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ANATOMICAL STRUCTURE OF THE CALYX TRANSVERSE SECTION OF SOME SPECIES OF THE *Hedysarum* L. GENUS (Fabaceae) FROM CENTRAL ASIA

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АНАТОМИЧЕСКОЕ СТРОЕНИЕ ПОПЕРЕЧНОГО СРЕЗА ЧАШЕЧКИ НЕКОТОРЫХ ВИДОВ РОДА *Hedysarum* L. (Fabaceae) ИЗ СРЕДНЕЙ АЗИИ

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Abstract. This research investigates the anatomical structure of the calyx transverse section of 11 species of the *Hedysarum* genus from Central Asia. The analysis revealed that all species exhibit a more or less smooth or slightly convoluted upper surface and a lower surface with varying degrees of tuberculation. Regarding the mesophyll structure of the calyx, the studied species are mainly divided into two groups: in *H. pumilum*, *H. severtzovii*, *H. micropterum*, and *H. wrightianum*, the mesophyll is differentiated into lower palisade and upper spongy layers, which is considered an adaptive and progressive feature for the calyx; in other species, an undifferentiated mesophyll is observed, regarded as a primitive trait. Furthermore, the formation of large and giant idioblasts is characteristic of all studied species, located on the lower side of the calyx (directly beneath the lower epidermis), along with a 2-4-layered chlorenchyma beneath the upper epidermis, representing adaptive features.

Аннотация. Рассмотрено анатомическое строение поперечного сечения чашечки у 11 видов рода *Hedysarum* из Средней Азии. Анализ выявил, что все виды характеризуются более или менее гладкой или слегка извилистой верхней поверхностью и нижней поверхностью с различной степенью бугорчатости. Что касается структуры мезофилла чашечки, исследуемые виды в основном разделены на две группы: у *H. pumilum*, *H. severtzovii*, *H. micropterum* и *H. wrightianum*, мезофилл дифференцирован на нижнюю палисадную и верхнюю губчатую паренхиму, что рассматривается как признак адаптивный и прогрессивный для чашечки; у других видов наблюдается недифференцированный мезофилл, рассматриваемый как примитивный признак. Кроме того, формирование крупных и гигантских идиобластов характерно для всех изученных видов, расположенных с нижней стороны чашечки (непосредственно под нижней эпидермой), а также 2–4-рядная хлоренхима под верхней эпидермой, представляющая собой признаки адаптации.

Keywords: calyx, mesophyll, palisade, parenchyma, idioblast.

Ключевые слова: чашечка, мезофилл, палисад, паренхима, идиобласт.

The *Hedysarum* genus, belonging to the Fabaceae family, stands out as a polymorphic genus and poses significant challenges in systematic classification. Recognized for their multifaceted qualities, representatives of the genus *Hedysarum* exhibit honey-producing, decorative, and medicinal properties. Moreover, like all legumes, they are esteemed as excellent fodder plants due to their substantial protein content and prolific green mass productivity. While the systematics and

evolution of species within the genus *Hedysarum* in Kazakhstan and Kyrgyzstan have been meticulously examined by M. S. Baytenov (1964) and B. A. Sultanova (1972), there exists a noticeable gap in literary information regarding the anatomical structure of the calyx in the studied representatives of the genus *Hedysarum* [1, 2]. Addressing this gap becomes imperative for a comprehensive understanding of the species within this genus.

Our study focused on several species of *Hedysarum* inhabiting Central Asia, including *H. chaitocarpum*, *H. pumilum*, *H. severtzovii*, *H. iomuticum*, *H. cephalotes*, *H. micropterum*, *H. daraut-kurganicum*, *H. drobovii*, *H. wrightianum*, *H. baldshuanicum*, and *H. songaricum* (Table 1). The subsequent sections delve into the anatomical details of selected species, shedding light on their calyx characteristics and transverse section structures. The investigation aims to contribute valuable insights into the anatomical peculiarities of the genus *Hedysarum*, supplementing existing knowledge and aiding in a more comprehensive taxonomic understanding.

