Morphological variability of *Malva alcea* L. populations from Poland

Zbigniew CELKA, Maria DRAPIKOWSKA, Katarzyna BUCZKOWSKA,
Alina BĄCZKIEWICZ & J. MARCINIAK

Abstract. *Malva alcea* was cultivated because of its healing, nutritive and colouring properties in prehistory and Middle Ages. This species is currently included in the group of relicts of cultivations whose occurrence is connected with archaeological structures, particularly with the remains of old cities and settlements. Nine populations of *M. alcea* L. in Poland have been studied as regards 5 morphological traits of seeds. Biometric data were subject to statistical analyses: multivariate analysis of variance, analysis of discriminant variables as well as the cluster analysis on the basis Euclidean distances. The considered populations proved to be significantly differentiated in terms of the morphological characters under study. There are differences between populations located in the Western (Germany and Western-Polish) and North-Eastern parts of the analysed territory.

Key words: *Malva alcea*, seed morphology, variation, biometry

On the territory of Poland there are 11 species of the tribe Malveae. They are all considered to be aliens (Mirek et al. 2002). *Malva alcea* is found all over Poland, and particularly frequently in its Western and South-Western parts (Zając, Zając 2001). The contemporary range of *M. alcea* is due to a great extent to its cultivation in prehistoric and medieval times as a medicinal, nutritious and dyeing plant. The species is considered a relict of former cultivation, which was imported by Slavs and cultivated in settlements, ancient cities and castles. Its current presence is related to the remains of the former constructions, and especially to the castles (Celka 1998, 1999, 2004). In taxonomy the most important traits are connected with features of fruits and seeds (Latowski 1982; Szkudlarz 2001). Moreover, in the genus *Malva* the main taxonomic traits are characters of flowers and pubescence (Walas 1959). Preliminary research has shown that carpological parameters can be used as a good tool to explain the taxonomic status of *M. alcea* s.l. The aim of this study was to analyse the morphological diversification of *M. alcea* from the territory of Poland and North-Eastern Germany in terms of seed traits.

Materials and Methods

The material under investigation was collected from nine locations in Central Europe. Eight of them are placed in Poland and one in North-Eastern Germany (Fig. 1). Six of the populations are on roadsides; one on a cemetery; and two on embankments of early medieval castles that are remains of very old settlements (Table 1).

The populations of *M. alcea* were examined in terms of 5 morphological traits of the seed (Fig. 2).

Data obtained from the morphological measurements were analysed statistically with the STATISTICA 7.1 for Windows software. The descriptive statistics of traits (means, standard deviations), coefficients of variation, and Pearson's correlations between all traits were computed to evaluate the range of variation of morphological traits. Analysis of variance and the standard method of discriminant analysis were performed. The matrix of mean values per population was used to perform complete linkage method of cluster analysis based on Euclidean distances, in order to visualize the variation among examined populations. In order to check the significance of Mahalanobis distances, the *F* statistic with Bonferroni correction was applied (Morrison 1990; Sokal & Rohlf 1997).

