

Carpology of some East Asian Cardueae (Asteraceae)

by

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Abstract

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The present paper deals with the morphological, anatomical structure of achenes in the East Asian species of *Rhaponticum*, *Klasea Serratula* and *Synurus*. The structure of pericarp epidermal cells, mesocarp, has been described, as well as the structure of testa epidermal cells. The specific characters of the genera, as well as the identification characters of the species, are described.

Keywords: Asteraceae, Cardueae, achene, anatomic structure.

Resumen

Zarembo, E.V. & Boyko, E.V. 2008. Carpología de algunas Cardueae (Asteraceae) de Asia oriental. *Anales Jard. Bot. Madrid* 65(1): 129-134 (en inglés).

El presente artículo se refiere a las características morfológicas, la estructura anatómica de los aquenios en las especies de *Rhaponticum*, *Klasea Serratula* y *Synurus* en Asia oriental. Se han descrito la estructura de células epidérmicas del pericarpio, y el mesocarpio, así como la de la testa de las células epidérmicas. También quedan descritos los caracteres específicos de los géneros, así como los caracteres de identificación de las especies.

Palabras clave: Asteraceae, Cardueae, aquenio, estructura anatómica.

Introduction

The morphological and anatomic structure of achenes in the tribe Cardueae Cass. is of great importance for hierarchical classification of the superspecific taxa. One of the first papers on achene anatomy of Asteraceae was published by Lavialle (1912), who had studied about 83 species of 15 genera: *Arctium* L., *Carduncellus* Adans., *Carduus* L., *Carthamus* L., *Centaurea* L., *Cnicus* L., *Cousinia* Cass., *Crupina* Cass., *Cynara* L., *Galactites* Moench, *Jurinea* Cass., *Onopordum* L., *Saussurea* DC., *Serratula* L. and *Silybum* Adans. Major achene characteristics, including the testa's epidermis pattern, of the representatives of the tribe were described in details. At the beginning of achene development the epidermal cells are isodiametrical in shape, in the course of its development they stretch in the radial direction, their walls get greatly sclerified. The radial elongation begins near the micropyle and spreads towards the subchalazal region. There are no cells directed perpendicularly to the tangent, they are inclined to the micropyle. Lavialle also paid great attention to specific structures

of the achene's integuments – crystals and secretory ducts. Calcium oxalate crystals were revealed in the inner parenchyma. Occurrence of calcium oxalate crystals in the inner parenchyma layer of pericarp in the Cardueae had been mentioned (Hanausek, 1911; Dormer, 1961; Singh & Pandey, 1984) as well.

The morphological and anatomic structure of achenes has been used in solving some taxonomic problems in the tribe Cardueae (Dittrich, 1968a; 1968b; 1968c, 1970, 1977, 1985). Besides, there are quite a number of papers that cover morphological and anatomic structure of achenes in individual species of the tribe or in groups of species (Fourment & al., 1956; Gochu, 1973; Karawya & al., 1974; Chargo-glyan, 1975; Namba & al., 1975; Pandey & Singh, 1977; Cherneva & Shurukhina, 1979; Wagenitz & al., 1982; Pérez-García & Duran; 1987; Chernik, 1984; Häffner, 2000).

Materials and methods

We have studied morphology and anatomy of achenes of East Asian representatives of the subtribe

Centaureinae (Cass.) Dumort: *Klasea* Cass., *Rhaponticum* Vaill. and *Serratula* (Leuzea DC., *Stemmacantha* (Cass.) and subtribe Carduinae (Cass.) Dumort. -*Synurus* Iljin. In the Far East of Russia the genus *Serratula* is represented by *S. manshurica* Kitag. The genus *Klasea* is represented by two species: *Klasea centauroides* (L.) Cass. and *K. komarovii* Iljin. The genus *Rhaponticum* is represented by two taxa: *Rh. uniflorum* (L.) DC. and *Rh. satzyperovii* Soskov. The genus *Synurus* is represented by 1 species, *Synurus deltoides* (Ait.) Nakai.

