INTRAPOPULATIONAL VARIABILITY OF *PINUS SYLVESTRIS* L. FROM PIEKIELNA GÓRA IN RESPECT TO CONE AND NEEDLE TRAITS

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ABSTRACT

From 37 Scots pine trees in Piekielna Góra the two-year old cones were collected and studied in respect to 14 morphological traits including the setting angle. One-year old cones from the same trees were examined in respect to their setting angle only. The data obtained for two-year old cones were subject to a whole range of multivariate analytical methods, to detect variability between randomly selected trees. Discriminant analysis was performed, Mahalanobis distances between each pair of trees were calculated and their significance was estimated using the Hotelling T^2 statistics. A minimum spanning tree was constructed on the basis of the shortest Mahalanobis distances while Euklidean distances served to perform cluster analysis. The randomly selected sample of Scots pine population did not show any internal, significantly differentiated groups and variability among the trees was low. Cone dimensions belonged to the most variable traits, but the ratio of cone length to cone width showed the lowest variability. The extensive similarity of the population to the other earlier examined populations of *Pinus sylvestris* L. from the Kłodzko District, and certain divergencies from the population are demonstrated.

KEY WORDS: Scots pine, variability, cones, needles

INTRODUCTION

Pinus sylvestris from Piekielna Góra has earlier provided grounds for interpopulational studies related to enzymatic variability (Prus-Głowacki and Szweykowski 1977, 1983, Krzakowa et al. 1984), serological variability (Prus-Głowacki and Szweykowski 1980, Prus-Głowacki et al. 1981), to variability of phenol compounds (Szweykowski and Urbaniak 1982), morphological variability of cones (Bobowicz et al. 1983), morphological and anatomical variability of needles (Bobowicz 1984) and of seed wings (Krzakowa et al. 1984). The internal variability of the population, examined in a randomly chosen sample of trees, has been described for morphological and anatomical traits of needles (Bobowicz and Radziejewska 1989). The present investigation provides the results of testing the same population sample of *Pinus sylvestris* from Piekielna Góra in respect to the traits of two-year old cones, the traits of needles and the traits of one-year old cones. Basing upon the results obtained in earlier studies (Bobowicz et al. 1983, Bobowicz and Radziejewska 1989) we attempted to demonstrate that the population in question, although it exhibits a variability more similar to that found in other populations of Scots pine in the Kłodzko District than to the one present in lowland pines, it also shows a marked divergence from the populations, indicated already by the interpopulational studies.

MATERIAL AND METHODS

In the population of *Pinus sylvestris*, growing on the top of Piekielna Góra (500 m above sea level) in the Kłodzko District, Wałbrzych voivodship (Fig. 1), 37 trees were randomly selected according to the methodology of random sampling. From the trees, 927 two-year old cones (7 to 30 cones per

Fig. 1. Geographical location of the investigated populations

- 1 - Scots pine from Piekielna Góra (Kłodzko District),
- 2 - Scots pine from Supraśl (Knyszyn Forest),
- 3 - *Pinus sylvestris* „subcarpatica” from Nowy Targ (Nowy Targ Valley),
- 4 - Scots pine from Bolewice (Wielkopolska),
- 5 - *Pinus mugo* from Hala Gąsienicowa (Tatra Mountains)

tree) and 407 one-year old cones were collected (4 to 30 one-year old cones per tree). The setting angle for one-year old cones was determined, as described earlier (Szweykowski and Bobowicz 1983, Bobowicz 1988, 1990a). Each of two-year old cones was measured in respect to 14 morphological traits (14-27), i.e.: (1-13 needle traits)

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 (traits 1/2).
4. Mean number of stomata in a 2 mm long section on the convex side of the needle.
5. Mean number of stomata 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. Cross-sectional width of needle, in μm .
10. Cross-sectional height of needle, in μm .
11. Height/width ratio of needle (traits 10/9).
12. Distance between vascular bundles, in μm .
13. Marcet coefficient (traits 9x12/10).
14. Closed cone length (cm).
15. Closed cone width (cm).
16. Distance between cone base and level of maximum cone diameter (cm).
17. Cone diameter measured at the top (cm).
18. Cone diameter measured in mid distance between its distal end and the level of maximum diameter (cm).
19. Number of cone scales.
20. Scale length (cm).
21. Scale width (cm).
22. Scale thickness (cm).
23. Angle between cone axis and cone stalk (setting angle).
24. Ratio of cone length to cone width (traits 14/15).
25. Ratio of cone length to the number of scales (traits 14/19).
26. Ratio of scale length to scale width (traits 20/21).
27. Ratio of scale length to scale thickness (traits 20/22).

