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Morphological differences between *Pinus mugo* Turra populations from the Tatra Mts. revealed by cone traits

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Abstract

Two-year-old cones were collected from 388 dwarf mountain pine (*Pinus mugo* Turra) plants of ten populations of this species from the Tatra Mts. — five of them from calcareous and five from calcium-free undersoil. Their 14 morphological traits are described. The data served for performing multivariate analysis of variance and testing of statistical hypotheses, for discriminant analysis, for calculating Mahalanobis distances between populations and plotting a dendrite based on the shortest Mahalanobis distances and for agglomerative clustering by the method of nearest neighbourhood. Wide differences in the populations were found as regards all the studied traits and the existence of two groups in the population, which, do not, however, correlate with the substrate type. The "calcareous and calcium-free" populations show statistically significant differences in six of the 14 studied traits.

Key words: dwarf mountain pine, cones variability

INTRODUCTION

Pinus mugo Turra (sensu Rothmaler 1963, Gaussen et al. 1964) extends its range mainly in the mountains of central Europe and the Balkan peninsula, where it usually appears above the timber line in the subalpine and alpine ranges, and only sometimes descends into the forest zone. It also grows on wet alpine and subalpine peatbogs (Gostyńska-Jakuszewska and Zieliński 1976). For the flora of Poland it is a typical representative of subalpine vegetation. It is found in the Sudety and Tatra Mountains, forming what is known as the dwarf mountain pine layer spreading in the Tatra Mts. from 1550 to 1800 m a.s.l. (Pawłowski 1972).

The anatomical variability of the *Pinus mugo* needles in the Tatra Mts. and on other sites of this species in Poland has been described by Szweykowski (1969). The morphological traits of cones, beside those of needles, served for establishing the variability of an artificially planted *Pinus mugo* Turra population from the Baltic coast dunes in Białogóra (Szweykowski et al. 1976b, Bobowicz et al. 1983b) and also for studying an isolated natural population of this species from Borowina in the Izerskie Mts. (Szweykowski et al. 1976a, Bobowicz et al. 1983a). The intermediate character as regards needles and cones, of the monocormic isolated population of the dwarf mountain pine (*Pinus mugo* Turra) as compared with the pure populations of this species in the Tatra Mts. is presented in the paper by Szweykowski and Bobowicz (1977). The characters of needles and cones of individuals of this species from nine Tatra Mts. populations served, beside the same characters of individuals of Scots pine (*Pinus sylvestris* L.) and the pine from Bór na Czerwonem for investigation of the canonical correlations between these two groups of characters (Krzyśko et al. 1980).

In the present study the variability of the dwarf mountain pine *P. mugo* Turra) from the Tatra Mts. was investigated on the basis of the morphological traits of cones as well as the eventual correlation between the type of undersoil on which the given population grows and the differences between the populations.

MATERIAL AND METHODS

The material for investigation consisted of cone samples collected in the autumn in 1975 and 1976 from ten stands in the Tatra Mts. (Table 1). Populations on stands 1-5 grow on a calcareous and those from stands 6-10 on calcium-free habitats. The situaton of the stands is shows in Fig. $1a_1$.

A total of 388 individuals of dwarf mountain pine were examined (4292 cones). Each cone was examined for the following 14 characters:

1. length of closed cone, cm,
2. width of closed cone, cm,
3. distance of maximal width from cone apex, cm,
4. diametre of cone apex, cm,
5. diametre at mid length between cone apex and maximal width, cm,
6. number of scales in cone,
7. length of scale, cm,
8. width of scale, cm,

9. thickness of scale, cm,
10. angle between cone axis and axis of cone stalk (for details see Szweykokowski et al. 1976a, b).
11. ratio of traits 1 and 2,
12. ratio of traits 1 and 6,
13. ratio of traits 7 and 8,
14. ratio of traits 7 and 9.

The data obtained in the measurements were transmitted to the Computer Centre of the Agricultural University in Poznań for calculation of:

1. the characteristics of 14 traits of cones for each population and jointly for populations (1-5) and (6-10),
2. multivariate analysis of variance with testing of statistical hypotheses,
3. discriminant analysis,
4. Mahalanobis distances together with minimum spanning tree constructed on the basis of the shortest Mahalanobis distances,
5. agglomerative clustering by the method of nearest neighbourhood.

