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Morphological variability of fruits and seeds of *Sorbus torminalis* in Poland

Abstract: The results of the study on morphological variation of fruits and seeds of a rare forest tree species *Sorbus torminalis* (L.) Crantz in Poland are presented and discussed. The ripe fruits were collected from 13 localities widespread within the range of the species. Fruits and seeds were measured according to 13 morphological traits. The biometric data were subjected to multivariate statistical analysis in attempt to define intra- and interpopulational variation. Most of the fruit and seed traits are significantly correlated and are characterised by moderate level of variation. Traits describing size and shape are higher variable in seeds than in fruits. High level of variation within examined populations was ascertained. The average among population component of variation was only 23.99%. Though the differences between sampled populations are significant, almost no geographical pattern of this differentiation was detected. The biological significance of some of fruit and seed features is discussed in the paper. Examining the collected material a single fruits with 5–6 seeds were found what suggests the presence of three carpels in gynoeceum, a number not previously reported in the species.

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Introduction

The genus *Sorbus* L. (Rosaceae: Maloideae) comprises about 250 species widespread in the Northern Hemisphere, with 91 species occurring in Europe (Phipps et al. 1990). Warburg and Kárpáti (1968) took into consideration only 19 species in Europe and according to a recent multivariate morphometric study of the genus *Sorbus* (Aldasoro et al. 1998a) only 12 species may be easily recognized in the area. The high number of European taxa (70 out of 91) given by Phipps et al. (1990) resulted from hybridization. In Poland seven *Sorbus* species occur in the wild (Mirek et al. 2002). *S. torminalis* is a rare, scattered tree species of our forests with north-eastern range limits in Poland, occurring mainly in its western part. The species is widely distributed across western, central and southern Europe, but also occurs in north-western Africa and south-western Asia (Browicz and Gostyńska-Jakuszewska 1966).

The genus *Sorbus* is characterized by pome fruit – a pulpous fruit with peculiar morphology and anatomy, typical for entire subfamily Maloideae. It arises both from syncarpic gynoeceum and from the hypanthium. Fruit's pericarp consists of membraneous exocarp (skin), the pulpous mesocarp (flesh, pulp), and of the xerocarpic endocarp (core). Gynoeceum in genus *Sorbus* is made of 2–5 carpels and forms 2–5 loculi respectively, with two ovules per each locule. Some species have a striking instability with regard to the number of carpels but in *S. torminalis* it was always constant and amounted two (Kovanda 1961; Aldasoro et

al. 1998a). Therefore the number of seeds per fruit in *S. torminalis* may be defined as ranging from 2–4, as indicated in many descriptions of the species. According to the study of subfamily Maloideae usually no more than 25–50% ovules per fruit develops into the matured seeds (Rohrer et al. 1991). The same, style number (2–5) is somewhat variable in most *Sorbus* species but *S. torminalis* consistently showed two (Gabrielian 1978; Aldasoro et al. 1998a)

Kovanda (1961) considered the anatomy structure of *Sorbus* fruit as well as its morphology, especially size and density of lenticels and consistency and position of sepals as the marks of high taxonomic value. The structure of the seed coat is considered to be of important character in *Sorbus* taxonomy too (Gabrielian 1978; Jankun 1993). On the other hand Aldasoro et al. (1998a, b) noted that some fruit and seed characters are under the strong influence of selection for species dispersal strategy (fruits are eaten and dispersed by birds and mammals) and this process may reduce their phylogenic significance. Some characters as fruit size are also very dependent on environmental conditions (McAllister 2005).

Fruits of *S. torminalis* are brown, densely dotted with lenticels. Sepals during ripeness are always deciduous (Kovanda 1961). According to Aldasoro et al. (1998a, b) the fruit has a multilayered epidermis which is a distinctive feature unknown in any other *Sorbus* species. Fruits of *S. torminalis* are very variable both in size and shape. Kárpáti (1960) listed seven following forms of fruits in the species: typus, sphaerocarpa, pisifera, macrocarpa, microcarpa, dolichocarpa and pomoida.

The main objective of this work was to describe intra- and interpopulational variation of fruits and seeds of *S. torminalis* in Poland, and to define variability between local populations in relation to their geographical distribution. The second objective was to complement and specify the knowledge about generative organs of *S. torminalis*, prevailing in the existing morphological descriptions. Some basic information on seed variability of *S. torminalis* is given in the recent paper of Bednorz and the others (2006a), but that study focused on comparison of seeds of five Polish species of the genus *Sorbus*.

Materials and methods

The fully ripened fruits were collected from 13 localities widespread within the range of the species in Poland (Fig. 1, Table 1).

Forty fruits from each population (from 10 trees, 4 fruits per tree) were sampled. From each fruit one fully developed seed was taken for measurements. The total of 520 fruits and 479 seeds were characterised in respect to 10 quantitative (1–10) and 3 qualitative (11–13) traits (Table 2).

Measurements and observations were carried out with the stereoscope microscope PZO type 131. The outline of seed and fruit was determined according to the length to width ratio and the position of the widest part of the seed in relation to its base, as given in table 3.