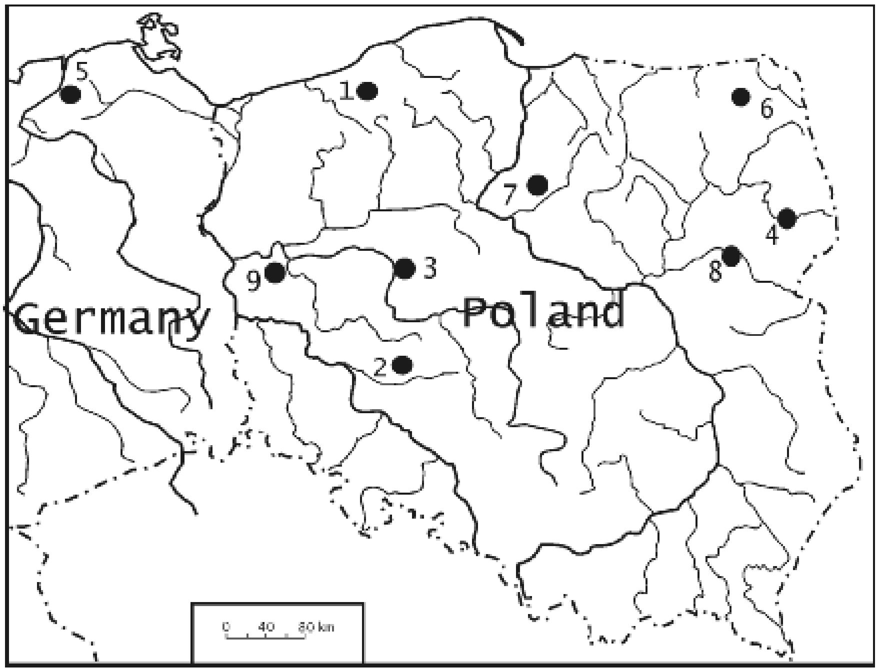

Fig. 1. Distribution of inspected locations of *Malva alcea* (see Table 1)

Table 1. Main characters of the studied populations of *Malva alcea*

Population no.	Location	Habitat	Geographical position
1	Radomyśl	roadside	N53°45`39,1``, E16°31`55,7``
2	Karzec	roadside	N51°45`06,0``, E16°53`33,3``
3	Koziegłowy	roadside at railroad	N52°26`23,6``, E16°58`55,5``
4	Płoski nad Narwią	roadside at a bridge	N52°54`13,1``, E23°13`58,5``
5	Groß Raden	turf on embankments of an early medieval castle	N53°44`07,7``, E11°52`36,7``
6	Boćwinka	roadside	N54°12`50,7``, E22°09`51,4``
7	Napole	xerothermal bank of an early medieval castle	N53°08`53,7``, E18°57`18,4``
8	Wirów	cemetery	N52°26`31,3``, E22°32`12,3``
9	Skwierzyna	roadside	N52°35`36,5``, E15°31`37,3``

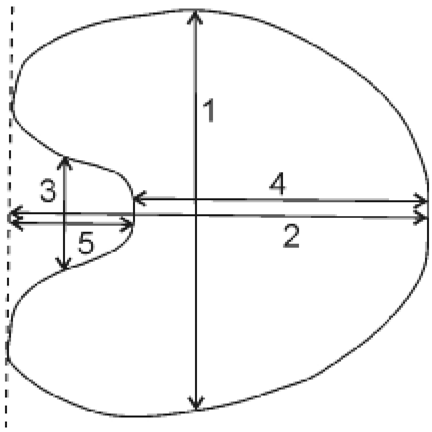

Fig. 2. *Malva alcea* seed with traits subject to examination. 1 - seed's length, 2 - seed's width, 3 - hilum's length, 4 - seed's width without hilum, 5 - hilum's width

Results

Means and coefficients of variation of all examined traits computed for each population are given in Table 2. All populations were characterized by the highest variation coefficient of traits 3 (hilum length) and. 5 (hilum width), whereas traits 1 (seed length) and 2 (seed width) were characterized by the lowest coefficients of variation. In most populations, coefficients of variation of traits 1 and 2. were very low, below 6.0%. Seed length (1) ranged from 1.92 mm in population 1 to 2.29 mm in population 7, while seed width (2) ranged from 1.78 mm in population 1 to 2.13 mm in population 2.

The strongest correlation in all 9 populations was found for trait 1 (seed length) and 2 (seed width) ($r \geq 0.81$) as well as traits 2 and 5 (seed width with the hilum width), $r \geq 0.79$. All the other traits we correlated in all the populations at the level of 0.05. Multivariate analysis of variance (MANOVA) showed statistically significant differences between examined populations in respect to all studied traits taken together (*F* = 38.44**). Univariate ANOVA for each of the variables showed that the studied populations differed statistically in respect of all traits (Table 3).