RESULTS

The characteristics of the examined traits are listed in Table 2. The following traits exhibit the widest amplitude for the whole material: 12 (ratio of cone length to number of scales), 9 (length of scale) and 14 (ratio of scale length to its thickness. The amplitude is smallest for the traits: 8 (width of scale), 3 (position of maximal width) and 2 (greatest width of cone). Most variable is trait 10 (angle between cone axis and that of cone stalk) and least variable trait 2 (maximal width of cone).

In tests of the general hypothesis in **multivariate analysis of variance** (Caliński 1970, Caliński et al. 1976, Ceranka et al. 1976) it appears that, as regards the 14 traits treated jointly, the examined populations differ significantly in the statistical sense ($F_{cal.} = 15.095 > F_{0.05} = 1.211$). The result of analysis of the differences between the populations separately for each of the studied 14 traits is shown in Table 3A. As seen, the means for populations differ significantly for each of the 14 traits separately ($F_{0.05}$ always smaller than $F_{cal.}$). The significance of differences was also tested for the "calcareous" populations (formed of populations from a calcareous habitat 1+2+3+4+5) and from "calcium-free" habitat population (6+7+8+9+10). It demonstrated that these groups differ significantly in six of the 14 examined traits (Table 3B). Significant differences occur in cone length (trait 1), cone shape (4, 5), dimensions of scale (8, 9) and ratio of cone length to number of scales (trait 12).

The result of **discriminant analysis** gives a graphic picture of interpopulational variability of the dwarf mountain pine in cone traits (Caliński and

Table 1

List of localities with *Pinus mugo* Turra from the Tatra Mts., from which material was collected for investigation. The number of plants and of cones taken from each population is given

No.	Locality	Altitude a.s.l.,m	No. of plants	No. of cones
1	Kopa Magury	1704	47	665
2	Giewont	1909	36	437
3	Sarnia Skała	1377	32	276
4	Kominy Tylkowe	1550	35	454
5	Kobylarz	1700	27	232
6	Hala Gąsienicowa	1500	74	1002
7	Hala Goryczkowa	1500	30	224
8	Morskie Oko	1393	36	451
9	Wyżni Toporowy Staw	1300	37	307
10	Ornak	1600	34	248

Table 3

Statistics $F_{calc.}$ values ($\alpha = 0.05$) in comparison of ten *Pinus mugo* Turra populations from the Tatra Mts. in reference to 14 traits of cones (A) and F statistics value in comparison of two populations: one from calcareous undersoil (populations 1+2+3+4+5) and "calcium-free" populations growing on granite habitats (6+7+8+ +9+10) (B)

Traits	A		B	
	$F_{calc.}$	$F_{0.05}$	$F_{calc.}$	$F_{0.05}$
1	15.045*	2.786	9.152*	8.595
2	11.293*	2.786	4.150	8.595
3	23.158*	2.786	3.220	8.595
4	39.389*	2.786	18.112*	8.595
5	32.148*	2.786	12.621*	8.595
6	5.785*	2.786	0.014	8.595
7	30.028*	2.786	6.599	8.595
8	22.212*	2.786	13.039*	8.595
9	15.246*	2.786	13.367*	8.595
10	6.553*	2.786	0.242	8.595
11	3.431*	2.786	5.246	8.595
12	7.680*	2.786	14.224*	8.595
13	13.432*	2.786	0.151	8.595
14	10.245*	2.786	1.843	8.595

* Value significant at $\alpha = 0.05$ level.

Kaczmarek 1973, Sneath and Sokal 1973, Caliński et al. 1975, Krzyśko 1982, Fig. 1b) within the space of the three first discriminant variables U_1, U_2, U_3 (they supply together 85.64 per cent of information from

Table 2

Arithmetical means (m), standard deviations (s.d.) and correlation coefficients (c.var.) for 14 traits of cones in ten *Pinus mugo* Turra populations from the Tatra Mts.