The biometric data of 10 quantitative traits were subjected to multivariate statistical analysis using STATISTICA 6 package in order to calculate:
1. numerical characteristics (mean value (M), range (Min., Max.), standard deviation (SD) and coefficient of variability (CV)) of applied traits of fruits and seeds,
2. Pearson's correlation coefficients between the trait values to show the interactions among the applied traits,
3. analysis of variance (ANOVA/MANOVA) with testing of statistical hypothesis and calculation of homogeneous groups of populations with Tukey's HSD test to demonstrate the differences or similarities between studied populations (Caliński and Kaczmarek 1973; Dobosz 2001),
4. Mahalanobis distances which show the significance of differences between studied objects (Karoński and Caliński 1973a; Dobosz 2001),
5. discriminant power of the traits based on analysis of discriminant function of traits (Caliński et al. 1974; Dobosz 2001),
6. cluster analysis (agglomerative grouping) on the basis of Euclidean distances by the Ward method to examine the relationships between populations (Ward 1963; Karoński and Caliński 1973b). Additionally, the interaction of the trait values with geographic latitude and longitude were verified using Pearson's correlation coefficient.

Results

On average, fruits of *S. torminalis* are 13.92 mm long (8.20–19.60 mm), and 11.66 mm (8.20–15.50 mm) wide (Table 4). They are usually longer than wider, and the mean length to width ratio is 1.20 (0.87–1.68). Considering fruit outline, they are mainly wide obovate (±57% analysed fruits) or roundish (±41%), and only sporadically obovate, elliptical or wide ovate (Fig. 2). The number of lenticiles on the fruit surface (trait 4) is a highly variable trait (coefficient of variability CV=37.00%). The most densely dotted fruits were found in population of 'Brzęki przy Starej Gajówce' reserve (no. 5), whereas the most sparsely dotted fruits were found in populations from 'Kawęczyńskie Brzęki' reserve (no. 7) and Tuchola (no. 1). Considering presence of hairs, most of the fruits (±70%) have only few hairs on their surface. Numerous hairs are present on about 23% of fruits, and they are absent only on 7% of fruits. The number of seeds per fruit (trait 5) varied

Fig. 1. Geographical distribution of sampled populations of *Sorbus torminalis*: 1. Localities of sampled populations (as in Table 1), 2. North-eastern range of *S. torminalis* in Poland

Table 1. Geographical coordinates of sampled populations of *Sorbus torminalis*

No. of population	Population (Locality)	Latitude N	Longitude E	Altitude (m)
1	Tuchola	53°31'	17°53'	100–110
2	Rogóźno	53°31'	18°58'	60–95
3	Goraj	52°53'	16°31'	50–80
4	'Bielinek nad Odrą' reserve	52°56'	14°10'	40–60
5	'Brzęki przy Starej Gajówce' reserve	52°28'	16°28'	100
6	Wielkopolski National Park	52°16'	16°48'	85–100
7	'Kawęczyńskie Brzęki' reserve	52°24'	18°37'	120–130
8	Potarzyca	51°52'	17°24'	130
9	Piaski	51°49'	17°12'	130
10	'Brekinia' reserve	51°17'	16°21'	110
11	Jawor	51°01'	16°08'	300–395
12	'Kamień Śląski' reserve	50°33'	18°05'	180–190
13	'Białowodzka Góra' reserve	49°41'	20°38'	500–550

Table 2. Analysed characters of fruits and seeds

No.	Trait	Accuracy
1	Length of fruit	0.1 mm
2	Max. width of fruit	0.1 mm
3	Ratio of fruit length to fruit width (1/2)	
4	Number of lenticiles (on the surface of 9 mm²)	
5	Number of seeds per fruit	
6	Length of seed	0.1 mm
7	Max. width of seed	0.1 mm
8	Thickness of seed	0.1 mm
9	Ratio of seed length to seed width (6/7)	
10	Ratio of seed thickness to seed width (8/7)	
11	Position of the widest part of fruit (1 – down the half, 2 – half the length, 3 – up the half)	
12	Presence of hairs on fruits (1 – absent, 2 – few, 3 – numerous)	
13	Position of the widest part of seed (1 – down the half, 2 – half the length, 3 – up the half)	

Table 3. Outline of fruits and seeds

Outline	Length to width ratio	Position of the widest part of fruit or seed
roundish	<1.5	in the middle of its length
wide obovate	<1.5	in the upper half of its length
wide ovate	<1.5	in the lower half of its length
elliptical	1.5–2.5	in the middle of its length
obovate	1.5–2.5	in the upper half of its length
ovate	1.5–2.5	in the lower half of its length
oblong	>2.5	in the middle of its length
oblanceolate	>2.5	in the upper half of its length
lanceolate	>2.5	in the lower half of its length

between 0 and 6 (most often 2), and the level of variability was the highest among all applied quantitative traits of fruits and seeds (CV=59.68%). Fruits with no seeds inside were found in five populations (nos. 6, 7, 10, 12, 13), but in the first place in population of 'Brekinia' reserve (no. 10). On average, fruits from Potarzyca and Piaski (populations nos. 8, 9) were the

richest in seeds. A single fruits with five seeds were found in populations nos. 3 and 5 (Goraj and 'Brzęki przy Starej Gajówce' reserve), and the only fruit with six seeds was found in population from Jawor (no. 11). The biggest fruits occurred in population of 'Kamień Śląski' reserve (no. 12), the smallest in population of Wielkopolski National Park (no. 6). Comparing outline of wild service fruits, the most prolate ones were found in 'Bielinek nad Odrą' reserve (no. 4), while the most roundish occurred in Wielkopolski National Park.

