



## MORPHOLOGICAL AND ANATOMICAL FEATURES OF THE GENUS GAGEA SALISB., GROWING IN THE EAST KAZAKHSTAN REGION

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### Abstract

*Due to ecological preferences among species of the genus GageaSalisb, many plants are qualified as rare and/or endangered. Therefore, the problem of rational use of natural resources, in particular protection of early spring plant species is very important. However, literary sources analysis only reveals data on the biology of species of this genus.*

*The present research, conducted in the spring of 2017-2019, focuses on anatomical and morphological features of two Altai species: Gagealutea and Gagea minima; these features were studied, clarified and confirmed by drawings and photographs. The anatomical structure of the stem and leaf blade was studied in detail.*

*The obtained research results will prove useful for studies of medicinal raw materials and honey plants.*

*The aforementioned species are similar in morphological features, yet G. minima is smaller in size, and its shoots appear earlier than those of other species.*

**Keywords :** Flora; gageas; Altai species; vegetative organs.

### I. Introduction

Relevance. At present, due to the large-scale industrial territorial development and the influence of anthropogenic factors, early spring flora –gageas – are on the brink of extinction. Therefore, rational use of natural resources and protection of these early spring plants is on the top of the agenda.

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The authors of the present research studied the two Altai species, *G. lutea* and *G. minima*, which are of practical importance in traditional medicine and as melliferous raw material.

Objectives:

- to determine the species composition of the genus *Gagea* Salisb, belonging to the early spring flora of the vicinity of Ust-Kamenogorsk;
- to establish the influence of the anthropogenic process on the development and habitat of the species.

Tasks:

- to study the morphological and anatomical structure of the vegetative organs of the genus *G. Salisb*, in particular the leaf and stem, collected on the right bank of the Ubinsky Range and in the vicinity of Ust-Kamenogorsk;
- to identify anatomical and morphological features of the species structure.

Scientific value: the present research was conducted in the spring of 2017-2019. The obtained research results on anatomical and morphological features of *G. lutea* and *G. minima* will prove useful for studies of medicinal raw materials and honey plants.

Novelty: the anatomical and morphological study of *G. lutea* and *G. minima* was conducted for the first time.

The largest merit in studying the genus *Gagea* belongs to I.G. Levichiev, who discovered and described the species *G. rubicunda* and *G. erubescens*. He justified the independence of the species *G. rubicunda* Mensh, characteristic of the north-west of the European part of Russia and Estonia, previously attributed to the synonyms of *G. erubescens* or *G. pusilla*. Its image and the characteristics of ontomorphogenesis and the difference from related species are described (XI-XII).

In *G. rubicunda* description, no significant indications of separating this taxon from *G. erubescens* were provided, which explains the persistent non-recognition of *G. rubicunda* as an independent species. Professional intuition prompted K. Meinsgauzen, S.V. Yuzepchuk and N.N. Tsvelev that a taxon that needs to be studied exists in the northwestern region. It was possible to ascertain this with the help of another material, although the old collections from Duderhof district helped restore the species independence of *G. rubicunda* (XXII).

Kulikov P.V. presented information about the distribution of the complex *G. fragifera* s. 1 (namely, *G. samojedorum* and *G. mirabilis*) in the Urals, and cited data on new discoveries of these taxa in the Southern Urals.

The complex *G. fragifera* s. 1. is represented in the Urals flora by two well-distinguishable taxa with different zonal timing, the ranges of which are separated by a small gap (no more than 170 km) falling in the forest-steppe and northern part of the steppe zone (XXIII).

Kotukhov Yu.A. described a new species of the genus *Gagea* Salisb – *G. azutavica* from the eastern spurs of the Azutau Range (Southern Altai) close to the western Tian Shan *G. pseudominutiflora* (V).

The researcher claims that the new species differs from the close species *G. pseudominutiflora* Levichev in larger size (5.5-6 cm instead of 3-5 cm), in the stem branched in the upper part (not from the base), a lower leaf equal to or bigger than the

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inflorescence (not shorter than the inflorescence) and longer sepals (6-8.2 mm instead of 5-6 mm)(VI).

Tsyganov A.P. gives a complete description of 7 species of the genus *Gagea* growing on the territory of East Kazakhstan. He characterizes the morphological data of each species, and their distribution (XVIII).

