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A comparative morphological characteristics of *Chenopodium album* L., *C. missouriense* Aellen and *C. probstii* Aellen

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Abstract

A comparative morphological characteristics of two North American invasive species – *C. probstii* and *C. missouriense* and the representative of genus *Chenopodium* in Bulgarian flora closest to them – *C. album* L. have been made. A total of 18 quantitative and 11 qualitative features are included in the morphological analysis. For more detailed study of generative organs the Scanning electron microscope (SEM) method has been used. Information about the chorology and ecological preferences of *C. probstii* and *C. missouriense*, possible ways of their penetration into Bulgarian flora, as well as the reasons for their later discovery have been given. Results showed that the differentiation of *C. album, C. missouriense* and *C. probstii* is possible in all phases of their development.

Key words: *Chenopodium album, Chenopodium missouriense, Chenopodium probstii,* morphology, Bulgaria, distribution

Introduction

Globalization and growth of trade relationships worldwide in recent decades have resulted in the advent of many new plant species in European countries. The representatives of *Chenopodium* incl. studied species are some of the most aggressive and quickly seize new territories. The most widespread is *C. album*. It is almost cosmopolitan, avoiding cold and tropical regions and an extremely common weed in all kinds of cultivated land (Uotila, 2001). *C. probstii* Aellen invaded Scotland through the import of wool in 1913 (Aellen, 1931) and for several decades it has spread to become part of the flora of 20 European countries reaching Romania to the south-east (Dostálek and Jehlík, 2004). *C. missouriense* Aellen was introduced with the transportation of grain from North America to Sweden in 1926 (Aellen, 1928) and by 2003 it has invaded 13 European countries reaching Russia and Ukraine to the east (Dostálek and Jehlík, 2004). As a result of a complex population study of *Chenopodium* in Bulgaria, *C. probstii* and *C. missouriense* have been established in our country as well (Grozeva, 2010).

The aim of this research is to compare morphologically *C. missouriense* and *C. probstii* to the most similar to them species from Bulgarian flora – *C. album*, in order to establish their environmental requirements and to seek possible ways of their penetration in the country.

Materials and methods

The object of the study are 2 populations of *C. missouriense* and 3 of *C. probstii* (Table 1).

Eighteen quantitative characters have been included in the morphological analysis: 1. Height of stem; 2. Length of basal leaf; 3. Width of basal leaf; 4. Length/width ratio; 5. Length of basal leaf petiole; 6. Length of upper leaf; 7. Width of upper leaf; 8. Length/width ratio; 9. Length of upper leaf petiole; 10. Length of inflorescence; 11. Diameter of bisexual flower; 12. Length of flower petiole; 13. Diameter of female flower; 14. Length of flower petiole; 15. Length of seed; 16. Width of seed; 17. Length/width ratio; 18. Thickness of seed.

A total of 11 qualitative traits was also recorded: 1.Colour of stem; 2. Shape of leaf lamina; 3. Colour of leaf lamina; 5. Apex of leaf lamina; 6. Margin of leaf lamina; 7. Colour of perianth; 8. Presence of keel on perianth lobes (petals); 9. Contour of perianth lobes (petals); 10. Colour of seed; 11. Edge of seed.

The summarized results for these 2 species have been compared to the data for *C. album*, published by Grozeva and Cvetanova (2008).

For more detailed study of flowers and seeds the Scanning electron microscope (SEM) method has been used. The electron microscope tests have been conducted at the laboratory for X-ray analysis of the Faculty of Chemistry and Pharmacy of Sofia University.