On average, seeds of *S. torminalis* are 6.20 mm long (3.20–8.10 mm), 3.25 mm (1.70–5.70 mm) wide, and

Table 4. Statistic description of 10 fruit and seed quantitative traits of *Sorbus torminalis*: M – arithmetic mean, Min. – minimum, Max – maximum, SD – standard deviation, CV – variation coefficient

Popula-tion	Statistics	Traits									
		1	2	3	4	5	6	7	8	9	10
1	M	14.58	11.39	1.28	9.63	1.75	6.51	3.69	2.55	1.78	0.70
	Min.	12.10	10.20	1.06	5.00	1.00	5.10	2.90	1.80	1.28	0.49
	Max	17.00	13.00	1.55	18.00	4.00	7.70	4.50	3.50	2.41	1.00
	SD	1.20	0.70	0.13	2.70	0.87	0.53	0.40	0.35	0.19	0.13
	CV[%]	8.23	6.15	9.92	28.01	49.70	8.10	10.85	13.83	10.88	18.79
2	M	13.86	11.63	1.19	14.95	1.20	6.76	3.75	2.67	1.81	0.72
	Min.	9.80	8.20	1.04	8.00	1.00	4.80	2.70	1.70	1.48	0.42
	Max	16.20	13.40	1.39	24.00	3.00	8.10	4.50	3.50	2.21	1.00
	SD	1.37	1.02	0.09	3.67	0.46	0.62	0.35	0.43	0.18	0.12
	CV[%]	9.87	8.77	7.88	24.56	38.67	9.16	9.39	16.02	10.07	16.15
3	M	13.33	11.92	1.12	11.45	2.05	5.63	3.12	2.32	1.84	0.75
	Min.	11.40	10.30	0.93	6.00	1.00	3.20	2.30	1.30	1.07	0.50
	Max	15.60	13.60	1.29	20.00	5.00	6.80	4.10	3.30	2.52	1.00
	SD	1.12	0.88	0.08	3.89	0.96	0.56	0.47	0.39	0.29	0.13
	CV[%]	8.37	7.40	7.37	33.97	46.80	9.90	14.91	16.64	15.85	17.43
4	M	14.14	10.96	1.29	16.18	2.30	6.42	2.97	2.01	2.19	0.68
	Min.	11.30	9.40	1.11	9.00	1.00	5.00	2.20	1.10	1.60	0.44
	Max	18.50	13.30	1.68	25.00	4.00	7.60	4.30	3.00	2.83	0.96
	SD	1.48	0.82	0.12	4.40	0.99	0.69	0.42	0.34	0.31	0.12
	CV[%]	10.45	7.45	9.33	27.18	43.14	10.82	14.23	16.92	14.02	17.54
5	M	13.81	11.19	1.24	19.10	2.00	6.34	3.24	2.49	1.99	0.77

