Scots pine (*Pinaceae*) from the Crimea compared to the species variation in Europe on the basis of cone traits

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Abstract. A sample of *Pinus sylvestris* cones from a Crimean population was examined in regard to six measured and other four calculated features. Results were compared with the Scots pine populations from Spain and Poland. Relation between the features was analysed, as well as their correlation to longitude and latitude. Range of variation of the Crimean pine cones falls within the total variation of species in Europe. No relations of cone features to longitude were found, while several features were correlated significantly to latitude. The question, whether this fact results from the reaction of cones to climatic conditions, or the reason is the origin of populations from different Pleistocene refugia, demands further investigation.

Key words: *Pinus sylvestris*, plant variation, Pleistocene refugia, statistical analysis

Introduction

The broad geographical range of *P. sylvestris* L. is the reason of species variation. However, the gradual type of variation makes difficult distinguishing of intraspecific taxa (Białobok 1967; Staszkiewicz 1970; Giertych 1991; Prus-Głowacki 1991).

Some isolated populations with their own characteristic features and range were described as different species, or subspecies of the Scots pine (Boratyński 1993). For instance, the population from the Crimean Peninsula has been occasionally considered together with the Caucasian populations as a distinct taxon. Ilin (1934) and Sokolov (1949) accepted them as *P. hamata* (Stev.) Sosn. Pravdin (1964) prefers the subspecific rank [(*P. sylvestris* subsp. *hamata* (Stev.) Fomin], and in the Molotkov & Patlaj modification (1991) it belongs to *P. sylvestris* subsp. *hamata* var. *subalpina* Fomin. On the other hand, Ruby & Wright (1976) treat them as *P. sylvestris* var. *armena* C. Koch within the group of varieties from South Europe and Turkey. In the Crimea *P. sylvestris* occurs in the mountains, on their northern and southern slopes (Wulff 1927).

Staszkiewicz (1961, 1968, 1993) had distinguished eight types of populations of the Scots pine, on the basis of cone features. According to his investigations, in the Caucasian mountains and on the Balkan Peninsula the *balcanico-caucasica* type could be found. *P. sylvestris* from the Crimea has not been analysed so far with regard to cone characters.

The aim of this work is morphological characterisation of a population of Scots pine from the Crimea on the basis of cone features. A further goal is to compare the analysed sample to other Scots pine populations examined by the same methods.

Material and methods

A sample of *P. sylvestris* cones from a Crimean population was used as material for examination. Cones were collected in May 2002, in the Nikitskaya Yayla, at the Nikitskiy Pass below Besedka Vetrov locality, at an altitude of approximately 1400 m (Table 1). Six features of each cone were measured and four other were calculated (Table 2).

Table 1. Location of the compared populations of *P. sylvestris*.

No	Location	Acronym	Longitude	Latitude N
			accuracy 1°	
1	Spain, Sierra de Baza	Baza	W 3°	37°
2	Spain, Sierra de Guadarrama, Puerto de los Cotos	Guadarrama	W 4°	41°
3	Spain, Central Pyrenees, Peña de Oroel	Pyrenees	W 1°	43°
4	Russia, Crimea, Nikitskaya Yayla	Crimea	E 36°	45°
5	Poland, Tuchola Forest	Tuchola	E 18°	53°

Table 2. Analysis of the cone characters.

No	Character	Accuracy and measure
1.	Cone length	1 mm
2.	Cone width	1 mm
3.	Cone scales number	–
4.	Apophyse of cone scale length	0.1 mm
5.	Apophyse of cone scale width	0.1 mm
6.	Apophyse of cone scale thickness	0.1 mm
7.	Ratio of cone length/width (1/2)	–
8.	Ratio of cone length/number of scales (1/3)	–
9.	Ratio of apophyse of cone scale length/width (4/5)	–
10.	Ratio of apophyse of cone scale length/thickness(4/6)	–

Methods of the collection and measurements of cones usually practiced for this type of examination were used (Staszkiewicz 1961; Marcysiak 2004). A cluster and a discriminant analysis were performed (Zar 1999) so as to compare the Crimean to other, earlier examined populations (Marcysiak 2005). The analyses were based on calculated features only. It was assumed that the size of cones reflected by the measured features can depend on the weather conditions, while the shape of cones is more stable (Staszkiewicz 1961, 1968). Correlations of features were also investigated, as well as relation between the analysed features and longitude and latitude (Table 1). All calculations were performed with the help of STATISTICA 6.0.