For the micromorphological observations, achenes were softened in a solution of glycerine, ethanol and water (1:1:1) for a few days, embedded in paraffin and cut by microtom. Sections were cut to a thickness of 8-15 μm . Longitudinal and cross sections were stained in safranin.

Results and Discussion

Achene integument

Achenes of the subtribe Cardueae are characterized by thick multilayer integuments and a palisade row of macrosclereids, which clearly sets apart the species of the subtribes Cardueae and Centaureinae from the representatives of the subtribe Carlininae.

Achenes of the studied species of *Klasea* and *Serratula* are characterized by equally developed pericarp and testa. The general thickness of the mature achene integuments varies from 100 to 230 μm due to the different thickness of pericarp. In the region of the large strands of mechanic tissue located around conducting bundles, the thickness of pericarp varies from 60-65 (*S. manshurica*) to 135 μm (*Klasea centauroides*), and from 25-40 (*Serratula*

manshurica) to 80 μm (*Klasea centauroides*) in the intercostals area (Figs. 2, 3, 4).

Achenes of *Synurus deltoides* are characterized by very thick pericarp and comparatively thin testa. The embryo is mostly protected by pericarp and to a lesser extent by testa. The thickness of mature achene integuments varies from 485-540 μm in the intercostals area, and to 640-660 μm on the ribs due to the different thickness of pericarp, which determines the occurrence of numerous longitudinal ribs on the achene surface (Fig. 1).

The studied representatives of *Rhaponticum* are characterized by relatively thick pericarp and thick testa. The embryo is equally protected by pericarp and testa. The mature achene integument thickness varies due to the different thickness of pericarp, which determines the occurrence of numerous longitudinal ribs on the achene surface. In the region of the large strands of mechanic tissue located around conducting bundles the thickness of the achene integuments reaches 270-360 μm on the ribs, and from 200 to 270 μm in the intercostals area. In the upper part of achene the thickness of the integument is 500-590 μm – due to enlargement of parenchyma cells in the peripheral region of the pericarp, as a result denticles on the margin of the achene apex are formed. The pericarp thickness varies from 25-80 μm in the intercostals area, and to 100-160 μm on the ribs (Fig. 5).

Topography of epidermal cells of pericarp

Mature pericarp is represented by exocarp and mesocarp. In the species of *Serratula* the exocarp is formed by one row of cube-shaped epidermal cells (*S. manshurica*). In *Klasea* these cells are oval (*S. centau-*

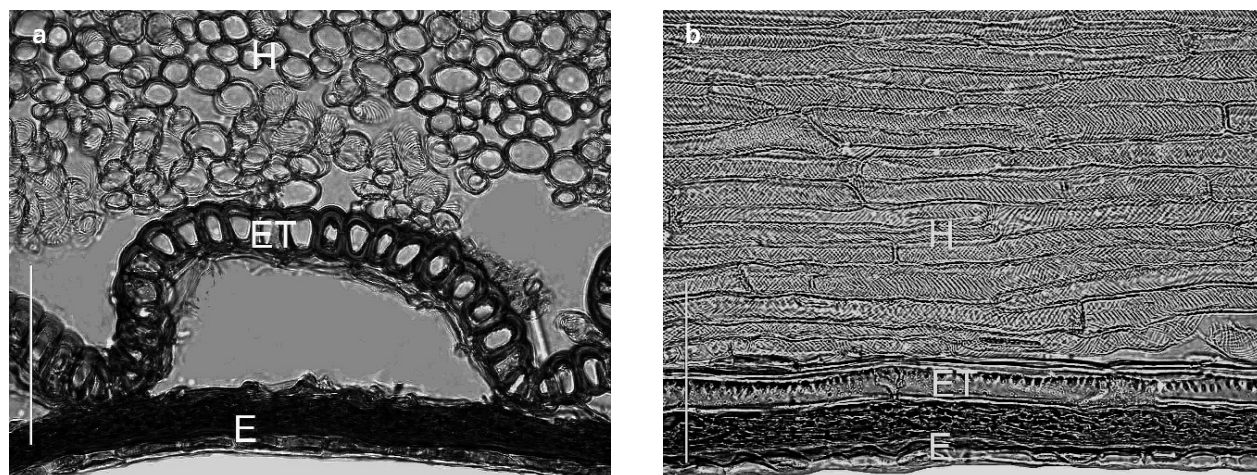


Fig. 1. *Synurus deltoides*: **a**, cross section of achenes; **b**, longitudinal section of achenes; ET, epidermal cells of testa; E, endosperm, H, hydrocytes. Scale bar: 0,1 mm.