Popula-tion	Statistics	Traits									
		1	2	3	4	5	6	7	8	9	10
9	Min.	10.80	9.00	1.03	10.00	1.00	5.00	2.00	1.80	1.55	0.57
	Max	16.80	13.80	1.51	32.00	5.00	7.60	4.00	3.60	3.20	1.00
	SD	1.58	1.17	0.12	4.71	1.13	0.67	0.39	0.44	0.36	0.10
	CV[%]	11.41	10.42	9.77	24.67	56.61	10.54	11.96	17.56	18.06	13.39
6	M	11.88	11.40	1.05	14.28	1.40	5.64	3.27	2.38	1.77	0.74
	Min.	8.20	9.00	0.87	6.00	0.00	3.50	2.20	1.40	1.02	0.47
	Max	14.70	14.70	1.33	28.00	4.00	6.60	5.70	3.60	2.40	0.94
	SD	1.48	1.33	0.11	4.90	1.10	0.72	0.68	0.57	0.30	0.14
	CV[%]	12.49	11.64	10.62	34.32	78.91	12.81	20.87	23.80	16.71	18.91
7	M	14.00	12.07	1.16	8.28	1.45	5.94	2.72	1.86	2.21	0.69
	Min.	10.50	10.00	0.95	4.00	0.00	4.20	1.70	1.20	1.62	0.50
	Max	17.00	14.70	1.40	16.00	4.00	8.00	3.50	2.50	3.00	0.95
	SD	1.29	0.90	0.10	2.60	1.01	0.89	0.43	0.30	0.34	0.10
	CV[%]	9.22	7.44	8.85	31.44	69.76	14.99	15.91	16.27	15.35	15.01
8	M	14.27	11.49	1.24	12.95	2.85	6.39	3.14	2.15	2.08	0.69
	Min.	11.10	9.30	1.07	6.00	1.00	4.80	2.30	1.20	1.58	0.44
	Max	17.20	13.20	1.46	23.00	4.00	7.90	4.00	2.90	3.00	0.84
	SD	1.57	0.94	0.12	4.56	0.86	0.71	0.48	0.39	0.37	0.09
	CV[%]	11.02	8.21	9.31	35.19	30.31	11.15	15.34	18.19	18.04	13.61
9	M	14.40	12.24	1.18	12.73	2.78	6.29	3.37	2.40	1.88	0.71
	Min.	10.50	10.00	0.94	6.00	1.00	4.70	2.50	1.90	1.20	0.54
	Max	18.60	14.70	1.38	25.00	4.00	8.00	4.00	3.80	2.32	0.95
	SD	2.06	1.29	0.11	4.48	1.03	0.84	0.34	0.35	0.28	0.09
	CV[%]	14.33	10.57	9.52	35.23	36.94	13.31	10.12	14.71	14.73	12.98
10	M	13.22	10.85	1.23	14.10	0.73	5.80	3.43	2.73	1.73	0.80
	Min.	10.80	8.20	0.89	7.00	0.00	4.80	2.10	1.00	1.33	0.29
	Max	16.00	12.60	1.54	22.00	2.00	7.10	4.50	3.90	2.57	1.00
	SD	1.35	1.19	0.14	3.96	0.51	0.57	0.61	0.70	0.29	0.15
	CV[%]	10.19	10.95	11.59	28.09	69.76	9.76	17.89	25.50	16.61	18.82
11	M	13.93	12.13	1.15	13.68	2.30	6.14	3.41	2.49	1.82	0.73
	Min.	10.00	10.50	0.91	6.00	1.00	4.30	2.60	1.60	1.39	0.57
	Max	16.80	15.50	1.46	29.00	6.00	7.30	4.00	3.40	2.31	0.97
	SD	1.42	0.98	0.11	5.45	1.22	0.59	0.38	0.44	0.26	0.10
	CV[%]	10.21	8.08	9.70	39.83	53.20	9.64	11.21	17.80	14.39	13.87
12	M	15.57	13.13	1.19	17.03	2.13	6.39	3.36	2.37	1.97	0.72
	Min.	12.50	10.80	0.88	10.00	0.00	4.40	1.80	1.20	1.23	0.49
	Max	19.60	15.00	1.58	27.00	4.00	7.80	5.00	4.20	2.89	0.98
	SD	1.94	1.24	0.17	4.11	1.26	0.89	0.75	0.51	0.44	0.13
	CV[%]	12.48	9.45	14.47	24.14	59.51	13.98	22.15	21.50	22.27	17.65
13	M	13.94	11.15	1.25	17.63	1.98	6.01	2.69	1.88	2.26	0.71
	Min.	9.70	9.80	0.95	8.00	0.00	3.70	1.80	1.20	1.54	0.44
	Max	18.00	12.80	1.53	26.00	4.00	7.50	3.50	2.70	3.00	0.96
	SD	1.86	0.68	0.14	5.23	1.14	0.72	0.41	0.32	0.32	0.14
	CV[%]	13.36	6.08	11.19	29.65	57.89	12.04	15.11	17.01	14.25	19.68
All samples	M	13.92	11.66	1.20	14.00	1.92	6.20	3.25	2.33	1.95	0.72
	Min.	8.20	8.20	0.87	4.00	0.00	3.20	1.70	1.00	1.02	0.29
	Max	19.60	15.50	1.68	32.00	6.00	8.10	5.70	4.20	3.20	1.00
	SD	1.73	1.19	0.14	5.18	1.14	0.76	0.56	0.50	0.35	0.12
	CV[%]	12.41	10.17	11.44	37.00	59.68	12.34	17.21	21.35	17.92	16.86

Fig. 2. Variation in shape and size of *Sorbus torminalis* fruits (Fot. M. Dziurla)

2.33 mm (1.10–4.20 mm) thick. The mean length to width ratio is 1.95 (1.02–3.20), and mean thick to width ratio is 0.72 (0.29–1.00), (Table 4). Considering seed outline, they are mainly obovate (±77% analysed seeds), sometimes elliptical (±12%) or oblanceolate (±6%), rarely wide obovate (±4%) and only sporadically oblong or roundish (Fig. 3). The biggest seeds occurred in population of Rogóźno (no. 12), the smallest in populations from Goraj, Wielkopolski National Park and 'Brekinia' reserve (nos. 3, 6, 10). The narrowest and most prolate seeds were found in fruits from 'Białowodzka Góra' reserve (no. 13), while the most roundish occurred in populations from 'Brekinia' reserve and Wielkopolski National Park.