B \ A	1			2			3			4			5			6			7		
	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %
1	3.11	0.54	17.35	1.92	0.26	13.74	2.14	0.39	18.29	0.59	0.11	18.68	1.26	0.17	13.40	75.43	10.64	14.10	0.70	0.10	14.03
2	2.88	0.34	11.70	1.79	0.17	9.48	2.00	0.25	12.64	0.48	0.04	8.11	1.24	0.11	8.89	71.35	7.90	11.08	0.54	0.08	14.35
3	2.75	0.51	18.64	1.80	0.19	10.38	1.97	0.35	17.92	0.46	0.06	13.74	1.15	0.12	10.85	79.99	10.97	13.71	0.55	0.10	18.18
4	2.80	0.43	15.36	1.79	0.18	10.10	2.00	0.32	15.99	0.47	0.05	11.52	1.15	0.13	10.97	79.26	8.11	10.23	0.55	0.09	16.06
5	3.43	0.49	14.13	2.01	0.21	10.43	2.69	0.39	14.50	0.53	0.06	11.28	1.51	0.20	13.40	74.24	5.64	7.60	0.65	0.05	8.28
1—5	2.99		15.43	1.86		10.82	2.14		15.86	0.51		12.66	1.25		11.50	75.98		11.34	0.60		14.18
6	3.36	0.43	12.78	2.01	0.21	10.24	2.18	0.27	12.52	0.68	0.14	20.00	1.35	0.15	11.43	79.42	8.93	11.24	0.69	0.09	12.34
7	2.57	0.43	16.74	1.70	0.23	13.79	1.79	0.27	14.80	0.49	0.07	14.92	1.13	0.15	13.59	71.60	7.38	10.31	0.51	0.09	17.45
8	3.03	0.38	12.52	1.80	0.15	8.56	2.14	0.26	12.13	0.47	0.03	7.30	1.17	0.13	10.99	73.56	10.06	13.67	0.60	0.07	11.86
9	3.19	0.42	13.20	1.89	0.26	13.67	2.37	0.33	13.76	0.47	0.06	11.82	1.36	0.21	15.60	78.46	9.09	11.59	0.60	0.06	10.18
10	3.21	0.37	11.44	2.02	0.15	7.61	2.54	0.35	13.63	0.56	0.07	13.15	1.58	0.20	12.83	72.95	4.64	6.35	0.67	0.05	8.18
6—10	3.14		13.33	1.91		10.77	2.21		13.36	0.56		13.43	1.35		12.88	76.09		10.63	0.63		12.00

B \ A	8			9			10			11				12			13				14	
	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %	m	m	s.d.	c.var. %	m	s.d.	c.var. %	m	s.d.	c.var. %
1	0.63	0.08	12.72	0.21	0.03	13.55	8.82	3.59	40.74	1.63	0.19	11.64	0.04	0.04	0.01	21.31	1.11	0.11	10.18	3.35	0.47	[illegible]
2	0.54	0.05	10.17	0.20	0.02	12.51	7.22	2.31	32.03	1.60	0.14	8.47	0.03	0.03	0.01	17.57	1.00	0.12	11.59	2.79	0.54	19.47
3	0.53	0.08	14.99	0.16	0.02	14.84	8.43	2.61	30.97	1.53	0.19	12.26	0.04	0.04	0.01	19.16	1.05	0.17	16.59	3.53	0.84	23.81
4	0.52	0.08	15.03	0.18	0.03	15.81	7.53	2.41	31.99	1.56	0.17	10.83	0.04	0.04	0.01	18.33	1.06	0.10	9.60	3.20	0.66	20.49
5	0.58	0.06	11.05	0.21	0.05	23.77	5.85	2.65	45.29	1.70	0.17	9.94	0.04	0.04	0.01	17.95	1.16	0.13	10.92	3.20	0.63	19.74
1—5	0.57		12.79	0.19		16.09	7.73		36.20	1.60		10.62	0.04	0.04		18.86	1.07		11.77	3.21		19.51
6	0.67	0.08	11.96	0.23	0.05	20.24	8.35	3.07	36.77	1.68	0.14	8.25	0.04	0.04	0.01	16.98	1.04	0.11	10.95	3.12	0.52	16.82
7	0.56	0.08	14.91	0.21	0.04	18.43	6.68	2.56	38.41	1.55	0.14	9.11	0.04	0.04	0.01	14.46	0.91	0.14	15.02	2.52	0.44	17.43
8	0.58	0.08	13.65	0.18	0.03	18.23	7.74	2.54	32.84	1.69	0.18	10.81	0.04	0.04	0.01	14.33	1.05	0.13	12.30	3.45	0.64	18.60
9	0.53	0.07	13.57	0.19	0.02	10.98	8.57	2.81	32.84	1.81	0.16	42.43	0.03	0.03	0.01	20.16	1.15	0.14	12.42	3.13	0.36	11.41
10	0.57	0.06	10.22	0.20	0.01	7.03	5.35	2.11	39.38	1.58	0.12	7.49	0.04	0.04	0.01	17.71	1.18	0.11	9.49	3.35	0.30	8.87
6—10	0.60		12.86	0.21		14.98	7.56		36.04	1.67		15.61	0.04	0.04		16.72	1.07		12.03	3.12		14.62

