

ACHENE CHARACTERISTICS OF TURKISH *CENTAUREA* (ASTERACEAE) AND THEIR SYSTEMATIC APPLICATION

MEHMET BONA*

Department of Pharmaceutical Botany, Pharmacy Faculty, İstanbul University, İstanbul, Turkey

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Abstract

This article investigates the exomorphic characteristics of the achenes which are achene size, color, and surface pattern, and pappus length, and colour. All these characteristics in seven taxa of Asteraceae namely, *C. aggregata* Fisch. & C.A. Mey. ex DC. subsp. *aggregata*, *C. sivasica* Wagenitz, *C. polypodiifolia* Boiss. var. *polypodiifolia*, *C. polypodiifolia* Boiss. var. *szowitziana* (Boiss.) Wagenitz, *C. iberica* Trev. ex Spreng, *C. urvillei* DC. subsp. *stepposa* Wagenitz, and *C. carduiformis* DC. subsp. *carduiformis* var. *carduiformis* in are described, illustrated and compared. The results of SEM at higher magnification showed three types of achene surface patterns: glebulate-ruminate, smooth, and rugose. In these patterns, there were diagnostic characteristics and differences at the specific level for *Centaurea*. A key to the taxa has been provided on the basis of these achene characteristics.

Introduction

The genus *Centaurea* L. (Asteraceae) has about 800 species in the Mediterranean area with SW Asia as its center of diversity (Wagenitz and Hellwig 1996). The genus was revised by Wagenitz (1975) for the Flora of Turkey in which 172 species plus six imperfectly known species were accepted. Turkey is one of the main centers of diversity of the genus (Wagenitz 1975). Here it is the third largest genus in terms of species number in Turkey. *Centaurea s.l.* has 217 species and endemism ratio is 66.8% in Turkey (Wagenitz 1975, Davis 1988, Güner *et al.* 2000, Özhatay *et al.* 2006, 2009, 2011). Recently, *Centaurea* L. has been divided into four genera (Wagenitz and Hellwig 2000, Greuter 2003a,b). The revised genera are *Centaurea*, *Rhaponticoides* Vaill., *Psephellus* Cass. and *Cyanus* Mill.

The traditional delimitation of *Centaurea* as a genus is problematical, because it results obviously in a non-monophyletic taxon (Garcia-Jacas *et al.* 2000, 2001). Therefore, since Wagenitz (1955) there has been increased interest in the phylogeny and evolution of characters of "*Centaurea*" and the subtribe *Centaureinae*, including floral and achene micromorphology, pollen morphology, karyology and as the most promising approach, DNA sequences (Bancheva and Greilhuber 2006).

This study examined the exomorphic characteristics of 7 *Centaurea sensu lato* seeds by using Scanning Electron Microscope (SEM) to highlight achene surface ornamentation.

Materials and Method

Mature achenes of 7 taxa of the genus *Centaurea* collected from their natural habitats in Turkey in 2012. The specimens collected were kept in the Herbarium (ISTE) of the Department of Pharmaceutical Botany Herbarium, İstanbul University (ISTE). The localities and voucher numbers of the taxa studied are given in Table 1. During Scanning Electron Microscopy (SEM), mature achenes (2 - 3) from each of the taxa were selected and mounted onto stubs with double-sided adhesive tape, and were then coated with gold. The achene surfaces were examined from the

*Author for correspondence: <mehmetbona@gmail.com>.

lateral sides. For each sample, photographs of testa were taken using the JEOL Neoscope 5000 at a magnification of 22×, 500×, 1000×, 2000× and 3000×. The terminology of achene characteristics in this work was based on the descriptions used by Stearn (1992), Bartholtt (1981) and Koul *et al.* (2000).

The present study showed three different types of seed surface patterns. These are: glebulate-ruminate: a type intermediate between glebulate and ruminate (very uneven and looking as if chewed with rounded elevations), smooth: not rough, rugose: wrinkled, the irregular elevations making up the wrinkles and running mostly in one direction.

Table 1. Localities and voucher numbers of studied *Centaurea* taxa.

