Pak. J. Bot., 47(2): 467-476, 2015.

MORPHOLOGICAL VARIABILITY OF HAIRS IN *MALVA ALCEA* L. (MALVACEAE) POPULATIONS FROM CENTRAL AND EASTERN EUROPE, AND CONSIDERATION OF THE STATUS OF *MALVA EXCISA* RCHB.

ZBIGNIEW CELKA[1*], MARIA DRAPIKOWSKA[2], SZYMON JUSIK[2], NATALIA OLEJNIK[1], MYROSLAV V. SHEVERA[3] AND PIOTR SZKUDLARZ[1]

[1]*Department of Plant Taxonomy, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61-614 Poznań, Poland*
[2]*Department of Ecology and Environmental Protection, University of Life Sciences in Poznań, Piątkowska 94, 61-691 Poznań, Poland*
[3]*Department of Systematics and Floristic of Vascular Plants, M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Tereshchenkivska 2, Kiev 01601, Ukraine*
**Corresponding author e-mail: zcelka@amu.edu.pl*

Abstract

Among the relics of medieval cultivation, *Malva alcea* L. is one of the most thoroughly studied species. In Central and Eastern Europe, a similar taxon – *Malva excisa* Rchb. – has been recognized. The key diagnostic characters used so far to distinguish the 2 species include the depth of petal sinus and types of stem hairs. This study was aimed to analyse the variability of stem and leaf hairs and their usefulness as diagnostic characters for both taxa. The research material was collected from 19 localities in Poland, Germany, Czech Republic, Belarus and Ukraine. Several types of hairs were observed on the stems and leaves of *M. alcea*: single, bifurcate and stellate. Single and bifurcate hairs were found on stems and leaves of plants from all the studied populations, more frequently on the lower part of the stem, as well as on the upper (adaxial) surface of the leaf. Stellate hairs, with 3-10 branches, were observed on stems, mainly in their upper parts, and on the lower (abaxial) surface of leaves. The principal component analysis for hairs from the upper and lower part of the stem showed that individuals from most of the studied populations were clustered in one large group and only single individuals from several different populations were outside this group. Based on the graphic presentation of the Manhattan distances, calculated with the use of the Ward method, 2 groups were distinguished, but they included a mixture of individuals from various populations and geographic regions. The studied populations are not distinguishable by their key morphological characters, so all samples can be considered as *M. alcea*. The results of this study show that *Malva alcea* is a highly variable species, and its specific morphological forms are not correlated with geographical or ecological factors. There are also scientific grounds to question the distinction of *M. excisa* as a separate species or subspecies.

Key words: *Malva alcea*, *Malva excisa*, Malvaceae, Variability, Hairs, Central Europe, Eastern Europe.

Introduction

Useful plants, in terms of species diversity, form a large group, important for their food, medicinal, economic and cultural values. Apart from popular species that have been cultivated for centuries, there is also a group of plants that were cultivated only in prehistoric times, Antiquity or the Middle Ages, but are not cultivated today. In fact, very often these plants are not perceived as useful anymore. They are termed ergasiolipophytes or – more often – 'relics of cultivation'. They include former medicinal herbs (e.g. *Leonurus cardiaca* L.), plants used for dyeing (e.g. *Isatis tinctoria* L.), spices (e.g. *Allium scorodoprasum* L.) or ornamental plants (e.g. *Lavatera thuringiaca* L.) (Celka, 2005, 2008).

A well-known relic of cultivation, *Malva alcea* (Celka & Drapikowska, 2008), is a member of the family Malvaceae. This family includes about 5000 species (Mabberley, 2010), several species are used by human beings. Recently, numerous studies on species of the Malvaceae were conducted, pertaining to taxonomy (Ray, 1995, 1998; Shaheen *et al.*, 2009a), morphology and anatomy of seeds and fruits (Kumar & Singh, 1991; Bojňanský & Fargašová, 2007; Melikian *et al.*, 2008, 2009), morphology of pollen grains (El Naggar, 2004; Shaheen *et al.*, 2010), hairs and other epidermal structures (Güvenç *et al.*, 2003; Celka *et al.*, 2006; Shaheen *et al.*, 2009b), as well as stability in a given locality and dispersal (Celka *et al.*, 2008, 2013).

Malva alcea is one of the best studied relics of cultivation. For years it was considered as native to Central Europe. Recent studies have shown that it is an archaeophyte. At present, it can be observed mainly at prehistoric or medieval archaeological sites, e.g. strongholds, castles or open settlements. In the Middle Ages it was used for healing, as food, for dyeing, as an ornamental plant and for magic rituals (cf. Celka & Drapikowska, 2008).

Some geobotanical publications from Central and Eastern Europe provide information on the occurrence of another closely related species that strongly resembles *Malva alcea* L., namely *M. excisa* Rchb. (Il`in, 1949; Walas, 1959). Sometimes, it is treated as of subspecies, as *M. alcea* L. subsp. *excisa* (Rchb.) Holub (e.g. Hegi, 1925; Olianytskaia, 1999; Tzvelev, 2000). The plant was cultivated for its ornamental values (Majorov, 2006). *Malva excisa* occurs on dry hills, roadsides and in thickets (Il`in, 1949; Walas, 1959). According to the literature, the first descriptions of *M. excisa* came from Germany, while a cotype was thought to be held in Saint Petersburg (Il`in, 1949), but we failed to find it in the Herbarium of the Komarov Botanical Institute (LE). One of very few images of this species was included in Reichenbach's work (1841, cf. Celka *et al.*, 2007). *M. excisa* was

reported mainly from Russia, Ukraine, Belarus and the Baltic States (Il`in, 1949). The western limit of the species' geographical range is considered to cross Eastern Poland (Walas, 1959). It has been assumed that the most important key characters that distinguish *M. excisa* from *M. alcea* are related to petals and stem hairs (Il`in, 1949).

So far, in order to establish the taxonomic status of both taxa, studies have been concentrated on petals (Celka *et al.*, 2007). Also, genetic variability was investigated at the level of both isoenzymes (Celka *et al.*, 2010) and selected DNA sequences (Celka *et al.*, 2012). The aim of this study is to analyse the variability of stem and leaf hairs in both species and their usefulness in taxonomic identification of *Malva alcea* and *M. excisa*.

Materials and Methods

The material for this study was collected in the field in 2006-2007. Additional, herbarium individuals acquired in Belarus in 2012 were used. In total, 19 populations from Central and Eastern Europe, from the geographical area of *Malva alcea* and the hypothetic range area of *M. excisa*, were studied. It included 11 populations from Poland, 2 from Germany, 1 from the Czech Republic, 1 from Belarus and 4 from Ukraine. Populations 1, 5, 7 and 14-19 are situated within the hypothetic range of *M. excisa*, determined on the basis of literature (Table 1). The selected localities demonstrate the whole spectrum of habitats of *M. alcea* and *M. excisa*: ramparts and conical medieval strongholds, roadside ditches and roadsides, shrubs and a graveyard (Table 1). From each locality, when possible, 5 individuals were collected for analysis. For each individual, 2 pieces of stem and 2 pieces of leaf were studied. The stem sections (2 cm in length each) were taken directly below the inflorescence and between the second and the third node above the stem base. Also, hairs from the upper (adaxial) and lower (abaxial) surfaces of the leaf subtending the inflorescence were analysed. The hair classification follows Celka *et al.* (2006). Name abbreviations of the distinguished hair types are explained under Table 2.