A — traits, B — populations: 1 — Kopa Magury, 2 — Giewont, 3 — Sarnia Skała, 4 — Kominy Tylkowe, 5 — Kobylarz, 6 — Hala Gąsienicowa, 7 — Hala Goryczkowa, 8 — Morskie Oko, 9 — Wyżni Toporowy Staw, 10 — Ornak, 1—5 "calcareous" populations (1+2+3+4+5), 6—10 "calcium-free" populations (6+7+8+9+10).

the set of 14 traits used). It is seen in the diagram that similarity is greater between populations 3, 4, 8 (first group), 6, 7, 1 (second group) and 2, 9, 5, 10 (third group).

It may be concluded, on the basis of correlation coefficients between the traits and the discriminant variables (included in Table 4) that it is

Tabela 4

Correlation coefficients between 14 traits of cones and the three first discriminant variables (U_1, U_2, U_3) for ten *Pinus mugo* Turra populations from the Tatra Mts.

Traits	U_1 54.34%	U_2 23.73%	U_3 7.57%
1	6.738	9.967	−1.363
2	6.140	9.373	−1.824
3	19.345	6.194	−2.839
4	−6.575	19.767	−0.280
5	21.410	10.726	−1.438
6	4.836	1.637	−2.415
7	3.641	16.777	−2.816
8	−8.205	14.048	0.068
9	−1.032	11.082	2.597
10	−8.151	1.495	−0.182
11	2.445	1.685	0.273
12	−5.162	3.251	−1.840
13	13.150	3.607	−3.437
14	1.087	1.234	−5.117

mainly the traits describing the shape of the cone that decide of this picture of variability (5, 3 for U_1, 4, 5, 1, 2 for U_2) and the traits of the cone scales (7, 8, 9 for U_2) as well as traits describing the ratio of the cone scale traits (i.e. traits 13 for U_1 and 13 and 14 for U_3).

The minimum spanning tree constructed on the basis of the shortest **Mahalnobis distances** (Caliński et al. 1975) is shown in Fig. 1c. It is seen from the critical values of the Mahalanobis distances (Caliński and Kaczmarek 1969, Table 5) that, populations 3 (from Sarnia Skała) and 4 (from Kominy Tylkowe) excepted, the remaining ones exhibit significant differences.

Agglomerative clustering by the method of nearest neighbourhood (Karoński and Caliński 1973, Fig. 1d) disclosed two groups among the studied populations differing somewhat in the altitude a.s.l. of their appearance. The first comprises populations nos: 7, 2, 8, 1, 10 and 5 and the second populations: 9, 6, 3, and 4. In the first group two subgroups may be distinguished: one with populations 7 and 2 and the second comprising populations 8, 1, 10 and 5. None of the divisions into groups is correlated with the type of habitat on which the given population grows.

