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Seed variability of the Polish species of the genus *Sorbus* (Rosaceae)

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Abstract: This paper presents the results of the study on morphological differentiation of seeds of five Polish species of the genus *Sorbus* L. (*S. aria* (L.) Crantz, *S. aucuparia* L. Emend. Hedl., *S. chamaemespilus* (L.) Crantz, *S. intermedia* (Ehrh.) Pers. and *S. torminalis* (L.) Crantz). The biometric data of 1980 seeds were subjected to multivariate statistical analysis in attempt to define intraspecific variation and to find differences between studied taxa. Most of the seed traits are significantly correlated and are characterised by moderate level of variation. Seeds of *S. aucuparia* (both subspecies) are the least variable while seeds of *S. torminalis* and *S. intermedia* the most. On the basis of size and shape traits of *Sorbus* seeds only seeds of *S. aucuparia* can be definitely distinguished from the others.

Additional key words: plant variation, plant taxonomy, statistical analysis, biometrics

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Introduction

The genus *Sorbus* L. (Rosaceae, Maloideae) includes around 250 species, occurring mainly in temperate regions of the Northern Hemisphere (Phipps et al. 1990). In Poland, seven following species have been recognized: *S. aria* (L.) Crantz, *S. aucuparia* L. Emend. Hedl., *S. carpatica* Borbás, *S. chamaemespilus* (L.) Crantz, *S. graeca* (Spach) Kotschy, *S. intermedia* (Ehrh.) Pers. and *S. torminalis* (L.) Crantz (Mirek et al. 2002). *S. aucuparia* is the most common species, widespread throughout Poland. In lowlands, it is represented by typic subspecies *aucuparia*, while in the mountains by subspecies *glabrata* (Wimm. & Grab.) Cajander. *S. torminalis* is a rare, scattered tree species with north-eastern limit of its range in Poland. *S. intermedia* as a northern species occurring naturally only on a few localities on the Baltic coast, is commonly planted a road tree and often naturalizes. The last four species grow in the wild only locally in southern Poland in Pieniny and Tatra Mountains.

Polish species of genus *Sorbus* were the subject of biometrical studies, but only leaves were taken into consideration (Tyszkiewicz and Staszkiewicz 1997; Staszkiewicz 1997 a, b). In systematic studies of subfamily *Maloideae* usually leaves, flowers and fruits

were investigated. The only multivariate morphometric study of the genus *Sorbus* included seed traits was carried out by Aldasoro et al. (1998).

The objective of this study was to define intraspecific variation of the seeds of Polish species of *Sorbus* and to evaluate whether size and shape traits of seeds can be useful in identification of examined taxa.

Materials and methods

The seeds of five Polish *Sorbus* species (*S. aria, S. aucuparia, S. chamaemespilus, S. intermedia* and *S. torminalis*) were analysed. In case of *S. aucuparia*, seeds of subspecies *aucuparia* and *glabrata* have been studied separately.

The samples of fruits with mature seeds were mainly collected from natural localities and sporadically from cultivated trees. The number of investigated samples (populations) depended on the range and rarity of individual species (see Appendix) and comprised one sample for *S. chamaemespilus*, four for *S. aria*, four for *S. intermedia*, 12 for *S. torminalis* and 27 for *S. aucuparia* (22 for type subspecies and five for subsp. *glabrata*).

The total of 1980 seeds from five species were characterised in respect to five quantitative (A–E) and one qualitative (a) following traits:

A – length of seed (mm),
B – max. width of seed (mm),
C – thickness of seed (mm),
D – ratio of seed length to seed width (A/B),
E – ratio of seed thickness to seed width (C/B),
a – position of the widest part of seed (1 – down the half, 2 – half the length, 3 – up the half).

Measurements were made with the stereoscope microscope type SZ-PT Olympus. The outline of seed was determined according to the length to width ratio and the position of the widest part of the seed in relation to hilum, as given in Table 1.

Each quantitative trait was analysed for its mean value (M), range (Min., Max.), standard deviation (SD) and coefficient of variability (CV). The Pearson's correlation coefficients between the trait values were also calculated.

Table 1.

Outline	Length to width ratio	Position of the widest part of seed
Roundish	<1.5	in the middle of its length
Wide obovate	<1.5	in the upper 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

The cluster analysis was applied in order to show relationships among 48 populations (samples) of five *Sorbus* species. Classification was carried out using Ward (minimal variance) method and Euklidean distances (Ward 1963; Walkowiak and Podleśny 1995).