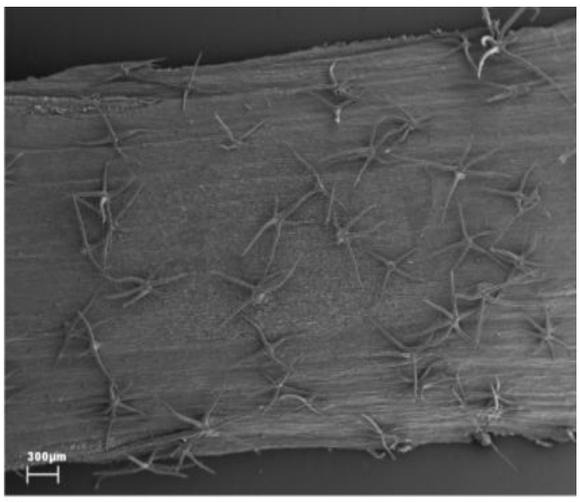
Table 1. Localities and habitats of the studied populations of *Malva alcea* (^{A}) and *M. excisa* (^{E}).

Number	Locality	Geographical location	Habitat	Collection date
1^{E}	Sucha Wieś (Podlaskie region, Poland)	53º57`31.6``N 22º49`20.5``E	Roadside, roadside ditch	01.08.2006
2^{A}	Daleszyn (Wielkopolskie region, Poland)	51º56`00.4``N 17º00`05.1``E	Cone-shaped mound of late medieval earthwork	25.07.2006
3^{A}	Sławsko (Zachodniopomorskie region, Poland)	54º23`13.9``N 16º42`50.6``E	Wasteland and roadside (near medieval rampart)	03.08.2006
4^{A}	Dusina (Wielkopolskie region, Poland)	51º55`17.7``N 17º01`15.2``E	Cone-shaped mound of early medieval earthwork	25.07.2006
5^{E}	Wirów near Drohiczyn on Bug (Podlaskie region, Poland)	52º26`35.7``N 22º32`12.3``E	Cemetery (roadside, roadside ditch)	31.07.2006
6^{A}	Ostrowite-Napole (Kujawsko-Bydgoskie region, Poland)	53º08`46.5``N 18º57`03.7``E	Embankments of early medieval rampart	01.08.2006
7^{E}	Nowosielec (Podkarpackie region, Poland)	50º25`23.5``N 22º07`54.8``E	Roadside ditch on forest edge	28.07.2006
8^{A}	Pątnów (Łódzkie region, Poland)	51º08`06.3``N 18º36`30.7``E	Roadside ditch	28.07.2006
9^{A}	Tum near Łęczyca (Łódzkie region, Poland)	52º03`22.5``N 19º13`57.9``E	Valley of early medieval rampart	29.07.2006
10^{A}	Koziegłowy (Wielkopolskie region, Poland)	52º28`25.1``N 16º58`55.3``E	Roadside, roadside ditch	20.09.2007
11^{A}	Mojęcice (Śląskie region, Poland)	51º17`28.0``N 16º35`41.4``E	Roadside, roadside ditch	18.09.2007
12^{A}	Teterow (Mecklenburg-Vorpommern, Germany)	53º47`22.6``N 12º35`52.3``E	Meadow on an island near embankments of early medieval rampart	14.08.2007
13^{A}	Fürstenwerder (Mecklenburg-Vorpommern, Germany)	53º22`36.4``N 13º34`06.5``E	Roadside, roadside ditch	14.08.2007
14^{A}	Vladař near Žlutice (Karlovarský region, Czech Republic)	50º04`42.1``N 13º12`50.0``E	Thickets on earthwork	24.08.2007
15^{E}	Pidluby (Zhytomyr region, Ukraine)	50º55`14.6``N 27º45`08.3``E	Roadside, roadside ditch	17.07.2007
16^{E}	Olevsk (Zhytomyr region, Ukraine)	51º12`26.0``N 27º39`41.0``E	Roadside	17.07.2007
17^{E}	Gubkiv (Rivne region, Ukraine)	50º49`34.1``N 27º02`42.2``E	Garden and roadside	18.07.2007
18^{E}	Rokytne (Rivne region, Ukraine)	51º16`59.4``N 27º12`29.2``E	Old cemetery	19.07.2007
19^{E}	Narachanski National Park (Miadzel district, Minsk region, Belarus)	54º58`18.1``N 26º48`03.2``E	Roadside	14.08.2012

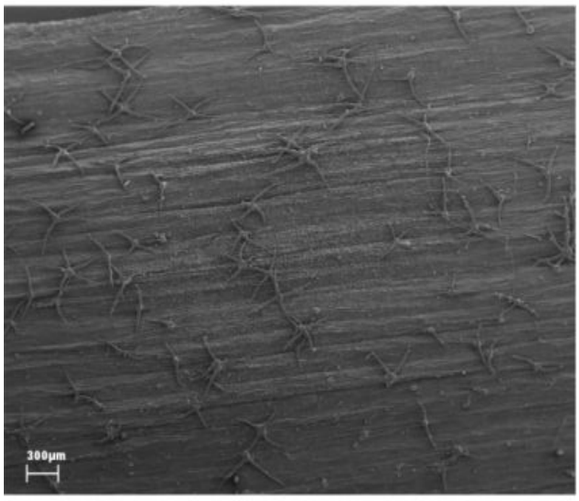
Table 2. Number of hairs of various types per 4 mm^2 of the sample surface of stem (S) and leaf (L) in the studied populations of *Malva alcea* (^{A}) and *M. excisa* (^{E}).

