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Comparative microscopic study of *Solidago* species from the Republic of Moldova flora

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Abstract

Background: Genus *Solidago* is represented in the Republic of Moldova flora by two species: *S. virgaurea* – spontaneous and *S. canadensis* – cultivated, known as medicinal plants in the world, also being studied in our country. The objective of this paper was the comparative microscopic study of *Solidago* species from the Republic of Moldova flora.

Material and methods: Superficial preparations and sections were made from vegetal products of *S. virgaurea* and *S. canadensis* species and studied in the *Micros* microscope coupled with digital camera.

Results: The main specific structural indicators with diagnostic role in the identification of g. *Solidago* species from the flora of the Republic of Moldova were highlighted: the presence of secretory channels in rhizome and stem (both species); the contour of stem in cross-section (polygonal outline – *S. virgaurea*, circular outline – *S. canadensis*); the mesophyll structure of leaf (dorsoventral mesophyll – *S. virgaurea*, equifacial mesophyll – *S. canadensis*); anomocytic type of stomata (both species); multicellular protective conical trichomes and flabelliform ones (both species); secretory trichomes (with unicellular foot – *S. virgaurea*, and with multicellular one – *S. canadensis*); abundant pappus composed of multiseriate bristles and spherical pollen grains (both species).

Conclusions: *S. virgaurea* and *S. canadensis* species from the Republic of the Moldova flora could be identified by specific structural indices that have an important diagnostic role.

Key words: genus *Solidago*, microscopy, structural indices.

Cite this article

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Introduction

The genus *Solidago* L. is one of the most complex genera of higher plants, including about 120 species, most of which are native to North America, less to Eurasia, being spread throughout the continents. In the Central Europe, there are 5 species of g. *Solidago*: 4 of them being of American origin – *S. canadensis* L., *S. gigantea* Aiton., *S. altissima* L. and *S. graminifolia* (L.) Elliot, and only one species – *S. virgaurea* L. is native to Europe [1, 2]. In the flora of the Republic of Moldova g. *Solidago* is represented by 2 species: the native one, spontaneously spread *S. virgaurea* and the cultivated species *S. canadensis*, known as adventive one [3, 4]. Species *S. virgaurea* with the common name European goldenrod is known for Romanian population as “*vargă-de-aur*”, “*splinuță*”, “*floare-boierească*”, “*mănunchi*”, “*splinăriță*”, “*smeoaică*”. The aerial parts of European goldenrod have been used for centuries as diuretic and anti-inflammatory agents in traditional medicine for the treatment of several urological symptoms, such as urolithiasis, kidney and bladder inflammation, cystitis, etc. [5-7].

On the other hand, Canada goldenrod (*S. canadensis*), known as popular Romanian common names: “*sălcioară*”, “*sânziană-de-grădina*”, is included in the uncultivated synanthropic flora of the Republic of Moldova, being specific for degraded ecosystems and rural areas, particularly in ruderal and human-created habitats, as well, being cultivated as an ornamental plant [3, 4]. Also, it has been used in the European phytotherapy for 700 years for the treatment of chronic nephritis, cystitis, urolithiasis, rheumatism and as an antiphlogistic drug [8-11]. The multi-pharmacological properties of g. *Solidago* species are due to the presence of many bioactive compounds: flavonoids, phenolic compounds, triterpene saponins, carotenoids, chlorophylls and essential oils [1, 5-17].

The increased interest for *Solidago* species as medicinal plants and the fact that *S. virgaurea* and *S. canadensis* species from the Republic of Moldova flora have not been practically researched, motivated us to carry out this comparative microscopic study.

