BIOMETRIC CHARACTERS OF SEEDS AND WINGS AS MARKERS OF GEOGRAPHICAL DIFFERENTIATION BETWEEN EUROPEAN SCOTS PINE (*PINUS SYLVESTRIS* L.) PROVENANCES

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ABSTRACT

Biometric characters of seeds and wings served to describe interprovenance differentiation of Scots pine in Europe. Grouping analysis was applied, Mahalanobis distances were calculated as well as Hotellings T^2 statistics were applied. The similarity of East European and Finnish provenances was conspicuous. The provenance from Scotland proved to be similar to provenances originating from the region of Scandinavia. On the other hand, two southern provenances 54(Rychtal, Poland) and 55(Luboml, Ukraine), were also found similar to provenances originating from the region of Scandinavia (western Norway). The obtained pattern of reciprocal relations may indicate pathways of Scots pine migration in the postglacial period or may be a result of adaptation to certain similar environmental conditions. No relations were detected between size of seeds and geographic origin of provenances.

KEY WORDS: *Pinus sylvestris* L., provenances trial IUFRO 1938, seeds and wings, differentiation, multivariate analysis.

INTRODUCTION

Scots pine is characterized by significant differentiation both within and between populations (Krzakowa et al. 1977, Gullberg et al. 1985, Mejnartowicz and Palowski 1989, Prus-Głowacki 1991, Prus-Głowacki et al. 1993, Prus-Głowacki and Stephan 1994). The species is even thought to be most polymorfic among species of the genus Pinus examined till now (Goncharenko et al. 1993, 1994). Studies involving provenance comparisons have introduced particularly numerous data on differentiation in its geographic aspect (Giertych 1979, 1991, Giertych and Oleksyn 1981, 1992, Oleksyn et al. 1986, 1992). Phenological, morfological, anatomical, biochemical data and several aspect important for tree breeding, indicate clinal variation among Scots pine populations (Langlet 1936, 1959, Vincent and Polnar 1953, Gowin 1972, Steiner 1979, Vidjakin 1979, Giertych 1993). There exist also opposite results, which point to ecotypic differentiation of Scots pine (Wright and Baldwin 1957, Wright and Bull 1963, Ruby and Wright 1976).

Some of the populations, the divergence of which is clearly marked as, for example, the population of Scotland, require further comparisons with continental and Scandinavian populations to define sources of their origin (Ennos 1991). There exists a multiplicity of different and frequently even contradictory views on the subject (Tobolski and Hanover 1971, Forrest 1982, Kinloch et al. 1986, Ennos 1991). The complex situation, which we now see in the description of intraspecific Scots pine variability, reflects to a large extend two reasons. The first involves multiple glaciations which developed on the European continent, particularly in its northern part, and on the adjacent seas during Pleistocene. The last of them, with culmination at about 25 ka BP, the Vistula glaciation, has caused Scots pine populations to migrate to refugia in the east and south of Europe (Staszkiewicz 1968, 1970, 1993, Tobolski and Hanover 1971, Huntley and Birks 1983). At the end of Pleistocene and at the threshold of the Holocene, parallel with warming of the climate, migration of Scots pine has taken place to new territories, which resulted in mixing of populations originating from different refugia. This is regarded to represent one of reasons for the observed significant differentiation within this species (Staszkiewicz 1968, 1970, Giertych 1979, Prus-Głowacki et al. 1993). Moreover, economic activity of man significantly affected genetic structure of the population of Scots pine (Giertych 1976, Broda 1993).

One of the provenance trials, representing the subject of the present study and established under auspices of IUFRO in 1938, was localized in Lubień-Poland and has already been analysed by several authors (Przybylski and Sztuka 1968, Giertych 1986, Prus-Głowacki et al. 1993). Giertych (1986) drew attention to the lower productivity of the Scandinavian populations, as compared to Scots pines originating from the lowland regions, positioned south of the Baltic Sea. Prus-Głowacki et al. (1993) distinguished in the same experiment a group of East European populations, genetically linked to the Scandinavian populations.