Population	Plant part	Hair type (unbranched or with 2-10 branches, on upper/lower stem part or leaf surface)									
		U u/l	2 u/l	3 u/l	4 u/l	5 u/l	6 u/l	7 u/l	8 u/l	9 u/l	10 u/l
1^E	S	0-10/1-7	0-16/0-3	0-11/0-2	0-12/0-1	0-11/0	0-3/0	0-1/0	0/0	0/0	0/0
Sucha Wieś	L	0-22/0-2	0-8/0-4	0-4/0-6	0-6/0-12	0-2/0-7	0-1/0-9	0/0-3	0/0-2	0/0	0/0
2^A	S	0-4/0-1	0-4/0-2	0-4/0-1	0-7/0-1	0-3/0-1	0-2/0	0/0	0/0	0/0	0/0
Daleszyn	L	0-22/0-2	0-6/0-7	0-2/0-6	0-11/1-9	0/0-5	0/0-3	0/0	0/0	0/0	0/0
3^A	S	0-4/0-7	0-5/0-4	0-9/0	0-12/0	0-4/0	0-4/0	0/0	0/0	0/0	0/0
Sławsko	L	0-39/0-4	0-19/0-11	0-1/0-4	0-1/0-10	0/0-10	0/0-7	0/0-1	0/0	0/0	0/0
4^A	S	0-1/0-3	0-3/0-2	0-5/0-1	0-13/0-1	0-4/0	0-2/0	0-1/0	0/0	0/0	0/0
Dusina	L	0-22/0-3	0-6/0-6	0-3/0-3	0-10/0-10	0-2/0-8	0/0-9	0/0-5	0/0-1	0/0	0/0
5^E	S	0-2/0-4	0-4/0-4	0-5/0-3	0-5/0-3	0-5/0-3	0-4/0-1	0/0-1	0/0	0/0	0/0
Wirów	L	0-7/0-2	0-11/0-3	0-5/0-3	0-6/0-7	0-3/0-5	0/0-9	0/0-8	0/0-3	0/0-2	0/0
6^A	S	0-3/0-3	0-7/0-5	0-5/0-2	0-10/0-2	0-9/0	0-5/0	0-1/0	0/0	0/0	0/0
Napole	L	0-16/0	0-22/0-3	0-9/0-3	0-17/0-12	0-3/0-13	0/0-14	0/0-3	0/0-2	0/0	0/0
7^E	S	0-2/0-3	0-4/0-1	0-4/0-1	0-4/0	0-1/0	0/0	0/0	0/0	0/0	0/0
Nowosielec	L	0-16/0-3	0-7/0-6	0/0-5	0/0-8	0/0-3	0/0-3	0/0	0/0	0/0	0/0
8^A	S	0-1/0-1	0-3/0-2	0-4/0-1	0-5/0-2	0-2/0-1	0-1/0-1	0/0-1	0/0	0/0	0/0
Pątnów	L	0-5/0	0-5/0-1	0-3/0-4	0-6/0-9	0-1/0-5	0/0-10	0/0-2	0/0	0/0	0/0
9^A	S	0-3/0-3	0-3/0-2	0-4/0	0-7/0	0-4/0	0-1/0	0/0	0/0	0/0	0/0
Tum	L	0-23/0	0-14/0	0-5/0-3	0-15/0-18	0-1/0-8	0/0-14	0/0	0/0	0/0	0/0
10^A	S	0-2/0-1	0-2/0-1	0-3/0	0-7/0	0-3/0	0-2/0	0-1/0	0/0	0/0	0/0
Koziegłowy	L	0-11/0-1	0-4/0-5	0-2/0-2	0-2/0-8	0/0-8	0/0-4	0/0-1	0/0	0/0	0/0
11^A	S	0-4/0-5	0-5/0-1	0-3/0-1	0-4/0	0-1/0	0/0	0/0	0/0	0/0	0/0
Mojęcice	L	0-10/0	0-11/0	0-3/0-3	0-4/0-6	0-2/0-7	0/0-9	0/0-3	0/0	0/0	0/0
12^A	S	0-5/0-6	0-10/0-3	0-7/0-3	0-25/0-5	0-13/0-2	0-7/0-1	0-4/0-1	0-2/0	0/0	0/0
Teterow	L	0-16/0	0-46/0-2	0-30/0-3	0-21/0-19	0-3/0-14	0/0-19	0/0-9	0/0-6	0/0-2	0/0-2
13^A	S	0-2/0-4	0-2/0-3	0-2/0-1	0-7/0-2	0-6/0-1	0-8/0-1	0-3/0	0-1/0	0/0	0-1/0
Fürstenwerder	L	0-21/0-1	0-22/0-4	0-7/0-10	0-20/2-15	0-4/1-12	0-2/1-18	0/0-6	0/0-10	0/0-4	0/0-1
14^A	S	0/0-4	0-1/0-2	0-2/0-1	0-8/0-1	0-5/0	0-4/0	0-1/0	0/0	0/0	0/0
Vladař	L	0-26/0-5	0-6/0-6	0-2/0-5	0/0-7	0/0-5	0/0-7	0/0-1	0/0	0/0	0/0
15^E	S	0-1/0-1	0-2/0	0-2/0	0-4/0	0-2/0	0-3/0	0-1/0	0/0	0/0	0/0
Pidluby	L	0-5/0	0-5/0-2	0-3/0-2	0-5/0-4	0/0-6	0/0-7	0/0-4	0/0-1	0/0-2	0/0
16^E	S	0-2/0-3	0-9/0-3	0-6/0-2	0-12/0-4	0-16/0-4	0-3/0	0/0	1/0	0/0	0/0
Olevsk	L	1-7/0-1	0-14/0-3	0-14/0-5	0-9/0-15	0-5/0-10	0/0-14	0/1-4	0/0-4	0/0	0/0
17^E	S	0/0-2	0-1/0-2	0-1/0-1	0-6/0-2	0-5/0	0-5/0	0-1/0	0-1/0	0/0	0/0
Gubkiv	L	4-12/0	1-6/0-1	0-2/0-3	0-1/1-5	0/0-4	0/1-4	0/0-3	0/0-1	0/0	0/0
18^E	S	0-8/0-7	0-5/0-4	0-2/0-3	0-7/0-2	0-8/0-1	0-2/0	0-1/0	0/0	0/0	0/0
Rokytne	L	4-12/0-5	1-6/0-3	0-2/0-4	0-1/0-9	0/0-7	0/0-8	0/0-6	0/0-4	0/0	0/0
19^E	S	0-14/0-9	0-12/0-6	0-15/0-3	1-30/0-3	0-11/0-1	0-2/0	0/0	0/0	0/0	0/0
Narachanski	L	0-17/0-4	0-3/0-5	0-11/0-4	3-28/0-48	1-20/0-34	0-6/0-3	0/0-3	0/0-1	0/0	0/0

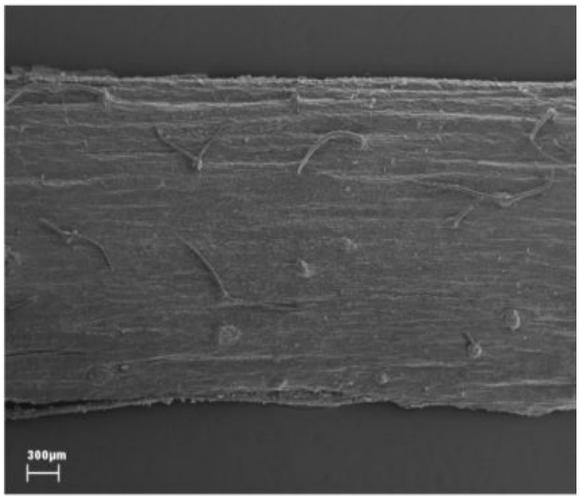
Hair types: u/l – upper/lower (stem part or leaf surface); U – simple hair (unbranched); 2 – bifurcate (2 branches); 3-10 – stellate (3-10 branches)



a



b



c

Fig 1. Morphology of hairs in *Malva alcea* and *M. excisa* (SEM): a – hairs on the upper part of the stem (Teterow, Germany); b – hairs on the upper part of the stem (Rokytne, Ukraine); c – hairs on the lower part of the stem (Rokytne, Ukraine).