Table 2. Means value (M) and coefficient of variation (V%) of 5 quantitative traits of 9 studied populations of *Malva alcea*

Trait	**1**M	**1**V%	2M	**2**V%	3M	3V%	4M	4V%	5M	5V%
1	1.92	5.89	2.27	5.70	2.14	5.71	2.11	5.44	2.10	4.79
2	1.78	7.68	2.13	5.76	1.97	5.76	1.97	5.79	1.91	4.76
3	0.36	12.37	0.45	13.23	0.38	13.23	0.38	11.39	0.34	11.58
4	1.31	9.64	1.45	7.17	1.31	7.17	1.35	6.04	1.32	4.71
5	0.47	11.78	0.68	11.77	0.66	11.77	0.62	13.51	0.59	10.81

Trait	6M	6V%	7M	7V%	8M	8V%	9M	9V%
1	2.05	3.43	2.29	3.53	1.96	5.51	2.24	3.01
2	1.94	3.40	2.05	4.03	1.79	5.85	2.05	3.31
3	0.34	11.26	0.39	10.91	0.44	15.91	0.49	15.26
4	1.34	5.66	1.30	6.67	1.28	7.19	1.41	5.79
5	0.59	11.61	0.75	11.43	0.50	16.47	0.64	13.23

Table 3. The *F* statistics for each trait separately for all populations (1- 9) *Malva alcea* (*** - $p \leq 0{,}001$)

Trait	***F***
1	89.42***
2	52.42***
3	69.93***
4	20.21***
5	55.41***

Table 4. Correlation coefficients between 5 traits and discriminat axes (U1, U2, U3) in the studied populations of *Malva alcea*

Trait	u_1	u_2	u_3
1	0.88	0.29	-0.05
2	0.74	0.23	-0.62
3	0.16	0.97	0.05
4	0.20	0.31	0.76
5	-0.70	-0.039	0.049