The principal component analysis – PCA as the ordination method was also performed to find the position of studied populations and species along the first two principal components (Morrison 1990). This method can also indicate which seed traits provide the greatest contribution to differences among the studied populations.

Analysis of variance (MANOVA) was used to check weather differences between studied taxa and obtained groups are statistically significant (Caliński and Kaczmarek 1973; Dobosz 2001). To fulfil the assumptions of analysis of variance, observations were standardized using Walkowiak (2000) method.

All numerical analyses were performed using the STATISTICA 7.1 package.

Results

Investigated species of *Sorbus* differ in seed outline (Table 2, Fig. 1). Seeds are most often obovate in *S. chamaemaspilus* and *S. torminalis* but elliptical in *S. aucuparia* and *S. intermedia*. *S. aria* have the most variable seeds in respect of outline. They are roughly equally divided into oblanceolate, obovate, oblong and elliptical.

Comparing size of seeds of studied species they are the biggest in *S. torminalis* and *S. chamaemespilus* and the smallest in *S. aucuparia*. Comparing shape of studied seeds, they are the least virgate (slender) in *S.*

Table 2. Seed outline of the investigated species of *Sorbus*

Species	Outline
S. aria	oblanceolate (± 38% analysed seeds), obovate (± 26%), oblong (± 20%), elliptical (± 16%)
S. aucuparia subsp. *aucuparia*	elliptical (± 85% analysed seeds), oblong (± 10%), obovate (± 5%), only sporadically roundish or oblanceolate
S. aucuparia subsp. *glabrata*	elliptical (± 88% analysed seeds), oblong (± 6%), obovate (± 4%) oblanceolate (± 2%)
S. chamaemaspilus	most often obovate (± 92% observed seeds), sporadically wide obovate (± 8%)
S. intermedia	elliptical (± 60% analysed seeds), obovate (± 19%), oblong (± 12%), oblanceolate (± 9%)
S. torminalis	obovate (± 77% analysed seeds), elliptical (± 12%), oblanceolate (± 6%), wide obovate (± 4%), oblong or roundish (± 1%)

torminalis and *S. chamaemespilus*, and they are the most dumpy in *S. intermedia* (Table 3).

All the applied quantitative traits of seeds except the length of seed in case of *S. aria*, *S. aucuparia* and *S. chamaemespilus* (little variable) are characterised by moderate level of variation (Wysocki and Lira 2003). The least variable among the considered features proved to be the length of seed (coefficient of variability CV=8.31–12.32%) while the most variable are the thickness of seed (CV=11.42–21.67%) and thickness/width ratio (CV=12.03–20.12%). Comparing the five analysed *Sorbus* species according to all studied morphological features, the seeds of *S. aucuparia* (both subspecies) are the least variable while the seeds of *S. torminalis* and *S. intermedia* the most.

Three basic seed traits that is its length, width and thickness are positively significantly correlated in all species except *S. chamaemespilus*. The width of seed is the trait which is the strongest correlated with the other traits. Comparing species, the highest number of significant correlations are found in *S. torminalis* the lowest in *S. chamaemespilus* (Table 4).

Dendrogram, which shows relations between 48 investigated samples of five *Sorbus* species (in respect to all traits together), divides them into two groups (Fig. 2). The samples of two subspecies of *S. aucuparia* make one group markedly distinct from the remaining *Sorbus* species, forming the second group. In this group there are two following pairs of similar species: *S. torminalis* – *S. chamaemespilus* and *S. intermedia* – *S. aria*.

Application of principal component analysis (PCA) allowed us to reduce five initial traits to two factors (U_1, U_2) and therefore to ordinate *Sorbus* pop-

Table 3. Arithmetic means (M), minimum (MIN), maximum (MAX), standard deviation (SD), coefficient of variability (CV) of the general samples of the native species of the genus *Sorbus* L. A – length, B – width, C – thickness, D – length/width ratio, E – thicknesss/width ratio, 1 – *S. aria*, 2 – *S. aucuparia* subsp. *aucuparia*, 2a – *S. aucuparia* subsp. *glabrata*, 3 – *S. chamaemespilus*, 4 – *S. intermedia*, 5 – *S. torminalis*

