by Bobowicz and Korczyk 1994) in respect to traits of two-year old cones (Fig. 1). The populations have been chosen taking into account quality of pine trees as far as their requirements in culture, their applicability and local origin are concerned (Korczyk 1986). The present study extends results of examining eight Polish populations of *Pinus sylvestris* L. in respect to their enzymatic traits (Krzakowa 1979, 1980, 1982), phenol compounds (Krzakowa et al. 1990), needle morphology and anatomy (Bobowicz and Korczyk 1994).

MATERIAL AND METHODS

In each of the chosen stand of trees within a given population, two-year old cones were collected in 1977, from standing trees. A total of 5115 cones were collected from 257 trees and were analyzed in respect to 11 traits listed in Table 2.

Results of measurements were transfered to the Computing Center, Agricultural School, Poznań and the Center for Informatics, Adam Mickiewicz University in Poznań in order to calculate:

1. characteristics of the applied 11 traits of cones, 2. correlation coefficients between trait values, 3. discriminative power of the traits, 4. multivariate analysis of variance with testing of statistic hypothesis, 5. discriminant analysis, 6. Mahalanobis distances and Hotelling T^2 statistics, 7. minimum spanning tree constructed on the basis of the shortest Mahalanobis distances, 8. agglomerative grouping by the method of the closest neighbourhood on the basis of Euklidean distances (dendrogram).

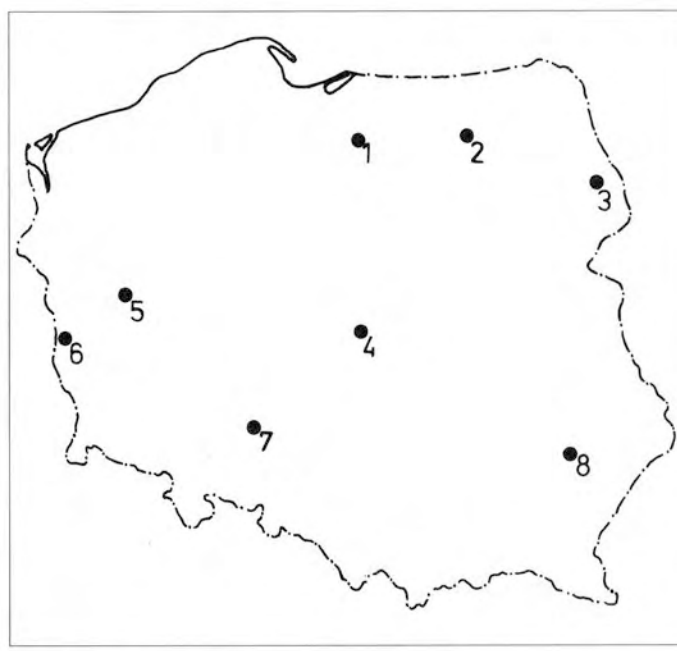


Fig. 1. Localities of studied populations: 1 – Miłomłyn, 2 – Ruciane, 3 – Supraśl, 4 – Spała, 5 – Bolewice, 6 – Gubin, 7 – Rychtal, 8 – Janów Lubelski.

TABLE 1. Means (I), standard deviations (II), variability coefficients (III), minimum (IV) and maximum (V) values. (A) for 11 cone traits (B) of 8 Polish populations (C) of *Pinus sylvestris* L.