Results

When compared to other European samples, the cones of the Scots pine from the Crimea look rather big, with moderately numerous, large and thick apophyses of the scales. Variation coefficients of features range from 10 % to 25 % (Table 3).

The discriminant analysis showed that the range of variation of the Crimean pine cones falls within the total variation of species in Europe (Fig. 1).

On the graph based on the mean values of the compared samples with regard to the first discriminant variable, depending mainly on feature 9 (ratio of apophyse of cone scale length/width) and 10 (ratio of apophyse of cone scale length/thickness), the Crimean population fell between the sample from Tuchola Forest in Poland and populations from Spain. On the other hand, with regard to the second discriminant variable, depending mostly on the eight feature (ratio of cone length/number of scales), it was closer to the Sierra de Baza sample (Fig. 2).

The cluster analysis showed similar results: on the graph, samples from Guadarrama and the Pyrenees were the closest, followed by the Sierra de Baza population, and the Crimean sample joined the same group, while the Tuchola Forest population was most distant (Fig. 3).

The Scots pine cone features are usually correlated to each other (Table 4). Some interesting relations to geographic reference turned out. There was no correlation to longitude, while almost every feature was correlated significantly to latitude. Relation to the shape of apophyse of the cone scale was the strongest (feature 9: ratio of apophyse of cone scale length/width) (Fig. 4).

Table 3. Characteristics of cone traits of the analysed samples.

	Character	1	2	3	4	5	6	7	8	9	10
Arythmetic mean	Tuchola	40.57	20.67	67.90	8.45	7.61	2.80	1.97	0.61	1.12	3.12
	Crimea	47.19	25.98	82.19	8.33	8.97	3.37	1.82	0.58	0.93	2.59
	Pyrenees	43.16	22.74	93.38	7.19	8.18	3.28	1.90	0.46	0.89	2.21
	Guadarrama	46.59	26.06	94.20	8.10	9.42	3.54	1.80	0.50	0.87	2.35
	Baza	42.22	23.12	81.20	6.38	8.49	3.23	1.83	0.52	0.75	2.05
	Total	**43.94**	**23.72**	**83.89**	**7.68**	**8.54**	**3.24**	**1.86**	**0.53**	**0.91**	**2.46**
Standard variation	Tuchola	5.01	2.43	10.11	0.95	0.93	0.55	0.18	0.09	0.15	0.63
	Crimea	6.79	3.16	9.70	0.96	0.97	0.76	0.22	0.08	0.11	0.66
	Pyrenees	6.63	2.64	12.17	1.04	1.04	0.59	0.18	0.09	0.14	0.52
	Guadarrama	4.38	2.05	8.38	0.99	0.85	0.60	0.20	0.06	0.13	0.47
	Baza	7.55	2.97	9.86	1.14	1.13	0.86	0.23	0.09	0.11	0.42
	Total	**6.64**	**3.36**	**13.92**	**1.28**	**1.17**	**0.72**	**0.21**	**0.10**	**0.17**	**0.66**
Variation coefficient	Tuchola	12.48	11.79	14.77	11.15	12.09	11.71	9.24	14.79	12.94	19.92
	Crimea	14.40	12.16	11.81	11.53	10.86	13.79	12.03	14.13	11.52	25.42
	Pyrenees	15.00	11.17	12.34	14.32	12.95	15.44	9.29	18.70	15.92	22.19
	Guadarrama	9.38	7.76	8.80	11.93	9.14	9.86	11.02	13.16	14.14	20.26
	Baza	17.88	12.83	12.15	17.85	13.32	16.58	12.56	17.91	14.72	20.68
	Total	**15.10**	**14.15**	**16.59**	**16.70**	**13.65**	**22.19**	**11.27**	**18.47**	**19.05**	**26.74**