Traits	Species	Statistical characteristics				
		M	MIN	MAX	SD	CV [%]
A	1	4.82	3.80	5.80	0.40	8.31
	2	3.88	3.00	5.00	0.34	8.71
	2a	3.91	2.90	4.70	0.38	9.73
	3	6.07	4.40	6.80	0.60	9.83
	4	5.69	4.10	7.10	0.64	11.25
	5	6.22	3.20	8.10	0.77	12.32
B	1	2.31	1.60	3.10	0.39	16.82
	2	1.80	1.20	2.40	0.21	11.67
	2a	1.76	1.50	2.30	0.18	10.08
	3	3.25	2.40	3.90	0.33	10.19
	4	2.52	1.80	3.40	0.30	11.97
	5	3.24	1.70	5.70	0.55	17.07
C	1	1.75	1.00	2.50	0.38	21.67
	2	1.07	0.70	2.10	0.13	11.82
	2a	1.05	0.80	1.40	0.12	11.42
	3	2.28	1.30	3.30	0.40	17.70
	4	2.09	1.20	3.20	0.37	17.73
	5	2.31	1.10	4.20	0.47	20.58
D (A/B)	1	2.14	1.57	2.72	0.33	15.30
	2	2.18	1.43	3.46	0.30	13.60
	2a	2.23	1.65	2.94	0.24	10.91
	3	1.88	1.37	2.43	0.24	12.92
	4	2.28	1.70	3.35	0.32	13.92
	5	1.96	1.02	3.20	0.35	17.71
E (C/B)	1	0.76	0.46	1.00	0.13	17.39
	2	0.60	0.40	0.95	0.07	12.03
	2a	0.60	0.43	0.81	0.08	12.76
	3	0.70	0.46	0.96	0.12	16.49
	4	0.84	0,52	1.50	0.17	20.12
	5	0.72	0.42	1.00	0.12	16.62

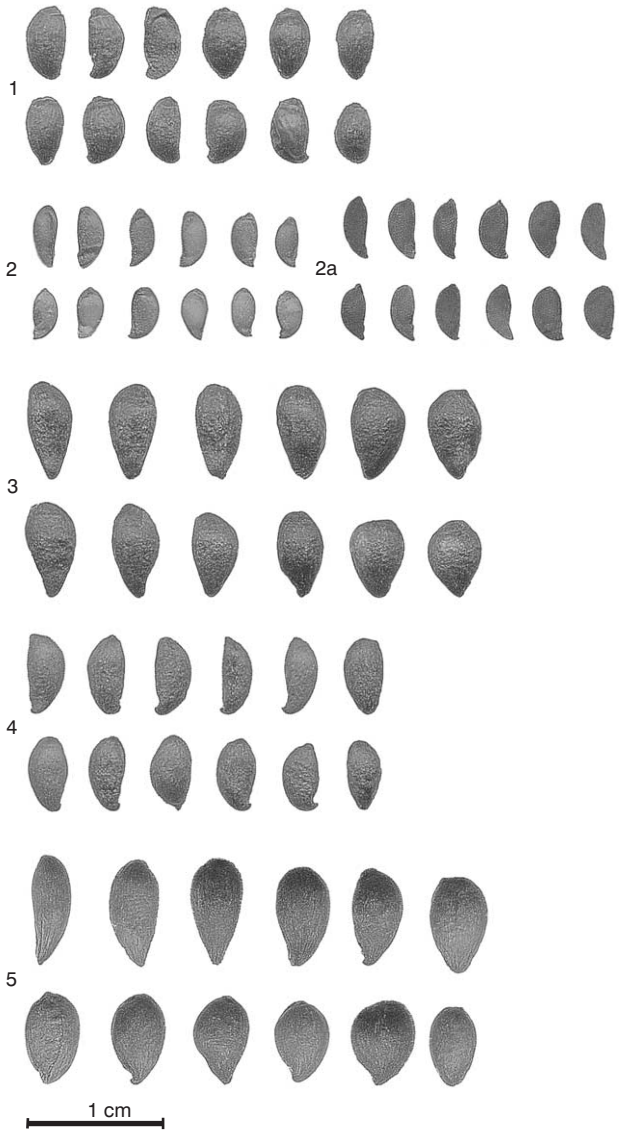

Fig. 1. Different outline of *Sorbus* seeds; 1 – *S. aria*, 2 – *S. aucuparia* subsp. *aucuparia*, 2a – *S. aucuparia* subsp. *glabrata*, 3 – *S. chamaemespilus*, 4 – *S. intermedia*, 5 – *S. torminalis*