Material and methods

Plant material. The different plant materials (rhizomes and roots – *rhizomata et radices*, aerial parts – *herba*, leaves – *folia*, and flowers – *flores*) were harvested in the middle of July, beginning of August (2019), during the flowering phase. Vegetal products of *S. virgaurea* species have been collected from “The Trebujeni landscape reservation”, Orhei district, and vegetal products of *S. canadensis* species – from the collection of the Scientific Centre for Medicinal Plants Cultivation of *Nicolae Testemitanu* State University of Medicine and Pharmacy. The plant material was dried in natural conditions, in dark, dry rooms, ventilated, thus preserving the color of the flowers and avoiding the molding of the biological material.

Microscopic method. The microscopic study was performed on clarified (with chloralhydrate or 3% NaOH) superficial preparations of the leaf, flowers, and on cross-sections through leaf lamina, stem, and rhizome according to the classical techniques [18]. The anatomical study was performed at the Department of pharmacognosy and pharmaceutical botany, *Nicolae Testemitanu* State University of Medicine and Pharmacy, using the binocular optical microscope *Micros* (Austria), with a digital camera, coupled to the computer, at 4x, 10x and 40x objective magnification.

The results of the microscopic determinations were statistically processed using the GraphPad Prism 7.0 program.

Results and discussion

Microscopy of *S. virgaurea* rhizome. In cross-section the rhizome has a cylindrical contour, with the following histological zones: periderm, cortex and the central cylinder. The covering tissue is represented by a multilayered periderm, consisting of thickened polygonal cells. The secretory channels are distributed in the endoderm region of the cortex. The central cylinder occupies most of the rhizome, which consists of a system of collateral-open vascular bundles, arranged in circle. Above the phloem there are thick-walled lignified cells – the pericyclic sclerenchyma (fig. 1 A, B).

Microscopy of *S. canadensis* rhizome. The structure is, in general, similar to that of the European goldenrod, with the same cylindrical contour of the rhizome. Inside, the collateral-open vascular bundles are located radially and the secretory channels are distributed in the endoderm region. In contrast to the European goldenrod rhizome, medullary parenchyma cells contain idioblasts with raphides (fig. 2 A, B).

Microscopy of *S. virgaurea* stem. According to the microscopic images, stem in cross-section has a polygonal contour. The epidermis is a single-layer, composed of cutinized, well-packed, polygonal cells. Below the epidermis, we mention the angular collenchyma with cell thickening at intercellular contact points, followed by the cortical parenchyma, comprising several layers of large, oval-spherical cells. At the border between cortical parenchyma and endo-

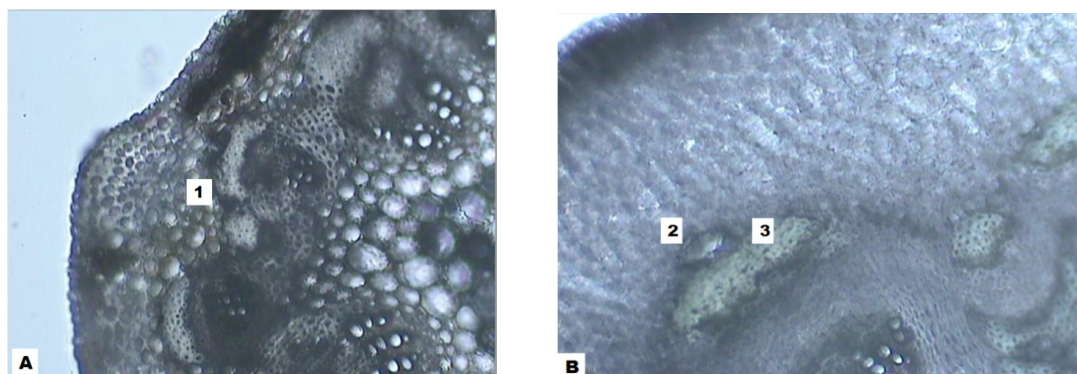


Fig. 1. Cross-section view of *S. virgaurea* rhizome: A (4x); B (10x);
1 – collateral-open vascular bundles, 2 – secretory channel, 3 – pericyclic sclerenchyma