Characters of seeds and of wings, used in present study to appraise differentiation within the species, have been studied till now to a restricted extent (Zajączkowski 1949, Knjazev 1954, Steven and Carlisle 1959, Fijałkowski 1968, Elicin

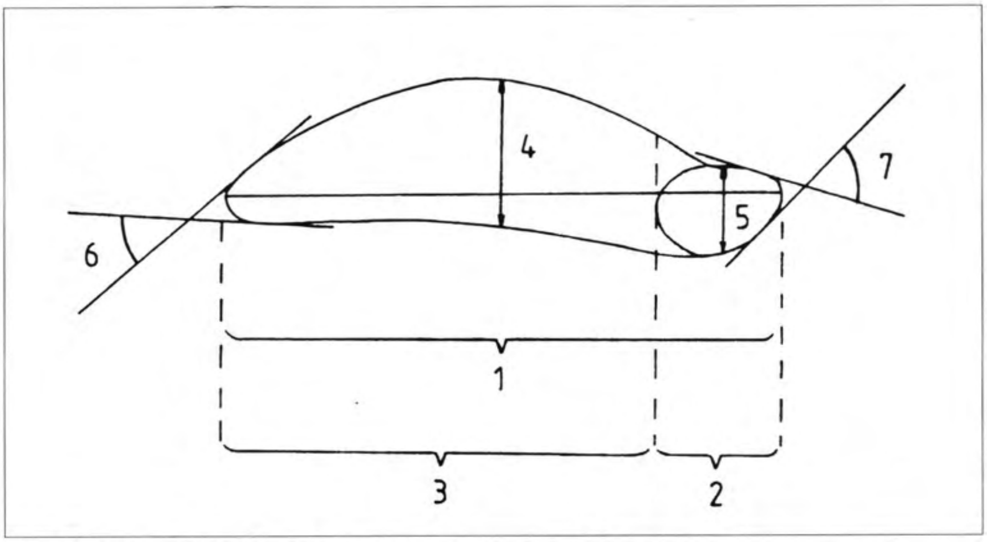

Fig. 1. Diagram showing the technique of measuring seeds and wings.

1971, Krzakowa et al. 1984, Staszkiewicz 1993). The data obtained till now indicate that Scots pine populations originating from the North European regions exibit smaller seeds of a lower mass (Patlai 1965, Ruby 1966, Pravdin 1969, Lähde 1976, Simak 1976, Reich et al. 1993). However, seed and wing characters have not been subjected till now to a complex multivariate analysis in the geographic aspect of the Scots pine differentiation. This topic was the main goal of the present study. Moreover, the study aimed at commenting the position of Scots pine populations from Scotland and Scandinavia against the background of other European populations.

MATERIAL AND METHODS

The provenance trial IUFRO 1938 was localized on the territory of central Poland in Lubień, Piotrków Trybunalski Forest District. The experiment included 18 provenances originating from the Northern Europe territory (Scandinavia and Scotland), West Europe (Belgium, Netherlands and Germany) and from the territories of Central and Eastern Europe (Lithuania, Latvia, Ukraine and Poland), (Table 1, Fig. 2). Cones were collected in March, 1985. From the collected cones of a given tree, the seeds were isolated and 10 of them were selected at random. The sample served as a representation of a given tree and means from seed and wing measurements from all trees within a given provenance served for further calculations. In total, the measurements included 3200 seeds and wings from 320 trees.

The following characters were measured: 1. length of the wing with seed in mm., 2. seed length, in mm., 3. wing length, in mm., 4. width of the wing at half of its length, in mm., 5. width of the seed at half of its length, in mm., 6. angle of the wing end, 7. angle of the seed end (Fig. 1). The obtained biometric data provided material for performing multivariate statistical analyses – grouping by the method of the nearest neighbourhood on the basis of Euklidean distances (dendrogram), calculation of Mahalanobis distances with Hotelling T^2 statistics, minimum spanning tree constructed on the basis of the shortest Mahalanobis distances and charac-

TABLE 1. Geographical data on provenances from the Lubień provenance trial used in the study.