Table 1

THE LIST OF STUDIED SPECIES
 OF THE GENUS *Hedysarum* AND THEIR PLACES OF GROWTH

No	Species	Places of Growth of Studied Species
1.	<i>H. chaitocarpum</i>	Fergana, Pasha-Ata River Basin, northeast slope at an altitude of 1300 m above sea level.
2.	<i>H. pumilum</i>	Syrdarya Region, Aulie-Ata District, Alexandrovskiy Range, opposite Akyr-Tyube, Taldy-Bulak location at an altitude of 1500 m above sea level; Chimkent District, Karatau Mountains at an altitude of 2000 m above sea level.
3.	<i>H. severtzovii</i>	Samarkand Region, Khodjent District, Mogol-tau Mountains, Bay-Bogut-Ata location at an altitude of 800-1000 m above sea level.
4.	<i>H. iomuticum</i>	Hissar Range, polychrome foothills, Baysun District at an altitude of 1500-2000 m above sea level.
5.	<i>H. cephalotes</i>	Eastern Pamir, Bash-Gumbez River Valley (transborder), middle course, first terrace at an altitude of 3000-3500 m above sea level; Hissar Range, Sardomyona River Basin, upper reaches, pass at an altitude of 3000-3500 m above sea level; Eastern Pamir, Chechekti location, Zor-Chechekti River Valley at an altitude of 3000 m above sea level.
6.	<i>H. micropterum</i>	Western Kopetdag (Kyurendag), vicinity of the Danat spring, limestone folds of low foothills.
7.	<i>H. daraut-kurganicum</i>	Western Alai, left bank of the Kyzyl-Suu River, Kaman location, hilly continental sands at an altitude of 2000-2500 m above sea level.
8.	<i>H. drobovii</i>	Pshekem Range, vicinity of the village of Burgmulla at an altitude of 1250-1500 m above sea level.
9.	<i>H. wrightianum</i>	Turkestan; Caspian Mountains, Big Balkhans at an altitude of 1000 m above sea level.
10.	<i>H. baldshuanicum</i>	Tajikistan. Southern Hissar-Darvaza, Tiryay Range at an altitude of 800-1000 m above sea level.

Findings and Discussion

The anatomical exploration of the calyx transverse section in 11 species of the genus *Hedysarum* in Central Asia revealed distinctive features. The analysis identified a division among the studied species based on the mesophyll structure of the calyx, with some, including *H. pumilum*, *H. severtzovii*, *H. micropterum*, and *H. wrightianum*, exhibiting a differentiated mesophyll into lower palisade and upper spongy layers, considered adaptive and progressive. On the other hand, other species displayed an undifferentiated mesophyll, perceived as a primitive trait. Additionally, the formation of large idioblasts beneath the lower epidermis, along with a 2-4-layered chlorenchyma beneath the upper epidermis, emerged as characteristic adaptive features across all

studied species. Connecting to this, the work of P. H. Davis in the “Flora of Turkey and the East Aegean Islands” provides a broader context for understanding the plant diversity in the region [3]. This multivolume reference, spanning volumes 3 to 10, serves as a comprehensive guide, aligning well with the need for detailed insights into the diverse plant species, making it a valuable resource for researchers exploring the botanical intricacies of Central Asia. Furthermore, the research paper by A. Guvenc and H. Duman on *Sideritis* in the Turkish Journal of Botany contributes to the broader understanding of plant anatomy, reinforcing the significance of detailed studies in the field [4, 5].

The *Hedysarum* genus is one of the polymorphic genera of the Fabaceae family, and it is considered one of the most interesting and challenging in terms of systematic classification. Moreover, representatives of the genus *Hedysarum* are known for their honey-producing, decorative, and medicinal properties, and like all legumes, they are considered excellent fodder plants due to their high protein content and large green mass productivity.

The systematics and evolution of species within the genus *Hedysarum* growing in Kazakhstan and Kyrgyzstan have been thoroughly examined by M. S. Baytenov (1964) and B. A. Sultanova (1972) [1, 2].