Taxa	Localities	Voucher numbers
<i>C. aggregata</i> subsp. <i>aggregata</i>	Kahramanmaraş	ISTE 99184
<i>C. sivasica</i>	Sivas	ISTE 99195
<i>C. polypodiifolia</i> var. <i>polypodiifolia</i>	Sivas	ISTE 99192
<i>C. polypodiifolia</i> var. <i>szowitziana</i>	Sivas	ISTE 99196
<i>C. iberica</i>	Kahramanmaraş	ISTE 99187
<i>C. urvillei</i> subsp. <i>stepposa</i>	Kahramanmaraş	ISTE 99188
<i>C. carduiiformis</i> subsp. <i>carduiiformis</i> var. <i>carduiiformis</i>	Sivas	ISTE 99200

Results and Discussion

SEM studies show that fruit, seed, and leaf surface patterns are useful taxonomic characteristics for different families and genera of angiosperms (Bona 2013). Fruit and seed characteristics should be critically evaluated in the light of molecular and other morphological data (Moazzeni *et al.* 2010). The results of the present investigation showed that the achene sizes of the studied taxa were 2 - 6 × 1.5 - 3.0 mm, and pappus length were 0.5 - 10 mm except. *C. sivasica* without any pappus. Achene surface is sparsely pilose. Testa cells are regularly arranged and elongated parallelly with the seed surface. Cell boundaries are soft lined.

Achene exomorphic characteristics including achene size, color and surface pattern and pappus length and colour are presented in Table 2.

The results of the studied taxa are discussed below, followed by a key prepared on the basis of the achene characteristics.

C. aggregata Fisch. & C.A. Mey. ex DC. subsp. *aggregata*: Achene greenish-brown, 2.5-3 × 1.5 mm, pappus white, 2 mm long. Seed surface pattern is glebulate-ruminate. The cell boundaries are very thin and the centers of the cells are higher than the boundaries (Fig. 1).

C. sivasica Wagenitz: Achene greenish-brown when young, later black, 2.5-3.5 × 1.5 mm, without pappus. Seed surface pattern is glebulate-ruminate. The cell boundaries are broad and have smooth structure and the boundaries seem higher than the cell center. Testa cells are slightly on the front of the cell (Fig. 1).

C. aggregata subsp. *aggregata* and *C. sivasica* were placed under Section Acrolophus by Wagenitz (1975). *C. aggregata* subsp. *aggregata* is a widespread taxon which is also distributed in N.W. Iran, W. Iran and N. Iraq (Wagenitz 1975). *C. sivasica* is an endemic species which is located only around Sivas and Kayseri in Turkey. Only these two taxa have glebulate-ruminate achene surface patterns in the studied taxa.

C. polypodiifolia Boiss. var. *polypodiifolia*: Achene grey-white when young, later greyish-black, 5-6 × 2-2.5 mm, pappus white, 7-8 mm long. Seed surface pattern is smooth. The cell boundaries are thin and the centers of the cells are placed at equal levels with the boundaries (Fig. 1).

Table 2. Achene characteristics of studied *Centaurea* taxa.

Taxa	Pappus			Achene	
	Length (mm)	Color	Size (mm)	Color	Pattern
<i>C. aggregata</i> subsp. <i>aggregata</i>	2	White	2.5-3 × 1.5	Greenish-brown	Glebulate-ruminate
<i>C. sivasica</i>	Absent	Absent	2.5-3.5 × 1.5	black	Glebulate-ruminate
<i>C. polypodiifolia</i> var. <i>polypodiifolia</i>	7-8	White	5-6 × 2-2.5	Grey-white or Greyish-Black	Smooth
<i>C. polypodiifolia</i> var. <i>szowitziana</i>	7-8	Brownish	4-5 × 2-3	Brownish	Smooth
<i>C. iberica</i>	0.5-1	White	2-3 × 1.5-2	Light to dark brown	Rugose
<i>C. urvillei</i> subsp. <i>stepposa</i>	7-9	Brownish	4-6 × 2.5-3	Silvery to yellowish	Smooth
<i>C. carduiiformis</i> subsp. <i>carduiiformis</i> var. <i>carduiiformis</i>	8-10	Silvery	5-6 × 2.5-3	Silvery	Smooth

C. polypodiifolia Boiss. var. *szowitziana* (Boiss.) Wagenitz: Achene yellowish when young, later brown (ones or two greyish black), 4 - 5 × 2 - 3 mm, pappus brownish, 7 - 8 mm long. Seed surface pattern is smooth. The cell boundaries are very thin and the centers of the cells are higher than the boundaries. Testa cells are on the front of the cells. This condition shows itself as waved layers (Fig. 1).

C. polypodiifolia var. *polypodiifolia* and *C. polypodiifolia* var. *szowitziana* were placed under Section *Microlophus* by Wagenitz (1975). These two taxa are separated from each other based on a few morphological characteristics of involucre width and leaf shape (Wagenitz 1975). This study shows that seed characteristics are useful in the separation of these taxa. Smooth achene patterns show differentiation in detailed investigations with high magnification. The cell boundaries are thin and the centers of the cells are placed at equal level with the boundaries in *C. polypodiifolia* var. *polypodiifolia*. The cell boundaries are very thin and the centers of the cells are higher than the boundaries. Testa cells are on the front of the cell. This condition shows itself as waved layers in *C. polypodiifolia* var. *szowitziana*. Beside this *C. polypodiifolia* var. *polypodiifolia* has white pappus and grey-white or greyish-black achene but *C. polypodiifolia* var. *szowitziana* has brownish pappus and achene.