IUFRO No.	Provenance	Country	Latitude N	Longitude E	Altitude m.	Tree No.
1	Inari	Finland	68°40'	27°37'	140	18
2	Rovaniemi	Finland	66°25'	26°26'	250	17
3	Sääminki	Finland	61°40'	28°55'	85	20
4	Tönset	Norway	62°22'	10°48'	550	20
6	Åsnes, Hamar	Norway	60°32'	12°11'	230	15
7	Svanöy	Norway	61°30'	5°07'	50	23
11	Vecmocas	Lativa	57°03'	23°10'	80	19
17	Glen Garry	Scotland	57°04'	4°55'	150	19
18	Herselt	Belgium	51°03'	4°56'	20	27
19	Diever	Holland	52°51'	6°21'	10	24
20	Brody	Poland	51°47'	14°46'	80	14
21	Göddenstedt	Germany	52°59'	10°50'	75	22
22	Ruciane	Poland	53°41'	21°26'	120	14
23	Elmstain	Germany	49°20'	7°57'	325	10
24	Zellhausen	Germany	50°01'	9°00'	140	6
53	Mustejki	Lithuania	54°08'	24°25'	130	10
54	Rychtal	Poland	51°12'	17°55'	190	21
55	Luboml	Ukraine	51°15'	24°05'	195	21