However, literary information about the anatomical structure of the calyx of the studied representatives of the genus *Hedysarum* has not been encountered, necessitating the need to fill this gap in the study of the species of this genus. The objects of our study were the following species of *Hedysarum* inhabiting Central Asia: *H. chaitocarpum*, *H. pumilum*, *H. severtzovii*, *H. iomuticum*, *H. cephalotes*, *H. micropterum*, *H. daraut-kurganicum*, *H. drobovii*, *H. wrightianum*, *H. baldshuanicum*, *H. songaricum* (Table 1).

H. chaitocarpum: The upper epidermis is larger-celled, with cells having strongly thickened (3 μm) outer walls, while the lower epidermis is comparatively smaller-celled, with less thickened (2 μm) outer walls. Stomata are located at the level or slightly above the level of the epidermis. Tangentially elongated cavities with mucilaginous substances are situated beneath the morphologically upper epidermis in the spongy parenchyma, forming giant idioblasts of round and oval shapes with mucus, tannins, lipid droplets, filling almost all the space between the upper and lower epidermis. Around the vascular bundles, there are 2-4 large cavities with mucilaginous substances. The upper surface of the calyx is smooth, and the lower surface is weakly tuberculate.

For *H. pumilum*, there are no cavities around the vascular bundles, and there are also no mucilaginous cells under the upper epidermis. The space between the lower and upper epidermis is occupied by idioblasts of various sizes and configurations with lipid droplets and other nutrients. In some areas free from idioblasts, the mesophyll consists of a single lower row of palisade and 1-3 rows of spongy parenchyma. In other similar areas, the mesophyll consists only of thin-walled parenchymal cells of various sizes. The spongy parenchyma contains many packets of crystals. The outer walls of the upper and lower epidermis are extremely thick (3-3.6 μm).

H. severtzovii: The transverse section structure of the calyx is similar to that of *H. pumilum* but differs only in the continuous arrangement of idioblasts.

H. iomuticum: There are few idioblasts in the calyx mesophyll, mostly above and near the veins on the lower side, and in other places, the mesophyll is undifferentiated, consisting of 2-3 tangentially elongated parenchymal cells.

For *H. cephalotes* and *H. micropterum*, the upper epidermis is almost smooth, and the thickness of the outer wall of both calyx surfaces does not exceed 2 μm . In other respects, the mesophyll structure is the same as in *H. pumilum*.

H. daraut-kurganicum: The upper epidermis is large-celled, the lower epidermis is small-

celled, and the space in the calyx mesophyll is filled with idioblasts of various shapes, often round or tangentially elongated.

For *H. drobovii*, the outer cell walls of the epidermis are of medium thickness (2.5-3 μm), and 1-2 rows of large tangentially elongated parenchymal cells are located beneath the upper epidermis. Numerous round-oval idioblasts are situated between the parenchyma and the lower epidermis. Stomata are positioned at the level of the upper and in the recesses of the lower epidermis.

In *H. wrightianum*, there are no idioblasts around the vascular bundles or they are rare. The outer epidermal wall on both sides is not thick (0.5-2 μm); beneath the upper epidermis, there are 1, occasionally 2 layers of tangentially elongated parenchymal cells, and the space between the upper and lower epidermis is filled with oval, round, more often tangentially elongated idioblasts. In areas free from idioblasts, the mesophyll differentiates into lower palisade and upper spongy parenchyma; stomata are located at the level or slightly above the level of the epidermis.

H. baldshuanicum: Idioblasts are located only on the lower side and near the vascular bundles; they are rarely encountered in other places. The upper and lower epidermis is weakly tuberculate, almost smooth; stomata are positioned below the level of the epidermis, and the outer cell walls of the epidermis are of medium thickness. The mesophyll consists of 2-3 layers of large tangentially elongated or elongated thin-walled parenchymal cells with chloroplasts.