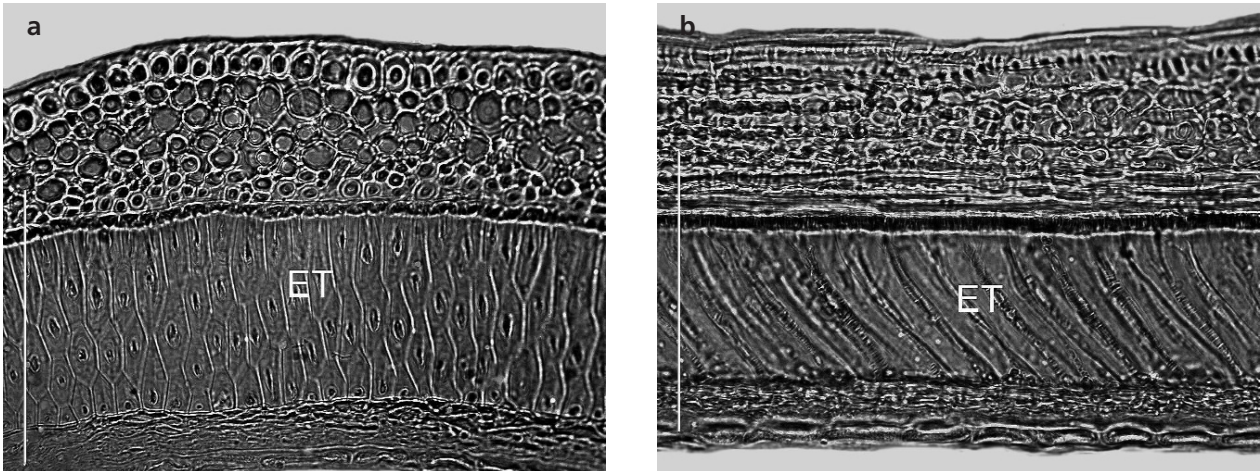


Fig. 2. *Klasea centauroides*: **a**, cross section of achenes; **b**, longitudinal section of achenes; ET, epidermal cells of testa. Scale bar: 0.1 mm.

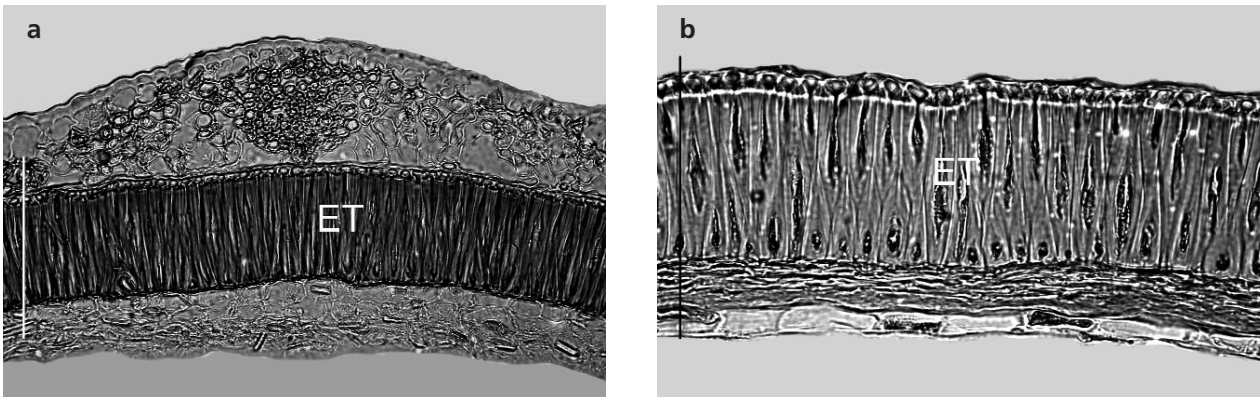


Fig. 3. *Serratula manshurica*: **a**, cross section of achenes; ET, epidermal cells of testa; **b**, epidermal cells of testa (cross section). Scale bar: 0.1 mm.