A	B C	1	2	3	4	5	6	7	8	9	10	11
I	1	31.98	17.98	58.63	7.85	7.30	1.96	41.21	1.84	0.54	1.08	0.55
	2	38.51	19.96	63.57	8.37	7.36	2.47	61.69	1.93	0.61	1.14	0.67
	3	36.29	18.59	62.35	8.26	7.39	2.42	84.43	1.95	0.58	1.11	0.62
	4	37.49	19.76	66.83	8.27	7.54	2.56	56.40	1.89	0.56	1.10	0.68
	5	40.69	21.34	61.69	8.68	8.14	1.88	35.06	1.91	0.66	1.07	0.47
	6	36.11	18.55	58.21	8.21	7.75	1.89	33.95	1.95	0.62	1.07	0.49
	7	38.07	20.34	53.35	8.21	8.06	2.30	38.67	1.87	0.72	1.02	0.57
	8	39.39	20.33	62.24	8.52	8.06	1.95	31.61	1.94	0.63	1.07	0.49
II	1	4.58	2.01	5.72	1.05	0.97	0.67	17.09	0.18	0.08	0.14	0.20
	2	5.12	2.32	8.48	0.98	0.85	0.40	6.69	0.15	0.08	0.16	0.10
	3	4.97	2.26	8.43	0.78	1.21	0.95	15.42	0.16	0.07	0.13	0.19
	4	5.72	2.60	9.73	1.06	0.92	0.71	14.29	0.16	0.08	0.13	0.18
	5	5.20	2.67	8.62	1.30	1.21	0.55	14.96	0.15	0.09	0.14	0.17
	6	4.56	2.12	8.16	1.01	1.09	0.63	14.82	0.16	0.09	0.14	0.17
	7	4.61	2.10	7.62	0.93	0.85	0.37	9.11	0.16	0.11	0.12	0.10
	8	5.06	2.33	6.84	0.84	0.98	0.62	11.25	0.14	0.06	0.15	0.17
III	1	14.33	11.59	9.76	13.31	13.34	33.96	41.48	9.65	14.38	12.97	36.54
	2	13.29	11.61	13.34	11.70	11.55	16.11	10.84	7.92	12.62	14.32	14.23
	3	13.69	12.14	13.51	9.49	16.31	39.45	31.84	7.96	11.96	11.65	30.52
	4	15.26	13.16	14.55	12.80	12.26	27.78	25.33	8.74	14.98	11.59	26.99
	5	12.78	12.51	13.97	14.99	14.87	29.50	42.66	7.66	14.22	13.07	35.70
	6	12.62	11.43	14.01	12.31	14.09	33.21	43.64	8.34	13.77	12.78	33.69
	7	12.12	10.33	14.29	11.31	10.58	16.21	23.55	8.82	14.76	11.62	17.74
	8	12.86	11.49	10.99	9.83	12.21	31.97	35.60	7.42	13.57	14.22	34.25
IV	1	20.00	12.00	39.00	4.00	3.00	1.00	8.00	1.21	0.31	0.66	0.22
	2	24.00	14.00	41.00	5.10	5.20	1.40	37.00	1.35	0.40	0.71	0.41
	3	22.00	12.00	37.00	5.90	1.00	1.00	10.00	1.30	0.38	0.76	0.22
	4	21.00	11.00	42.00	5.00	4.20	1.00	12.00	1.22	0.33	0.75	0.21
	5	25.00	14.00	36.00	5.40	5.00	0.80	2.00	1.34	0.45	0.69	0.18
	6	25.00	13.00	38.00	5.00	5.00	1.00	6.00	1.35	0.43	0.75	0.20
	7	24.00	13.00	35.00	5.00	5.50	1.60	8.00	1.33	0.50	0.75	0.37
	8	28.00	14.00	44.00	6.00	6.00	1.00	3.00	1.52	0.28	0.61	0.20
V	1	46.00	23.00	78.00	11.00	10.00	4.00	90.00	2.58	0.78	1.66	1.33
	2	55.00	29.00	95.00	11.20	10.00	3.80	90.00	2.31	0.88	1.70	1.01
	3	55.00	27.00	88.00	10.80	11.20	8.00	90.00	2.50	1.02	1.53	1.29
	4	58.00	29.00	96.00	11.50	11.30	5.00	90.00	2.66	0.81	1.44	1.12
	5	59.00	32.00	85.00	13.20	12.30	3.80	88.00	2.52	1.18	1.80	1.28
	6	51.00	25.00	82.00	12.00	10.00	4.00	86.00	2.53	1.10	1.66	1.20
	7	52.00	29.00	75.00	11.30	10.00	4.20	72.00	2.38	1.09	1.42	1.08
	8	59.00	28.00	83.00	11.00	13.00	5.00	81.00	2.61	0.96	1.83	1.25

Populations: 1 – Miłomłyn n = 27, 2 – Ruciane n = 31, 3 – Supraśl n = 30, 4 – Spała n = 30, 5 – Bolewice n = 45, 6 – Gubin n = 35, 7 – Rychtal n = 35, 8 – Janów Lubelski n = 24.

Geographic variability was determined using Bryant's test (Bryant 1977).

RESULTS

As shown by trait characteristics (Table 1), trait variability within the studied eight populations ranged between 7.42% and 43.64%. The cone setting angle proved to be the most variable trait in all populations, showing the highest variability coefficient. In the population from Gubin it reached value close to 44%. The lowest variability in all populations was noted for the ratio of cone length to cone width and the lowest value of variability coefficient (7.42%) was noted in the population from Janów Lubelski. Out of 55 (11 x 11) variability coefficients tested, the highest number or 45 (81.81%) significant correlation coefficients (both at 0.05 and 0.01 levels) were present in the population from Bolewice and the lowest number of significant correlation coefficients were observed in the population from Miłomłyn (35 or 63.63%). At $\alpha = 0.01$ level, the highest number of significant correlation coefficients (41 or 97.61% significant correlation coefficients) were detected in the population from Spała and the lowest number (31 or 81.57%) – in the population from Supraśl. In all populations, the most closely corre-

TABLE 2 Results of testing discriminant power of 11 traits of cones originating from eight *Pinus sylvestris* L. populations