Table 5

Mahalanobis distances calculated between 10 *Pinus mugo* Turra populations on the basis of 14 cone traits ($D_{calc.}$) and critical values for all these distances ($D_{0.05}$)

2	2.727 **1.1065**								
3	3.150 **1.1445**	3.197 **1.2132**							
4	2.749 **1.1149**	2.482 **1.1840**	0.993 **1.2211**						
5	4.009 **1.2058**	3.333 **1.2713**	4.919 **1.3049**	4.285 **1.2790**					
6	2.058 **0.9316**	3.440 **1.0147**	3.200 **1.0565**	2.984 **1.0244**	4.809 **1.1227**				
7	3.209 **1.1668**	2.375 **1.2343**	2.346 **1.2690**	1.886 **1.2424**	4.697 **1.3247**	3.030 **1.0808**			
8	2.688 **1.1065**	2.437 **1.1770**	1.614 **1.2132**	1.375 **1.1840**	4.095 **1.2713**	2.841 **1.0147**	2.082 **1.2343**		
9	3.181 **1.0975**	2.211 **1.1690**	3.758 **1.2055**	3.130 **1.1774**	2.401 **1.2643**	4.151 **1.0054**	3.778 **1.2268**	3.204 **1.1690**	
10	4.075 **1.1242**	3.702 **1.1438**	5.196 **1.2299**	4.631 **1.2024**	1.490 **1.2867**	4.987 **1.0346**	5.045 **1.2508**	4.640 **1.1438**	2.737 **1.1863**
	1	2	3	4	5	6	7	8	9

2.727 $D_{calc.}$
1.1065 $D_{0.05}$

DISCUSSION

The results of the present investigations indicate that *Pinus mugo* Turra populations from the Tatra Mts. differ significantly in all the 14 traits of cones examined. Only two among the 10 studied populations did not differ from one another in the statistical sense ($D_{calc.} = 0.993 < D_{0.05} = 1.221$), the population from Sarnia Skała, namely, and that from Kominy Tylkowe. The populations from Sarnia Skała and Ornak differ most widely according to the Mahalanobis distances ($D_{calc.} = 5.196$), from Hala Goryczkowa and Ornak ($D_{calc.} = 5.045$), from Hala Gąsienicowa and Ornak ($D_{calc.} = 4.987$), from Sarnia Skała and Kobylarz ($D_{calc.} = 4.919$) and from Kobylarz and Hala Gąsienicowa ($D_{calc.} = 4.809$). The traits which mainly decide of the obtained picture of variability and differences between *Pinus mugo* Turra from the Tatra Mts. are those describing the dimentions and shape of the cones and those connected with the dimensions of the cone scales. Among the traits of shape, of highest significance is the cone diametre measured at mid