Samples were studied using stereoscopic microscope, at a magnification of 25×. For each sample, the hairs of each type were counted in an area of 4 mm^2. The herbarium material was deposited in the Herbarium of the Department of Taxonomy at the Adam Mickiewicz University in Poznań (POZ). The SEM photographs were taken in the Electron Microscopy Laboratory of the Faculty of Biology at the same university.

Data obtained from the morphological measurements were analysed statistically using STATISTICA 7.1 for Windows software. Variability of morphological characters was analysed with the principal component analysis (PCA) and cluster analysis based on Ward's method (Ward, 1963; Morrison, 1990; Sokal & Rohlf, 1997).

Results

In the studied samples of stems and leaves of *Malva alcea* and *M. excisa*, several types of hairs were observed: single (unbranched, simple), bifurcate (2-branched) and stellate (3-10 branches) hairs (Table 2, Fig. 1). Single and bifurcate hairs occurred on stems and leaves of plants from all populations examined, but more often on the lower part of the stem and the upper side of the leaf (Table 2). Stellate hairs were mainly observed on the upper part of the stem and the lower side of the leaf. The stellate hairs on the upper part of the stem (small and large) had mostly 3-7 branches. Single and bifurcate hairs were less frequent. On the contrary, the lower part of the *M. alcea* stem was almost glabrous – single and bifurcate hairs were dominant, with only a few stellate hairs, usually with fewer branches (3-5). On the upper surface of the leaf, single and bifurcate hairs predominated, with a few stellate hairs, usually with only 3-5 branches, while the lower surface was densely covered with stellate hairs (3-10 branches), mixed with few single and bifurcate hairs (Table 2).

The PCA performed for the hairs from the upper and lower parts of stems showed that individuals from the studied populations form one large group (Fig. 2). PCA1 separated single individuals from 2 German populations (no. 12 – Teterow and no. 13 – Fürstenwerder) and from the Ukrainian population (no. 16 – Olevsk), while PCA2 separated a single individual from the Ukrainian population Rokytne (no. 18) and 2 individuals from the German population Fürstenwerder (no. 13). PCA1 was correlated with the presence of stellate hairs with 6 and 7 branches on the upper part of the stem, 6, 7 or 8 branches on the upper part of the leaf, and 3 branches on the lower part of the leaf (Table 3), while PCA2 was correlated with the presence of bifurcate hairs on the upper part of the stem and stellate with 3 branches on the upper surface of the leaf (Table 3).

The PCA conducted for 10 key characters (number of hairs of each type on the upper and lower parts of stem) in the studied taxa showed also that individuals from the majority of the examined populations are concentrated in one compact group (Fig. 3). PCA1 separated only one individual from the Ukrainian population Olevsk (no. 16) and one from the German population Teterow (no. 12). In addition, positive values of PCA1 separated also 2 individuals each from the

German populations Fürstenwerder (no. 13) and Teterow (no. 12), and one individual from the Ukrainian population Rokytne (no. 18). PCA2 separates one individual each from the Polish population Sucha Wieś (no.1) and German population Teterow (no. 12). PCA1 is most strongly correlated with the presence of stellate hairs with 5 branches on the upper surface of the leaf, while PCA2 with the presence of bifurcate hairs on the upper part of the stem (Table 4).

Dendrogram divided individuals into two groups: A and B (Fig. 4). Group A comprises all individuals from populations in Ostrowite-Napole (no. 6, Poland), Teterow (no. 12; Germany), Vladař (no. 14, Czech Republic), as well as Olevsk, Gubkiv and Rokytne (no. 16, 17, 18; Ukraine) and Narachanski National Park (no. 19, Belarus). This group can be further subdivided into several subgroups that differ significantly in terms of Manhattan distances. Specific subgroups are composed of individuals from different populations. Group B can be divided into subgroups that differ only to a small extent. Interestingly, group B comprises most of individuals from Nowosielec, Pątnów and Mojęcice (populations no. 7, 8, 11, Poland) as well as all individuals from Pidluby (population no. 15; Ukraine).

Our results show that: (*i*) the individuals from populations representing both studied taxa do not form distinct groups in the dendrogram (Fig. 4), (*ii*) in the majority of analysed populations, the individuals representing populations of a given taxon (*M. alcea* or *M. excisa*) are scattered in the whole dendrogram, (*iii*) in the vast majority of cases, the individuals from a given population, which grow side by side in the wild, do not make a distinct subgroup but are scattered within the clade or in the whole dendrogram, (*iv*) individuals from geographically very remote populations often belong to the same clade.

Discussion

The key characters differentiating *Malva alcea* from *M. excisa* are the depth of sinus in petals as well as hair types and density (Abromeit *et. al.*, 1898; Il`in, 1949; Walas, 1959). The characteristics of petals have already been analysed in a separate work (Celka *et al.*, 2007). The stronger pilosity of stems of *M. excisa* versus *M. alcea* was considered to be a differentiating character, mentioned in the works of German naturalists from the 19th and early 20th century (Fiek, 1881; Ascherson & Graebner, 1898-1899; Hegi, 1925; Wünsche, 1932). According to Il`in (1949), the hairs on *M. alcea* has stem are spreading, many-branched, 2-branched and simple hairs, while in *Malva excisa*, stems are covered by dense appressed stellate hairs. In Polish taxonomic keys, which follow Il`in (1949), this key character was described as follows: all stem hairs of *M. alcea* are large and include simple ones, 2- and 3-branched hairs with long protruding branches, and shrubby-stellate hairs. In contrast, *M. excisa* stem hairs are only stellate, either small, with appressed branches (the dominant type) or large, shrubby-stellate, with protruding branches, or are sometimes mixed (Walas, 1959; Rutkowski, 2011). According to Tzvelev (2000), *M. excisa* has, on its upper and mid-stem, only stellate hairs, while *M. alcea* has both stellate and bifurcate hairs on the whole stem, with an admixture of single ones.