The generic Latin name 'Gagea' comes from the surname of English amateur botanist Thomas Gage (1781-1820) (XXI, XV). The Russian name 'goose onions' reflects its characteristic feature - geese and their younger offspring grazing on spring meadows and slopes give it a clear preference over other plants.

The genus *Gagea* includes about 70 species common in temperate regions of Eurasia and North Africa, from forest-tundra and glaciers in the mountains to semi-deserts (XIV).

*Gageas* are early spring ephemeroïds. In spring, their yellow star-shaped flowers cover mountain meadows, gravelly slopes and rock fissures. They are also found in the steppe, sometimes on saline soil and limestone, in separate clumps in deciduous forests and on park lawns, or like weeds in crops. 3-35 cm in height, they are the smallest plants in the subfamily Liliaceae. They have 1 or 2-3 onions if the mother bulb produces 1 or 2 onion flowers that are preserved in the mother plant (XIII).

*Gageas* are widely used for medicinal purposes. Decoction is a universal herbal remedy reducing the sugar level in blood, stabilizing metabolism, preventing cholesterol deposits and removing bodily toxins (I). Plant-based herbal remedies are successfully used to treat vitamin deficiency, hepatitis, bronchial asthma, and epilepsy.

Chemical composition of *gageas* has antiseptic, anti-inflammatory and wound healing properties since their stems and bulbs contain vitamins B, C, E, PP; organic acids; carotene; essential oils, especially garlic oils which are sulfur-containing elements; mineral salts; iodine; and inulin.

Bulb decoction is used to treat jaundice, asthma and edema – 1 tablespoonful of crushed raw materials is boiled for 3-5 minutes in 300 ml of water, infused for 2 hours and strained; 1 tablespoonful 4 times a day is recommended for 2 weeks with one-month breaks. To prevent epileptic attacks, a few chopped onions are boiled for 5 minutes in 130 ml of milk, and 2-3 teaspoonfuls are taken 3 times a day for two weeks.

Bulb juice or pulp is also used to treat trophic ulcers and wounds – grated pulp or freshly made juice is applied under the bandage on the damaged areas; the bandage is to be changed every 24 hours. Note that grass and bulbs used for medicinal purposes are to be picked up in early spring, before flowering, or in late autumn. Picking up bulbs for culinary purposes is carried out in summer.

The plant is also used for cosmetic purposes. Onion pulp is an effective means to strengthen the hair – it is rubbed into the scalp and rinsed off with shampoo 30 minutes later. Bulb facemask improves skin condition and helps get rid of acne, pigment spots and freckles.

However, consulting a doctor is strongly recommended before using the plant for medicinal purposes in case of individual intolerance of one or several components. Caution is required while using gageas during pregnancy and lactation.

Nutritional properties of gageas are well known; all parts of the plant are edible and have a pleasant taste and aroma. The bulbs are baked and boiled or added to soups to improve the taste. Dried bulbs used to be ground into flour which was added to pastry. The leaves, rich in vitamins and minerals, are also used for making various soups, spring salads and other spicy dishes.

Some of the species of this highly versatile plant are used as feed for farm animals; therefore, we cannot allow this type of plant to be included in the list of endangered species and, worse still, to become extinct (IV).

As stated above, gageas are small (10-30 cm) and frail bulbous spring plants that appear in April and May. Perianth consists of six free sepals, yellow or reddish on the inside, which are not shed after flowering. Six stamens are attached to one base; stigma is capitate; three-lobed or less often tripartite; capsule is most frequently triangular; seeds are ovoid-oblong or flat. Bulbs are two or three, differ in size, usually enclosed in dense leathery coloured scales. Stems are usually straight, ending with a raceme or semi-umbel inflorescence of five or more flowers (XIX).

Spotting gageas may be difficult since the moderately-sized plant is usually covered by last year's shed leaves; however, very bright yellow flowers serve as a certain 'beacon' (XVII).

The genus *Gagea* Salisb unites 37 species growing on the territory of Kazakhstan. 9 species belong to East Kazakhstan: *G. altaica*, *G. emarginata*, *G. alberti*, *G. minima*, *G. lutea*, *G. fedtschenkoana*, *G. filiformis*, *G. pseadaerubescens*, and *G. granulosa* (VII – IX).

The following 4 types of gageas are frequent in the outskirts of Ust-Kamenogorsk:

- 1) *Gagea granulosa* Turcz. (rare species).
- 2) *Gagea emarginata* Kar. (rare melliferous species).
- 3) *Gagea lutea* L. (rare melliferous species).
- 4) *Gagea minima* L. (decorative melliferous species).