No.	Traits	F statistics
1	Cone length (mm)	2.150**
2	Cone width (mm)	1.765*
3	Number of scales	2.838**
4	Scale length (mm)	2.534**
5	Scale width (mm)	2.391**
6	Scale thickness (mm)	3.894**
7	Cone setting angle	31.382**
8	Ratio of cone lenght to cone width	1.722*
9	Ratio of cone lenght to the number of scales	4.515**
10	Ratio of scale length to scale width	2.424**
11	Ratio of scale thickness to 1/2 scale width	2.534**

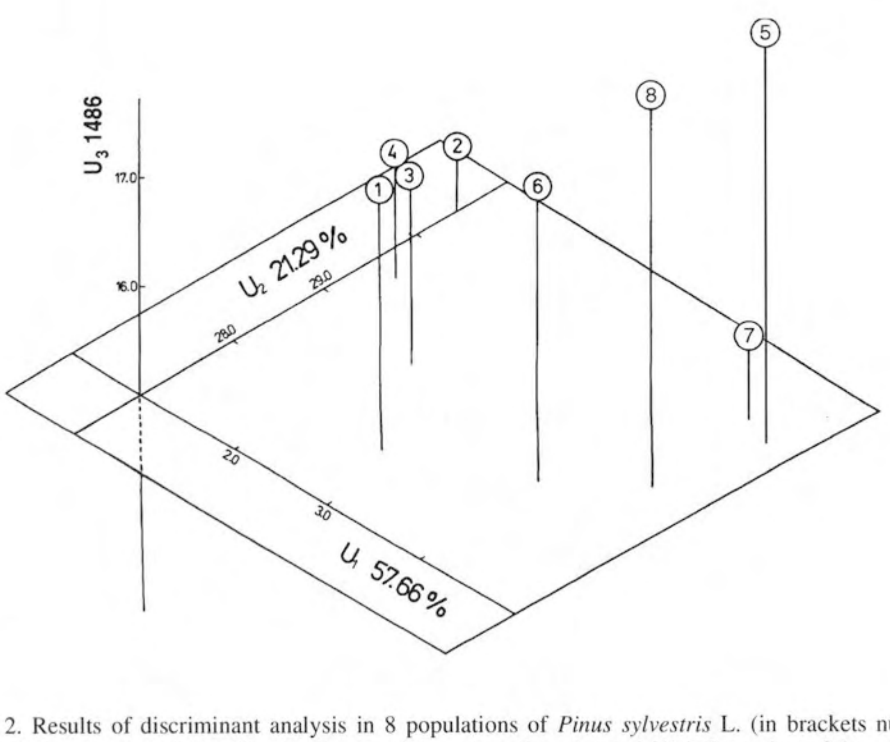
** principal variables, * associative variables

lated traits were: scale thickness and ratio of scale thickness to 1/2 scale width (traits 6 and 11), cone length and cone width (traits 1 and 2). Correlations coefficients for the traits 6 and 11 showed values ranging between 0.51 (population from Supraśl) and 0.93 (population from Janów Lubelski). Values for correlation coefficient of traits 1 and 2 ranged between 0.69 (population from Rychtal) to 0.82 (populations from Supraśl and Spała). Cone setting angle was the trait which was least correlated with the remaining traits. The number of significant correlations which the trait showed with the remaining traits ranged between 1 (in the population from Miłomłyn) to 7 (in the population from Spała) out of 10 correlations tested).

In studies on trait discriminant power (Caliński et al. 1974) all studied traits showed significant discriminant power ($F_{calc} > F_{0.05}$) Apart from cone width and the ratio of cone length to cone width, which were of the associative trait character, the remaining traits form a principal set of variables (Table 2). The exceptionally distinct value of F statistics in discriminating the studied pine populations was for cone setting angle.

Testing of hypothesis in multivariate analysis of variance (Caliński 1970, Caliński et al. 1976, Ceranka et al. 1976) indicated that only 4 out of 28 contrasts or comparisons of population pairs proved to be not significantly differentiated in respect to any of 11 cone traits ($F_{0.05} > F_{calc}$). This pertained the following contrasts: Ruciane – Supraśl, Supraśl – Spała, Bolewice – Janów Lubelski, Gubin – Janów Lubelski. The remaining 24 contrasts were significantly differentiated in respect to 10 traits of cones (except the contrast Supraśl – Gubin which was not differentiated in respect to cone width). The ratio of cone length to cone width did not differ significantly in any of the contrasts. Scale length and the ratio of scale length to scale width differed significantly each in one contrast only while scale width differed significantly in three contrasts.