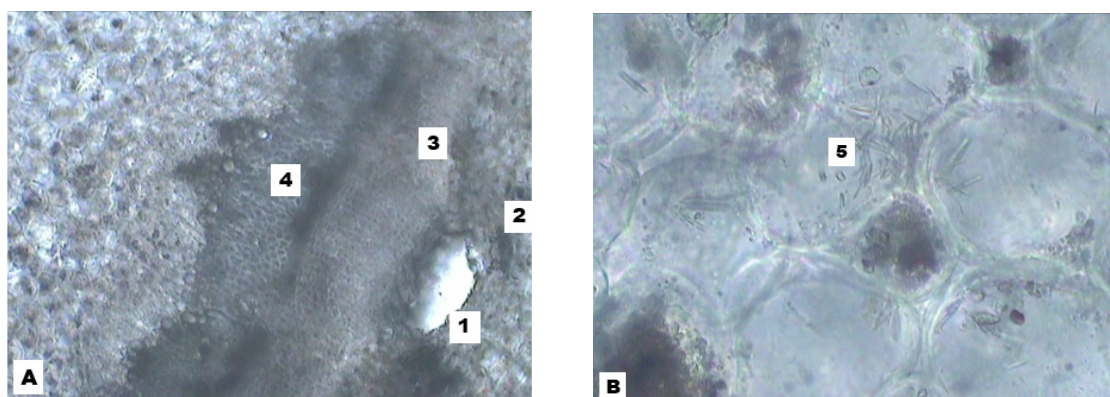


Fig. 2. Cross-section view of *S. canadensis* rhizome: A (10x); B (40x);
1 – secretory channel, 2 – cortical parenchyma, 3 – phloem, 4 – xylem, 5 – idioblasts with raphides

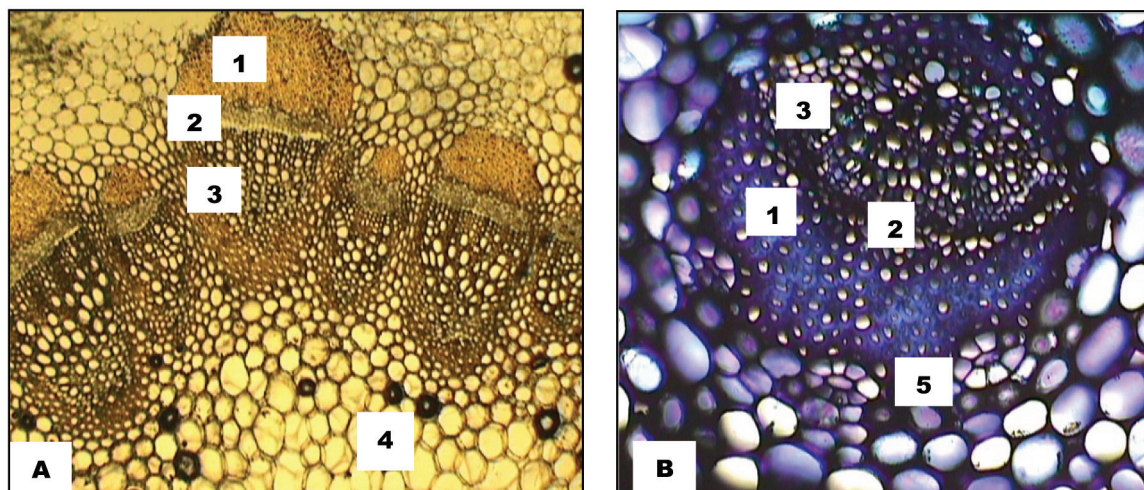


Fig. 3. Cross-section view of *S. virgaurea* stem: A (10×), Lugol solution; B (40×), Methylene blue solution; 1 – phloem, 2 – cambium, 3 – xylem, 4 – medullary parenchyma, 5 – secretory channel