Urbanization and population growth lead to the development of new territories and to a reduction in the number of species and the habitat of early spring flora.

*G. altaica* is 3-13 cm tall; single ovate bulb with hard lengthwise grayish-brown scales extending into the neck and surrounding the stem base to the height of 9-22 mm; the stem with the inflorescence is leafy, glabrous or pubescent (Fig.1).

The lower leaf is acicular, folded lengthwise, equal to or twice as long as the stem. Stem leaves are shorter (2.5-4.5 mm), oblong, obtuse, golden-yellow on the inside, greenish-brown on the outside, usually with a reddish tinge; stamens are 1/3 shorter than the perianth, ovary is prismatic IV-V. Grows on gravelly tops of low mountains (II).



**Fig. 1:** *G. altaica*

*G. emarginata* is 7-15 cm tall; two bulbs with hard brownish scales, one ovoid and large (about 5 mm long), the other small (about 2 mm long) (Figure 2). Stem is strong with one, rarely two, basal leaves, hollow, thick, semi-cylindrical, 2-5 mm wide, equal to or slightly longer than the stem. Two almost opposite bracts – the lower one is lanceolate, widening at the bottom, equal to or shorter than the inflorescence, the upper one is shorter and narrower than the lower one.

Inflorescence consists of 2 to 6 flowers on unequal, more or less pubescent, less often almost glabrous pedicels; perianth lobes are 15-18 mm long, lanceolate-elliptical, narrowing at the ends, obtuse, truncate or emarginate, yellow on the inside and greenish on the outside; stamens are twice as long as the perianth; flowers are V-VI. Grows in mountain meadows, subalpine and alpine zones.



**Fig. 2:** *G. emarginata*

*G. alberti* is 8-15 cm tall; bulb is ovoid, with reticulate scales continued upwards into a dense tall tube that almost reaches the inflorescence (Figure 3).

Single basal leaf, filiform, exceeding the inflorescence, pubescent at the bottom, glabrous at the top. Stem leaves are filiform, the lower ones exceed the

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inflorescence; inflorescence is a corymb or a raceme, of several flowers with more or less pubescent pedicels. Perianth lobes are 10-12 mm long, lanceolate-oblong, obtuse, pale yellow on the inside, greenish on the outside, with whitish rims. Anthers are linear-oblong; flowers III-IV. Grows on the mountain slopes.



**Fig.3:***G.alberti*

*G. minima* is 7-20 cm tall; two bulbs of different sizes in one common shell of brown scales (Fig. 4). Stem is glabrous; one basal leaf, linear, flat or slightly grooved, narrowing at both ends (1-3 mm wide); lower bract is lanceolate with an expanded base (4-8 mm wide), the next one is narrower, linear, slightly higher at the base of the next branching; pedicels are 3-4 times as long as flowers, glabrous or pubescent with small bare or ciliated bracts; perianth lobes are yellow on the inside and greenish on the outside, 10-15 mm long, linear-lanceolate; stamens are 1.5-2 times shorter than the perianth with small, widely elliptical anthers much shorter than the filaments. Flower IV-V. Grows on forest edges, meadows, among shrubs. Early spring ephemeroïd having a summer period of rest; growing season lasts 2-3 weeks.

*G. minima* is by high reproductive capacity by daughter bulbs and, unlike *G. lutea*, retains the ability of limited reproduction by bulbs in the reproductive state.



**Fig. 4:** *G. minima*

*G. lutea* is 10-25 cm tall; bulb is small, oblong-ovate, 6-10 mm thick, covered with gray-brown hard scales. Stem is glabrous, basal leaf is lanceolate, 7-15 mm wide, cuspidate, exceeds the stem; two bract leaves, the lower lanceolate, usually exceeding the inflorescence, the next smaller, linear-lanceolate or linear, usually shorter than the inflorescence. Inflorescence consists of 2-10 unequal flowers; 6 tepals of the perianth are arranged in two rows, they are lanceolate, yellow, obtuse, 11-13 mm long and 2.5-4 mm wide, pale yellow on the inside, green on the outside (Figure 5). Perianth is almost twice as long as the stamens; stamens are 6; capsule is globular and shorter than the perianth. Flower IV-V. Stigma is capitate, three-lobate. Early spring ephemeroïd with a period of rest in summer. By the end of summer and by autumn, the budding of the next year is fully formed in the buds of renewal, including inflorescences and flowers. Leaves tops look like a solid bright edge consisting of a group of cells of mechanical tissue; it serves to exit from under the layer of frozen soil, fallen leaves, from under the snow cover and ice cover. Grows mainly in the northern part of Kazakhstan Altai, in steppes and semi-deserts, deciduous forests, among shrubs in glades, gardens, and meadows, and along ravines (III).