Table 3. Results of principal component analysis (PCA) for individuals of *Malva alcea* and *M. excisa* from 19 populations and the loadings of 20 characters (number of hairs of various types on stems and leaves) for the first 2 principal components (PCA1-PCA2). Values in bold face are the loadings for the characters that were highly correlated ($r = 0.7$) with the principal components

Character	PCA1	PCA2	Character	PCA1	PCA2
U S u	0.07	0.56	U L u	-0.05	0.46
2 S u	0.21	**0.71**	2 L u	-0.09	0.52
3 S u	0.45	0.60	3 L u	0.11	**0.70**
4 S u	0.61	0.29	4 L u	0.37	0.64
5 S u	0.68	0.13	5 L u	0.56	0.22
6 S u	**0.76**	-0.26	6 L u	**0.72**	-0.11
7 S u	**0.77**	-0.24	7 L u	**0.70**	-0.29
8 S u	0.58	0.01	8 L u	**0.75**	-0.22
9 S u	0.03	0.03	9 L u	0.58	-0.35
10 S u	0.32	-0.10	10 L u	0.65	-0.21
U S l	0.29	0.59	U L l	0.02	0.61
2 S l	0.54	0.37	2 L l	0.66	0.02
3 S l	0.51	0.34	3 L l	**0.76**	-0.18
4 S l	0.49	0.03	4 L l	0.58	-0.34
5 S l	0.46	0.12	5 L l	0.65	0.08
6 S l	0.59	-0.25	6 L l	0.03	-0.15
7 S l	0.07	-0.14	7 L l	0.00	0.08
8 S l	0.14	0.02	8 L l	0.37	-0.28
9 S l	0.14	0.02	9 L l	0.09	0.14
10 S l	0.13	-0.10	10 L l	0.03	0.03

Hair types: U – simple (unbranched); 2 – bifurcate (2 branches); 3-10 – stellate (3-10 branches); L – leaf'; S – stem; l – lower (stem part or leaf surface); u – upper (stem part or leaf surface)

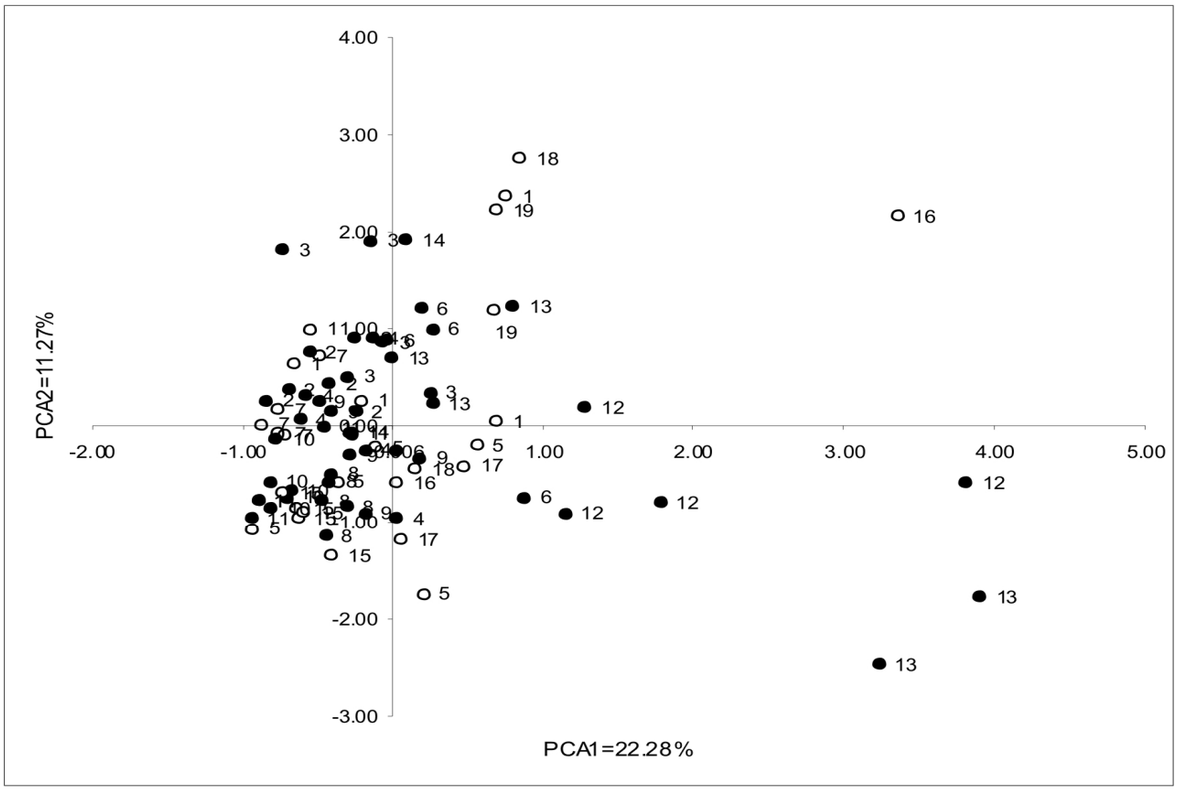


Fig. 2. Results of principal component analysis (PCA) – a scatter diagram of individuals from populations of *Malva alcea* and *M. excisa* (for 20 characters). Solid circles – *M. alcea*; hollow circles – *M. excisa.*