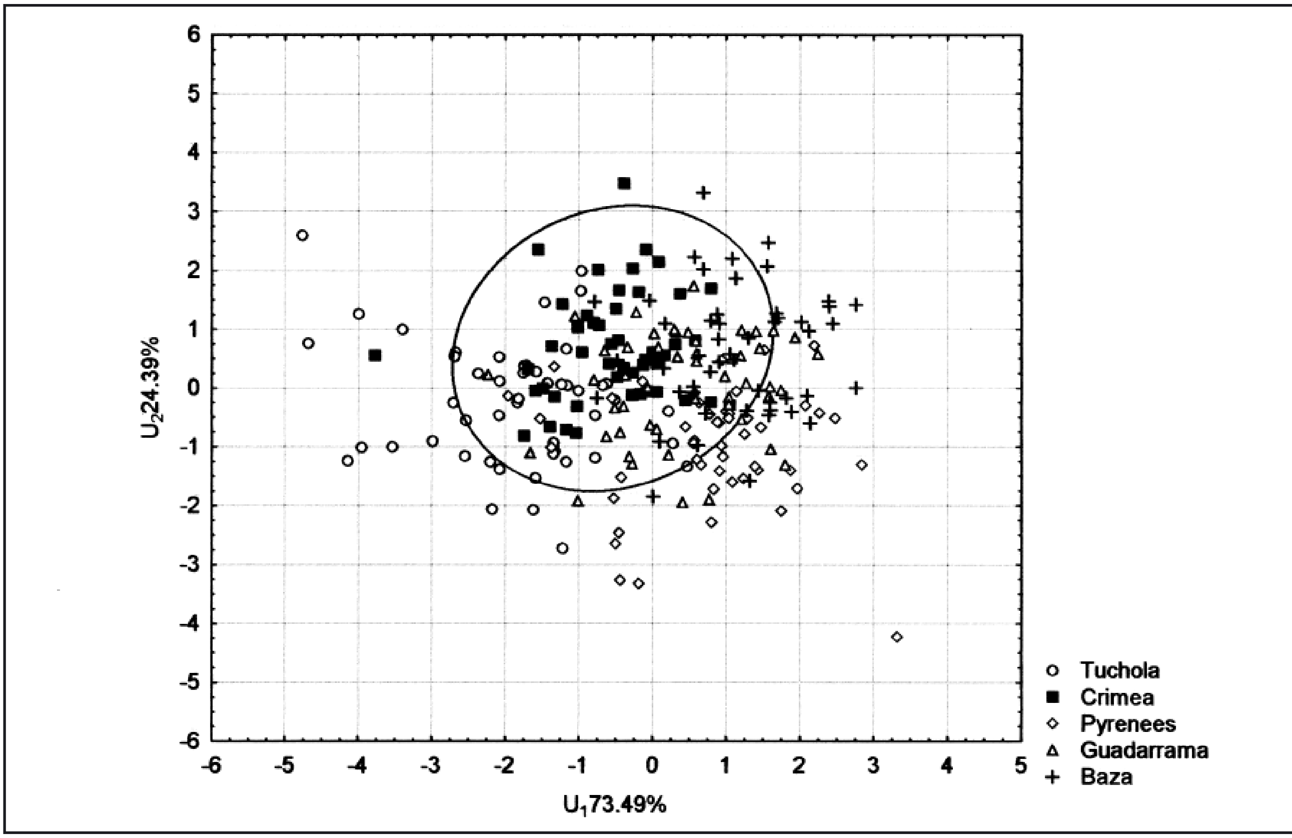

Fig. 1. Result of the discriminant analysis based on cone characters 7–10 plotted st the two firts discriminant variables U_1 and U_2, for all cases.

