The variability of Scots pine from Piekielna Góra as expressed by morphological and anatomical traits of needles

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Abstract

Two-year old needles were collected from 30 standing Scots pine trees on Piekielna Góra. These needles were analysed in respect to 13 morphological and anatomical traits. The data so obtained was subjected to a whole range of multi-trait analytical methods in an attempt to determine the variability among the randomly chosen trees. Multivariate analysis of variance and canonical analysis were done as well as calculation of Mahalanobis distances between each pair of trees and their significance was tested by the Hotelling T^2 statistics. A minimum spanning tree was constructed on the basis of the shortest Mahalanobis distances, while a dendrogram (cluster analysis) was compiled on the basis of Euclidean distances. It was found that in spite of the fact that the studied population sample of pines did not form internal, significantly differentiated groups, the variability among particular trees was large and depended on the given trait. The number of resin canals best differentiated the studied trees, while the Marcet coefficient did not significantly differentiate any pair of trees.

Key words: Scots pine, variability, needles

INTRODUCTION

The populations of Scots pine found in submontane regions (Kłodzko Basin, Nowy Targ Basin) are characterized by significant differences between them and the populations from the remaining geographical regions of Poland. From among the former populations, the one from Piekielna Góra is noted for its exceptional variability (Bobowicz et al. 1983, Bobowicz 1984). The studies reported herein were aimed at determining the variability within a randomly chosen sample of 30 Scots pine trees from Piekielna Góra on the basis of the morphological and anatomical traits of their needles.

MATERIAL AND METHODS

The material used in these studies was collected from a population of *Pinus sylvestris* L. from Piekielna Góra in October, 1985 in accordance with the methodology of random sample collection. Piekielna Góra (500 m a.s.l.) lies between Polanica Zdrój and Duszniki Zdrój in the Kłodzko Basin (Wałbrzych Voivodship). Two-year old needles and cones and one-year old cones were collected from 30 standing Scots pines. This paper reports on the results of studies conducted on the two-year old needles. Thirty short shoots were randomly sampled from each tree.

The following morphological traits (1-5) and anatomical traits (6-13) were examined in each needle sample:

1. The number of stomal rows on the convex side of the needle.
2. The number of stomal rows on the flat side of the needle.
3. Stomal row quotient (ratio of trait 1 to 2).
4. Mean number of stomas in a 2 mm long section on the convex side of the needle.
5. Mean number of stomas in a 2 mm long section on the flat side of the needle.
6. Number of resin canals.
7. Thickness of epidermis on the flat side of the needle. in μm .
8. Mean width of 3 epidermis cells, in μm .
9. Crossection width of the needle, in μm .
10. Crossection height of needle, in μm .
11. Ratio of height to width of needle (ratio of trait 10 to 9).
12. Distance between vascular bundles, in μm .
13. Marcet coefficient (1967) = $\text{trait 9} \times \text{trait 12} / \text{trait 10}$

The manner of carrying out these measurements is presented, among others, in the papers by Szweykowski et al. (1976a, b).

The data obtained from the measurements of the needles were sent to the Computer Center of the Adam Mickiewicz University in Poznań, where the following were calculated:

1. The characteristics of the applied traits.
2. The correlation coefficients between the studied traits.
3. The discrimination power of the traits.
4. Multivariate analysis of variance.
5. Canonical analysis.
6. The Mahalanobis distances between trees along with the minimum spanning tree constructed on the basis of the shortest Mahalanobis distances and the Hotelling T^2 statistics.
7. Clustering using the nearest neighbor method.

RESULTS

The characteristics of the traits (Table 1) show that the variability of any traits at no time exceeded 21% or fell to below 3%. The most variable were Marcet's coefficient (13), 20.77% and the number of resin canals (6), 19.12%. The lowest variability was characteristic for (5) the mean number of stomas on a 2 mm long fragment of the flat side of the needle, 3.50%.

Table 1

The characteristics of 13 traits of needles collected from 30 Scots pine trees from Pickielna Góra

No.	$\bar{X}$	S	$S/\bar{X} \cdot 100\%$	Min	Max
1*	11.9544	0.9480	7.93	9.9667	14.1667
2	10.6044	1.1291	10.65	8.6333	13.0333
3	1.1415	0.0842	7.38	1.0040	1.3507
4	25.9626	1.0953	4.22	23.5067	27.8867
5	26.2523	0.9190	3.50	24.2767	28.5167
6	13.1167	2.5078	19.12	9.5667	17.7000
7	17.8815	0.9152	5.12	16.1077	19.9027
8	15.8541	0.8654	5.46	14.1553	17.8787
9	1.4348	0.0956	6.66	1.2185	1.6142
10	0.7227	0.0409	5.66	0.6395	0.7986
11	0.5043	0.0220	4.36	0.4633	0.5521
12	0.2187	0.0386	17.66	0.1309	0.2860
13	0.4354	0.0905	20.77	0.2639	0.5932

*The traits are listed in Material and Methods.