H. songaricum: The space between the epidermis on both sides of the calyx is occupied by round or slightly oval large idioblasts, forming almost continuous layers. The surface of the calyx is finely tuberculate, and the outer cell walls of the epidermis are relatively not thick (1.4-1.6 μm); stomata are mainly located in recesses.

In *H. cephalotes*, in places with more or less large vascular bundles, triangular-shaped elevations are formed. The lower side of the epidermis is weakly or significantly grooved, while the upper side is almost smooth. Idioblasts are mainly located on the lower side and are absent in other places. The mesophyll is 2-3-layered, large-celled, and differentiated – in some areas, groups of 3-6 palisade parenchymal cells are encountered. Stomata are positioned below the level of the lower epidermis and almost at the level of the upper epidermis.

The analysis of anatomical features in the cross-section of the calyx of the 11 studied species allows us to conclude that all species exhibit a more or less smooth or slightly convoluted upper surface and a lower surface with varying degrees of tuberculation. Regarding the mesophyll structure of the calyx, the studied species are predominantly divided into two groups: in *H. pumilum*, *H. severtzovii*, *H. micropterum*, and *H. wrightianum*, the mesophyll is differentiated into lower palisade and upper spongy parenchyma, which is considered an adaptive, progressive feature for the calyx; in other species, it is undifferentiated and considered a primitive trait. Additionally, the formation of large and giant idioblasts located beneath the lower surface of the calyx (directly under the lower epidermis) and 2-4-layered chlorenchyma beneath the upper epidermis is a common adaptive feature in all studied species.

The positioning of idioblasts beneath the lower surface of the calyx, unlike leaves (where they are located under the upper epidermis), is apparently associated with the greater illumination of the lower surface of the calyx due to its almost vertical orientation, resulting in weaker illumination from the upper side (Table 2).

Conclusion

The anatomical analysis of the calyx cross-section in the 11 studied *Hedysarum* species reveals common and distinct features. All species exhibit a more or less smooth upper surface and a lower surface with varying degrees of tuberculation. Regarding mesophyll differentiation, a notable

pattern emerges, with species like *H. pumilum*, *H. severtzovii*, *H. micropterum*, and *H. wrightianum* showing a differentiated mesophyll with lower palisade and upper spongy parenchyma — a feature considered adaptive and progressive for the calyx. In contrast, other species exhibit an undifferentiated mesophyll, suggesting a primitive trait.

Table 2

ANATOMICAL FEATURES OF THE CALYX CROSS-SECTION
 IN 11 STUDIED SPECIES OF *Hedysarum*

<i>Species</i>	<i>Upper Surface</i>	<i>Lower Surface</i>	<i>Mesophyll Differentiation</i>	<i>Idioblast Formation</i>
<i>H. pumilum</i>	More or less smooth	Varied tuberculation	Differentiated: Lower palisade, Upper spongy	Large and giant idioblasts beneath the calyx
<i>H. severtzovii</i>	More or less smooth	Varied tuberculation	Differentiated: Lower palisade, Upper spongy	Large and giant idioblasts beneath the calyx
<i>H. micropterum</i>	More or less smooth	Varied tuberculation	Differentiated: Lower palisade, Upper spongy	Large and giant idioblasts beneath the calyx
<i>H. wrightianum</i>	More or less smooth	Varied tuberculation	Differentiated: Lower palisade, Upper spongy	Large and giant idioblasts beneath the calyx

A consistent characteristic across all studied species is the formation of large and giant idioblasts located beneath the calyx, directly under the lower epidermis. Additionally, a 2-4-layered chlorenchyma beneath the upper epidermis is observed, indicating adaptability in response to environmental factors. The positioning of idioblasts beneath the lower surface of the calyx, unlike leaves, is hypothesized to be related to the vertical orientation of the calyx, resulting in increased illumination from the lower side. This study contributes valuable insights into the anatomical adaptations of the calyx in *Hedysarum* species, shedding light on the diverse strategies employed by these plants in response to their environmental conditions.

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