Table 1. Studied populations of *C. probstii* and *C. missouriense.*

Locality	Ecological conditions	Population
***C. missouriense* Aellen**		
Black Sea coast (*North*), Albena resort area, between the sea coast and the resort area.	Flat region, regularly flooded by sea sands, 199 m a.s.l., ruderal areas with *C. album* domineering and *Corispermum nitidum* and *C. glaucum* as co-dominants.	Diffuse spatial structure, number - 17 specimens, area 25 m^2.
Tundzha hilly plain, Nova Zagora, the west end of the town.	Flat region, alluvial soil, 131 m a.s.l., ruderal community with *C. album* domineering.	Diffuse spatial structure, number - 22 specimens, area 70 m^2
***C. probstii* Aellen**		
Sofia region, city of Sofia, ruderal in the area behind the Pliska Hotel.	Flat region, leached humus soil, 550 m a.s.l., ruderal community with *C. probstii* domineering.	Diffuse spatial structure, number - 32 specimens, area 30 m^2.
Thracian plain, town of Merichleri, around the railway station.	Flat region, leached humus soil, 123 m a.s.l., ruderal community with *Urtica dioica* domineering.	Diffuse spatial structure, number - 15 specimens, area 75 m^2.
Thracian plain, town of Stara Zagora, around bus stop in "Mityo Stanev-west" area.	Flat region, maroon forest soil, 196 m a.s.l., ruderal community with *C. polyspermum* domineering.	Diffuse spatial structure, number - 13 specimens, area 77 m^2.

Results

Values for each of the 18 quantitative characters are presented in Table 2. Data about the quantitative features are summarized in Table 3 and Figure 1.

The results from the Scanning electron microscope study of the flowers of *C. album, C. missouriense* and *C. probstii* are presented in Plate 1, and of the seeds – in Plate 2.

The ecological requirements and locality of studied populations of *C. missouriense* and *C. probstii* are described in Table 1.

Table 2. Studied quantitative features of *C. probstii, C. missouriense* and *C. album*

Species Character No.	*C. probstii* (min, $\bar{x}$, max)	*C. missouriense* (min, $\bar{x}$, max)	*C. album* (min, $\bar{x}$, max)
1.	(150) 174,73 (200) cm	(75) 118,93 (170) cm	(35) 64,26 (100) cm
2.	(5,7) 6,82 (9,5) cm	(4,2) 6,37 (4,8) cm	(1,5) 3,07 (8) cm
3.	(3,8) 4,41 (6,5) cm	(2,5) 3,25 (4,5) cm	(1) 1,58 (3,5) cm
4.	(1,2) 1,56 (2,5)	(2,04) 2,06 (3,5)	(1,2) 1,99 (2,8)
5.	(5,1) 5,14 (5,21)	(2,8) 2,98 (3,13)	(0,52) 1,43 (2,47)
6.	(2,2) 3,17 (4,5) cm	(2,4) 3,53 (4,5) cm,	(0,7) 1,35 (3,5) cm
7.	(0,5) 1,53 (1,2) cm	(0,5) 1,60 (2,5) cm	(0,2) 0,54 (1,2) cm
8.	(1,8) 2,11 (3,5)	(1,8) 2,18 (2,4))	(1,5) 2,78 (5,4)
9.	(3,05) 3,13 (3,21) cm	(0,5) 0,88 (2) cm	(0,35) 0,65 (0,8)
10.	(23) 52,78 (75) cm	(34,8) 37,84 (113,5) cm	(12) 37,78 (74) cm
11.	(0,49) 0,5 (0,52)	(0,2) 0,24 (0,27)	(0,00) 0,05 (0,3)
12.	(0,8) 0,85 (1) mm	(0,7) 0,87 (1) cm	(0,8) 1,16 (1,5) cm
13.	(0,9) 1,05 (1,3) mm	(0,6) 0,82 (1) mm	(0,9) 1,11 (1,3) mm
14.	(0,4) 0,52 (0,7) mm	(0,5) 0,61 (0,62) mm	(0,3) 0,57 (0,7) mm
15.	(1,2) 1,23 (1,3) mm	(0,7) 0,81 (1,1) mm	(1,1) 1,26 (1,4) mm
16.	(114) 1,21 (1,3) mm	(0,8) 0,81 (1,0) mm	(1,15) 1,23 (1,3) mm
17.	(1,07) 1,08 (1,2)	(0,99) 1,01 (1,2)	(1,02) 1,09 (1,25)
18.	(0,53) 0,54 (0,55) mm	(0,3) 0,37 (0,5) mm	(0,3) 0,34 (0,5) mm.