Most of applied quantitative traits of fruits and seeds (except highly variable traits 4 and 5) are characterised by moderate level of variation (Wysocki and Lira 2003). The least variable among considered traits proved to be fruit width (CV=10.17%), and fruit and seed length (CV=12.41% and 12.34%, respectively). Generally, traits describing size and shape are higher variable in seeds than in fruits. Coefficients of variability differed not only among applied traits but also among studied populations. The least variable are fruits and seeds from Tuchola, the most variable

fruits and seeds occur in population of Wielkopolski National Park.

Correlation coefficients of 10 quantitative trait values were calculated for 479 fruits and seeds (41 fruits with no seeds were excluded). The whole material indicates about 69% statistically significant correlations between traits at the level 0.01, with 100% significant correlations between seed traits (Table 5). Dimensional traits of fruits and seeds are positively significantly correlated, with the highest correlation (0.72) between the length of fruit and seed (traits 1, 6). The number of seeds per fruit (trait 5) is positively significantly correlated with fruit size (traits 1, 2) and seed length (trait 6), and negatively with seed width and thickness (traits 7 and 8). The number of lenticiles on the fruit surface (trait 4) is the least correlated with other traits. In respect of all 10 quantitative traits of fruits and seeds, the most frequent significant correlation coefficients were observed for the populations of Potarzyca and Jawor (nos. 8, 11; 38%), and the least frequent significant correlation coefficients were found for the population of 'Kawęczyńskie Brzęki' reserve (no. 7; 20%).

Testing the general hypothesis in multivariate analysis of variance MANOVA showed, that in re-

Fig. 3. Variation in shape and size of *Sorbus torminalis* seeds (Fot. M. Dziurla)

spect to the applied 10 traits of fruits and seeds taken together, the examined populations differed significantly between each other, as indicated by the calculated value of F statistics ($F_{calc}=9.10$, $F_{0.05}=1.226$).

Testing of the first group of detailed hypotheses (ANOVA), involving differentiation between 13 populations in respect to each of the applied 10 traits of fruits and seeds, all the examined differences were found significant ($F_{calc}>F_{0.05}$). The percent of variation among populations for particular traits ranged from 6.57 to 35.11 (with mean 23.99). Additionally,

an applied Tukey's HSD test shows homogeneous groups of populations in respect to each of the applied 10 traits of fruits and seeds separately (Table 6).

Testing the second set of detailed hypotheses examined differentiation of 13 populations arranged into 78 contrasts in MANOVA (comparisons of population pairs) in respect to all applied traits of fruits and seeds taken together. All the examined contrasts were found significant ($F_{calc}>F_{0.05}$) except one – between population of Piaski and population of Jawor (nos. 9, 11).

Table 5. Correlation coefficients of 10 quantitative trait values of *Sorbus torminalis* fruits and seeds

Traits	1	2	3	4	5	6	7	8	9
10	−0.15**	−0.11*	−0.05	0.11*	−0.22**	−0.16**	−0.24**	0.61**	0.13**
9	0.32**	−0.13**	0.45**	0.11*	0.28**	0.35**	−0.73**	−0.50**	
8	0.04	0.15**	−0.09*	−0.01	−0.34**	0.16**	−0.62**		
7	0.19**	0.30**	−0.07	−0.11*	−0.19**	0.35**			
6	0.72**	0.26**	0.51**	0.00	0.15**				
5	0.18**	0.34**	−0.11*	−0.07*					
4	−0.06	−0.19**	0.11*						
3	0.64**	−0.39**							
2	0.45**								

**Significant at the level 0.01
*Significant at the level 0.05

Table 6. Values of F statistics defining differentiation of 13 *Sorbus torminalis* populations in respect to 10 quantitative traits of fruits and seeds (separately); S_A^2 [%] – percent variation among populations; $F_{0.05}=1.771$ (fruits) and $F_{0.05}=1.773$ (seeds)

Traits	S_A^2 [%]	F calc.	Homogenous groups
1	22.17	12.034	6 3 10 5 2 11 4 7 8 13 9 1 12
2	26.01	14.850	4 5 13 1 10 8 2 6 3 11 7 9 12
3	23.18	12.748	6 3 11 12 7 9 10 2 5 8 13 1 4
4	35.11	22.863	7 1 3 6 9 8 10 11 2 4 13 12 5
5	25.94	14.797	10 2 1 7 6 5 3 13 11 4 12 9 8
6	18.62	8.887	3 6 10 7 13 11 9 5 12 8 4 1 2
7	29.94	16.594	13 7 4 3 8 5 6 12 9 11 10 1 2
8	27.92	15.041	7 13 4 8 3 12 6 9 11 5 1 2 10
9	24.40	12.530	10 6 1 2 11 3 9 12 5 8 4 7 13
10	6.57	2.731	4 8 7 1 13 9 2 12 11 6 3 5 10

Table 7. Mahalanobis distances between 13 *Sorbus torminalis* populations calculated on the basis of 10 quantitative traits of fruits and seeds