*G. lutea* blooms in April immediately after the snow melts; therefore, the plant is sometimes called yellow snowdrops (*G. mimima*, for instance, appears only in may). Valuable early pollen plant, providing bees with pollen (and partially nectar) for 2-3 weeks; this stimulates the spring development of bee colonies and provides supporting honey collection. Honey productivity is 8-12 kg per 1 ha. The vegetation period lasts 2 to 3 weeks. Flowers open at 10 o'clock in the morning, close at 16-17 o'clock and in cloudy and rainy weather. Pollinators are small flies, beetles and bees attracted by nectar which accumulates in droplets between the bases of the leaves and filaments (XVI).

Ontogenesis of *G. lutea* is divided into two periods. In the first period, before flowering, there is an increased vegetative reproduction through the formation of daughter bulbs appearing at the base of the mother bulb. Bulbs formed in spring are

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covered with a corked layer and do not germinate the following spring, only during the third year. In the spring of the fourth and fifth year, the width of the leaf, the size of the bulb and the number of daughter bulbs (up to 7-16) increase. In the spring of the sixth year, the plant blooms and enters the second period of life –it loses the ability to form daughter bulbs and until the end of life cycle is reproduced only by seed. Both of these methods provide spread and reproduction of the species.



**Fig. 5:** *G. lutea*

*G. fedtschenkoanais* 3-10 cm tall; bulb is small, ovate-spherical, 10-18 mm long, with large areas of frigid brown-grayish scales; stem is thin; one basal leaf considerably exceeding the stem, carinate, curved, 1-3 mm wide; two almost opposite bracts (Figure 6). Lower bract is linear-lanceolate, ciliate, shorter or slightly longer than the inflorescence; upper bract is shorter and narrower; inflorescence is umbel, has 1-5 flowers with pedicels equal to or 1.5-2 times longer than flowers; perianth lobes are oblong-elliptical, 8-15 mm long, obtuse, whitish-yellowish or golden on the inside, brownish-reddish or dark brown on the outside. Stamens are 1/3-1/2 shorter than the perianth.

Capsule is trihedral ovate, 2 times shorter than the perianth; flowers are IV-V. Grows on stony steppe slopes, along forest edges (X).





**Fig.6:** *G. fedtchenkoana*

*G. filiformis* is 5-10 cm tall; one or several bulbs twisted and in brown scales; stem is thin and frail. Basal leaf is flat, linear, 1-3 mm wide, equal to or slightly exceeding the stem. The bract is usually wider than the basal, linear, pointed, 5-7 mm wide, equal or shorter than the inflorescence; the next bract is almost opposite, small, linear, sometimes with small bracts on the pedicel (Figure 7).

Inflorescence has 1-6 flowers, is equal to or slightly shorter than the stem. Pedicels are much longer than flowers, bulged after flowering. Sepals are pale yellow, 8-10 mm long, the outer ones are pointy, the inner ones obtuse. Stamens are 1/3 shorter than perianth; anthers are small and rounded. Flowers IV-V. Grows on meadow slopes.



**Fig. 7:** *G. filiformis*

*G. pseadaerubescens* 10-20 cm; two bulbs, the smaller one giving rise to the stem; scales are thin, black-brown; stem is thin. Single basal leaf, equal to or longer than the stem, flat, linear, 5-10 mm wide. Bracts are lanceolate, up to 15 mm wide, acicular, equal to or slightly longer than the inflorescence (Figure 8).

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Sometimes small bracts are developed on pedicels. Inflorescences have few flowers and are 1.5-2 times shorter or almost equal to the stem. Pedicels are thin, much longer than the flowers. Perianths are 8-12 mm long, light yellow on the inside, green on the outside, the outer acicular, the inner obtuse. Stamens are 1/3 shorter than the perianths, with small, round anthers. Flowers are IV-V. Grows on mountain and foothill slopes, among meadows and shrubs (XX).