The way the traits were measured was demonstrated in the paper of Bobowicz 1990b. The results of cone measurements were transmitted to the Computer Center, Adam Mickiewicz University to calculate: 1.) characteristics of the applied traits of two-year old cones, 2.) correlation coefficients between the traits, 3.) Student's *t* test, 4.) discriminant analysis, 5.) Mahalanobis distances between the trees and the minimum spanning tree, constructed on the basis of the shortest Mahalanobis distances and Hotelling T^2 statistics, 6.) agglomerative grouping by the nearest neighbourhood method on grounds of the shortest Euklidean distances. The analyses described in points 3. to 6. were conducted also for the joint set of 27 traits of needles (traits 1-13) and two-year old cones (traits 14-27), used to describe 30 randomly chosen trees from which the needles were collected. The results of testing variability in a population sample of 30 trees of Scots pine in respect to 13 morphological and anatomical traits of needles only were described earlier by Bobowicz and Radziejewska (1989).

The position of the pine population from Piekłna Góra was examined against *Pinus sylvestris* populations from Supraśl (Knyszyn Forest), Bolewice (Wielkopolska), Nowy Targ (Nowy Targ Valley), Lasówka (Bystrzyckie Mountains), Batorów (Stołowe Mountains) as well as *Pinus mugo* population from the Tatra Mountains. Similar studies performed earlier on these populations provided necessary data for such a comparison (Bobowicz 1990a).

RESULTS

Two-year old cone and needle traits – As indicated in Table 1, the variability in the set of the applied 14 cone traits ranged from 7.53% for the ratio of cone length to cone width to 35% for the cone setting angle. Both cone length and cone width as well as the two cone diameters belonged to the most variable traits. Scale thickness and the ratio of scale length to scale thickness fitted the range of significant variability.

TABLE 1. Means ($\bar{x}$), standard deviations (s), coefficients of variability ($s/\bar{x}$ 100%), min. and max. of 14 traits of Scots pine cones from Piekłna Góra

No. of trait	$\bar{X}$	S	$S/\bar{X} \cdot 100\%$	Min	Max
14*	3.81	1.08	28.28	2.59	5.60
15	1.99	0.53	26.78	1.35	2.80
16	3.15	0.88	27.91	2.01	4.54
17	0.36	0.10	26.38	0.12	1.33
18	1.54	0.23	14.99	0.33	2.65
19	60.17	6.78	11.27	38.00	80.00
20	0.75	0.09	11.75	0.53	1.06
21	0.81	0.10	12.21	0.55	1.11
22	0.25	0.07	28.55	0.11	0.55
23	27.26	9.55	35.01	1.00	50.00
24	1.92	0.14	7.53	1.53	2.30
25	0.06	0.01	12.07	0.04	0.09
26	0.93	0.11	12.36	0.63	1.30
27	3.20	0.91	28.29	1.27	6.55

* Explanation of traits in text.

Out of 105 tested correlations between 14 cone traits 65, i.e. close to 62% showed highly significant coefficients and other 8 (i.e. 7.7%) showed significant coefficients of correlation. Correlation coefficients above 0.95 were noted for such cone dimensions as cone length, cone width, and the level of maximum cone width. Scale length and scale thickness also remained very strongly correlated with each other. The correlation coefficient for these traits amounted to 0.86 and the correlation was negative.

The differentiation of the trees randomly selected for the studies was conducted using the Student's *t* test. The extent of differentiation was given in percents, separately for each needle trait. Since needle traits were also taken into account (for their list – see Bobowicz and Radziejewska 1989), the percentages pertain a total of 435 possible contrasts between 30 trees. The results of testing are listed in Table 2. As evident from the Table, the ratio of cone length to cone width differentiated the greatest number of means for the trees and among needle traits the same was true for the number of resin canals. The traits differentiating the studied trees very well included also the distance between vascular bundles, Marcet coefficient and cone length.

The result of the discriminant analysis (Sneath and Sokal 1973, Caliński et al. 1975, Krzyśko 1982) for 37 Scots pine trees, randomly selected from the population on the top of Piekłna Góra (further on called Piekłna Góra population) indicates that the population was not internally differentiated. The dispersion of the individual trees was small.

On the basis of determination coefficients between 14 cone traits and the two first discriminant variables U_1 , U_2 , we concluded that the obtained pine variability pattern is determined by the ratio of cone length to cone width and, to a much lower extent, by scale length, scale thickness and by the ratio of scale length to scale width.

TABLE 2. Fractions of significantly differentiated connections between 30 trees of *Pinus sylvestris* L. in respect to 27 needle and cone traits calculated by means of Student's *t* test

No. of needle trait	%	No. of cone trait	%
1*	40.00	14	68.74
2	52.18	15	63.91
3	28.97	16	66.67
4	47.82	17	42.76
5	37.24	18	63.45
6	75.40	19	45.29
7	42.99	20	64.60
8	40.69	21	66.44
9	66.90	22	56.55
10	64.83	23	48.74
11	60.46	24	84.14
12	71.26	25	64.37
13	71.04	26	64.60
		27	63.68

* Explanations of traits listed in Material and Methods

The results of discriminant analysis of the population of 30 trees in respect to the set of 27 needle and cone traits correspond with those obtained for the pattern of cone traits: the population sample was not internally differentiated, no tree groups were distinguished, the range of individual variability was narrow.