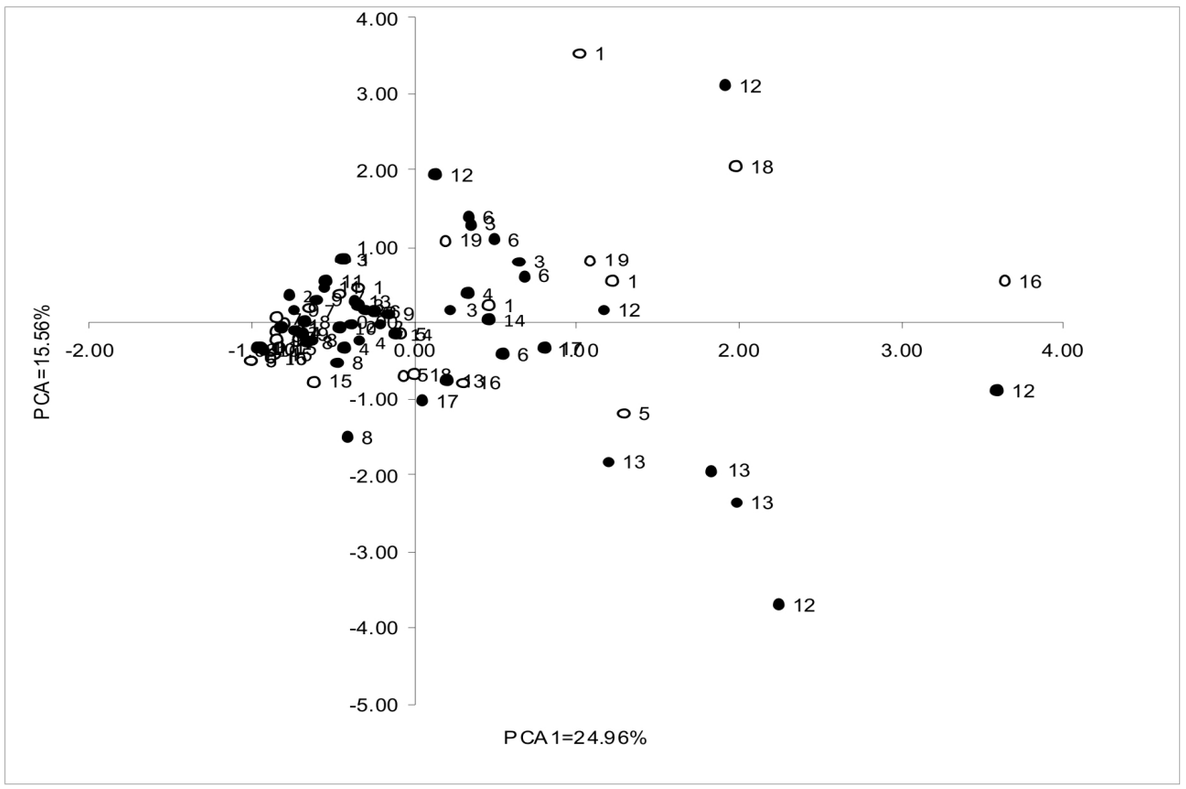


Fig. 3. Results of principal component analysis (PCA) – a scatter diagram of individuals from populations of *Malva alcea* and *M. excisa* (for key diagnostic characters no. 1-10). Solid circles – *M. alcea*; hollow circles – *M. excisa.*

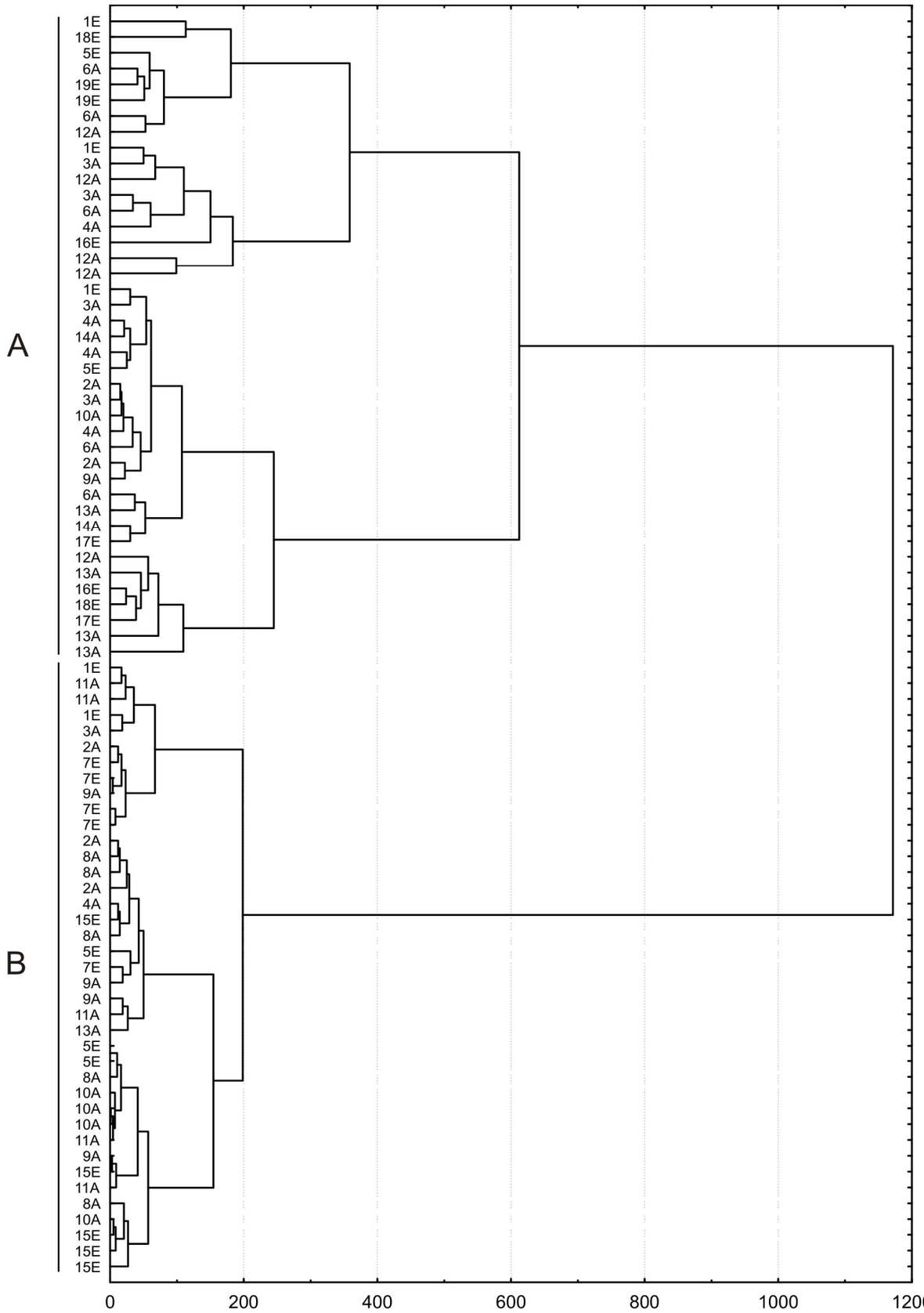


Fig. 4. Dendrogram of the studied individuals from all the populations (1-19) of *Malva alcea* and *M. excisa*, constructed on the basis of Manhattan distances (Ward's method) using a set of key diagnostic characters (1-10). A – *M. alcea*, E – *M. excisa.*

Table 4. Results of principal component analysis (PCA) for individuals of *Malva alcea* and *M. excisa* from 19 populations and the loadings of 10 key characters (number of hairs of various types on the upper and lower stem parts) for the first 2 principal components (PCA1-PCA2). Values in bold face are the loadings for the characters that were highly correlated ($r = 0.7$) with the principal components.

Character	PCA1	PCA2
U S u	0.14	0.59
2 S u	0.35	**0.75**
3 S u	0.59	0.59
4 S u	0.69	0.31
5 S u	**0.75**	0.03
6 S u	0.70	-0.42
7 S u	0.60	-0.28
8 S u	0.58	-0.24
9 S u	0.03	-0.10
10 S u	0.26	-0.31
U S l	0.43	0.63
2 S l	0.69	0.16
3 S l	0.70	0.00
4 S l	0.60	-0.41
5 S l	0.52	-0.17
6 S l	0.47	-0.41
7 S l	0.17	-0.37
8 S l	0.21	0.34
9 S l	0.21	0.34
10 S l	0.26	-0.39

Hair types: U – simple (unbranched); 2 – bifurcate (2 branches); 3-10 – stellate (3-10 branches); S – stem; l – lower part of stem; u – upper part of stem

In the family Malvaceae, characteristics of hairs are considered as key diagnostic features (cf. Il`in, 1949; Walas, 1959; Hill, 1982; Inamdar *et al.*, 1983; Dorr, 1990; Bayer & Kubitzki, 2003). An analysis of available works has demonstrated that terminology related to hairs of *Malva alcea* and *M. excisa* is very ambiguous. Establishing a proper classification is hindered by issues resulting from different hair descriptions (cf. McClerry, 1907; Esau, 1973; Payne, 1978; Inamdar *et al.*, 1983; Judd *et al.*, 2010). An additional difficulty is caused by the variable pilosity of *M. alcea*, which has been emphasized in a number of works (Hegi, 1925; Walas, 1959; Dalby, 1968; Hlavaček, 1982; Slavík, 1992). Detailed research, based on Payne's classification (1978), showed that trichomes of *M. alcea* can be divided into 3 basic groups: single (unbranched), bifurcate (2-branched), and stellate (with 3-10 branches) (Celka *et al.*, 2006).