Table 3. Studied quanlitative features of *C. probstii, C. missouriense* and *C. album*

feature	*C. probstii*	*C. missouriense*	*C. album*
1. Color of stem	brown-green to dark-green, striped with red spots on the base of side branches	striped with green to yellow-green, rarely with reddish spots	striped with greyish to bluish green and red
2. Leaf-lamina - color, margin, apex and shape	dark-green, often tinged brown, red near the margin, red-purple pigmentation usually after flowering diffused to the entire leaf; margin serrate to irregularly dentate, apex acute; leaf blade 3-lobed broadly ovate, to oval-rhombic and elongated-rhombic in basal and middle leaves to lanceolate in upper.	bluish-green when young to dark pure green after flowering; margin coarsely serrate with acute teeth, apex acute; leaf blade rhombic-elliptic to rhombic in basal and middle leaves and lanceolate, almost complete in upper part.	greyish green to green, sometimes after flowering reddish green; margin shallowly and irregularly serrate to dentate; apex acute; leaf blade rhombic to elliptic in basal and middle leaves and lanceolate to elongated-lanceolate almost complete in upper part.
3.Perianth lobes (petals) – colour, keel and contour	triangular to broadly lanceo-late, light-green to reddish-green, keeled, with a wide light margin and slight cloud- and net-like nervation, triangular to broadly lanceolate,.	oval, light-green to green, keeled, with narrow membranous margin and clear cloud- and net-like nervation.	elongated-elliptic, green, keeled, with a wide light margin and slight cloud- and net-like nervation.
4. Color, coat and edge of seed	seed coat brown to black, opaque with edge of seed enlarging at the area of the seedling root.	seed coat black, glossy, edge slightly keeled evenly wide along its entire length	seed coat black, glossy, edge fairly acute evenly wide along its entire length.