Table 4. Correlation coefficients between trait values of seeds of the native species of the genus *Sorbus* L. A – length, B – width, C – thickness, D – length/width ratio, E – thicknesss/width ratio, 1 – *S. aria*, 2 – *S. aucuparia* subsp. *aucuparia*, 2a – *S. aucuparia* subsp. *glabrata*, 3 – *S. chamaemespilus*, 4 – *S. intermedia*, 5 – *S. torminalis*

Species	Traits	Correlation coefficients			
		A	B	C	D
1	B	0.40**			
	C	0.28*	0.60**		
	D	0.08	–0.87**	–0.52**	
	E	–0.08	–0.23	0.63**	0.19
2	B	0.22**			
	C	0.05	0.47**		
	D	0.49**	–0.74**	–0.36**	
	E	–0.15**	–0.53**	0.49**	0.39
2a	B	0.38**			
	C	0.23**	0.27**		
	D	0.56**	–0.54**	–0.03	
	E	–0.08	–0.50**	0.69**	0.38**
3	B	0.18			
	C	–0.14	0.40**		
	D	0.62**	–0.65**	–0.42**	
	E	–0.28	–0.20	0.82**	–0.06
4	B	0.35**			
	C	0.36**	0.17*		
	D	0.55**	–0.59**	0.17*	
	E	0.14	–0.44**	0.80**	0.54**
5	B	0.36**			
	C	0.18**	0.61**		
	D	0.35**	–0.73**	–0.48**	
	E	–0.15**	–0.27**	0.59**	0.16**

**significant at level p=0.01
*significant at level p=0.05

ulations in two-dimensional space (Fig. 3, Table 5). Principal component U_1 accounts for 71.64% of total variation; the first two factors account for 92.85%. Principal component U_1 is determined mostly by three dimensional traits: seed thickness (trait C), seed width (trait B) and seed length (trait A). On the other hand, principal component U_2 is determined mostly by shape traits: ratio of seed length to seed width (trait D) and ratio of seed thickness to seed width (trait E). The populations representing five *Sorbus* species have been divided into three groups clearly shown in the plot. The first group is formed by