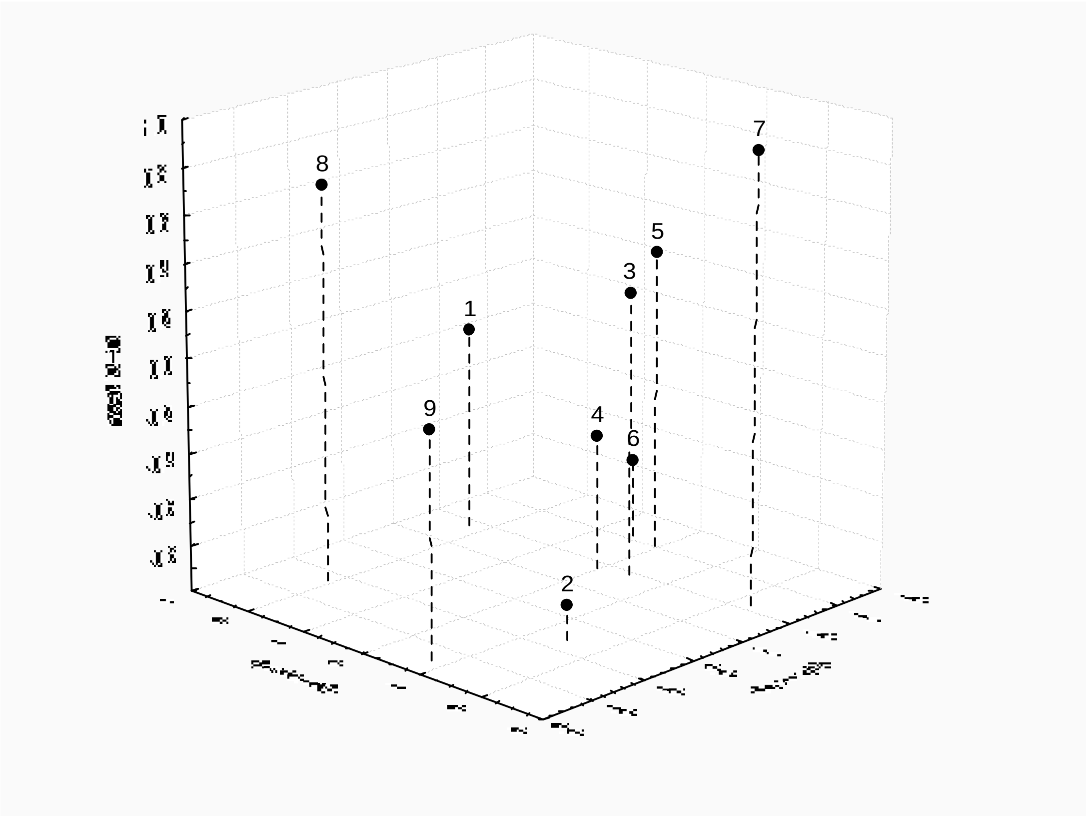

Fig. 3. Scatter diagram for 9 *Malva alcea* populations on the plane of the three first discriminative variables (U1, U2, U3)

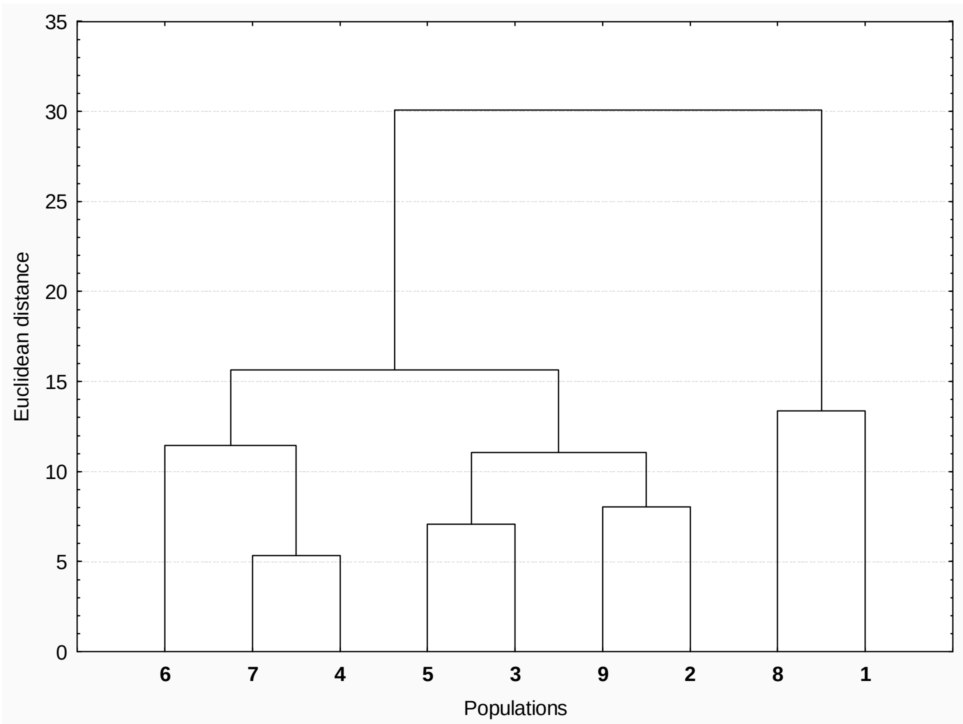

Fig. 4. Dendrogram of the studied populations (1-9) of *Malva alcea* constructed on the basis of the shortest Euclidean distances using set of 5 traits

The first three discriminant axes (U1, U2, U3) explain 99.3% of total variation included in 5 examined traits, and the traits most strongly correlated with the first discriminant axis (U1) were 1, 2 and 5, with the 2nd discriminant axis (U2) and with 3rd (U3) axis: traits 2 and 4. The distribution of centroids of the examined populations in the space of the first three discriminant axes (U1, U2, U3) showed that populations 3, 4, 5 and 6 constitute a group. And then populations 7, 8, 1, 2 and 9 prove to have a different character (Fig. 3).