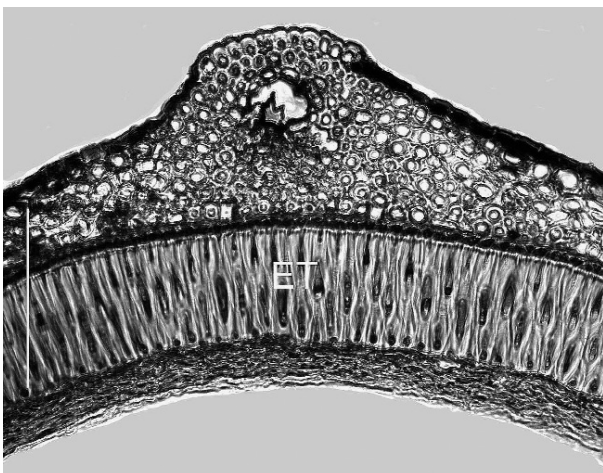


Fig. 4. *Klasea komarovii* (cross section of achenes): ET, epidermal cells of testa. Scale bar: 0.1 mm.

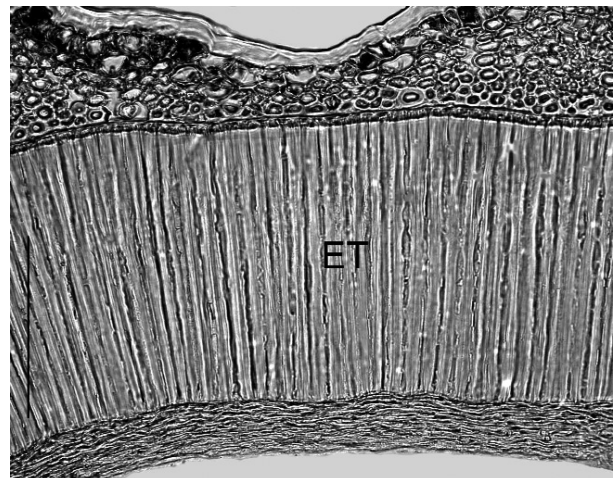


Fig. 5. *Rhaponticum uniflorum* (cross section of achenes): ET, epidermal cells of testa. Scale bar: 0.1 mm.

roides) or rectangular (*S. komarovii*) (cross section). The epidermal cells of mature achenes of *S. manshurica* are thin-walled, cube-shaped, 10-25 µm wide and 8-15 µm high. In *Klasea centauroides* the epidermal cells are oval, slightly radially elongated, with uniformly thickened walls, 12-15 µm high and 13 µm wide; in *Klasea komarovii* the cells are rectangular, 4-6 µm high and 10-25 µm wide, tangentially elongated, the cell lumen is filled up with phlobaphenes, therefore the achenes are dark brown.

The exocarp of the representatives of the *Rhaponticum* is formed by one row of epidermal cells. From the outside the fruit is covered with thick smooth cuticle up to 10 µm wide. The epidermal cells are large, rectangular, tangentially stretched, thin-walled, 25 µm wide and 15 µm high (cross section), the cells are rectangular in longitudinal section, with inclined radial walls, up to 55 µm long, the lumen of some cells is filled up with phlobaphene.

The epidermal cells of *Synurus deltooides* are cube-shaped, 12-15 µm high and 10-18 µm (cross section) wide, rectangular in longitudinal section, up to 25-40 µm long.

Mesocarp structure

In the studied species of *Klasea* and *Serratula* the mesocarp is rather peculiar and is represented by external (parenchymatous tissue consisting of several rows of thin-walled cells) and internal (sclerenchymatous tissue) layers. Besides, specific structures are formed in the mesocarp: calcium oxalate crystals and secretory ducts.