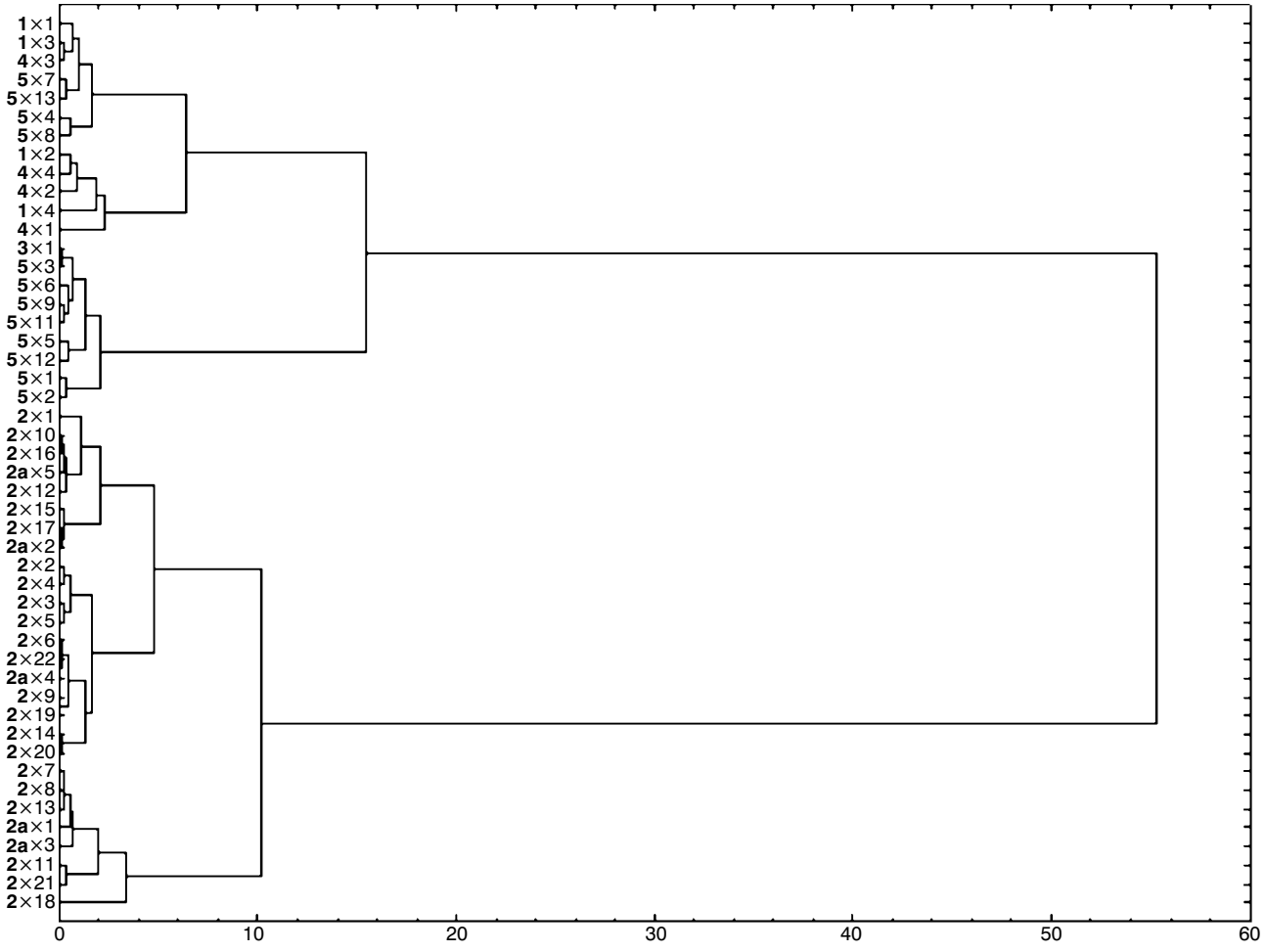

Fig. 2. Dendrogram of similarity of 48 examined samples of *Sorbus* species in respect to five seed traits; **species** × sample (population)