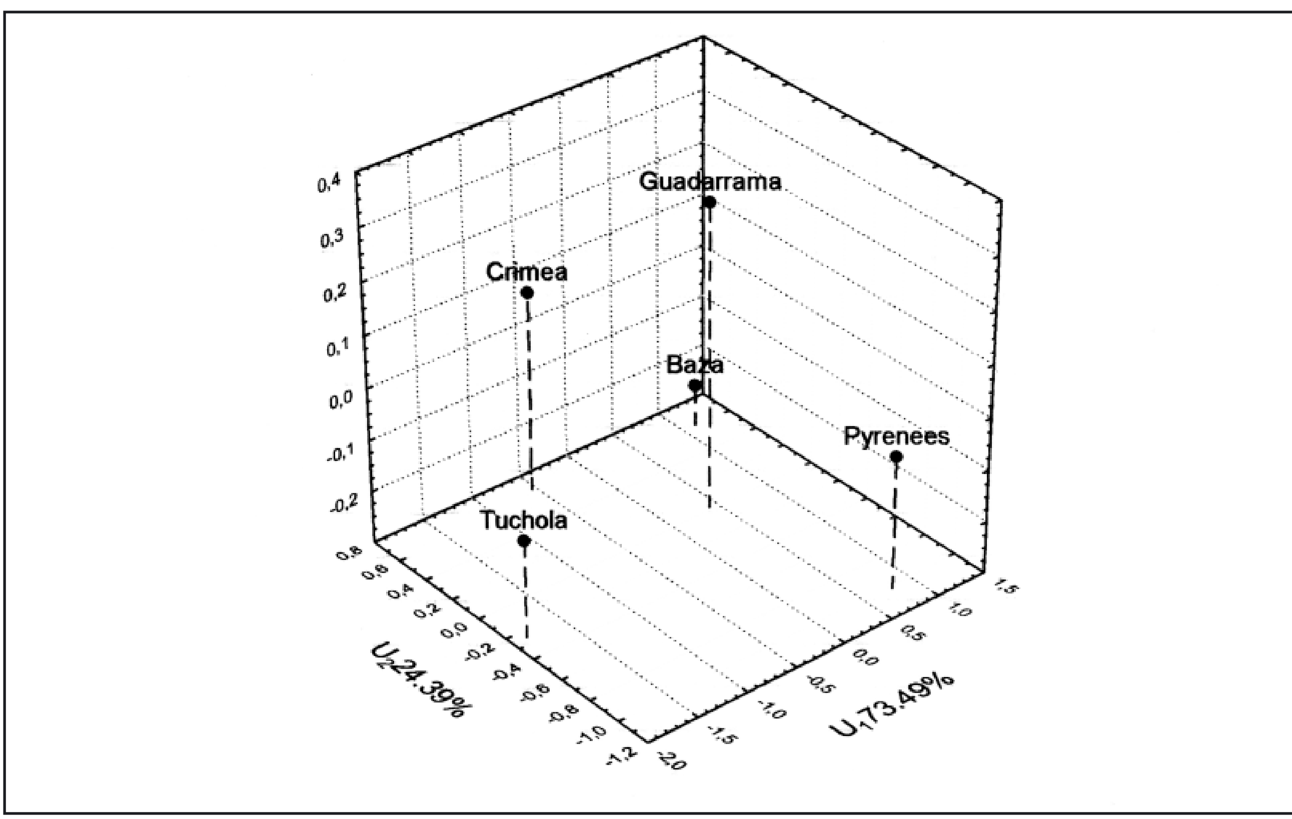

Fig. 2. Result of the discriminant analysis based on cone characters 7–10 plotted against the three first discriminant variables U_1, U_2 and U_3, for samples' averages.