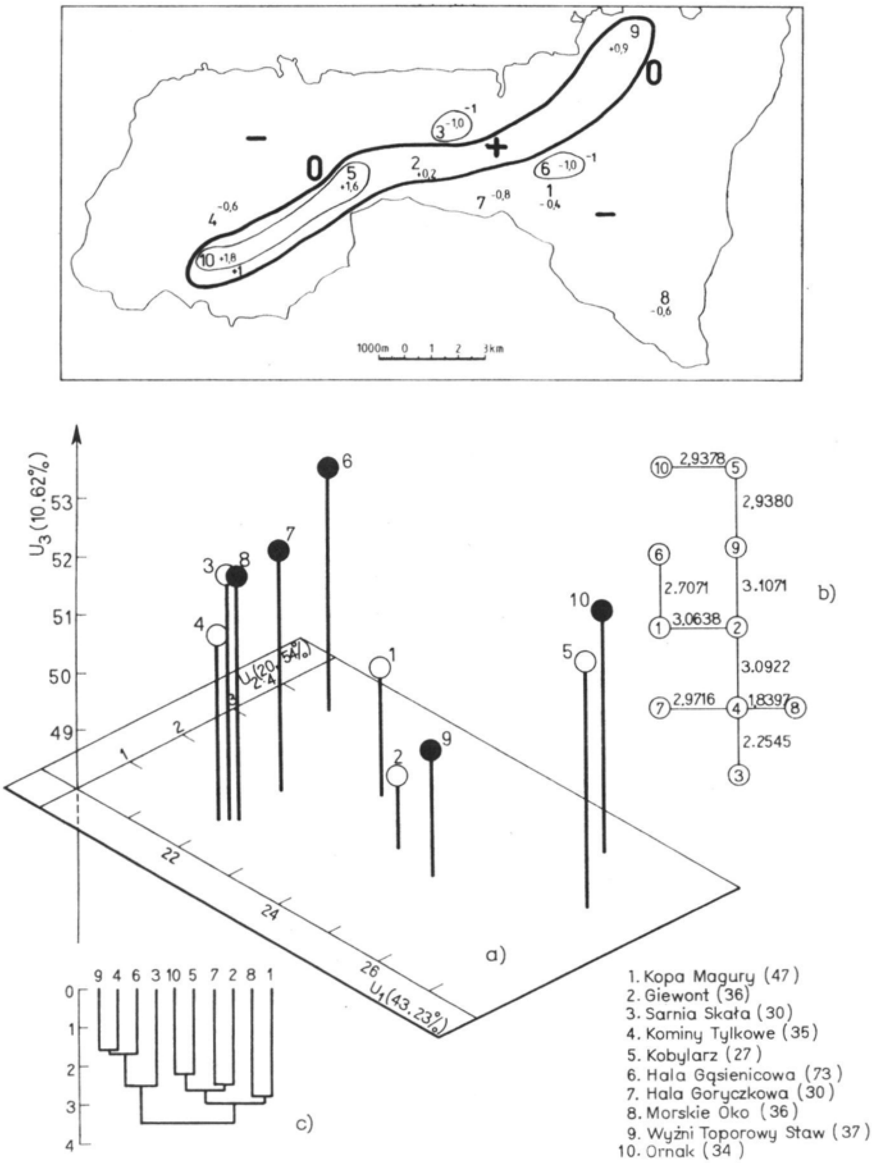

Fig. 1. **a** — Situation of studied area. On an enlarged map (Fig. $1a_1$) the Tatra Mts. the distribution of the examined stands with *Pinus mugo* Turra is marked and so is with the use of the zero isophene after Bryant the geographical (spatial) division of these stands into two groups marked "+" and "−". Standardised values of the first discriminant variable are given with the list of stands (map after Myczkowski 1967). **b** — Result of discriminant analysis in the space of the three first discriminant variables (jointly 85.64% of information from the used set of 14 traits of cones). Populations from calcareous substrate (nos. 1-5) marked by clear circles, populations from granite substrate (nos. 6-10) with black circles. **c** — Minimum spanning tree constructed on the basis of the shortest Mahalanobis distances. **d** — Result of agglomerative clustering of ten of the studied populations