In mesocarp of *Synurus deltooides* some complex differentiation of tissues is observed. This is formed by parenchymatous cells with spiral thickenings (hydrocytes). Hydrocytic cells are prosenchymatous in longitudinal section, they form 44-50 rows. In the peripheral region of mesocarp they are significantly smaller in height than the cells adjacent to the testa. Moreover, *S. deltooides* is characterized by occurrence of calcium oxalate crystals and secretory ducts of schizogenous origin, which are located in the peripheral part of pericarp (Fig. 1).

In the mesocarp of the studied representatives of *Rhaponticum* the parenchymatous cells form 3-5 rows in the intercostals areas and 10-16 cell rows on ribs, they vary both in size and in the degree of wall incrassation. In the peripheral part of mesocarp the cells are thin-walled, large around the conducting bundles and, at the border with testa, there are smaller parenchymatous cells up to 7 µm in diameter. The most incrassate are the walls of the cells directly surrounding the conducting bundles, in this region they are represented by typical sclerenchymatous cells. The thickness of the

sclerenchyma cell walls reaches 2.5 µm. The parenchymatous cells at the border with testa also undergo intensive incrassation; in this region they are also represented by typical sclerenchyma cells arranged in 1-2, rarely 3, rows. The cell diameter is 7-8 µm. The conducting bundles of pericarp are located closer to testa.

Secretory ducts

Secretory ducts are of great importance in the taxonomy of the Cardueae s. l. (Dittrich, 1977). Thus, Lavielle (1912) pointed out that in *Serratula coronata* L. the pericarp is entirely lacking in secretory ducts during all stages of achene development, which distinguishes it from the other species of *Serratula* such as *S. tinctoria* L. Secretory ducts are also absent in species of *Klasea*. Secretory ducts have been found in the species of the genera *Amberboa* (Pers.) Less., *Carthamus* (Chauhan, 1972; Singh & Pandey, 1984), *Centaurodendron* Johow and *Yunquea* Skottsbo. (Carlquist, 1958), *Serratula*, and species of some sections of *Centaurea* (Dittrich, 1977).

Secretory ducts of schizogenous origin lined with epithelium have been found in mesocarp in the studied species of *Serratula* and *Synurus*. In *S. centauroides* and *S. komarovii*, there are 4 secretory ducts located in the ribs of achene (Fig. 4). There are remains of conducting bundle elements under them. In *S. manshurica* secretory ducts have not been found. The same ducts have been revealed in the peripheral part of mesocarp in *Synurus deltooides*. Moreover, in one rib several (usually 2) small ducts are located, they are not connected with conducting bundles and do not influence the rib size.

Crystals, their topography and localization

In the inner layers of pericarp and testa there are crystals. The crystals are formed by calcium oxalate and have complex inner organization. Their occurrence has been recorded by many authors (Hanausek, 1911; Dormer, 1961, 1962; Gochu, 1973; Namba & al., 1975; Singh & Pandey, 1984). Dormer pays special attention to the physical characteristics of crystals: geometrical shape, average size, refraction index. In Dormer's (1961, 1962) opinion, the crystal type correlates with other morphological characters (pollen structure, occurrence of secretory ducts in the flower).

Crystals have been found in *S. manshurica* and *S. komarovii* in the inner region of mesocarp adjacent to the testa. The crystals of *S. manshurica* are polygonal in shape, 60-70 µm long and 4.5-5.5 µm high (Fig. 3a). In *S. centauroides* the crystals have not been revealed.

Synurus deltooides is characterized by needle-shaped crystals, 50-77 μm long, 7.5-7.7 μm high and located at the border between pericarp and testa.

Testa epidermal cells topography

Epidermal cells of testa (size, shape, their orientation regarding the achene surface in longitudinal and cross sections, radial wall thickening pattern) in the species of one genus are similar and are of no importance for species differentiation; they are, however, unique in structure and are a diagnostic character of genus.