Population	1	2	3	4	5	6	7	8	9	10	11	12
13	9.191**	9.951**	4.849**	2.124**	4.495**	6.977**	6.841**	3.293**	4.939**	6.399**	4.732**	5.532**
12	10.877**	9.688**	5.880**	7.476**	6.332**	7.182**	10.794**	6.964**	4.585**	7.390**	3.874**	
11	4.063**	4.015**	1.625**	3.654**	2.788**	1.832**	8.120**	1.906**	0.546	2.401**		
10	4.353**	4.390**	2.572**	6.517**	4.968**	3.051**	8.122**	5.682**	4.237**			
9	4.125**	5.888**	2.109**	3.870**	3.755**	3.455**	8.866**	1.279**				
8	4.031**	6.470**	3.676**	1.393**	3.310**	4.576**	8.630**					
7	11.160**	13.135**	4.680**	9.888**	14.876**	6.889**						
6	5.871**	4.707**	1.486**	5.973**	5.611**							
5	6.693**	4.022**	6.316**	2.041**								
4	5.492**	5.873**	5.680**									
3	4.823**	7.053**										
2	4.784**											

** Significant at the level 0.01
* Significant at the level 0.05

The Mahalanobis distances, between 13 populations of wild service tree also demonstrated absence of significant differences only between population of Piaski and population of Jawor. All the remaining populations differ significantly between themselves (Table 7). The minimum spanning tree (Fig. 4) constructed on the basis of the shortest Mahalanobis distances also shows the divergent character of populations of 'Kawęczyńskie Brzęki' reserve (no. 7), Tuchola and Rogóźno (nos. 1, 2). Population no. 7 is
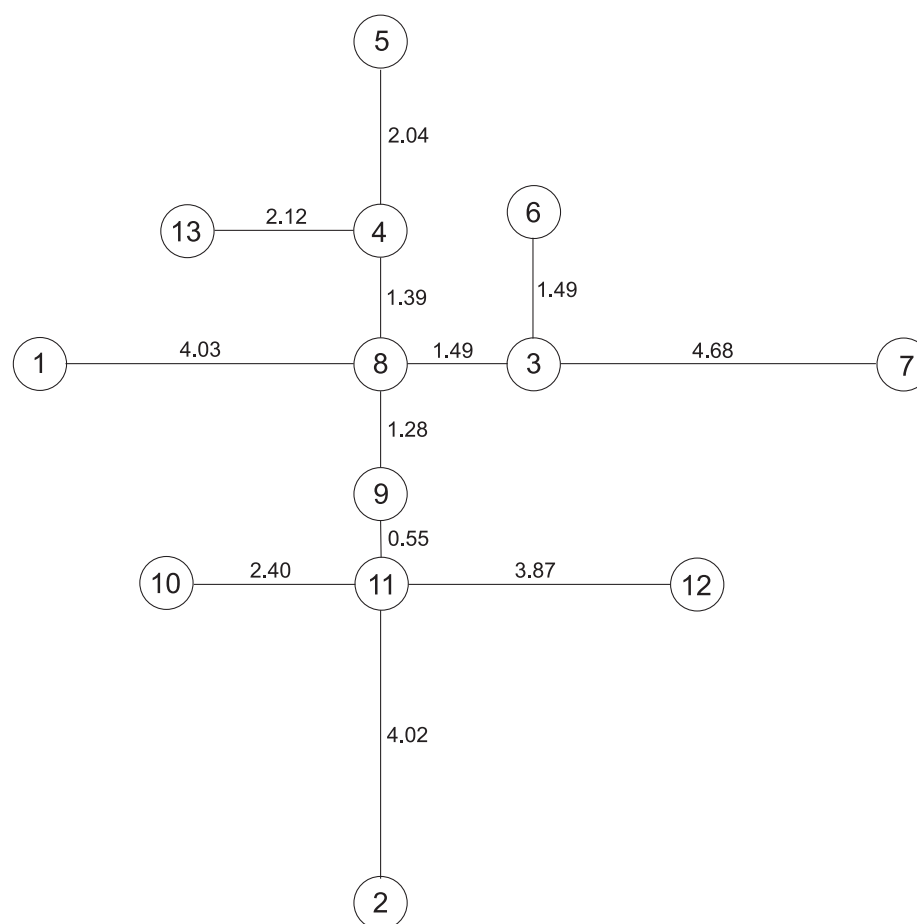