Several recent works from Germany (Garcke *et al.*, 1972; Rothmaler *et al.*, 2005), the Czech Republic (Slavík, 1992, 2002; Danihelka *et al.*, 2012) and Slovakia (Hlavaček, 1982) do not recognize *M. excisa*. The main reason for this approach is the great variability of key characters, as well as the lack of geographic and ecological correlations. In Ukraine (Dobrochaeva, 1955; Olianytskaia, 1999) and Belarus (Zubkevich, 1999) only *M. excisa* is distinguished, while the most recent Ukrainian study recognizes *M. excisa* as a synonym of *M. alcea* (Shevera *et al.*, 2010). In contrast, a recent Russian monograph (Majorov, 2006) states that both species are present. However, the latter work indicates also that *M. excisa* has not been found in central Russia for the last few decades. Moreover, the conducted genetic studies using isoenzymes and both ISSR (inter-simple sequence repeat) and ISJ (intron-exon splice junction) markers (Celka *et al.*, 2010, 2012) do not support the distinction of *M. excisa*.

Conclusions

Results of this study of stem and leaf hair variability (both from the upper and lower part of the stem) in 19 local populations of *Malva alcea* and *M. excisa* in Central and Eastern Europe indicate that there are no grounds for distinguishing *Malva excisa* as a separate species or subspecies. Summing up, the analysed characters of hairs show such a high variability that they cannot be used as diagnostic features.

Acknowledgments

Our sincere thanks are due to Dr Dmytro Iakushenko and Petr Kočár, MSc, for their valuable help in material collection. The study was supported in 2005-2008 by the Ministry of Science and Higher Education, Warsaw, Poland (grant no. 2 P04G 050 29).

References

Abromeit, J., A. Jentzsch and G. Vogel. 1898. *Flora von Ost- und Westpreussen*. In Komission bei R. Friedländer & Sohn, Berlin.

Ascherson, P. and P. Graebner. 1898-1899. *Flora des Nordostdeutschen Flachlandes (ausser Ostpreussen).* Verlag von Gebrüder Borntraeger, Berlin.

Bayer, C. and K. Kubitzki. 2003. Malvaceae. In: *The Families and Genera of Vascular Plants, V, Flowering Plants, Dicotyledons: Malvales, Capparales and Not-betalain Caryophyllales*. (Eds.): Kubitzki, K. and C. Bayer. Springer-Verlag Berlin, Heidelberg, New York, pp. 225-311.

Bojňanský, V. and A. Fargašová. 2007. *Atlas of Seeds and Fruits of Central and East-European Flora. The Carpathian Mountains Region*. Springer, Dordrecht.

Celka, Z., M. Szczecińska, J. Sawicki and M.V. Shevera. 2012. Molecular studies did not support the distinctiveness of *Malva alcea* and *M. excisa* (Malvaceae) in Central and Eastern Europe. *Biologia*, 67(6): 1088-1098.

Celka, Z. 2005. Relikty dawnych upraw we współczesnej florze Polski. In: *Roślinne ślady człowieka*. (Eds.): Wasylikowa, K., M. Lityńska-Zając and A. Bieniek. Botanical Guidebooks vol. 28, pp. 281-296.

Celka, Z. 2008. Relikty dawnych upraw – jak rośliny pomagają w badaniach archeologicznych. In: *Człowiek i środowisko*

przyrodnicze we wczesnym średniowieczu w świetle badań interdyscyplinarnych. (Ed.): Chudziak, W. Wyd. Nauk. Uniwersytetu Mikołaja Kopernika, Toruń, pp. 107-121.

Celka, Z. and M. Drapikowska. 2008. Relics of cultivation in Central Europe: *Malva alcea* L. as an example. *Veget. Hist. Archaeobot.*, 17(Suppl 1): 251-255.

Celka, Z., K. Buczkowska, A. Bączkiewicz and M. Drapikowska. 2010. Genetic differentiation among geographically close populations of *Malva alcea*. *Acta Biologia Cracoviensia Series Botanica*, 52(2): 32-41.

Celka, Z., M. Drapikowska, K. Ogrodowicz, M.V. Shevera and P. Szkudlarz. 2007. Differentiation of petals in the *Malva alcea* populations from the region of Central and Eastern Europe. *Biodiv. Res. Conserv*., 5-6: 17-24.

Celka, Z., M. Drapikowska, M. Lembicz, L. Kubiak and P. Szkudlarz. 2008. The population of *Malva alcea* at the medieval settlements: from distribution to the reproduction of individuals. *Scripta Facultatis Rerum Naturalium Universitatis Ostraviensis*, 186: 224-230.

Celka, Z., M. Drapikowska, M. Lembicz, P. Szkudlarz, K. Talaga and K. Wydra. 2013. *Lavatera thuringiaca* – a relict of former cultivation on an historic earthwork in Poland: distribution and reproduction of individuals. *Ukr. Botan. Journ.*, 70(2): 209-214.

Celka, Z., P. Szkudlarz and U. Biereżnoj. 2006. Morphological variation of hairs in *Malva alcea* L. (Malvaceae). *Biodiv. Res. Conserv*., 3-4: 258-261

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

Danihelka, J., J. Chrtek Jr and Z. Kaplan. 2012. Checklist of vascular plants of the Czech Republic. *Preslia*, 84(3): 647-811.

Dobrochaeva, D.M. 1955. Malvaceae. In: *Flora UkrRSR,* (Eds.): Klokov, M.V. and O.D. Visjulina. Vol. 7. Vydavnyctvo Akademiĭ Nauk Ukraĭns`koĭ RSR, Kiev, pp. 261-301.

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

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

Esau, K. 1973. *Anatomia roślin*. PWRiL, Warszawa.

Fiek, E. 1881. *Flora von Schlesien preussischen und österreichischen Antheils, enthaltend die wildwachsenden, verwilderten und angebauten Phanerogamen und Gefäss-Cryptogamen*. J. U. Kern`s Verlag, Breslau.

Garcke, A., K. Weihe, D. Fürnkranz, H. Grebe, E. Schenk, A. Seithe, D. Vogellehner and W. Zimmermann. 1972. *Illustrierte Flora Deutschland und angrenzende Gebiete*. Verlag Paul Parey, Berlin und Hamburg.