The traits which did differ significantly in the highest number of contrasts included: cone setting angle which differed in 15 contrasts, the ratio of cone length to number of scales which differed in 11 contrasts and the ratio of scale length to scale width which differed in 10 contrasts. Peak values of statistics F (against the critical value of $F_{0.05}$ = 14.668 were shown by the contrasts: Ruciane – Bolewice, F_{calc} = 181.513, Ruciane – Gubin, F_{calc} = 176.607, Ruciane – Janów Lubelski, F_{calc} = 170.682, Ruciane – Rychtal, F_{calc} = 122.141, Spała – Bolewice, F_{calc} = 114.233 and Spała – Janów Lubelski, F_{calc} = 113.625, all in respect to cone setting angle. The other strongly differentiated contrasts included: Miłomłyn – Bolewice in respect to width and length of cones, Spała – Rychtal in respect to the ratio of cone length to the number of scales and the cone setting angle and Supraśl – Rychtal in respect to the ratio of cone length to the number of scales. The highest number, i.e. 7 traits differed significantly ($F_{calc} > F_{0.05}$) in the



1 – Miłomłyn (27)
2 – Ruciane (31)
3 – Supraśl (30)
4 – Spała (30)
5 – Bolewice (45)
6 – Gubin (35)
7 – Rychtal (35)
8 – Janów Lubelski (24)

Fig. 2. Results of discriminant analysis in 8 populations of *Pinus sylvestris* L. (in brackets number of studied trees) in the space of the first three discriminant variables U_1, U_2, U_3 containing altogether almost 94% information of the applied set of 11 cone traits.

contrast Supraśl – Bolewice while 6 traits differed significantly in the contrast Miłomłyn – Spała.

Graphically detected variability between the 8 populations was presented in the space of the first three discriminant variables U_1, U_2, U_3 (Fig. 2), calculated in discriminant analysis (Caliński and Kaczmarek 1973, Caliński etal. 1975, Krzyśko 1979, 1982). The variables containted altogether almost 94% information from the applied set of 11 cone traits and, therefore, the obtained populational variability pattern is highly reliable. In Fig. 2 high interpopulational variability was illustrated, particularly in respect to the third discriminant variable. In the variability, populations from Ruciane and Rychtal, from Bolewice and Janów Lubelski showed special character.

The studied populations formed two groups, as demonstrated in Fig. 3 presenting results of discriminant analysis on the plane of the first two discriminant variables. The first group included the populations: from Miłomłyn, Ruciane, Supraśl and the population from Spała. The other group included the remaining four south-western populations.

On the basis of determination coefficients between 11 cone traits and the first three discriminant variables, U_1, U_2, U_3 the variability pattern shown in Fig. 2 seemed to be determined first of all by the following traits: cone setting angle, ratio of scale thickness to scale width, ratio of cone length to the number of scales, cone width and cone length and the number of scales. The latter character plus cone length and cone width were mainly responsible for variability of studied populations in respect to the third discriminat variable. The minimum spanning tree, constructed on the basis of the shortest Mahalanobis distances (Caliński et al. 1975) and the Hotelling T^2 statistics is presented in Fig. 4. Comparison of the calculated values of Hotelling's statistics with the appropriate critical value indicated that none of the minimum spanning tree forming population pairs was significantly differentiated in the statistical sense ($T^2_{0.05} > T^2_{calc}$) in respect to the calculated Mahalanobis distances. The table of Mahalanobis distances (Table 3) indicated that, apart from the dendrite forming population pairs (Fig. 4), the following population pairs were insignificantly different ($T^2_{0.05} > T^2_{calc}$): Miłomłyn – Spała, Ruciane – Supraśl, Ruciane – Bolewice, Supraśl – Gubin, Bolewice – Gubin, Bolewice – Rychtal, Janów Lubelski – Miłomłyn, Janów Lubelski – Supraśl and Janów Lubelski – Rychtal. The remaining population pairs were significantly differentiated in respect to the applied 11 cone traits ($T^2_{calc} > T^2_{0.05}$) The greatest Mahalanobis distance of 3.95 linked the population from Ruciane with the population from Janów Lubelski. In respect to this criterion, the populations from Ruciane and Rychtal (3.87) and those from Ruciane and Bolewice (3.83) were also distant from each other.

The dendrogram constructed on grounds of agglomerative grouping by the method of closest neighbourhood using Eu-