Fig. 4. Minimum spanning tree of 13 *Sorbus torminalis* populations for 10 quantitative traits of fruits and seeds constructed on the basis of Mahalanobis distances
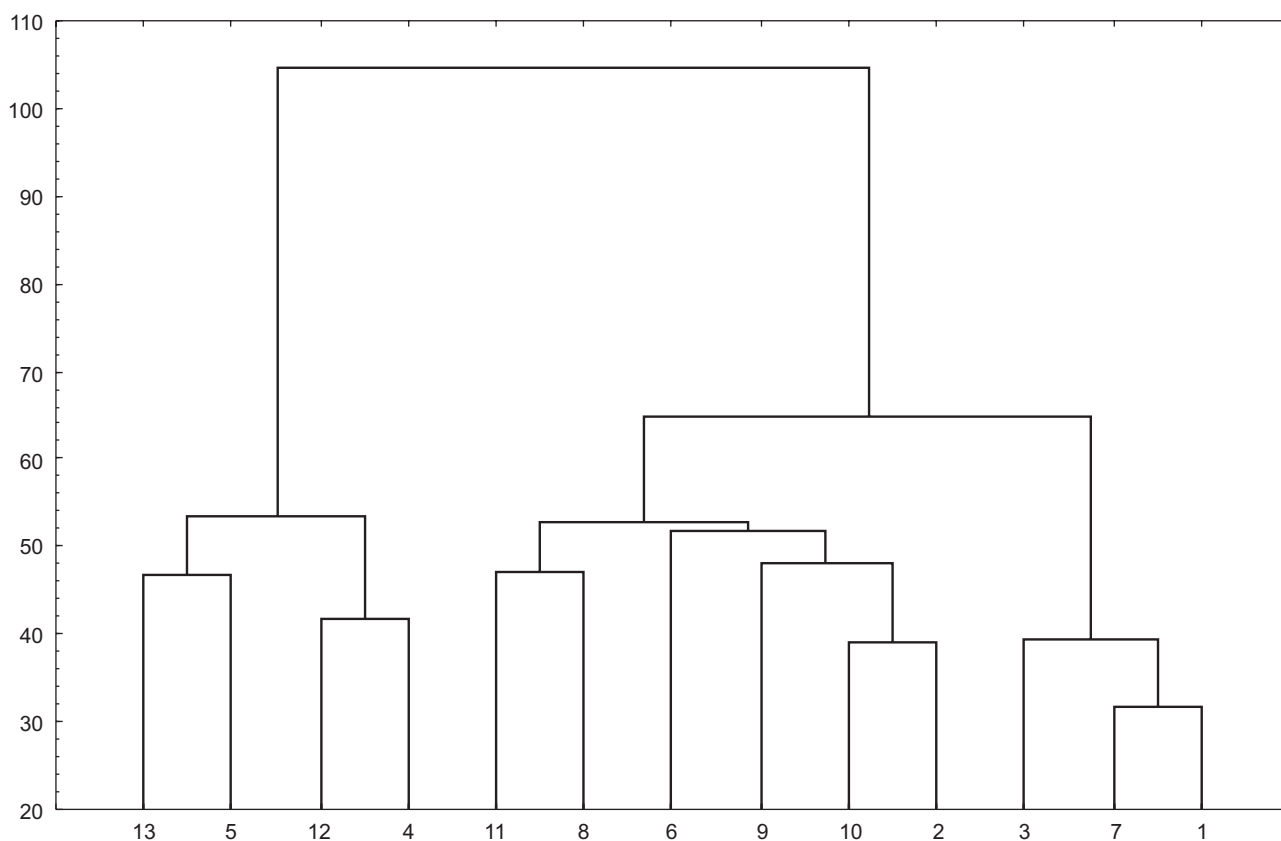
Fig. 5. Dendrogram of 13 *Sorbus torminalis* populations constructed on the basis of the shortest Euclidean distances (calculated on the basis of 10 quantitative traits of fruits and seeds)

conspicuous by few lenticiles and small and dumpy seeds, whereas populations nos. 1 and 2 are distinguishable by big and numerous seeds. Also a distinct character of population of 'Białowodzka Góra' reserve (no. 13) from other populations (nos. 10, 11, 12) from southern Poland can be noticed.

The analysis of discriminant function was applied to decide which of fruit and seed traits (variables) discriminate best 13 analysed populations of *S. torminalis*. This analysis showed that three traits: the number of lenticiles (trait 4), the number of seeds per fruit (trait 5), and seed length (trait 6), had the highest contribution to discrimination of the populations (Table 8). The maximum width of seed (trait 7), maximum width of fruit (trait 2) and seed thickness (trait 8) demonstrated the lowest discriminant power among all applied traits (showed the highest values of Partial Lambda Wilksa and p- level). The analysis of discriminant function showed that all applied traits except seed width (trait 7) demonstrated significant discriminant power at p=0.05.

Dendrogram, showing relations between investigated populations (in respect to all traits together), divides them into two groups only very weakly connected with their geographic distribution (Fig. 5). Also, no statistically significant correlation between values of particular traits and geographic latitude and longitude was recorded. However some similarities

Table 8. The discriminant power of 10 quantitative traits of fruits and seeds collected from 13 *Sorbus torminalis* populations

Traits	Lambda Wilksa statistics	Partial Wilksa	p level	Tolerance
1	0.134	0.947	0.013	0.010
2	0.133	0.950	0.023	0.016
3	0.134	0.945	0.011	0.011
4	0.190	0.665	0.000	0.937
5	0.168	0.751	0.000	0.672
6	0.143	0.884	0.000	0.078
7	0.132	0.959	0.083	0.036
8	0.133	0.950	0.024	0.026
9	0.136	0.929	0.001	0.048
10	0.133	0.948	0.016	0.030

can be found between populations from Lower Silesia (nos. 10, 11) and southern Wielkopolska (nos. 6, 8, 9).