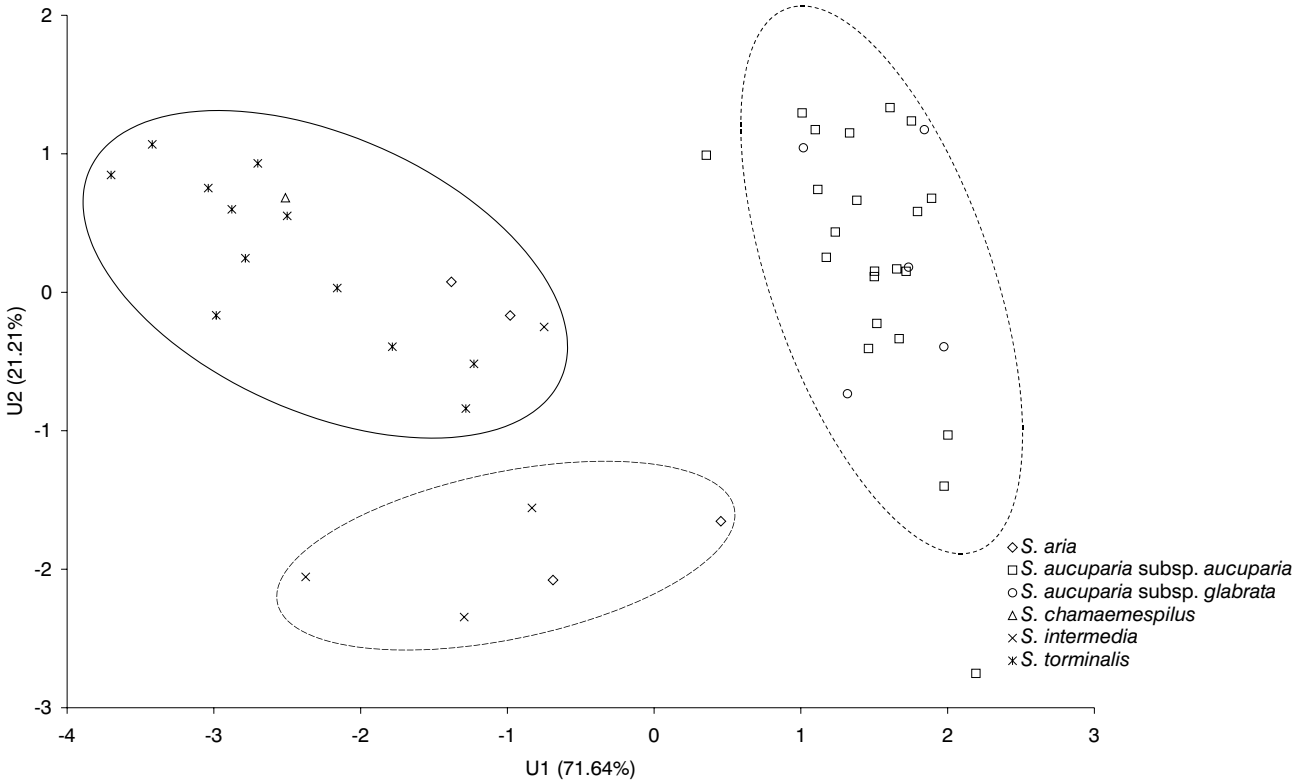

Fig. 3. Results of principal component analysis of 48 examined samples of *Sorbus* species plotted along the two first principal components U_1 and U_2, which accounted for 92.85% of total variation

Table 5. Co-ordinates of two first principal components U_1 and U_2; A – length, B – width, C – thickness, D – length/width ratio, E – thicknesss/width ratio

Traits	U_1	U_2
A	–0.943	–0.142
B	–0.969	0.180
C	–0.998	–0.044
D	0.499	–0.824
E	–0.712	–0.573

populations of both subspecies of *S. aucuparia* which differed markedly from remaining species in respect to size traits. Some populations of *S. intermedia* and *S. aria* form the second group. The third group is formed by populations of *S. torminalis*, *S. chamaemespilus* and the remaining populations of two species from the second group.

Finally, the analysis of variance (MANOVA) was applied to state whether differences between seeds of examined taxa are statistically significant or not. Testing of the general hypothesis showed that in respect to the applied five traits of seeds taken together, the differences between *Sorbus* species were statistically significant (at $p=0.01$). However, detailed testing of comparisons of each taxa pairs, showed the lack of statistically significant differences between two subspecies of *S. aucuparia* ($p=0.113$) and between *S. torminalis* and *S. chamaemespilus* ($p=0.98$).

Discussion

A total of 1980 seeds collected in Poland from five *Sorbus* species were examined according to five quantitative morphological traits. The highest level of variation found in the thickness of seeds is easy to explain. This feature is strongly related to the number of seeds in the fruits and this in turn is very variable in *Sorbus* fruits (Bednorz, unpublished data). Comparing seed dimensions of five *Sorbus* species analysed by us in Poland and Aldasoro et al. (1998) in Europe and in North Africa, some differences can be noticed. In Poland, the biggest seeds were found in *S. torminalis* and *S. chamaemespilus* whereas in Europe and in North Africa, *S. aria* was characterised by the biggest seeds. The differences in seed size were the smallest in *S. torminalis*, and the biggest in *S. aria* and *S. chamaemespilus*.

The study of Maciejewska-Rutkowska and Bednorz (2004) shows that seed morphology, especially its microsculpture may be an important character in distinguishing species within genus *Sorbus*. Using microsculpture characters together with the size and shape of seeds it is easy to recognize three following native *Sorbus* species; *S. aucuparia*, *S. chamaemespilus* and *S. torminalis*. However, it is highly difficult to distinguish the seeds of *S. intermedia* and *S. aria*. It is clear from this biometrical study that on the basis of size

and shape traits of *Sorbus* the seeds only seeds of *S. aucuparia* can be definitely distinguished from the others. According to Aldasoro et al. (1998) seed shape is one of the useful characters in discriminating *Sorbus* species. The results of our study did not confirm this statement.

In case of *S. aucuparia*, we have compared the seeds of subspecies *aucuparia* and *glabrata*. According to Tyszkiewicz and Staszkiewicz (1997) studying variability *of S. aucuparia* leaves, the leaves of both subspecies do not differ in any metrical trait. The only important feature in differentiating of two taxa is pubescence of the leaves. The study of Maciejewska-Rutkowska and Bednorz (2004) shows that also observing microsculpture of seeds using SEM it is impossible to distinguish the two subspecies of *S. aucuparia*. The present study shows that on the basis of metrical traits of seeds the two subspecies do not differ significantly between themselves as well.