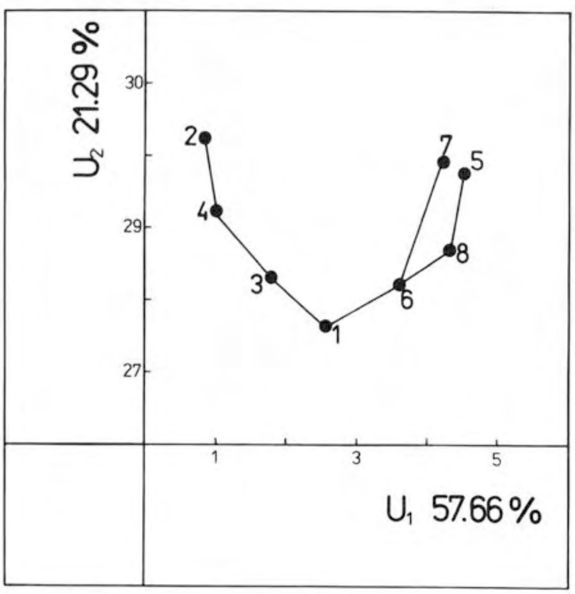


Fig. 3. Results of discriminant analysis in 8 populations of *Pinus sylvestris* L. (described in Fig. 1) on the plane of the first two discriminant variables U_1, U_2 (almost 79% information of the applied set of 11 cone traits) linked into the minimum spanning tree by the shortest Mahalanobis distances.

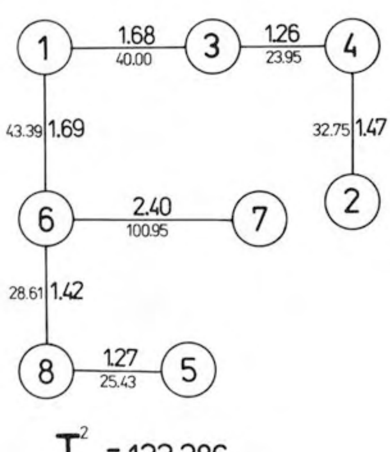


Fig. 4. Minimum spanning tree of 8 *Pinus sylvestris* L. populations (described in Fig. 1) constructed on the basis of the shortest Mahalanobis distances. Each distance of two populations is described additionally by Hotelling T^2 statistics (small numbers). $T^2_{0.05}$ denotes critical value of Hotelling T^2 statistics.

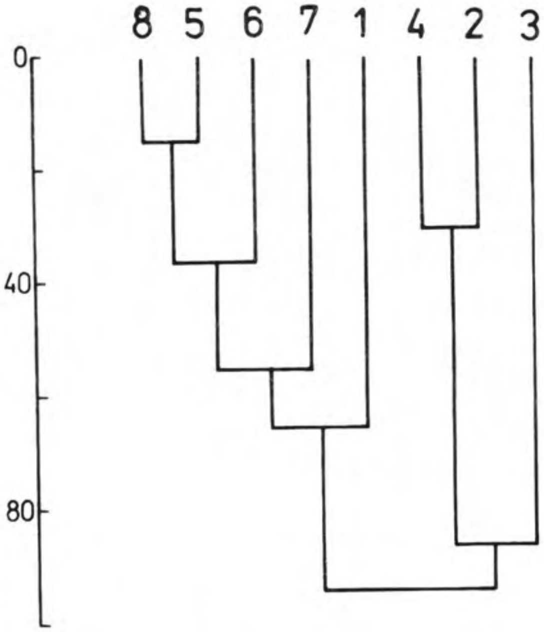


Fig. 5. Dendrogram of 8 *Pinus sylvestris* L. populations (described in Fig. 1) constructed on the basis of the shortest Euklidean distances.

klidean distances (Karoński and Caliński 1973) is presented in Fig. 5. The examined populations formed two groups: one including the populations from Janów Lubelski, Bolewice, Gubin, Rychtal and Miłomłyn and the other, including the remaining populations, i.e. those from Spała, Ruciane and, the relatively divergent from them, Supraśl.

In order to uncover geographic pattern of the detected variability, the calculated minimum spanning tree was projected onto a map of the eight populations loci (Fig. 6). The obtained pattern clearly stressed greater reciprocal similarity of populations from Miłomłyn (1), Supraśl (3), Spała (4) and Ruciane (2) than similarity of the populations to the remaining populations. The two population groups were linked to each other by the pines from Gubin (6).

The bryant's test (Bryant 1977) was used to uncover spatial (geographic) distribution of the studied populations. The isophen 0, drawn on the biotope map for the first discriminant variable (Fig. 7), separated the populations from Miłomłyn (1), Ruciane (2), Supraśl (3) and Spała (4) from the remaining ones. The isophen 0 drawn for the second discriminant variable (Fig. 8) included populations from Miłomłyn (1), Supraśl (3), Gubin (6) and Janów Lubelski (8) to one group and the remaining populations to the other.