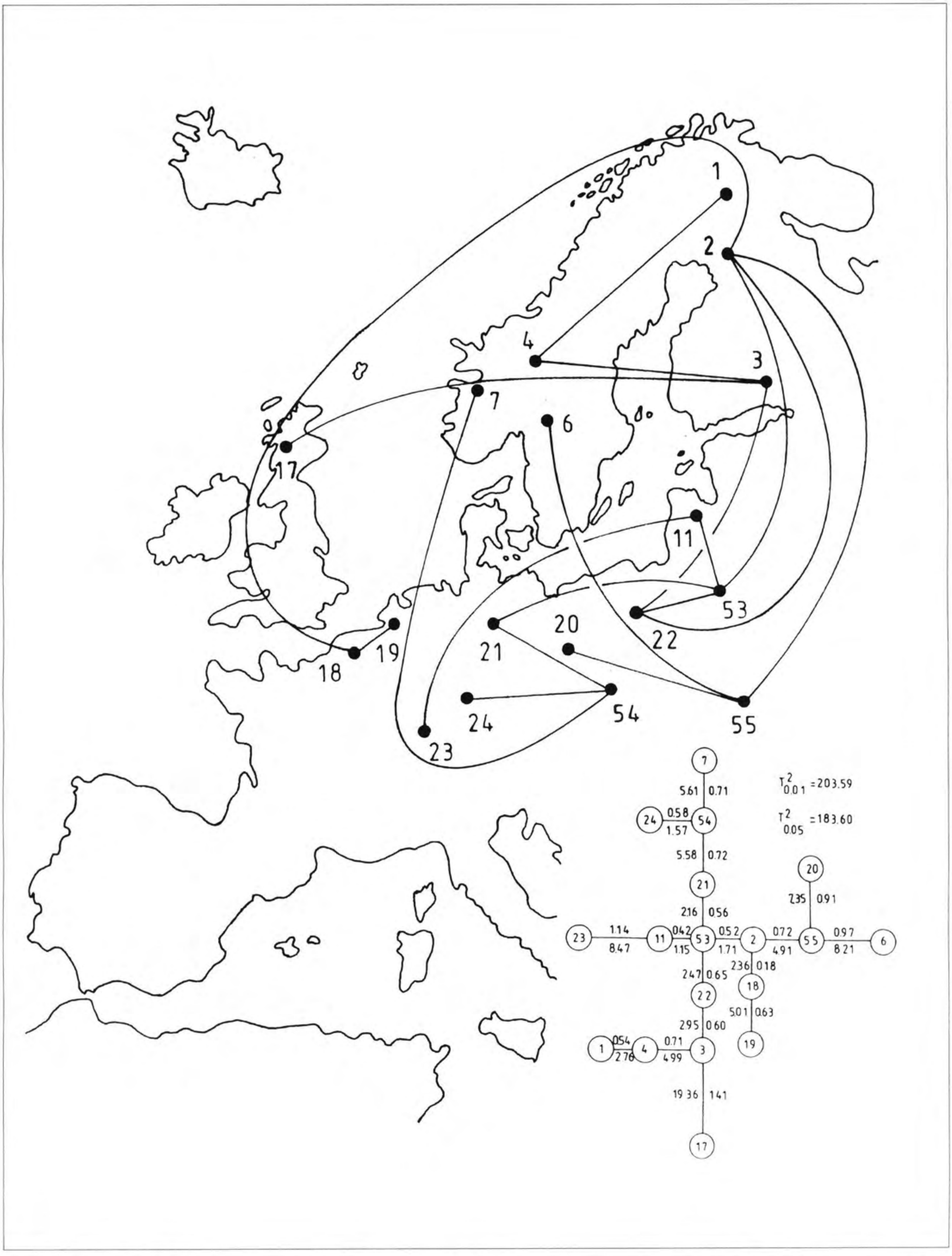

Fig. 2. Site of origin of studied provenances including the minimum spanning tree (dendrite) constructed on the basis of Mahalanobis generalized distances and its projection to the map; figures to the left or below represent values of Hotellings T^2 statistics.

teristics of the applied 2 characters- 2(seed length) and 5(seed width at half of its length) characters by means, variability coefficients, minimum and maximum.

RESULTS AND DISCUSSION

Means, variability coefficients, minimum and maximum values for character 2(seed length) and character 5(seed width at half of its length) are presented in Table 2. Differences between the mean values of the characters for individual provenances were small, and for character 2 fitted the range between 3.8 mm to 4.3 mm. For character 5 mean values ranged from 2.4 mm to 2.8 mm. The values fit the range regarded as typical for Scots pine (Knjazev 1954, Fijałkowski 1968, Elicin 1971). The previously reported data, indicating that seeds are larger in Scots pine populations from the regions of Central Europe as compared North European populations (Ruby 1966), were not confirmed in the present study. Variability coefficients calculated for the two characters point to their moderate variability within individual provenances (Table 2).

The dendrite and its projection on to the map of Europe, in which individual stands have been linked by the shortest Mahalanobis distances, are presented in Figure 2. None of the distances are statistically significant. The same can be seen from Table 3, in which Mahalanobis distances and Hotelling T^2 statistics do not differentiate individual provenances (T^2 0.01=203.6, T^2 0.05= 183.6).

The pattern of reciprocal relations between provenances presented in the dendrite, is of multidirectional type in the sense of geographic correlations. First of all, the Scots pine provenance originating from the territory of Scotland – 17(Glen Garry) corresponds to provenances originating from Finland – 3(Sääminki).