C. iberica Trev. ex Spreng: Achene mostly light brown, sometimes darker, 2 - 3 × 1.5 - 2 mm, pappus white, 0.5 - 1 mm long. Seed surface pattern is rugose. The cell boundaries are broad and the boundaries seem higher than the cell center (Fig. 2).

C. iberica is the only specimen that has rugose seed surface pattern. The taxon was placed under Section *Calcitrapa* by Wagenitz (1975).

C. urvillei DC. subsp. *stepposa* Wagenitz: Achene silvery when young, later yellowish, 4 - 6 × 2.5 - 3 mm, pappus brownish, 7 - 9 mm long. Seed surface pattern is smooth. The cell boundaries are very thin and the centers of the cells are slightly higher than the boundaries. Testa cells are slightly on the front of the cell (Fig. 2).

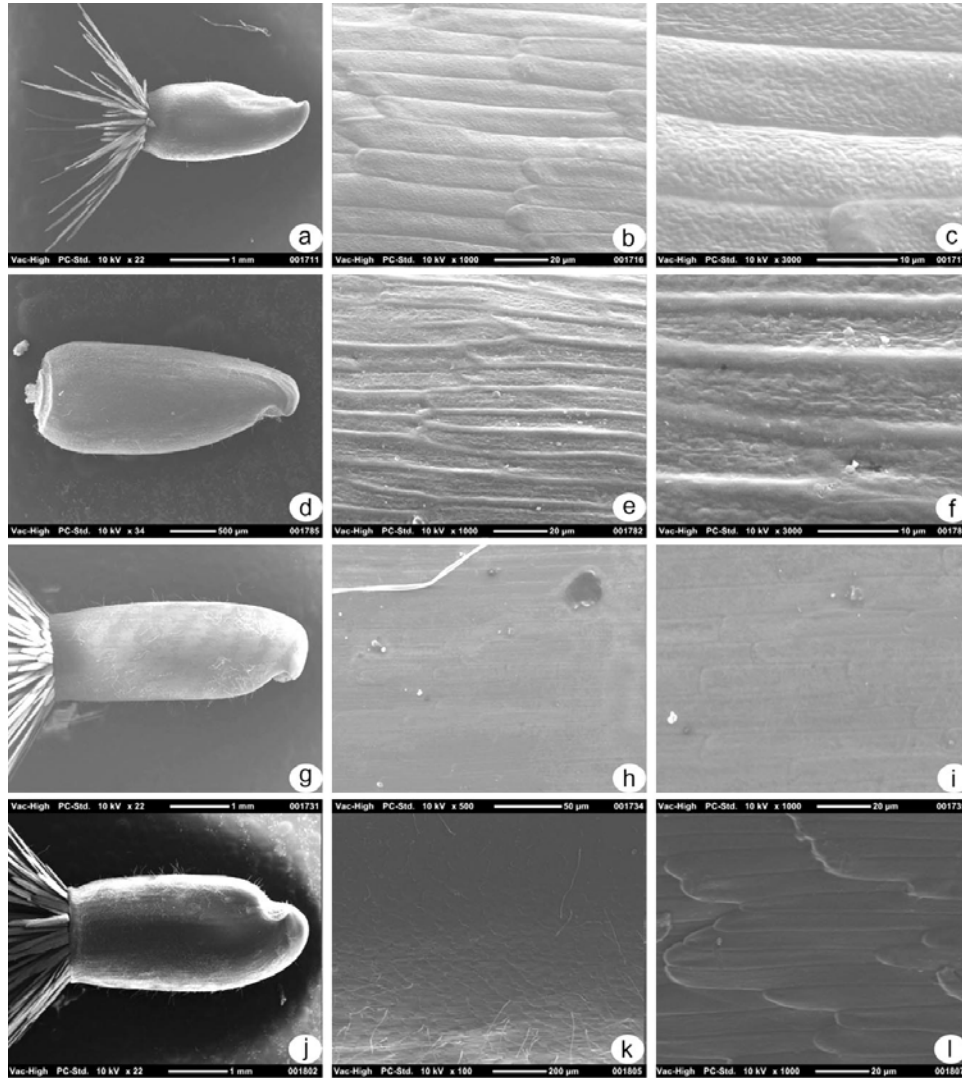


Fig. 1. SEM micrographs of achenes of Turkish *Centaurea*. *C. aggregata* subsp. *aggregata* (a-c), *C. sivasica* (d-f), *C. polypodiifolia* var. *polypodiifolia* (g-i), *C. polypodiifolia* var. *szowitsiana* (j-l).