DISCUSSION

Studies on interpopulational variability of *Pinus sylvestris* L. from the region of Poland based on the cone traits have been conducted, among other, by Sokołowski (1931), Zajączkowski (1949), Staszkiewicz (1961, 1968, 1970), Przybylski (1966), Bobowicz et al. (1983). In this study, results on testing the variability between eight Polish populations of *P. sylvestris* L. in respect to 11 traits of two-year old cones have been presented. The studies indicate that the populations remain significantly differentiated in the majority of contrasts and the populations most differentiated from the remaining ones include those from Ruciane and Rychtal. Such conclusion can be drawn, first of all, from results of multivariate analysis of variance. Extensive differentiation between pines from Ruciane and those from Rychtal can be observed in Table 3, which illustrates Mahalanobis distances between the eight populations. The distance between Ruciane and Rychtal populations is the second in length, following the distance between Ruciane and Janów Lubelski populations. High variability is noted also between Ruciane and Rychtal populations, particularly in respect to the third discriminant variable, U_3 (Fig. 2). Values of determination coefficients between the first three discriminant variables, U_1, U_2, U_3 and 11 cone traits indicate that the variability pattern illustrated for 8 populations in Fig. 2. is determined, among other, by the number of scales which

TABLE 3. Mahalanobis distances (D_{calc}) between 8 Polish populations of *Pinus sylvestris* calculated on the basis of 11 cone traits with Hotelling T^2 statistics (T^2_{calc}).
$T^2_{0.05}$ – critical value of Hotelling T^2 statistics. * - significant at the level of 0.05
$D_{calc} = 3.34^*$, $T^2_{calc} = 160.98$, $T^2_{0.05} = 122.386$

	1	2	3	4	5	6	7	8
1								
2	3.34* 160.98							
3	1.68 40.00	2.08 66.15						
4	2.58 94.57	1.47 32.75	1.26 23.95					
5	3.16* 168.79	3.83 26.97	3.17* 180.61	3.68* 243.22				
6	1.69 43.39	3.60* 212.78	2.02 65.65	3.02* 147.28	2.27 101.68			
7	3.20* 156.05	3.87* 245.78	3.18* 163.15	3.68* 218.59	2.48 120.69	2.40 100.95		
8	2.45 76.26	3.95 211.06	2.64 93.16	3.40* 154.56	1.27 25.43	1.42 28.61	2.56 93.56	

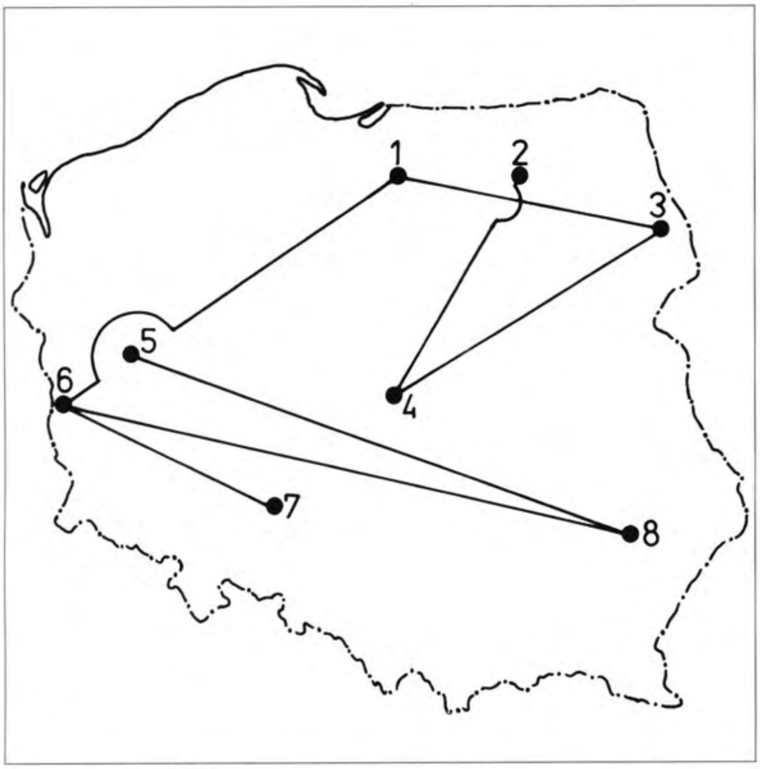


Fig. 6. Minimum spanning tree of 8 *Pinus sylvestris* L. populations constructed on the basis of the shortest Mahalanobis distances and projected onto a map of biotopes.