The analysis of determination coefficients between the two first discriminant variables U_1 , U_2 and 27 needle and cone traits showed that the pine variability was determined mainly by the ratio of cone length to cone width and by the number of resin canals.

The lack of internal variation within the population in question can be seen in the minimum spanning tree (Fig. 2) constructed on the basis of the shortest Mahalanobis distances (Caliński 1970, Caliński and Kaczmarek 1969, 1973). None of the Mahalanobis distances in the minimum spanning tree differed significantly ($T_{crit}^2 > T_{calc}^2$), i.e. none of the tree pairs forming the minimum spanning tree differed from each other in a significant manner in respect to the applied 14 cone traits.

Employing the tables of Mahalanobis distances, providing connections between any two trees out of 37 individuals randomly selected for the studies, and Hotelling T^2 statistics calculated for each connection (666 connections), 13 connections (1.95%) were found highly significantly differentiated in the statistical sense ($T_{calc}^2 > T_{0.01}^2$), 2 connections (0.3%) were found significantly differentiated ($T_{calc}^2 > T_{0.05}^2$). The distances showed similar values between $D_{calc} = 7.05$ and $D_{calc} = 8.66$.

In the minimum spanning tree, constructed on the basis of the shortest Mahalanobis distances for the needle and cone traits together, no significantly differentiated connection was observed ($T_{crit}^2 > T_{calc}^2$). The conclusion was also true for the entire table of Mahalanobis distances (435 connections) calculated on the basis of 27 traits of needles and cones.

The dendrogram (Fig. 3) – drawn on the basis of agglomerative grouping by the nearest neighbourhood method on Euclidean distances (Karoński and Caliński 1973) – indicated also the lack of internal variation within the population. The highest variation was demonstrated by trees no. 15, 20 and 21.

The conclusion on the lack of internal, differentiated groups of trees in the examined population held also for the dendrogram, constructed on the basis of 27 needle and cone traits jointly.

Fig. 2. Minimum spanning tree of 37 Scots pine trees from Piekielna Góra, constructed on the basis of Mahalanobis distances (cone traits).

Each distance, marking a connection between two trees in the minimum spanning tree, is additionally described by Hotelling T^2 statistics (italics). $T_{0.01}^2$ and $T_{0.05}^2$ – critical values of Hotelling statistics

One-year old cones – In the Piekielna Góra population, the setting angle of one-year old cones averaged between 139.9° and 191.5° . For the lowland pine (Bolevice) the same angle fitted the range between 110° to 240° . Histograms of the trait, both for the Piekielna Góra population and for the trees of a lowland population (Bolevice) are presented in Figure 4. In addition to the population from Bolevice, the histogram of the same trait is presenting setting angles of *Pinus mugo* Turra from the Tatra Mountains. As compared to the angles of cones in Bolevice, the angles of one-year old cone settings in Piekielna Góra are slightly lower.

DISCUSSION

The present study supplements the short list of publications on the internal structure of Polish Scots pine populations (Staszkiwicz 1958, 1961, Krzakowa et al. 1977, 1991, Krzakowa 1980, Prus-Głowacki 1982, Szwejkowski and Urbaniak 1982, Bobowicz et al. 1983, Bobowicz 1984, 1990b, Bobowicz and Korczyk 1990, Bobowicz and Radziejewska 1989). The obtained results permit to conclude that statistically significant differentiation of trees drawn at random from the pine

Fig. 3. Agglomerative clustering by the method of the nearest neighbourhood (dendrogram) of 37 Scots pine trees from Piekielna Góra (cone traits)

Fig. 4. Histogram of one-year old cone setting angle for *Pinus sylvestris* from Piekielna Góra as compared to respective histograms for *Pinus sylvestris* from Bolewice and for *Pinus mugo* Turra from the Tatra Mountains