C. carduiiformis DC. subsp. *carduiiformis* var. *carduiiformis*: Achene silvery, 5 - 6 × 2.5 - 3 mm, pappus silvery, 8 - 10 mm long, inner row different, c. 2 mm long. Seed surface pattern is smooth. The cell boundaries are very thin and the centers of the cells are slightly higher than the boundaries. Testa cells are sulcate and slightly on the front of the cell (Fig. 2).

The endemic taxa, *C. urvillei* subsp. *stepposa* and *C. carduiiformis* subsp. *carduiiformis* var. *carduiiformis* were placed under Section Acrocentron by Wagenitz (1975). *C. carduiiformis* subsp. *carduiiformis* var. *carduiiformis* has silvery pappus and sulcate testa cells and because of this it is easily separated from all other specimens.

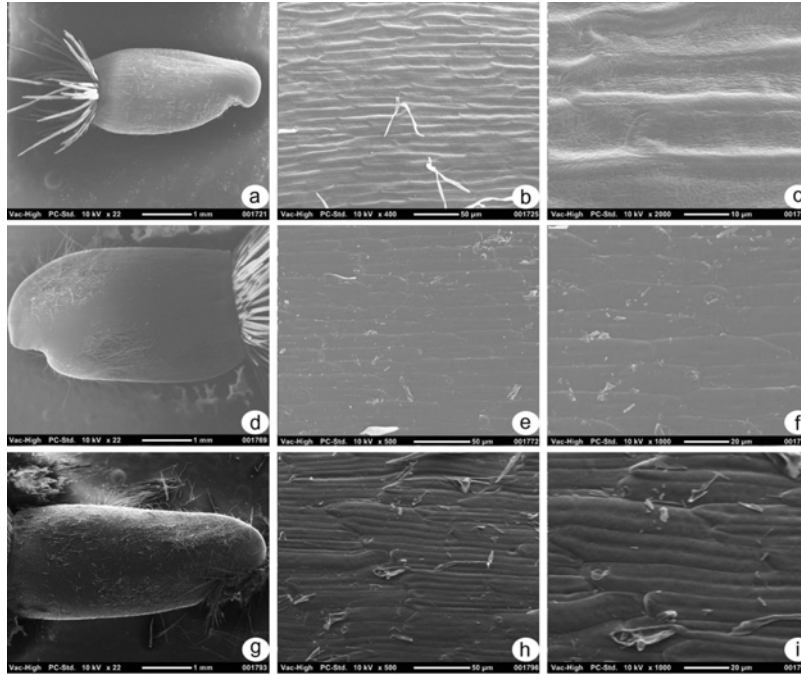


Fig. 2. SEM micrographs of achenes of Turkish *Centaurea*. *C. iberica* (a-c), *C. urvillei* subsp. *stepposa* (d-f), *C. carduiiformis* subsp. *carduiiformis* var. *carduiiformis* (g-i).

Key to the studied taxa according to achene characteristics

- | | |
|--|---|
| 1. Pappus absent | <i>C. sivasica</i> |
| 1. Pappus present | 2 |
| 2. Pappus white | |
| 3. Pappus up to 7 mm long | <i>C. polypodiifolia</i> var. <i>polypodiifolia</i> |
| 3. Pappus up to 2 mm long | |
| 4. Seed surface pattern glebulate-ruminata | <i>C. aggregata</i> subsp. <i>aggregata</i> |
| 4. Seed surface pattern rugose | <i>C. iberica</i> |
| 2. Pappus not white | |
| 5. Achene brownish | <i>C. polypodiifolia</i> var. <i>szowitsiana</i> |
| 5. Achene not brownish | |
| 6. Pappus silvery | <i>C. carduiiformis</i> subsp. <i>carduiiformis</i> var. <i>carduiiformis</i> |
| 6. Pappus brownish | <i>C. urvillei</i> subsp. <i>stepposa</i> |

In conclusion, this study supports the use of achene surface patterns as diagnostic characteristics at species and subspecies levels for the genus *Centaurea* s.l. Furthermore, achene surface pattern seems to be useful at sectional level because of glebulate-ruminata patterns in

Section Acrolophus. There are other achene characteristics like achene length and colour, pappus length and colour that might be helpful to distinguish certain more taxa. However, through achene characteristics provide strong support in the delimitation of the studied taxa at specific level, understanding the importance of these characteristics at generic and subgeneric levels requires further study.

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