Discussion

Size of fruit and seed of *S. torminalis* collected from Polish populations are comparable to those from other European countries (Kovanda 1961; Aldasoro et al. 1998a). Fruits varied considerably in outline, from wide obovate (most often) through roundish and elliptical to wide ovate. Six out of seven different

fruit forms described in *S. torminalis* by Kárpáti (1960) were found in Polish populations. Only form dolichocarpa (big fruits 2.5–3 times longer than wider) did not happened among examined fruits. Also seeds of *S. torminalis* varied considerably in outline, but obovate ones are observed most often.

McAllister (2005) claims that fruit size in *Sorbus*, especially length, can be a useful character. According to this author fruit length is more constant than width, which varies according to water availability and number of viable seeds. My study did not confirm this statement. In *S. torminalis*, fruit width was more stable than length despite high variation in the number of seeds.

Number and size of fruits and seeds are important biological features which among others decide of generative propagation abilities. Most often in examined populations fruits contained two seeds, but fruits with no seeds and with up to six seeds also happened. The highest rate of fruits with no seeds inside were found in populations of 'Brekinia' reserve (no. 10). From my own field observations it is evident that in this reserve *S. torminalis* trees predominantly reproduce vegetatively from root suckers. Intensive vegetative propagation in *S. torminalis* often appears as a result of poor generative propagation abilities. Producing root suckers may increase the tree's competitive abilities. This is also the mayor way to colonise disturbed areas (Demesure-Mush and Oddou-Muratorio 2004).

Some morphological features of fruits (e.g. shape, colour, number and size of lenticiles) and seeds (microsculpture, shape) are of high importance in distinguishing species within genus *Sorbus* (Kovanda 1961; Aldasoro et al. 1998a; Maciejewska-Rutkowska and Bednorz 2004; McAllister 2005). A number of lenticiles differs considerably between *Sorbus* species and this trait may be a good discriminating factor. Among *Sorbus* species the number of lenticiles is the highest in *S. torminalis* (Aldasoro et al. 1998a). Brown colour of *S. torminalis* fruits and copious lenticiles permitting scent to emanate favour their dispersal by mammals (Herrera 1987, 1989). The fact that these characters are affected by selection for a particular dispersal strategy reduces their phylogenetic value (Aldasoro et al. 1998a). In my study the density of lenticiles was a highly variable trait but not significantly correlated with other fruit characters. The recent studies on morphological differentiation of seeds of Polish species of the genus *Sorbus* showed that microsculpture characters together with the size and shape ones allow to easily recognize three following species: *S. aucuparia*, *S. chamaemespilus* and *S. torminalis* (Maciejewska-Rutkowska and Bednorz 2004; Bednorz et al. 2006a). The study of Bednorz and others (2006a) also shows that seeds of *S. torminalis* are the most variable among five native *Sorbus* species.

Substantial morphological differentiation of fruits and seeds of wild service tree in Poland was observed mainly within populations. The percent of variation among populations within total variation ranged from 6.57 to 35.11 (with mean 23.99) regarding particular traits. Hence, fruits and seeds discriminate populations of wild service tree less than leaves for which the share of variation among populations within total variation is higher (13.35–72.33%), (Bednorz 2006). Moreover, in case of fruits, the ability of collection of plant material is a limiting factor. In small populations usually only a few trees bear fruits, thus the collection of statistically representative sample is impossible. Though significant differences between the sampled populations were ascertained, almost no geographical pattern of this differentiation was detected in Poland. It seems that fruit and seed traits are of no great importance in studies on geographical variation in *S. torminalis*. The extensive studies on morphological variability of leaves and genetic diversity in *S. torminalis* in Poland seems to confirm this opinion (Bednorz 2006; Bednorz et al. 2006b). The cited studies revealed some divergence of populations from north-western and southern Poland, which corresponds with two presumable directions of the species migration to Poland after the last glaciations (Pawłowski 1925; Szafer 1927; Czubiński 1950).

As already stated in the introduction, gynoeceum in *S. torminalis* consistently showed two carpels and formed two loculi with two ovules per each locule. Therefore four seeds in the fruit was the highest possible number. According to most of the authors there are usually 2–4 seeds in the fruit. McAllister (2005) emphasizes that previously published number of carpels in *Sorbus* fruits must be treated with caution as they were often derived from observations made on very few fruits on a herbarium material. Counting the seeds in 520 fruits collected in 13 Polish populations of *S. torminalis* I have found a few fruits with 5–6 seeds what suggests the presence of three carpels in gynoeceum, a number not previously reported in the species. The same refers to the number of styles. I have reported and documented earlier the sporadic presence of three styles in gynoeceum of *S. torminalis* flowers (L. Bednorz, unpubl. data). Therefore the statement that the number of carpels and styles in gynoeceum of *S. torminalis* flowers is constant should be verified.

Acknowledgements

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