The differences between Scots pine from Scotland and the continental populations as well as from Scandinavia have been stressed several times (Carlisie 1958, Ennos 1991). Origin of the Scots pine and pathways of its migration to the region of Scotland, or its endemic character, have provided the subject for a lively and till now not concluded discussion (Wright and Bull 1963, Staszkiewicz 1968, Tobolski and Hanover 1971, Forrest 1982, Kinloch et al. 1986, Ennos 1991). Similarity of provenance 17(Glen Garry, Scotland) to Scots pine from Finland, is consistent with results obtained by isoenzyme analysis, and speaks in favour of genetic similarity of Scots pine from the two distant regions of Northern Europe (Prus-Głowacki et al. 1993). This is not a new suggestion since morphological studies on cones and biochemical studies of terpens have also pointed to close similarity of Scots pine populations from that region of Scandinavia and Scotland (Staszkiewicz 1968, Tobolski and Hanover 1971, Forrest 1982). The Finnish provenance 3(Sääminki) corresponds also to Scots pine from North Eastern Poland 22(Ruciane), and this in turn is related to the geographically close Lithuanian provenance 53(Mustejki), which is linked by the shortest distance with the Latvian provenance 11(Vecmokas), (Fig. 3.).

The genetic similarity of Scots pine populations from the Baltic countries and their high productivity was observed several times (Giertych 1979, 1981). Moreover, populations from Ukraine 55(Luboml), from North-Eastern Poland 22(Ruciane) and from Lithuania 53(Mustejki) in the analysed characters of seeds and wings resemble the Finnish population 2(Rovaniemi), while population 55(Luboml) resembles also population 6(Åsnes-Hamar) from Norway (Fig. 3.).

Similarity of East European populations, as an entire group, to the Scandinavian populations seems to point to the related genetic character which may reflect the origin from common glacial refugia (Prus-Głowacki et al. 1993). Scots pine has migrated to the region of Scandinavian Peninsula from multiple directions (Mirov 1967, Staszkiewicz 1968, Tobolski and Hanover 1971, Huntley and Birks 1983). One of the directions led through the Jutland Peninsula, forming a landbridge with Skane. Similarity of provenances 54(Rychtal, Poland) and 55 (Luboml, Ukraine) to two provenances from the western part of Norway seems to indicate the pathway of Scots pine migration in the postglacial period. In the region of eastern Carpatian Mountains and the Balkan Peninsula relatively large glacial refugia were situated (Frenzel 1968, Sta-

TABLE 2. Means (I), variability coefficients (II), minimum (III) and maximum (IV) values for two (A) characters-2 (seed length) and 5 (width of the seed at half of its length) in mm.

		PROVENANCES																	
	A	1	2	3	4	6	7	11	17	18	19	20	21	22	23	24	53	54	55
I	2	4.3	4.2	4.3	4.3	3.9	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.3	3.9	4.3	4.1	4.3	4.2
	5	2.7	2.7	2.7	2.8	2.4	2.5	2.6	2.8	2.7	2.6	2.4	2.6	2.7	2.4	2.6	2.6	2.7	2.6
II	2	11.0	5.7	5.9	6.3	10.6	8.1	10.8	10.8	9.1	5.6	14.4	6.3	7.9	15.5	9.3	5.4	5.1	8.7
	5	10.4	7.0	7.1	7.5	10.6	10.3	9.1	11.9	7.7	5.3	11.9	7.2	5.5	11.8	4.6	6.7	6.8	6.9
III	2	2.8	3.7	3.8	3.9	3.1	3.3	3.3	3.3	3.5	3.7	3.0	3.5	3.6	2.8	3.8	3.8	3.8	3.1
	5	1.9	2.4	2.4	2.4	2.0	1.8	2.1	2.1	2.1	2.3	2.1	2.2	2.4	1.9	2.4	2.3	2.3	2.2
IV	2	5.0	4.6	5.0	4.9	4.5	4.7	4.9	4.8	4.9	4.6	5.2	4.5	4.7	4.6	4.7	4.5	4.6	4.7
	5	31.	3.2	3.1	3.2	2.7	3.0	3.0	3.4	3.1	2.9	3.0	3.0	2.9	2.8	2.7	2.9	3.0	2.9