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Appendix

Samples (populations) studied:

S. aria: WIELKOPOLSKIE PROV. – 1. Poznań, 24.10.2002, *leg*. L. Bednorz; MAŁOPOLSKIE PROV. – 2. Pieniny Mts. (Kirowe Skałki), 15.09.2002, *leg*. G. Vončina; – 3. Tatry Mts. (Mountain Botanical Garden – GOB Zakopane), 02.10.2002, *leg*. A. Delimat; – 4. Tatry Mts. (Strążyska Valley), 17.09.2002, *leg*. L. Bednorz.

S. aucuparia subsp. *aucuparia*: ZACHODNIOPOMORSKIE PROV. – 1. Podczele, 08.2003, I. Maciejewska-Rutkowska; – 2. Resko forest inspectorate, 24.08.00, *leg*. Paweł Rutkowski; – 3. Mieszkowice, 23.08.1998, *leg*. Ł. Nosal; POMORSKIE PROV. – 4. Słowiński National Park (Mierzeja Łebska), 18.08.2002, *leg*. L. Bednorz; KUJAWSKO-POMORSKIE PROV. – 5. Bory Tucholskie National Park (Lubiana), 14.09.1997, *leg*. I. Maciejewska; – 6. Bory Tucholskie National Park (Charzykowy), 17.09.1997, *leg*. I. Maciejewska; – 7. Włocławek forest inspectorate, 07.1997, *leg*. M. Jatczak; WIELKOPOLSKIE PROV. – 8. Wielkopolski National Park, 30.10.1997, *leg*. I. Maciejewska, T. Maliński; – 9. Borówiec, 23.09.1998, *leg*. I. Maciejewska, A. Zientarska; – 10. Jarocin forest inspectorate 08.1997, *leg*. A.

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S. aucuparia subsp. *glabrata*: DOLNOŚLĄSKIE PROV. – 1. Karkonosze Mts. (Śnieżne Kotły), 10.10.2001, *leg*. L. Bednorz; – 2. Karkonosze Mts. (Bronek Czech's glade), 09.1995, *leg*. W. Danielewicz; – 3. Karkonosze Mts. (over Strzecha Akademicka), 09.1995, *leg*. W. Danielewicz; MAŁOPOLSKIE PROV. – 4. Tatry Mts. (Sarnia Skała), 17.08.2002, *leg*. L. Bednorz; – 5. Gorce Mts., 10.1997, *leg*. J. Lach.

S. chamaemespilus: MAŁOPOLSKIE PROV. – 1. Tatry Mts. (GOB Zakopane), 22.09.2002, *leg*. A. Delimat.

S. intermedia: ZACHODNIOPOMORSKIE PROV – 1. Mielno, 10.1997, *leg*. A. Harat; POMORSKIE PROV. – 2. "Kępa Redłowska" reserve, 01.10.2002, *leg*. J. Szramka; – 3. Kolbudy, 01.10.2002, *leg*. J. Szramka; WIELKOPOLSKIE PROV – 4. Poznań (Dendrological Garden), 22.10.2001, *leg*. L. Bednorz.

S. torminalis: ZACHODNIOPOMORSKIE PROV. – 1. "Bielinek nad Odrą" reserve, 04.09.2002, *leg*. L. Bednorz; POMORSKIE PROV. – 2. Tuchola, 06.10.2000, *leg*. L. Bednorz; KUJAWSKO-POMORSKIE PROV. – 3. Rogóźno, 05.10.2000, *leg*. L. Bednorz; WIELKOPOLSKIE PROV. – 4. Goraj, 28.09.2000, *leg*. L. Bednorz; – 5. "Brzęki przy Starej Gajówce" reserve, 24.09.2000, *leg*. L. Bednorz; – 6. Wielkopolski National Park, 25.09.1999, *leg*. L. Bednorz; – 7. "Kawęczyńskie Brzęki" reserve, 30.09.2000, *leg*. L. Bednorz; – 8. Potarzyca, 27.09.2000, *leg*. L. Bednorz; – 9. Piaski, 27.09.2000, *leg*. L. Bednorz; DOLNOŚLĄSKIE PROV. – 10. Jawor, 02.10.2000, *leg*. L. Bednorz; OPOLSKIE PROV. – 11. "Kamień Śląski" reserve, 19.09.2002, *leg*. L. Bednorz; MAŁOPOLSKIE PROV. – 12. "Białowodzka Góra" reserve, 16.09.2002, *leg*. L. Bednorz.