The largest squares of Mahalanobis distances were noted between populations 7 (Napole) and 8 (Wirów) (22.05, $p \leq 0.05$ - statistical significance with Bonferroni correction) as well as 7 and 1 (Radomyśl) (21.47, $p \leq 0.05$), and the smallest between populations 3 (Koziegłowy) and 4 (Płoski) (0.60 n.s.) as well as 6 (Boćwinka) and 4 (Płoski) (0.76 n.s.). The cluster analysis based on the shortest Euclidean distance showed that populations 8 (Wirów) and 1 (Karzec) are the most distinctive ones as far as the examined traits are concerned. The remaining populations constitute two subsets: the first one covers populations 4, 6 and 7, the other populations 2, 3, 9 and 5. The most similar in respect to examined traits are populations 7 and 4 (Fig. 4).

Discussion

Research on morphological and genetic diversification of the Malvaceae has been carried out in numerous research centres worldwide for many years. Among others they are dedicated to the taxonomic revision of the genus *Callirhoe* (Dorr 1990), to the the analysis of the DNA sequence, i.e. ITS (Tate et al. 2005) and ndhF (Alverson at al. 1999), to the epidermal structures and pubescence (Inamdar & Chohan 1969; Celka et al. 2005) and pollen (El Naggar 2004), but there are no data on morphological variation of *M. alcea* seeds.

Nine populations of *M. alcea* from different parts of Poland were compared in this study. The selected morphological traits of the seeds showed a significant statistical differentiation in the examined populations. The greatest impact was exerted by traits 2 (seed width) and 4 (seed width without hilum) (see Table 4). The variation coefficient reached the highest values for populations 1 (Karzec) and 8 (Wirów). The least variable were traits 1 (seed length) and 2 (seed width) (see Table 2). Differentiation between examined populations determined by means of discriminant variable analysis indicated that populations 3, 4, 5 and 6 are clearly different from populations 7, 8, 1, 2 and 9. Seeds from populations 1 and 8 were characterized by the smallest mean values of traits, whereas in populations 7 and 9 the seeds were bigger. The differences can be possibly caused by e.g. environmental impact and/or intra-species genetic differentiation (Dalby 1968). For example, environmental conditions (temperature and precipitation) influence seed size in *Flourensia cernua* DC. (Valenzia-Díaz 2005). While analysing the graphical image of the Euclidean distance it was found that populations 8 (Wirów) and 1 (Karzec) are the most distinctive ones in respect of the analysed traits. The remaining populations constitute two subsets: the first subset comprises populations 4, 6 and 7, the other populations 2, 3 and 9. In the first case these are populations located East of the Vistula river, in North-Eastern Poland. The second group comprises populations from Western Poland and Groß Raden in Germany. The most similar in respect of examined traits are populations 7 and 4 (Fig. 4). Results of the research show that traits of the seeds, next to pubescence and petals (Iljin 1949, Walas 1959) can enable identification of species in the *Malva alcea* s.l.

Conclusions

1. Populations under study were significantly differentiated in terms of analysed morphological traits of seeds.

2. There are differences between populations located in the Western Poland (and Germany) and North-Eastern Poland.

Acknowledgments

Scientific work financed from resources earmarked for science in years 2005-2008 as Research Project no. 2 P04G 050 29.

References

Alverson W. S., Whitlock B. A., Nyffeler R., Bayer C. & Baum D. A. 1999. Phylogeny of the core Malvales: evidence from ndhF sequence data. American Journal of Botany, 86 (10): 1474-1486.

Celka Z. 1998. *Malva alcea* L. as a relict of prehistoric and mediaeval cultivation. Phytocoenosis vol. 10 (N.S.). Suppl. Cartogr. Geobot., 9: 155-162.

Celka Z. 1999. The Vascular Plants of the Earthworks of Wielkopolska. Publications of the Department of Plant Taxonomy of the Adam Mickiewicz University in Poznań, 9: 1- 159.

Celka Z. 2004. Distribution Atlas of Vascular Plants on the Earthworks of Wielkopolska. Publications of the Department of Plant Taxonomy of the Adam Mickiewicz University in Poznań, 13:1-447.