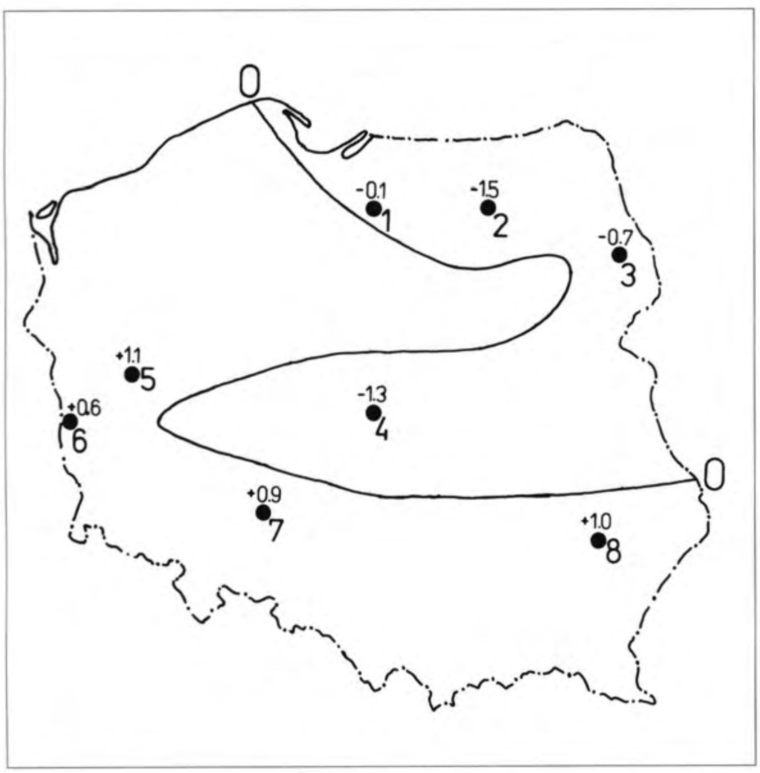


Fig. 7. Geographic variability of 8 *Pinus sylvestris* L. populations (described in Fig. 1) using Bryant's test (isophen 0) for the first discriminant variable.

dominates the third discriminant variable, U_3. Thus, the trait is responsible for the variability pattern observed in Fig. 2 for pines from Rychtal and those from Ruciane. In the grouping analysis (Fig. 5), Rychtal shares the group with Miłomłyn, Bolewice, Gubin and Janów Lubelski while Ruciane shares the group with Supraśl and Spała. With the exception of pines from Miłomłyn, the groups correspond with the geographic distribution illustrated in Fig. 7, obtained with the use of Bryant's test. Isophen 0 for the first discriminant variable, U_1, has separated pines from Miłomłyn, Ruciane, Supraśl and Spała from the remaining ones. Ruciane – Supraśl and Supraśl – Spała contrasts or population comparisons in multivariate analysis of variance as well as Bolewice – Janów Lubelski and Gubin – Janów Lubelski contrasts (the latter included in the second geographical group presented in Fig. 7) are the only population pairs which remain significantly undifferentiated in respect to any of the 11 applied cone traits. Since the isophen 0 links values derived from the second discriminant variable U_1, determination coefficients between the variable and the 11 cone traits permit to ascribe the detected population distribution to the trait of cone setting angle. In the first discriminant variable, containing almost 58% information

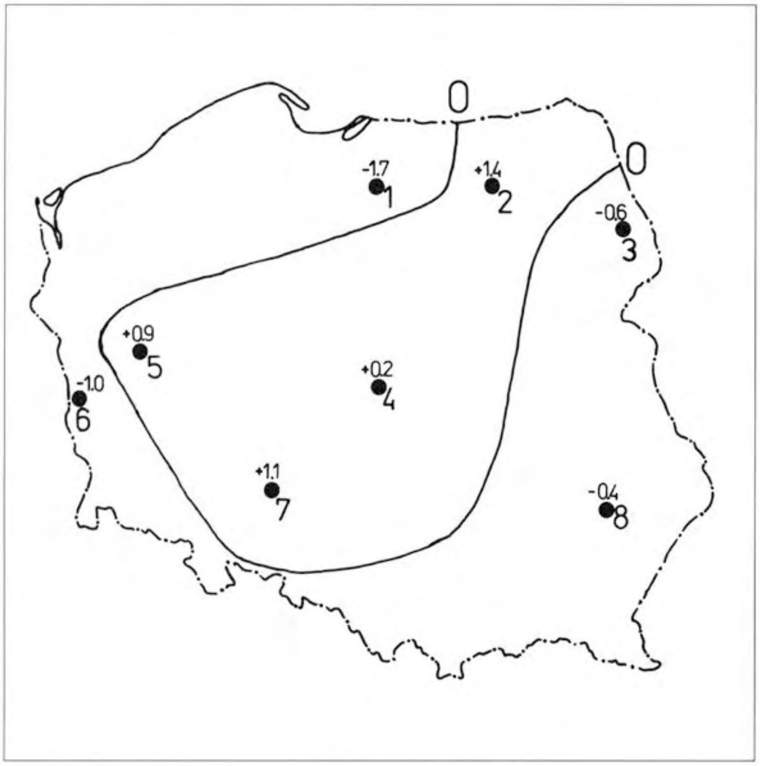


Fig. 8. Geographic variability of 8 *Pinus sylvestris* L. populations (described in Fig. 1) detected using the Bryant's test (isophen 0) for the second discriminant variable.

of the applied set of cone traits, the cone setting angle plays a dominant role. The geographical group presented in Fig. 8 reflects differences between populations in cone width and length. Isophen 0, which distinguishes the groups, has been shaped by values of the second discriminant variable (containing more than 21% of the applied set of 11 cone traits). Determination coefficients between the variable U_2, and the cone traits show that it is just the width and length of cones which are the main determinants of U_2, In the discussed distribution Ruciane and Rychtal share the geographical group with Spała and Bolewice, Miłomłyn, Supraśl, Gubin and Janów Lubelski form the other population group.