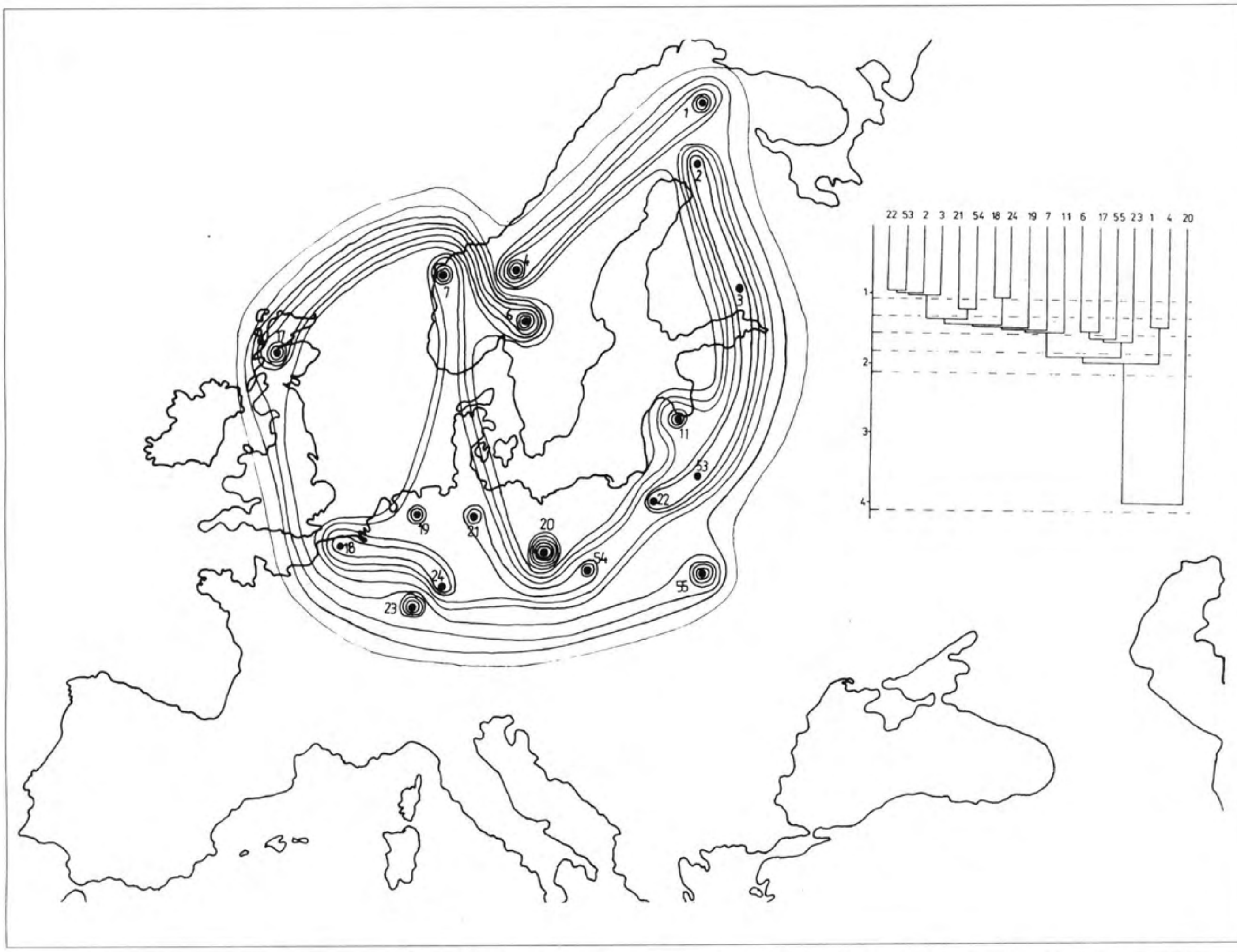

Fig. 3. Graphical presentation (dendrogram) of results of the clustering performed according to the UPGMA procedure, based on Euclidean distances and its projection to the map of Europe.