distance between the apex and the level of greatest width of the cone. Almost equally important in determining variability is the situation of the greatest width of the cone in relation to its top. Of great significance is also the ratio of scale length to its width. As regards the dimensions and shape of the cones and dimensions of the scales, the populations may be divided into three groups. The first comprises populations from Sarnia Skała, Kominy Tylkowe and Morskie Oko, the second populations from Hala Gąsienicowa, Hala Goryczkowa and Kopa Magury, and the third the remaining four populations from: Giewont, Wyżni Toporowy Staw, Kobylarz and Ornak. As regards traits describing the ratio of scale length to their width and scale length to their thickenss, the examined populations are mostly similar (Kominy Tylkowe, Morskie Oko, Hala Gąsienicowa, Kopa Magury, Kobylarz, Ornak). Among the four remaining ones the populations from Sarnia Skała and Giewont exhibit the greatest diversity. Diverse from other populations and similar to one another are also those from Hala Goryczkowa and Wyżni Toporowy Staw. In clustering on the basis of Euclidean distances ten of the populations were found to form two groups: the first consisting of populations from Hala Goryczkowa, Giewont, Morskie Oko, Kopa Magury, Ornak and Kobylarz, and the second comprising populations from Wyżni Toporowy Staw, Hala Gąsienicowa, Sarnia Skała and Kominy Tylkowe. These groups are not homogeneous as regards habitats occupied by the populations in the group. Thus, in the rather differentiated first group Hala Goryczkowa is close to Giewont, Kopa Magury to Morskie Oko and Kobylarz to Ornak, that means that the population from the calcareous habitat is paired with that from the calcium-free habitat. The second group also includes two populations from calcium-free habitats: Wyżni Toporowy Staw and Hala Gąsienicowa and populations from calcareous habitats: Sarnia Skała, Kominy Tylkowe. All these four populations are, in the clustering picture very similar. Thus, the groups obtained contradict the existence of correlation between the detected variability and the type of habitat. Testing of the significance of differences between the group of populations from the calcareous substrate and the group from the calcium-free substrate proved that significant differences appear in six of the tested 14 traits. These traits are: diametre of cone apex, ratio of cone length to number of its scales, thickness and width of scale, diametre of cone at mid distance between top and greatest width and length of cone (the traits are given according to the diminishing values in statistics $F_{calc.}$ from Table 3B). As seen, other traits decide mainly of the detected picture of variability of ten populations, and other ones determine the differences between these populations in reference to the occupied habitat. This, probably, is the cause of lack of correlation between the detected differences in the populations and the habitat. In order to check whether the detected morphological variability has any connection with the geographical distribution of the population, Bryant's test was performed (1977). The values of the first discriminant variable U_1 are plotted on the axis of abscissae and the population size on the ordinate axis. A histogram is formed indicating the existence or lack of spatial groups. If such groups exist, the values of the first discriminant variable are standardised and plotted on the population map. The line joining points with the same sign (called zero isophene) running between values "+" and "−" (for the given populations) marks the boundary (or boundaries) between groups. As the result of this procedure the examined populations were divided into two groups: the first comprising those from Giewont, Kobylarz, Wyżni Toporowy Staw and Ornak and the second including the remaining populations from: Kopa Magury, Sarnia Skała, Kominy Tylkowe, Hala Gąsienicowa, Hala Goryczkowa and Morskie Oko.

The obtained geographical division (plotted on the map of sites in Fig. $1a_1$) agrees rather well with the division obtained in discriminant analysis (Fig. 1b) and is not contradictory to the result of ordering the populations on the minimum spanning tree constructed on the basis of the shortest Mahalanobis distances (Fig. 1c). It is possible that one cause of such differentiation is the geomorphological age of the undersoil and the age of the populations growing there connected with it.

To sum up the results we may say that:

1. The populations from Sarnia Skała and Kominy Tylkowe excepted, the remaining dwarf mountain pine populations from the Tatra Mts. differ significantly in the traits of their cones.
2. Statistically significant differences between populations concern all the studied morphological traits of the cones.
3. Among the examined populations 2(3) groups were distinguished.
4. The main traits deciding of the picture of variability obtained are those describing the cone shape (1, 2, 3, 4, 5) and traits of the cone scales (7, 8, 9, 13, 14).
5. No correlation was found between the character of morphological variability of cones and the kind of substrate on which the populations grow.
6. Neither do the altitudes above sea level at which the given populations grow correspond to the variability found.
7. From the geographical (spatial) point of view the populations of *Pinus mugo* Turra can be distinguished as belonging to two groups.

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Morfologiczne międzypopulacyjne zróżnicowanie kosodrzewiny (Pinus mugo Turra) z Tatr wyrażone za pomocą cech szyszek

Streszczenie

Z 388 roślin kosodrzewiny, *Pinus mugo* Turra, pochodzących z 10 populacji tego gatunku z Tatr — po 5 z podłoża wapiennego i bezwapiennego — zebrano 2-letnie szyszki, które opracowano pod względem 14 cech morfologicznych. Uzyskane dane posłużyły do wykonania wielozmiennej analizy wariancji wraz z testowaniem hipotez statystycznych, do analizy zmiennych dyskryminacyjnych, do obliczenia odległości Mahalanobisa między populacjami wraz z dendrytem skonstruowanym na podstawie najkrótszych odległości Mahalanobisa oraz do przeprowadzenia grupowania aglomeratywnego metodą najbliższego sąsiedztwa. Stwierdzono duże zróżnicowanie populacji pod względem wszystkich badanych cech oraz tworzenie 2 grup populacji, które jednak nie korelują z typem podłoża. Populacje "wapienne" i "bezwapienne" różnią się statystycznie istotnie pod względem 6 cech na 14 zbadanych.