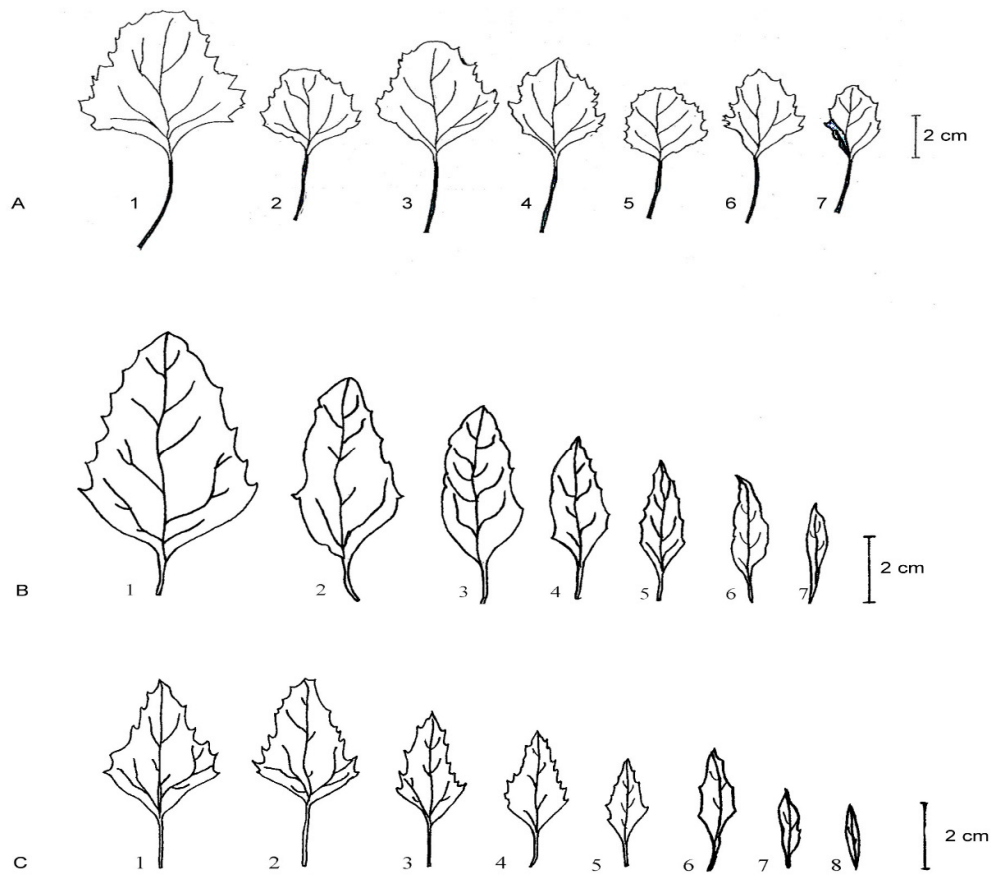

Figure 1. Variation of shape of: A) *C. probstii*;
B) *C. missouriense*; C) *C. album*
1-2 basal leaves; 3-5 middle leaves; 6-7 upper leaves.

Discussion

The results of our studies reveal that the morphological characteristics of *C. missouriense, C. probstii* and *C. album* coincide with the data by Aellen (1960); Dvořák (1987, 1994); Dostálek et al. (1990); Akeroyd (1993), Uotila (2001), Dostálek and Jehlík (2004). The authors who had studied the above species think that their distinction before flowering is almost impossible. The main distinctive features in their opinion are the seed characteristics complemented by those of the leaves.

The present study revealed that the distinction of *C. missouriense, C. probstii* and *C. album* by using the morphological characteristics of stems and leaves is also possible before the generative phases. *C. album* plants are up to 1 m high with alternating reddish, white and green stripes on stems (Tables 2, 3). Plants of *C. probstii* and *C. missouriense* are significantly taller but in the first species stems are dark green with more or less reddish tinge and in the second they are light green (Tables 2, 3).

From the leaf characteristics the most significant for the distinction of the three species are color, shape and margin. *C. probstii* is the easiest to be distinguished. Its leaf-blade is dark green to reddish-violet, with unevenly dentate margin, for basal and middle leaves – 3-lobed, oval-rhombic to rhombic, for the upper ones – elongated rhombic to lanceolate (Table 3, Fig. 1A). For *C. missouriense* the leaf-blade is bluish-green to green, rhombic-elliptic to rhombic in basal and middle leaves and lanceolate, almost entire in upper and margin is coarsely serrate with acute teeth (Table 3, Fig. 1B). *C. album* has green to dark green leaf-blade; rhombic to elliptic in basal and middle leaves and lanceolate to elongated-lanceolate almost entire in upper leaves with shallowly and irregularly serrate to dentate margin (Table 3, Fig. 1C). It is well distinguished from the other two species by its smaller leaves, too (Table 2).

During flowering and fruiting stems of all three species become ligneous, usually the basal and some of the middle leaves fall off.

That is why during the generative phases mainly the characteristics of flowers and seeds are used for distinction purposes. *C. probstii* can be distinguished from the other two species by a stronger and marked keel of perianth lobes (Plate I, Fig. 1). In *C. missouriense* the cloud- and net-like nervation of perianth lobes is very pronounced (Plate I, figs 2,3), while in the other two species it is slightly noticeable (Plate I, Fig. 4).