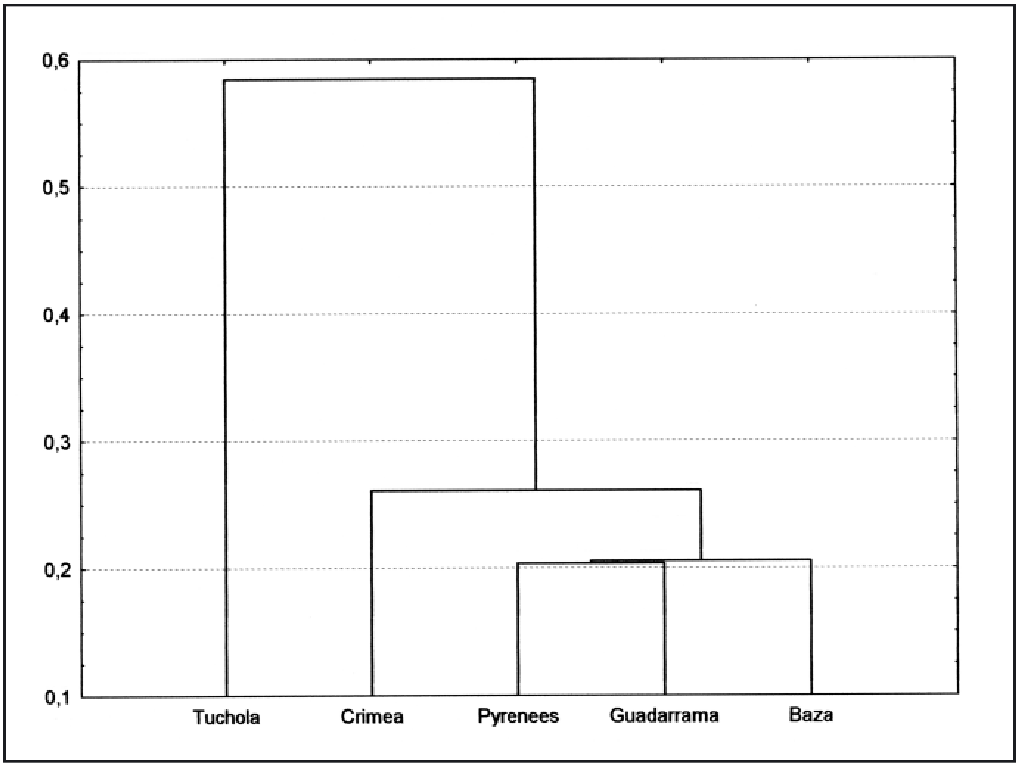

Fig. 3. Dendrogram of samples constructed on the basis of the shortest Euclidean distances.