The cone setting angle represents the trait which differentiates the best the studied populations. It belongs to the set of 9 principal variables and is distinguished in the set by the very high value of statistics F (Table 2). Length of cone also belongs to the set of principal variables while cone width and the ratio of cone length to cone width form the set of associative variables. Length and width of cones are highly positively correlated with each other in all populations. Cone setting angle is the trait least correlated with the remaining cone traits. It is also the trait most variable of all (Table 1). Variability coefficients for cone length and width exhibit average values (10% –16%). On the other hand, the ratio of cone length to cone width is the least variable trait and the respective variability coefficients (7% to 10%) are the lowest in Table 1.

CONCLUSIONS

1. Using multivariate analysis of variance 28 population pairs have been contrasted in respect to a set of 10 cone traits. Twenty-four contrasts have proven significantly different ($F_{calc} > F_{0.05}$) in respect to the entire set of traits. Population contrasts: Ruciane – Supraśl, Supraśl – Spała, Bolewice – Janów Lubelski and Gubin – Janów Lubelski have been found insignificantly different. The following population pairs have been noted as divergent: Ruciane – Bolewice, Ruciane – Gubin, Ruciane – Janów Lubelski, Ruciane – Rychtal, Spała – Bolewice, Spała – Janów Lubelski, tested in respect to cone setting angle. Out of all the applied cone traits the latter trait significantly differentiates the highest number of contrasts. The ratio of cone length to cone thickness has not differentiated significantly any of the contrasts and, thus, has shown the character of an associative variable.
2. The calculated Mahalanobis distances allowed to note that 12 out of 28 realized links between the eight studied populations have proven significant ($T^2_{calc} > T^2_{0.05}$). In respect to this criterion the population pairs Ruciane – Janów Lubelski, Ruciane – Rychtal, Ruciane – Bolewice have proven most distant.
3. Grouping based upon Euklidean distances have provided evidence for existence of two groups among the studied populations. One group is formed by Janów Lubelski, Bolewice, Gubin, Rychtal and Miłomłyn while the other by populations from Spała, Ruciane and Supraśl.
4. Except of cone width and the ratio of cone length to cone width which show the character of the associative variable, the remaining traits form the principal set of variables in determining differentiation between populations. Cone setting angle plays the decisive role in this set.
5. Populations from Ruciane and Rychtal are the most divergent populations.
6. Populations from Miłomłyn, Ruciane, Supraśl and Spała form one geographical group in respect to the cone setting angle and the other group is formed by populations from Bolewice, Gubin, Rychtal and Janów Lubelski, as proven by Bryant's test. Cone width and cone length have also separated the populations into two groups: one is formed by populations from Ruciane, Spała, Bolewice and Rychtal and the other by populations from Miłomłyn, Supraśl, Gubin and Janów Lubelski.

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ZMIENNOŚĆ OŚMIU POLSKICH POPULACJI *PINUS SYLVESTRIS* L. WYRAŻONA ZA POMOCĄ CECH SZYSZEK

STRESZCZENIE

Z 257 rosnących drzew *Pinus sylvestris* L. reprezentujących osiem polskich populacji pozyskano dwuletnie szyszki, które opracowano pod względem 11 cech morfologicznych. Uzyskane dane poddano wielocechowym analizom statystycznym, za pomocą których starano się określić zmienność między populacjami. Przeprowadzono wielozmienną analizę wariancji wraz z testowaniem hipotez statystycznych, analizą zmiennych dyskryminacyjnych, obliczono odległości Mahalanobisa między każdymi dwoma populacjami i oceniono ich istotność za pomocą statystki T^2 Hotellinga. Na podstawie najkrótszych odległości Mahalanobisa zbudowano dendryt, a na podstawie odległości Euklidesa przeprowadzono grupowanie hierarchiczne. Stwierdzono, że większość populacji różni się statystycznie istotnie w porównaniach z pozostałymi. Najbardziej odrębną okazała się populacja z Rucianego. Kąt osadzenia szyszek jest cechą najlepiej różnicującą zbadane populacje. Dzięki testowi Bryant'a wykryto, że omawiane populacje tworzą dwie grupy geograficzne: północno-wschodnią oraz południowo-zachodnią.

SŁOWA KLUCZOWE: *Pinus sylvestris* L., populacje, szyszki, zmienność, analizy wielozmienne.