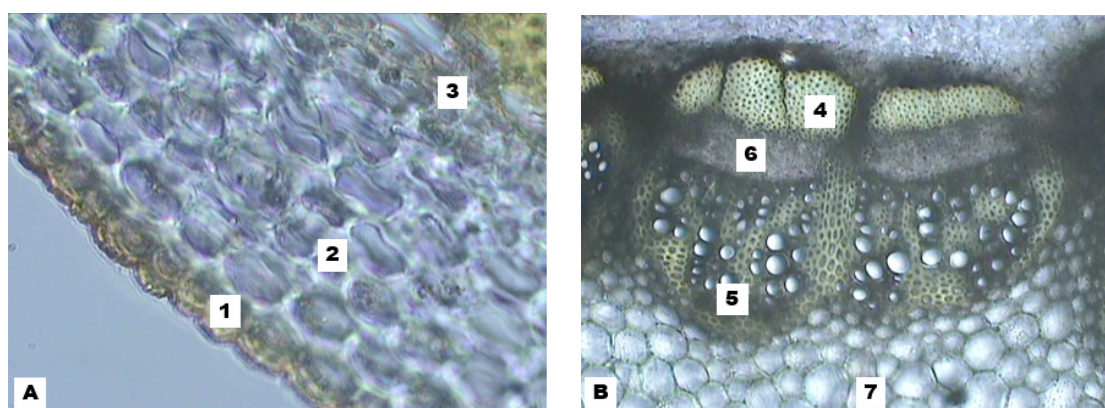


Fig. 4. Cross-section view of *S. canadensis* stem: A (40×); B (10×); 1 – epidermis, 2 – cortical parenchyma, 3 – sclerenchyma, 4 – phloem, 5 – xylem, 6 – cambium, 7 – medullary parenchyma

dermis, secretory channels are present. The vascular cylinder is made up of roundly arranged collateral-open vascular bundles, situated very close to each other (fig. 3 A, B).

Microscopy of *S. canadensis* stem. In comparison with European goldenrod stem, the microscopic analysis of Canada goldenrod reveals that stem in cross-section has a circular outline. The epidermis is unilayered and consists of well-packed oval cells. Similar to European goldenrod, the cortex contains secretory channels, and the endoderm is differentiated on the outside of the phloem tissue of the vascular bundle. The central cylinder consists of collateral-open vascular bundles, arranged radially, being located very close to each other (fig. 4 A, B).

Microscopy of *S. virgaurea* and *S. canadensis* leaf. The analysis of superficial preparations of leaves from both *Solidago* species, reveals similar structures of epidermis, which is single-layered and composed of well-wrapped cells. The cells of the upper epidermis of the leaf are polygonal, isodiametric, with slightly sinuous and uniformly thickened external walls. Stomata are present on both epidermises (amphistomatic leaf), but numerically, more on the abaxial surface. For the upper epidermis, it is specific the anomo-

cyclic type of stomata: the guard cells are surrounded by 4-5 subsidiary cells of the same shape as other epidermal cells. For the lower epidermis, it is specific the anomotetracytic type of stomata: the guard cells are surrounded by rule of 3-5 cells, moreover there are 4 subsidiary cells.

According to our analysis of epidermis and the previous one [19], for both *Solidago* species, there were found the following specific trichomes, which presented only some numerical variations:

1. Multicellular protective trichomes describing a conical shape, consisting of a single row of 2-7 cells; the cell walls are thin, with a smooth or slightly wavy surface. They are frequent on the both surfaces of the leaf blade, mainly on the veins and leaf margins. Often, the apical cell of the trichome is curved or may easily break, only the basal cells of the trichomes remaining on the leaves (fig. 5 A). Usually, around the trichomes, the epidermal cells are radially disposed, forming a basal rosette. The basal cells of the trichomes are filled with a brownish-red content (fig. 5 A). This type of trichomes is found in abundance on the leaves of both *Solidago* species (fig. 5 A, D)