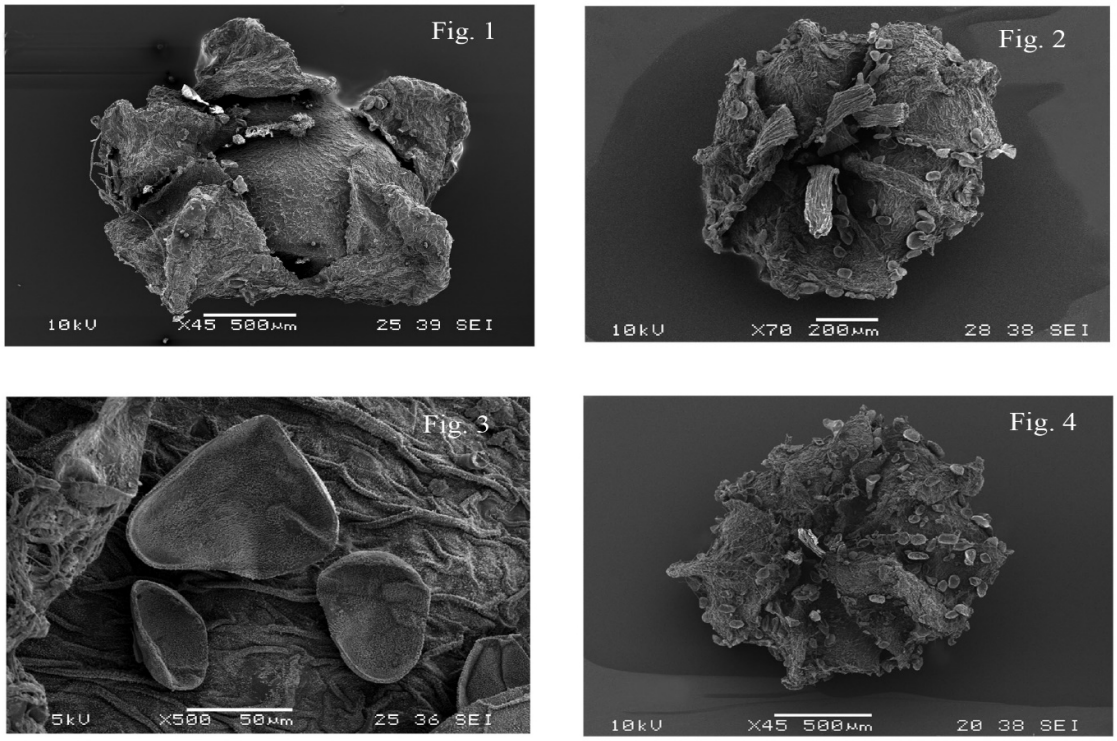

Plate I. Scanning electron micrographs of flowers: Fig. 1. *C. probstii,* Figs 2-3. *C. missouriense*; Fig. 4. *C. album.*

By the size of seeds *C. probstii* and *C. album* are quite similar, while *C. missouriense* has smaller seeds (Table 2, Plate II, Fig. 4). The perfect distinction of the first two species is by the colour and the edge of seeds – in *C. probstii* these are brownish-black, opaque with typical broadening of the edge in the area of the seedling root (Plate II, Figs 1-3), while in *C. album* they are black, glossy with a narrower edge of an even width along its entire length (Plate II, Figs 5, 6).

The greatest is the area of occurrence of *C. album* (Aellen, 1960; Dostálek et al., 1990; Uotila, 2001). The geographic area of *C. probstii* comprises of North America, Central and South-East Europe, North Australia, East Asia (North Korea), North Africa (Dostálek et al., 1990; Uotila, 2001; Dostálek and Jehlík, 2004). The most restricted is the area of *C. missouriense* comprising North America, North and Central Europe (Dostálek et al., 1990; Uotila, 2001; Dostálek and Jehlík, 2004).