Celka Z., Szkudlarz P. & Biereżnoj U. 2005. Morphologic diversification of hairs of *Malva alcea* L. (Malvaceae): preliminary research results. [In:] Jackowiak B., Celka Z. (eds.). Taxonomy, chorology and ecology of plants at times of endangerment to biological differentiation. Materials for a scientific conference dedicated to Professor Waldemar Żukowski, Sc.D. on his 70th birthday. Page 172. Poznań.

Dalby D. H. 1968. *Malva* L. [In:] Tutin T. G., Heywood V. H., Burges N. A., Moore D.M., Valentine D. H., Walters S. M., Weeb D. A. (eds.). Flora Europea. Rosaceae to Umbelliferae.Vol. 2: 249-251. Cambridge University Press.

Dorr L. J. 1990. A Revision of the North American Genus *Callirhoe* (Malvaceae). Memoirs of The New York Botanical Garden, 56: 1-76.

Iljin M. M. 1949. *Malvaceae* Juss. [In:] Šiškin B. K., Bobrov E. G. (eds.). Flora URSS, 15: 23-184, Editio Academiae Scientiraum URSS, Moskwa-Leningrad.

Inamdar J. A. & Chohan A. J. 1969. Epidermal Structure and Stomatal Development in Some Malvaceae and Bombacaceae. Oxford Journals - Annals of Botany, 33: 865-878.

Latowski K. 1982. Taxonomic carpological study of Eurasian species of *Lepidium* L. genus. Wyd. Nauk. UAM Poznań, Seria Biologia 23: 1-105.

Mirek Z., Piękoś-Mirkowa H., Zając A. & Zając M. 2002. Flowering Plants and Pteridophytes of Poland. A checklist. Biodiversity of Poland, 1: 1-442.

Morrison D. F. 1990. Multivariate statistic analysis. PWN, Warszawa.

El Naggar S. M. 2004. Pollen Morphology of Egyptian Malvaceae: An Assessment of Taxonomic Value. Turk. J. Bot., 28: 227-240.

Sokal R. & Rohlf T. J. 1997. Biometry. The principles and practice of statistics in biological research. Freeman W. H. and Comp., San Francisco.

Szkudlarz P. 2001. Morphological and anatomical structure of seeds in the family *Ericaceae*. Biol. Bull. Poznań., 38 (2): 113-132.

Tate J. A., Aguilar J. F., Wagstaff S. J., La Duke J. C., Bodo Slotta T. A., Simpson B. B. 2005. Phylogenetic relationships within the tribe Malveae (Malvaceae, subfamily Malvoideae) as inferred from ITS sequence data. American Journal of Botany, 92 (4):584-602.

Walas J. 1959. Malvaceae. [In:] Szafer W., Pawłowski B. (eds.). Polish flora. Vascular plants of Poland and neighboring lands, 8: 278-301. PWN, Warszawa.

Valencia-Díaz S. & Montana C. 2005. Temporal variability in the maternal environment and its effect on seed size and seed quality in *Flourensia cernua* DC. (Asteraceae). Journal of Arid Environments. 63: 686-695.

Zając A. & Zając M. (eds.). 2001. Distribution Atlas of Vascular Plants in Poland. 716 pp. Laboratory of Computer Chorology. Institute of Botany, Jagiellonian University, Cracov.

Celka Zbigniew
Department of Plant Taxonomy, Adam Mickiewicz University, 61-614 Poznań,
Umultowska 89, Poland; zcelka@amu.edu.pl

Drapikowska Maria
Department of Ecology and Environmental Protection, August Cieszkowski University, 61-691 Poznań,
Piątkowska 94, Poland; mariadra@au.poznan.pl

Buczkowska Katarzyna & Bączkiewicz Alina
Department of Genetics, Adam Mickiewicz University, 60-371 Poznań, Międzychodzka 5, Poland;
androsac@amu.edu.pl, alinbacz@amu.edu.pl

Marciniak J.
Department of Ecology and Environmental Protection, August Cieszkowski University,
61-691 Poznań, Piątkowska 94, Poland; mariadra@au.poznan.pl