Güvenç, A., A.M. Özkan, S.C. Erdurak and M. Coskun. 2003. Root, stem and leaf anatomy of *Abutilon theophrastii* Medik. (Malvaceae). *Pak. J. Bot.*, (35): 351-359.

Hegi, G. 1925. Malvaceae. In: *Illustrierte Flora von Mitteleuropa*, vol. 5(1). J. F. Lehmanns Verlag, München, pp. 453-498.

Hill, S.R. 1982. A monograph of the genus *Malvastrum* A. Gray (Malvaceae: Malveae). *Rhodora*, 84: 1-83, 159-264, 317-409.

Hlavaček, A. 1982. Malvaceae Juss. Slezovité. In: *Flora Slóvenska*, (Eds.): Futák, J. and L. Bertová. Vol. 3. VEDA, vydavateľstvo Slovenskej akadémie vied, Bratislava, pp. 372-405.

Il`in, M.M. 1949. Malvaceae Juss. In: *Flora USSR*, (Eds.): Shishkin, B.K. and E.G. Bobrov. Vol. 15. Editio Academiae Scientiarum USSR, Moskva-Leningrad, pp. 23-184.

Inamdar, J.A., R. Balakrishna Bhat and T.V. Ramana Rao. 1983. Structure, ontogeny, classification, and taxonomic significance of trichomes in Malvales. *Korean J. Bot.*, 26: 151-160.

Judd, W.S., Ch.S. Campbell, E.A. Kellogg, P.F. Stevens and M.J. Donoghue. 2010. *Plant systematics a phylogenetic approach.* Sinauer Associates, Ins. Publishers. Sunderland, Massachusetts USA.

Kumar, P. and D. Singh. 1991. Development and structure of seed coat in *Malva* L. *Phytomorphology*, 41(1-2): 147-153.

Mabberley, D.J. 2010. *Mabberley`s Plant-Book*. University Press, Cambridge.

Majorov, S.R. 2006. Malvaceae. In: *Flora sredneĭ polosy evropeĭskoĭ chasti Rossii.* (Ed.): Maevskiĭ P.F. Tovarishchestvo nauchnykh izdaniĭ KMK, Moskva, pp. 361-364.

McClerry, E.M. 1907. Stellate hairs and peltate scales of Ohio plants. *The Ohio Naturalist*, 7(3): 51-56.

Melikian, A.P., Kh.Kh. Djalilova, A.V. Bobrov and M.S. Romanov. 2008. Comparative carpology in the family Malvaceae s. str.: Tribes *Malopeae* and *Hibisceae*. *Bulletin of Moscow Society of Naturalists*, 113(5): 58-67.

Melikian, A.P., Kh. Djalilova, A.V. Bobrov and M.S. Romanov. 2009. Comparative carpology in the family *Malvaceae* s. str. tribes *Malveae*, *Abutileae* and *Ureneae*. *Bulletin of Moscow Society of Naturalists*, 114(5): 3-14.

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

Olianytskaia, L.G. 1999. Malvaceae. In: *Opredelitel` vysshikh rasteniĭ Ukrainy*. (Eds.): Prokudin, Yu. N., D.N. Dobrochaeva, B.V. Zaverukha, V.I. Chopik, V.V. Protopopova and L.I. Kritskaya. M.G. Kholodny Institute of botany of the National Academy of Sciences of Ukraine, Kiev, pp. 141-143.

Payne, W.W. 1978. A glossary of plant hair terminology. *Brittonia*, 30(2): 239-255.

Ray, M.F. 1995. Systematics of *Lavatera* and *Malva* (Malvaceae*,* Malveae) – a new perspective. *Pl. Syst. Evol.*, 198: 29-53.

Ray, M.F. 1998. New Combinations in *Malva* (Malvaceae: Malveae). *Novon*, 8: 288-295.

Reichenbach, L. 1841. *Icones florae germanicae et helveticae*. Apud Fridericum Hofmeister, Lipsiae.

Rothmaler, W., E.J. Jäger and K. Werner. 2005. *Exkursionsflora von Deutschland. Vol. 4 Gefäßpflanzen: Kritischer Band*. Spektrum Akademischer Verlag Elsevier München.

Rutkowski, L. 2011. *Klucz do oznaczania roślin naczyniowych Polski nižowej*. Wyd. Nauk. PWN, Warszawa.

Shaheen, N., M. Ajab, G. Yasmin and M.Q. Hayat. 2009a. Diversity of Foliar Trichomes and Their Systematic Relevance in the Genus *Hibiscus* (Malvaceae). *Int. J. Agric. Biol.*, 11: 279-284.

Shaheen, N., M.A. Khan, G. Yasmin, M.Q. Hayat, M. Ahmad, M. Zafar and A. Jabeen. 2009b. Implication of foliar epidermal features in the taxonomy of *Abutilon* Mill. (Malvaceae). *Journal of Medicinal Plants Research*, 3(12): 1002-1008.

Shaheen, N., M.A. Khan, G. Yasmin, M.Q. Hayat, S. Munsif and K. Ahmad. 2010. Foliar epidermal anatomy and pollen morphology of the genera *Alcea* and *Althaea* (Malvaceae) from Pakistan. *Int. J. Agric. Biol.*, 12: 329-334.

Shevera, M.V., Z. Celka, Ya.P. Didukh and I.A. Korotchenko. 2010 *Malva alcea* L. s.l. In: *Ecoflora of Ukraine*, (Ed.): Ya. P. Didukh. Vol. 6. Phytosociocentre, Kiev, pp. 296-297.

Slavík, B. 1992. Malvaceae Juss. slézovité. In: *Květena České Republiky*, (Eds.): Hejný, S. and B. Slavík. Vol. 3. Academia, Praha, pp. 282-316.

Slavík, B. 2002. Malvaceae Juss. – slézovité. In: *Klíč ke květeně České republiky*. (Ed.): Kubát, K. Academia, Praha, pp. 286-290.

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

Tzvelev, N.N. 2000. *Manual of the vascular plants of north-west Russia (Leningrad, Pskov and Novgorod provinces)*. St.-Petersburg State Chemical-Pharmaceutical Academy Press.

Walas, J. 1959. Malvaceae, Ślazowate. In: *Flora polska. Rośliny naczyniowe Polski i ziem ościennych*, (Eds.): Szafer, W. and B. Pawłowski. Vol. 8. PWN, Warszawa, pp. 278-301.

Ward, J.H. 1963. Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, 58: 1-236.

Wünsche, O. 1932. *Die Pflanzen Deutschland. Eine Anleitung zu ihrer Kenntnis*. Verlag und Druck von B. G. Teubner. Leipzig und Berlin.

Zubkevich, G.I. 1999. Malvaceae Juss. In: *Opredelitel` vysshikh rasteniĭ Belarusi*. (Ed.): Parfenov, V.I. Minsk, Izdatel`stvo Dizaĭi PRO, pp. 133-135.

(Received for publication 20 December 2013)