The testa in the studied species consists of epidermis and several layers of mesoderm. Epidermal cells are macrosclereids with greatly incrassate walls, radially stretched and forming a palisade row of cells. The testa structure in the studied species of *Serratula* and *Rhaponticum* is similar to that of other representatives of the subtribes Centaureinae (*Crupina*, *Carthamus*, *Amberboa*, *Centaurea*) and Carduineae (*Silybum* Adans., *Cirsium*, *Saussurea*). Such structure of epidermis is a constant specific character in the representatives of the subtribes Carduineae and Centaureinae (Dittrich, 1977). Besides, epidermal cells (longitudinal section) may be not precisely perpendicular to the achene surface, but also angularly, and this is observed in the species of *Serratula* we studied. This peculiarity can be revealed only in longitudinal section, since the cross section cuts several cell rows and the epidermis seems to be multirowed. Singh and Pandey (1984) investigated achene development in *Carthamus oxyacantha* Bieb., *Centaurea moschata* L. and *Silybum marianum* (L.) Gaertn., as well as anatomic structure of mature achenes in *Carthamus baeticus* Nym., *Centaurea cyanus* L., *Onopordum algeriense* Pomel., *Saussurea albescens* Hook. and *Saussurea heteromella* (Don) Hand-Mazz. and found out that in all studied species the testa epidermis was represented by a single row radially elongated, incrassate, lignified cells – macrosclereids. In longitudinal sections these cells are inclined at an angle towards the achene surface, therefore the epidermis looks multirowed (2-7 rows) in cross sections. This is observed in *Carthamus oxyacantha*, *Centaurea moschata*, *Silybum marianum*, *Carthamus baeticus*, *Centaurea cyanus*, *Onopordum algeriense*, *Saussurea albescens* and *S. heteromella*. The structure of epidermal cells was a reason for erroneous statements about testa multirowed epidermis being found in species of *Carthamus* (Hanausek, 1911; Ebert & Knowles, 1968).

In all the species of *Klasea* and *Serratula* we studied, the testa is similar in structure and is a character connecting both genera. Due to the intensive radial growth and great secondary thickening of the wall, the epidermal cells turn into macrosclereids forming

the palisade row of cells. Epidermal cells arranged at the angle 55-60° to the achene axis (longitudinal section), as a result, the cross section cuts several cell rows and the testa appears multirowed in cross section (Figs. 2a, 3b). The radial cell walls are strongly incrassate (longitudinal section), as a result, a narrow channel remains in the cell, the outer and inner tangential walls are not incrassate. The cell lumen looks like a narrow channel widened in the area of tangential walls (longitudinal section).

In the species of *Rhaponticum* the epidermal cells of testa are narrow-rectangular, from 150 to 180 μm high and 10-13 μm wide, their radial walls are strongly incrassate (the walls reach up to 5 μm thick), the tangential walls stay parenchymatic. The cell lumen looks like a narrow channel. In contrast to *Serratula* the epidermal cells of the representatives of *Rhaponticum* are oriented in radial direction (Fig. 5).

Synurus deltooides is characterized by a peculiar structure of testa epidermal cells. The epidermal cells of *S. deltooides* are oval in shape, thick-walled, uniformly incrassate (unlike *Klasea*, *Rhaponticum* and *Serratula*) with well-pronounced layering (the walls are 1.5-2 μm thick), the cell height is 3, 6-7 times (respectively) less than in the species of *Serratula* and *Rhaponticum* (cross section). In the longitudinal section the cells are rectangular (Fig. 1b), 130-160 μm long and tangentially elongated (in *Serratula* and *Rhaponticum* – radially).

As a result of our investigations on morphological and anatomic structure of fruit in the tribe Cardueae s.l. we determined that some characters can be diagnostic at the species level: 1) topography of epidermal cells of pericarp, 2) presence of phlobaphenes in them, 3) occurrence of calcium oxalate crystals, their topography and localization, 4) occurrence and location of secretory ducts in mesocarp. The diagnostic character of a genus is the structure of epidermal cells of testa (size, form, orientation, wall incrassation character).

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