Means ($\bar{X}$), standard deviation (S), variability coefficients ($S/\bar{X} \cdot 100\%$), minimums (Min), maximums (Max).

The correlation coefficients between the 13 studied traits are presented in Table 2. Traits 12 and 13 were the most highly correlated (the distance between vascular bundles and the Marcet coefficient). The least correlated with the other traits were found to be traits: 6 (the number of resin canals), 7 (epidermis thickness on the flat side of the needle) and 5 (mean number of stomas on a 2 mm long section of the flat side of the needle).

Analysis of the discrimination power of the traits (Caliński et al. 1974) showed that all of the examined traits significantly differentiate the randomly chosen trees. The trait with the highest F statistics value and therefore with the highest discriminating power in respect to the trees was the number of resin canals (Table 3).

Comparison of the mean values of each of the 13 studied traits by pairing each tree with each of the remaining ones in multivariate analysis of variance

Table 2

Correlation coefficients among the 13 traits of needles from Scots pines on Piekielna Góra, defined in Material and Methods

1													
2	0.74**												
3	0.00	-0.66**											
4	0.20	0.42*	-0.43*										
5	0.24	0.31	-0.21	0.74**									
6	0.29	0.01	0.30	-0.24	-0.23								
7	-0.06	0.01	-0.07	0.05	-0.09	-0.22							
8	0.02	-0.20	0.31	-0.06	0.04	-0.04	0.47**						
9	0.51**	0.59	-0.30	0.02	0.10	0.08	0.23	0.30					
10	0.45	0.40*	-0.08	0.09	0.25	0.13	0.09	0.46*	0.77**				
11	-0.18	-0.39*	0.38*	0.08	0.18	0.06	-0.25	0.13	-0.56**	0.09			
12	0.37*	0.41*	-0.18	-0.22	-0.20	0.21	0.24	0.03	0.68**	0.35	-0.62**		
13	0.38*	0.47**	-0.26	-0.17	-0.20	0.20	0.26	-0.01	0.70**	0.29	-0.73**	0.98**	
	1	2	3	4	5	6	7	8	9	10	11	12	13

* Significant correlation at the level 0.05.

** Significant correlation at the level 0.01.

Table 3

The discrimination power (F statistics) of 13 traits of needles, determining the differentiation of 30 Scots pines from Pieklna Góra and the number of tree pairs (XX) significantly differentiated in respect to each of the 13 needle traits ($\alpha = 0.05$)

No.	F statistics	XX
A ₁	2.863*	3
2	3.407*	4
3	2.661*	12
4	9.931*	32
5	7.309*	42
6	107.053*	63
7	8.207*	78
8	6.127*	70
9	1.870*	66
10	7.435*	47
11	6.755*	13
12	1.094*	3
13	14.812*	0
F _{0.05} 1.481		

* Significant at the level of 0.05.

A — The traits are listed in Material and Methods.

(Ceranka et al. 1976) showed that at the level of 0.05, the greatest number of tree pairs were significantly differentiated by traits: 7 (thickness of the epidermis on the flat side of the needle) and 6 (number of resin canals). Only three pairs of trees were significantly differentiated by trait 1 (the number of stoma rows on the convex side of the needle) and 12 (distance between vascular bundles). In respect to the Marcet coefficient (trait 13), no pair of trees was significantly discriminated. The results of the multivariate analysis of variance are summed up in Table 3.

The variability between 30 Scots pine trees from Pieklna Góra discovered using graphics is presented on the scatter diagram of the canonical analysis (Sneath and Sokal 1974, Caliński et al. 1975, Krzyśko 1982). The relative positions of the 30 randomly chosen trees on the plane of the first two canonical variables is presented on Fig. 1. The selected population sample (called further on population) is not internally varied. The dispersion of the individual trees is small.

It can be stated on the basis of the correlation coefficients between the 13

Fig. 1. Results of canonical analysis of 30 Scots pines from Piekielna Góra on the plane of the first two canonical variables, V_1 , V_2 jointly providing 61.4% of the information obtained from the set of 13 needle traits

studied traits of the needles and the first three canonical variables (Table 4) that the following traits are primarily responsible for maintaining the picture of the variability of the 30 Scots pines from Piekielna Góra, shown on Fig. 1: number of resin canals (6), Marcet's coefficient (13), distance between vascular bundles (12), width (9) and height (10) of the cross-section of the needle.