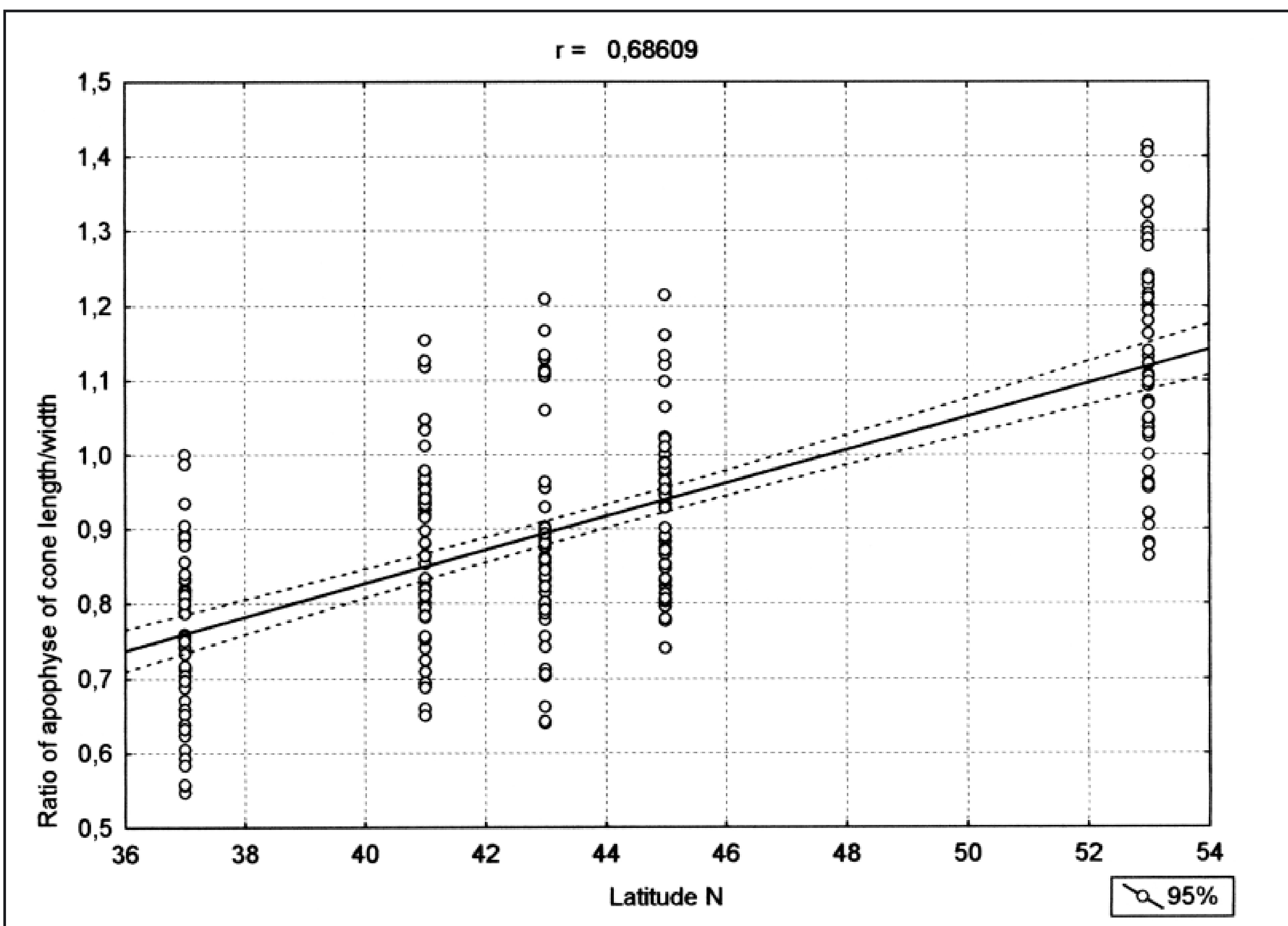

Fig. 4. Correlation between 9th cone character and Latitude N.

Table 4. Correlation coefficients between 10 pine cone traits and latitude.

	Character 1	Character 2	Character 3	Character 4	Character 5	Character 6	Character 7	Character 8	Character 9	Character 10
Character 2	0.69*									
Character 3	0.36*	0.49*								
Character 4	0.40*	0.21*	-0.22*							
Character 5	0.59*	0.66*	0.29*	0.29*						
Character 6	0.34*	0.52*	0.24*	0.15*	0.32*					
Character 7	0.47*	-0.30*	-0.15	0.29	-0.02*	-0.21*				
Character 8	0.46*	0.09	-0.62*	0.55*	0.20	0.02*	0.51*			
Character 9	-0.08	-0.29*	-0.43*	0.69*	-0.48	-0.10*	0.28*	0.37*		
Character 10	-0.10	-0.34*	-0.41*	0.52	-0.13*	-0.68*	0.32*	0.34*	0.57*	
Latitude N	-0.13	-0.30*	-0.45*	0.46*	-0.32*	-0.25*	0.24*	0.36*	0.69*	0.55*

*** statistically significant at level p<0. 0.01**

Discussion

The interspecific taxa distinguished within *P. sylvestris*, as well as the cone type variation both indicate that Scots pine is more variable in the north-south than in the east-west direction (Boratyński 1993). During the present investigations, populations from South Europe were more similar to each other, even though they originated from the easternmost (the Crimean Peninsula) and the westernmost (the Iberian Peninsula) species stands, while the sample from the northern part of Central Europe (Tuchola Forest) was most distant. Within the populations from the Iberian Peninsula, the sample from Sierra de Baza was the most isolated. It was already described with regard to the terpene contents (Pardos & al. 1990), isoenzyme patterns (Prus-Głowacki & Stephan 1994), mitochondrial DNA variation (Sinclair & al. 1999; Soranzo & al. 2000), genetic differentiation (Prus-Głowacki & al. 2003), and morphological cone characters (Marcysiak 2005). The other two Spanish populations were quite similar, as far as the cone characters are concerned. Prus-Głowacki & al. (2003) has proved that the Scots pine from the Iberian Peninsula had probably not taken part in the colonisation of Europe after the last glaciation and represented the original ancient Tertiary gene pool. Even more interesting is the similarity of cone characters of the Spanish populations to the Crimean sample found in the present study. Yena & al. (2005) have described the southern part of the Crimea as an extensive refugium of the Mediterranean flora during the last glaciation. The importance of the southeastern part of Europe, including of the Caucasian mountains, as a Pleistocene refugium, was also emphasized by Staszkiewicz (1968). The analysed sample of pine cones from the Crimea should be classified as a *balcano-caucasica* type differentiated by this author, which can be found in the Caucasian mountains at least since the last Interglacial (Staszkiewicz 1993).

The question whether the variation of cone samples observed in the present study results from the reaction of cones to climatic conditions, or the reason is the origin from different Pleistocene refugia, demands further investigation with the help of genetic markers.

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