szkiewicz 1968). On the other hand, similarity of provenance 22(Ruciane, North-Eastern Poland), 53(Mustejki, Lithuania) and again 55(Luboml, Ukraine) to Finnish provenances – 2(Rovaniemi) and 3(Sääminki) indicates probably another migration pathway in the postglacial period. The pathway would lead from Carpatian refugia to north east and further through the lowland regions to Eastern Europe to Scandinavia. The genetic similarity of Scots pine provenances from the region of Finland to provenances from the Baltic countries and from North-Eastern Poland has been pointed out by Prus-Głowacki (1994), who explained this by the common migration pathway. However, the ordering of provenance may be explained otherwise. They may be a consequence of some planned or unplanned selection by man. Besides, it is possible that they result from adaptation to certain similar environmental factors, where similar genotypes survive due to natural selection.

Some relations within continental Europe and Scandinavia are along similar lattitudes (Fig. 2.). This pertains the following provenance pairs: 18(Herselt, Belgium) and 19(Diever, Nederland), 21(Göddenstedt, Germany) and 53(Mustejki, Lithuania), 24(Zellhausen, Germany) and 54 (Rychtal, Poland), 22(Ruciane, Poland) and 53(Mustejki, Lithuania), 55(Luboml, Ukraine) and 20(Brody, Poland), 21(Göddenstedt, Germany) and 54(Rychtal, Poland), 4(Tönset, Norwey) and 3(Sääminki, Finland), 17(Glen Garry, Scotland) and 3(Sääminki, Finland). The differentiation of Scots pine populations in respect to phenolic compounds in the region of Poland is of a similar character (Szweykowski and Urbaniak 1982, Krzakowa et al. 1994). In these studies three groups of populations have been distinguished: the northern one, in the center of the country and the southern one, differing in a significant way in the frequency of defined phenolic compounds. In turn, this kind of ordering of provenances may reflect the above-mentioned adaptation to certain environmental conditions. It should be remembered that the climate of this part of Europe changes gradually depending on the latitude.

Interprovenance differentiation has been studied also using the grouping analysis by the closest neighbourhood method. The obtained dendrogram in the form of contour lines has been projected on to the map of Europe (Fig. 3.). The general pattern of similarity for provenances points in part to their individual character. The greatest divergence has been observed in provenance 20(Brody, Poland). The Scotish population – 17(Glen Garry) corresponds again to the pine from Scandinavia, this time to the Norwegian sample – 6(Åsnes, Hamar) which, together with provenances 55(Luboml, Ukraine) and 23(Elmstein, Germany) form a separate group. Provenances – 22(Ruciane, Poland) and 53(Mustejki, Lithuania) together

TABLE 3. Mahalanobis distances between 18 provenances of *Pinus sylvestris* calculated on the basis of 7 seeds and wings characters with Hotelling T^2 statistics. T^2 0.05-critical value of Hotelling T^2 statistics=183.60.