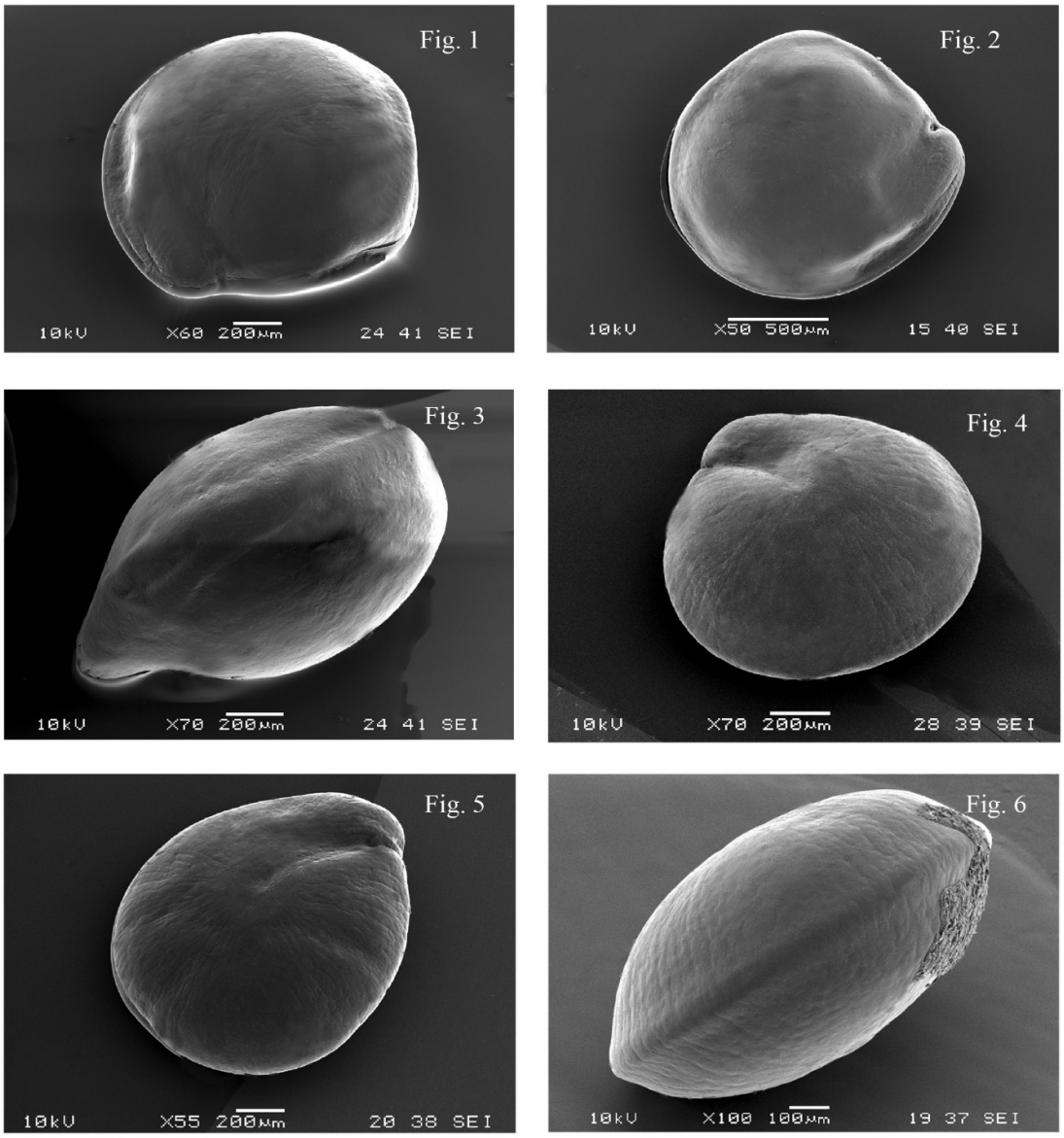

Plate II. Scanning electron micrographs of seeds: Figs 1-3. *C. probstii,* Fig. 4. *C. missouriense*; Figs 5-6. *C. album.*

Most probably the advent of both North American species in our country is related to the import of plant materials and the carrying of their tiny seeds by air currents.

Both in our country (Fig. 2) and in other European countries *C. probstii* is distributed and adapted more rapidly in comparison with *C. missouriense*. One of the most probable causes for

that is the more abundant fruiting and mass ripening of the seeds of the species found out in the present study. *C. missouriense* is quite rare which probably results from the weaker fruiting and the failure of a considerable part of its seeds to ripen. It may well be that the reference data about its more restricted distribution results from its wrong classification to *C. album* due to the difficult distinction between both species.

The results of this study confirm the statement of Dostálek and Jehlík (2004), that *C. probstii* and C*. missouriense* have similar ecological requirements – they occur mainly in ruderal communities. Their ecological preferences (Table 1) are quite similar to the ones found for the Bulgarian populations of *C. album* (Grozeva and Cvetanova 2008). Their probable finding among weeds in cultural communities is an issue of the near future.

Conclusion

The distinction of *C. album, C. missouriense* and *C. probstii* is possible both before flowering, and during flowering and fruiting. The main distinctive features before flowering are colour and height of stem; colour, margin and shape of the leaf blade. During flowering the three species can be diagnosed by keel, contour and nervation of perianth lobes (petals). During fruiting of paramount importance for their differentiation and distinction are colour, size and edge of seed.

C. album, C. missouriense and *C. probstii* occur most often in ruderal communities. Basic mechanisms for their distribution are anthropochoria (through imported plant materials) and anemochoria.

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