**Fig. 8:** *G. pseadaerubescens*

*G. granulosa* is 10-30 cm tall; bulb is ovate, 5-6 mm thick, surrounded at the base by numerous small bulbs. Stem is thin and whitish at the bottom. One flat cuspidate basal leaf, 4-9 mm wide, 1.5 cm long. Two bracts, the lower is 6-10 mm wide, the upper is almost opposite, much narrower and shorter (Figure 9). Inflorescence has 1-5 flowers on unequal stalks.

Perianth segments are yellow, with greenish stripes on the outside, 12-13 mm long, lanceolate, obtuse. Flowers are IV-V. Grows along forest edges and among shrubs (XX).



**Fig. 9:** *G. granulosa*

## **II. Materials and Methods**

The research materials were personal herbal gatherings made from March to May 2017-2018 in the vicinity of Ust-Kamenogorsk. For anatomical and morphological studies of vegetative organs, two common types of gageas were selected: *G. lutea* and *G. minima*. The collected material was processed with Yakovlev fixing solution which causes rapid coagulation of protoplasm and is a good medium for the storage and compaction of the material.

Microscopic examination of fixed materials was performed; for this, sections from the vegetative organs of plants were made. Stem and leaf sections were taken from the middle part. The leaf structure was studied on transverse sections, and the base of the leaf blade was studied at the passage of the main vein. After the cross sections were made, each was examined to select the most equal, fine and whole. The present research used microscopes MBI-4, MBI-6, and Biomed; photographs were taken with the help of the latter.

Initially, the fixed material was dehydrated; that is, the best, thinnest slices were processed with ethanol solutions of increasing concentration. Dehydration ended by keeping the object in absolute alcohol. The whole procedure lasted 20 minutes.

Subsequently, temporary and permanent microscopic preparations in glycerin-gelatin were made from the obtained sections. The studied objects were placed in water. In this case, preparations cannot be stored for a long time since water evaporates quickly. In extreme cases, they can be stored for several days in a humid atmosphere under a glass bell. However, it is often necessary to store a preparation for a longer period, for which not water but glycerin, glycerin-gelatin or fir balm are used.

Concentrated glycerin is used to make permanent microscopic preparations and to whiten the sections; in addition, glycerin serves as a medium for microscopy and preservation of finished products and as a dehydrating and highly plasmolyzing medium. Some preparations are investigated in diluted glycerin as well, and it is used to soften the hard parts of the plants before cutting them.

Generally, the mechanism is as follows: special substances (in the liquid state) are capable of passing into the solid state and of keeping preparations unchanged for many years. Therefore, the authors of the present research used glycerin-gelatin as one of such substances; it is applied to the overwhelming majority of preparations in laboratory experiments.

After completing all the above mentioned steps, the authors of the present research studied the anatomical and morphological features of selected plant species; at the same time, comparative analysis of *G. lutea* and *G. minima* was made to define similar and distinctive features.

## **III. Results**

*Anatomical study of the vegetative organs of G.lutea (Figure 10) and G. minima (Figure 11).*



**Fig. 10:** *G.lutea*, May 11, 2018.



**Fig. 11:** *G. minima*, May 17, 2018.

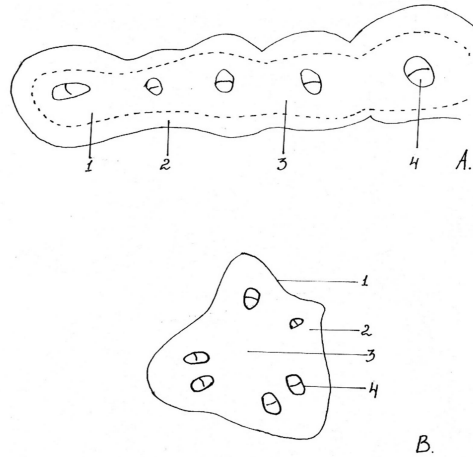
The cross section of the *G. Lutea* leaf has a wavy shape (Figure 12). One conductive bundle is located in each segment, surrounded by colorless parenchymal lining.

The transverse section of the stem can be characterized as triangular, with three conductive bundles at the top of each face. The stem is covered with a single layer of the epidermis with large cells. The epidermis is covered on the outside with a thick layer of cuticle. Cells of the primary cortex have different shapes, lie loosely with large intercellular spaces and contain chloroplasts. The core cells are round and of different sizes, tightly spaced. In the conducting bundle, the volume of xylem and phloem are the same. Phloem has a rounded shape, and the xylem contains 4-5 large veins. Parenchymal cells around the conductive bundles are small.