The lack of internal variability of the studied population is supported by minimum spanning tree constructed on the basis of the shortest Mahalanobis distances (Caliński 1970, Caliński and Kaczmarek 1973) shown on Fig. 2. The comparison of the calculated Hotelling values with the critical value, $T^2_{0.05}$ allows the conclusion that there is not one significantly different distance in the minimum spanning tree in question ($T^2_{0.05} > T^2_{cal}$), therefore,

Table 4

The determination coefficients between the 13 traits of needles and the first two canonical variables V_1 , V_2

Traits	V_1 45.95%	V_2 15.19%
*1	0.0000	0.1466
2	0.7028	0.1324
3	0.5297	0.0028
4	0.3829	1.7087
5	0.3018	1.0841
6	20.3374	3.4888
7	0.3615	0.2050
8	0.0614	0.0597
9	1.7958	4.2506
10	0.5297	0.9364
11	0.9915	2.5107
12	0.2815	5.1523
13	0.6585	9.7234

* The traits are listed in Materials and Methods.

no pair of the trees forming the minimum spanning tree differs significantly in respect to the 13 studied needle traits.

The Mahalanobis distances were calculated for each pair of trees. For each such distance, the T^2 Hotelling statistic (data in the documentation of this study) was calculated. Comparison of the calculated T^2 Hotelling value and critical value $T^2_{0.05}$ showed which of the calculated Mahalanobis distances are significantly different ($T^2_{cal} > T^2_{0.05}$). Examination of the table of Mahalanobis distances shows that for the 435 connections made between the 30 Scots pines from Piekielna Góra, 101 (23.22%) were significantly different in the statistical sense. The greatest among these statistically significant Mahalanobis differences reached a value of $D_{cal} = 8.17$ between no. 24 and 26. Dendrogram (Fig. 3) drawn on the basis of clustering by the nearest neighbor method on Euclidean distances (Karoński and Caliński 1973) also show the lack of internal differentiation of the population. Tree no. 14 is characterized by a certain degree of distinctness. On the minimum spanning tree it is connected with tree no. 21 by the longest Mahalanobis distance $D_{cal} = 2.96$. However, as shown by comparison of the calculated (130.99) and critical (401.604) Hotelling values trees nos. 14 and 21 are not significantly differentiated.

Fig. 2. Minimum spanning tree of 30 Scots pines from Piekielna Góra constructed on the basis of Mahalanobis distances. Each such distance marking the connection of two trees in the minimum spanning tree is additionally described by the T^2 Hotelling statistics (*italics*). $T^2_{0,05}$ – critical value of Hotelling statistics

Fig. 3. Clustering by the nearest neighbor method (dendrogram) of 30 Scots pines from Piekielna Góra

DISCUSSION

Not many studies to date have focused on determining the internal structure of Scots pine populations (Staszkievicz and Tyszkiewicz 1969, 1972, Krzakowa et al. 1977, Prus-Głowacki 1982, Szweykowski and Urbaniak 1982, Bobowicz et al. 1983, Bobowicz 1984, 1990). As shown on the basis of the results obtained in this study, individual Scots pines in the population from Piekielna Góra are not significantly differentiated in respect to a whole set of morphological and anatomical traits of needles. The lack of internal differentiation is visible both from the picture of population variability emerging from canonical analysis (Fig. 1), of the minimum spanning tree (Fig. 2) and from the dendrogram (Fig. 3). The discriminating power of all the traits (Table 3) was found to be adequate to determine the differentiation of 30 trees. The decidedly outstanding trait in this respect, in the examined set was the number of resin canals (6). The variability of the traits was small and did not exceed 21%. Marcet's coefficient was the most variable, while the number of stomas on a 2 mm long fragment of the flat side of the needle, the least variable.

All of our previous analyses of the population on Piekielna Góra (Bobowicz, unpublished) have shown it to be distinctly different from the remaining Scots pine populations. This in conjunction with the current results showing it to be internally undifferentiated make it a population deserving further study.

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Zmienność sosny zwyczajnej z Piekielnej Góry wyrażona za pomocą cech morfologicznych i anatomicznych igieł

Streszczenie

Z 30 stojących drzew sosny zwyczajnej z Piekielnej Góry zebrano dwuletnie igły, które opracowano pod względem 13 cech morfologicznych i anatomicznych. Uzyskane dane poddano całemu kompleksowi metod wielocechowych, za pomocą którego starano się wykryć zmienność między wylosowanymi drzewami. Wykonano analizę wariancji, analizę zmiennych kanonicznych, obliczono odległości Mahalanobisa między każdymi dwoma drzewami i oceniono ich istotność za pomocą statystyki T^2 Hotellinga. Na podstawie najkrótszych odległości Mahalanobisa zbudowano dendryt, a na podstawie odległości Euklidesa przeprowadzono grupowanie hierarchiczne (dendrogram). Stwierdzono, że pomimo, iż zbadana próba populacyjna sosny nie tworzy wewnętrznych, istotnie zróżnicowanych grup, zmienność między poszczególnymi drzewami jest duża i zależy od danej cechy. Liczba kanałów żywicznych najlepiej różnicuje zbadane drzewa, podczas gdy wskaźnik Marcetá nie różni istotnie żadnej pary drzew.