	1	2	3	4	6	7	11	17	18	19	20	21	22	23	24	53	54	55
1																		
2	0.88 6.8																	
3	0.74 5.2	0.80 5.8																
4	0.54 2.8	0.96 8.5	0.71 5.0															
6	1.88 28.8	1.27 12.8	1.54 20.4	2.03 35.3														
7	1.57 24.9	1.04 10.6	1.59 27.2	1.86 37.1	1.41 18.1													
11	1.17 12.6	0.71 4.5	0.66 4.2	1.18 13.5	1.11 10.3	1.31 17.8												
17	1.87 32.4	1.69 25.5	1.41 19.4	1.62 25.6	2.10 36.8	2.44 62.1	1.53 22.3											
18	1.20 15.6	0.48 2.4	0.90 9.2	1.13 14.6	1.32 16.9	1.22 18.4	0.74 6.0	1.59 28.1										
19	1.58 25.7	0.77 5.9	1.31 18.8	1.61 28.3	1.29 15.3	0.90 9.4	0.93 9.2	1.94 39.9	0.63 5.0									
20	2.00 31.6	1.61 19.9	1.68 23.3	2.27 42.5	1.05 7.9	1.44 18.0	1.43 16.4	2.32 43.5	1.75 28.1	1.57 21.7								
21	1.25 15.4	0.60 3.5	1.24 16.1	1.37 19.5	1.16 12.1	1.04 12.1	0.91 8.5	1.90 36.6	0.90 9.9	0.93 1.00	1.66 23.7							
22	0.72 4.1	0.80 4.9	0.60 3.0	0.92 6.9	1.52 16.7	1.34 15.5	0.67 3.6	1.81 26.5	1.09 10.9	1.28 14.6	1.57 17.4	1.05 9.4						
23	1.87 22.5	1.46 13.4	1.42 13.4	1.97 2.6	1.21 8.8	1.56 17.0	1.14 8.5	2.01 26.5	1.28 12.0	1.41 14.0	1.55 14.1	1.65 18.7	1.57 14.4					
24	1.48 9.9	1.07 5.1	1.44 10.0	1.64 12.4	1.71 12.5	0.87 3.6	1.10 5.5	2.19 21.8	1.24 7.6	0.99 4.7	1.77 13.2	1.00 4.7	1.07 4.8	1.74 11.3				
53	1.03 6.8	0.52 1.7	0.76 3.9	1.10 8.0	1.08 7.0	1.21 10.2	0.42 1.1	1.56 16.0	0.77 4.3	0.97 6.6	1.48 12.7	0.56 2.2	0.65 2.5	1.37 9.4	1.03 4.0			
54	1.22 14.3	0.72 4.9	1.32 17.9	1.39 19.8	1.59 22.2	0.71 5.6	1.08 11.7	2.21 48.9	0.98 11.3	0.82 7.6	1.80 27.1	0.72 5.6	1.01 8.5	1.76 21.1	0.58 1.6	0.91 5.7		
55	1.23 14.6	0.72 4.9	1.04 11.0	1.47 22.1	0.97 8.2	0.93 9.4	0.86 7.3	1.94 37.4	0.97 11.2	0.92 9.4	0.94 7.3	0.91 8.9	0.92 7.1	1.43 13.9	1.21 6.9	0.78 4.1	1.01 10.1	

with two Finnish provenances 3(Sääminki) and 2(Rovaniemi) resamble each other. The Scandinavian group seems also distinguished, containing – 1(Inari, Finland) and 4(Tönset, Norway) provenances.

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ZRÓŻNICOWANIE GEOGRAFICZNE EUROPEJSKICH PROWENIENCJI SOSNY ZWYCZAJNEJ (*PINUS SYLVESTRIS* L.) NA PODSTAWIE CECH BIOMETRYCZNYCH NASION I SKRZYDEŁEK

STRESZCZENIE

Na podstawie charakterystyki biometrycznej nasion i skrzydełek opisano zróżnicowanie międzyproweniencyjne sosny zwyczajnej na terenie Europy. Zastosowano analizę grupowania, odległości Mahalanobisa i statystykę T^2 Hotellinga. Zwrócono uwagę na podobieństwo proweniencji pochodzących z terenu Europy Wschodniej i z terenu Finlandii. Proweniencja szkocka nawiązuje do proweniencji z terenu Skandynawii. Proweniencje południowe – 54 (Rychtal, Polska) i 55(Luboml, Ukraina) są także podobne do proweniencji z terenu Skandynawii (zachodnia Norwegia). Uzyskany obraz wzajemnych powiązań może wskazywać na drogi migracji sosny w okresie postglacialnym lub też może być rezultatem przystosowania do określonych podobnych warunków środowiska. Nie wykryto korelacji między rozmiarami nasion a geograficznym pochodzeniem proweniencji.

SŁOWA KLUCZOWE: *Pinus sylvestris* L., doświadczenie proweniencyjne IUFRO 1938, nasiona i skrzydełka, zróżnicowanie, analizy wielocechowe.