Elongated two-layer mesophyll cells in the form of rays protrude from the lining. These are connected by large and small parenchymal cells. The stomata are found in the lower and upper epidermis; cells of the upper and lower epidermis do not

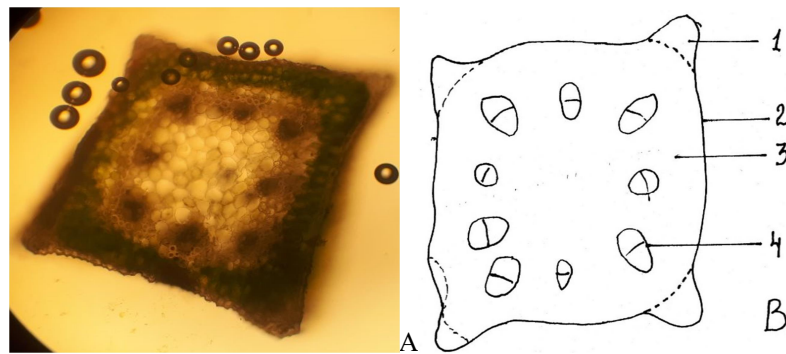
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differ. Conductive bundles are of the closed-collateral type; their spiral trachea are clearly visible in the transverse section.



**Fig. 12:** The structure of the leaf (A) and stem (B) of *G. lutea*. A: 1–epidermis, 2 –columnar mesophyll, 3 – spongy mesophyll, 4 – central bundle. B: 1–epidermis, 2 – cortex, 3 –core, 4 –bundle.

The *G. minima* stem is tetrahedral. The peculiarity of this species is the face formed by the collenchyma. Epidermis covers the cuticle in a thin layer and has outgrowths.



**Fig. 13:** Transverse section of the *G. minima* stem: A –photo under the microscope, B –schematic drawing; 1 – rib, 2 – epidermis, 3 – cortex, 4 – bundle.

Bundles are similar in size and arranged in a circle. The cells of the primary cortex are rounded, densely located. Stem core is represented by large parenchymal cells; bundle is ovate; xylem is three times bigger than the phloem. Size of parenchymal cells increases from the periphery to the center.

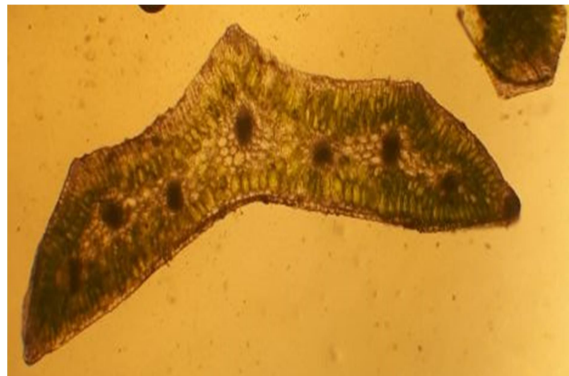
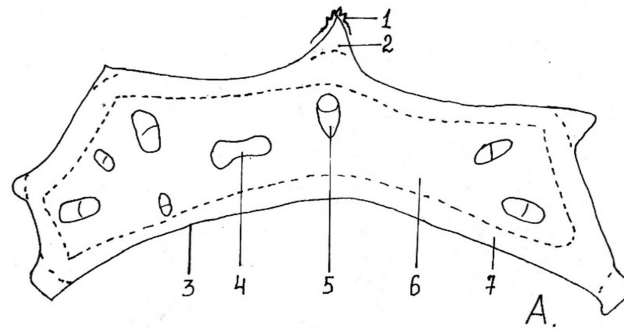
The *G. minima* leaf resembles a curly bracket in shape (Figure 14). The mesophyll is spongy and columnar. A characteristic feature of this species is a rib

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formed from mechanical tissue and located in the underside and at the sides of the leaf.