population inhabiting the top of Piekielna Góra is very low. The table of Mahalanobis distances, listing connections between each pair of trees, indicates that only 2% of the connections remain significantly different in respect to all of the applied two-year old cone traits. The variation is much lower than the one noted in needle traits (Bobowicz and Radziejewska 1989) where more than 23% of individuals differed significantly from each other in the statistical sense. The lack of internal variation within the population is noticeable in the variability patterns resulting from the discriminant analysis, from the minimum spanning tree (Fig. 2) and from agglomerative grouping (Fig. 3). The ratio of cone length to cone width differentiates the greatest number of trees (more than 84% connections). The variability of traits remains at the average level, never exceeding 36%. The cone setting angle appears to be the most variable character while the ratio of cone length to cone width is the most stable character. The analysis performed for the joint set of 27 needle and cone traits confirmed the conclusion, formulated earlier for individual groups of traits, on the uniform character of the population and lack of internal variation. The value of the setting angle of one-year old cone fits the range for standard lowland populations (Fig. 4). However, the setting angles of one-year-old cones from Piekielna Góra are somewhat lower in comparison with those from the population of Bolewice (Fig. 4). The setting angle of two-year-old cones and the Marcet coefficient are the most variable traits among the applied traits of needles and cones while the number of resin canals carries the highest discriminant power. In some trees from Piekielna Góra the setting angle of two-year old cones is shifted toward lower values, found earlier as typical of *Pinus mugo* (Bobowicz 1988). In respect to the trait, the pines from Piekielna Góra resemble the pines of the „subcarpatica” variety from Nowy Targ Valley, the pines from Lasówka (Bystrzyckie Mountains) and from Batorów (Stołowe Mountains) in Kłodzko District (Bobowicz 1990a). The relations are similar in the case of Marcet coefficient, however, the population most similar in the trait as well as in the number of resin canals to the population from Piekielna Góra is the pine population from the top of Szczeliniec Wielki (Stołowe Mountains) (Bobowicz 1988). The shift in the setting angle value of two-year

old cone toward values lower than recorded in lowland populations is evident in the scatter diagram of one-year and two-year old cone setting angles (Fig. 5). In the Piekielna Góra population some trees can be seen in which two-year old cones in respect to their setting angle, are markedly shifted toward the „subcarpatica” population. When pine trees from Supraśl (Bobowicz and Korczyk 1990) are introduced to the diagram for the number of resin canals and for the Marcet coefficient the shift of the Piekielna Góra population of lower values is manifested even better (Fig. 6).

In summary, it can be stated that in the uniform and invariable population of Scots pine from the top of Piekielna Góra

there are two-year old needles which are more variable than the two-year old cones. The population resembles in variability other pine populations examined in the Kłodzko District and the „subcarpatica” population from Nowy Targ Valley. The Piekielna Góra population, similarly to the above populations, includes the trees for which the values of some individual traits are lower than the values characteristic of lowland pines.

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Fig. 5. Scatter diagram for 37 *Pinus sylvestris* trees from Piekielna Góra for setting angles for one-year-old and two-year-old cones as compared to the lowland population of *Pinus sylvestris* from Bolewice, *Pinus sylvestris* „subcarpatica” from Kotlina Nowotarska and *Pinus mugo* from the Tatra Mountains

Fig. 6. Scatter diagram for 30 trees of *Pinus sylvestris* from Piekielna Góra in respect to the setting angle of two-year old cones and in respect to Marcet coefficient against the populations of *Pinus sylvestris* from Supraśl (Knyszyn Forest) and *Pinus mugo* from the Tatra Mountains

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WEWNĄTRZPOPULACYJNA ZMIENNOŚĆ *PINUS SYLVESTRIS* L. Z PIEKIELNEJ GÓRY
POD WZGLĘDEM CECH SZYSZEK I IGIEŁ

STRESZCZENIE

Z 37 drzew sosny zwyczajnej z Piekielnej Góry pozyskano dwuletnie szyszki, które opracowano pod względem 14 cech morfologicznych, w tym pod względem kąta osadzenia szyszki oraz szyszki jednoroczne, którym zmierzono tylko kąt osadzenia. Dane biometryczne o szyszkach dwuletnich, a także połączone dane dla igieł i szyszek, poddano kompleksowej analizie z zastosowaniem wielozmiennych metod statystycznych, za pomocą których starano się wykryć zmienność między wylosowanymi drzewami. Wykonano analizę zmiennych dyskryminacyjnych, obliczono odległości Mahalanobisa między każdymi dwoma drzewami i oceniono ich istotność za pomocą statystyki T^2 Hotellinga. Na bazie najkrótszych odległości Mahalanobisa zbudowano dendryt, a na podstawie odległości Euklidesa przeprowadzono grupowanie hierarchiczne. Stwierdzono, że wylosowana próba populacyjna sosny nie tworzy wewnętrznych, istotnie zróżnicowanych grup, a zmienność drzew jest mała. Wymiary szyszek należą do cech najbardziej zmiennych, ale stosunek długości do grubości szyszki jest cechą o najmniejszej zmienności. Potwierdzono wnioski już wynikami wcześniejszych prac duże podobieństwo, ale i pewną odrębność tej populacji względem innych zbadanych populacji *Pinus sylvestris* L. z Ziemi Kłodzkiej.

SŁOWA KLUCZOWE: sosna zwyczajna, zmienność, szyszki, igły