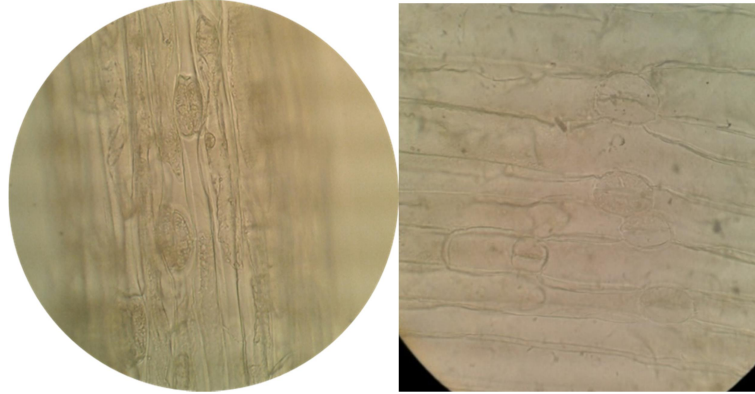
On one side of the leaf, two bundles beams from the central vein connect and form a figure eight; on the other side of the main vein, two small bundles are located near the middle bundle. Stomata are found in the lower and upper epidermis. The cells of the upper epidermis are 6-7 times larger than the cells of the lower epidermis. One side has two ribs, the other side has one. The middle leaf cells are round and large, and are located more densely and have an elongated shape under the upper and lower epidermis. Around the leaf, the mesophyll cells are smaller than others. The upper and lower epidermis both have stomata (Figure 15).

In the lower epidermis of *G. lutea*, the cells are elongated-tetrahedral. The small and large ovate parallel stomata are found in the lower and upper epidermis. Note that in the upper epidermis, the stomata are larger than in the lower epidermis.



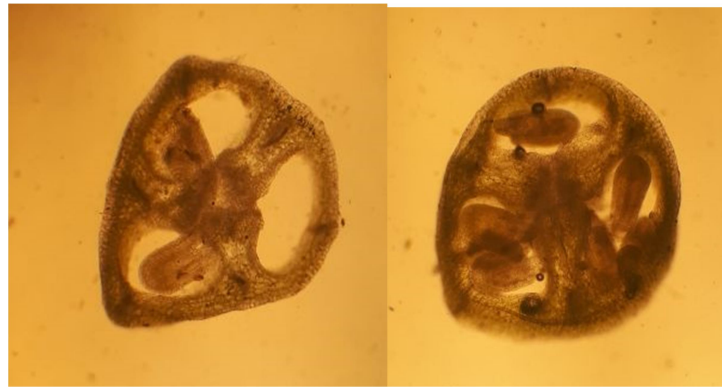
**Fig. 14:** Cross-section of the *G. minima* leaf: A – schematic drawing, B – photo under a microscope; 1 – cuticle, 2 – mechanical lining, 3 – epidermis, 4 - combined bundle, 5 – central bundle, 6 – spongy mesophyll, 7 – columnar mesophyll.

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**Fig. 15:** The stoma of *G. lutea L.* and *G. minima L.*

Note that in the cross section of the ovary, the coenocarpoustricarpellategynoecium is clearly visible. Carpels contain developed ovules. Figure 16 shows its structural features.



**Fig. 16:**Coenocarpousgynoecium

As mentioned above, East Kazakhstan species of gageas are ephemera with a life cycle of only 10-12 days. The species studied by the authors (*G. lutea* and *G. minima*) are similar in morphological features, but *G. minima* is small, and its shoots appear earlier than in other species.

#### **IV. Conclusion**

The literature analysis and the study of the anatomical and morphological structure of the genus *Gagea* yielded the following results:

- 1) In the outskirts of Ust-Kamenogorsk, 4 types of gageas are most frequent: *G. lutea L.*, *G. granulosa Turcz.*, *G. emarginata Kar.*, and *G. minima*.
- 2) Representatives of this genus are early flowering plants, 15-18 cm tall with yellow small flowers and lanceolate or filiform leaves.

3) *G. lutea* L. and *G. minima* are morphologically similar, but for the former, the yellow basal leaf is 2 times wider than for the latter. The number of flowers of for the former exceeds those of the latter.

4) The stem of *G. lutea* is triangular, and tetrahedral with faces covered with thick cuticle with outgrowths in *G. minima*. Each face has three bundles.

5) The cross-section of the *G. lutea* leaf has a wave-like shape with segments, that of *G. minima* resembles a curly bracket. One side of the leaf blade has two outgrowths, the other side has one. *G. lutea* has one bundle in each leaf segment; *G. minima* leaf blade has two bundles that form a figure eight on one side of the main vein, and there are two small bundles on the other side.

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