2. Uniseriate multicellular trichomes consisting of 2-3

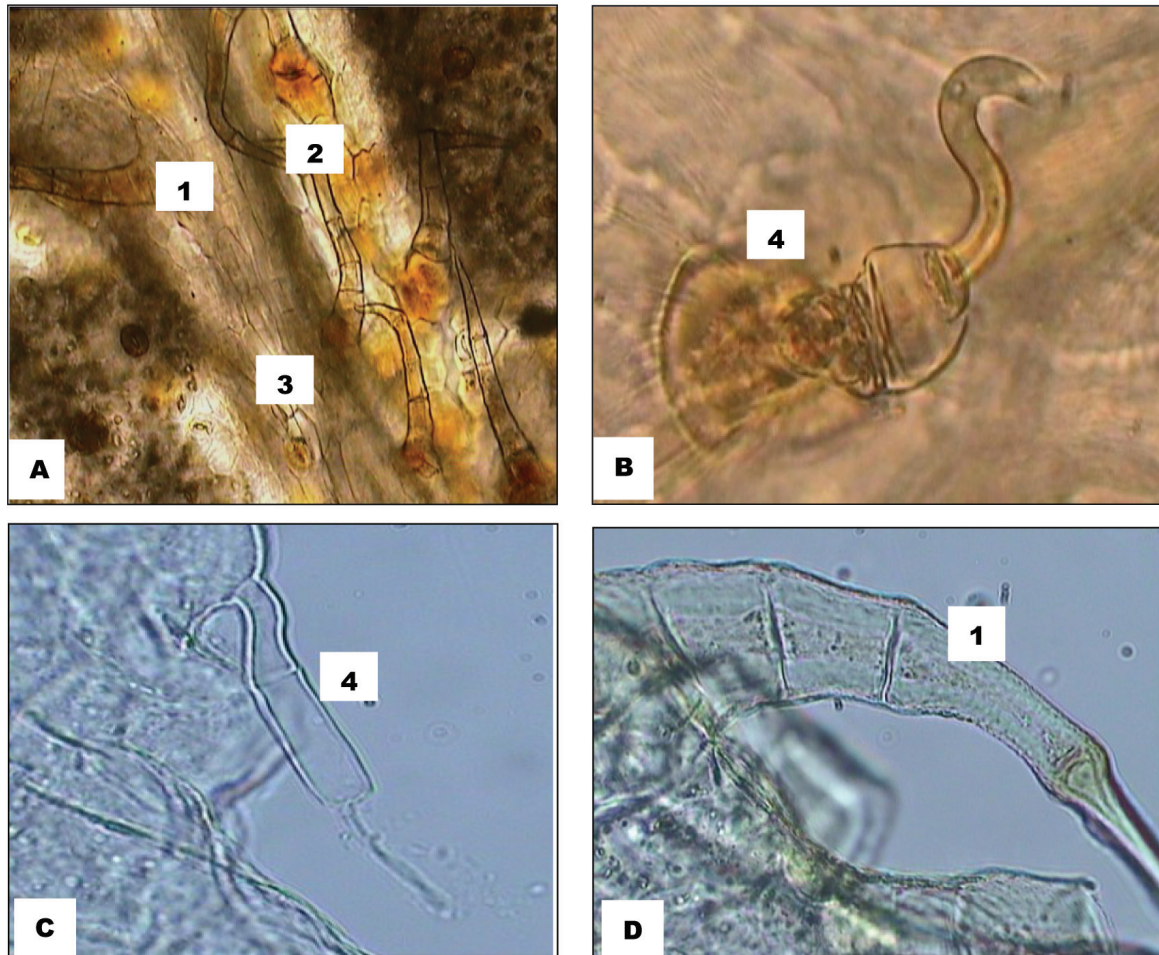


Fig. 5. Superficial view of *Solidago* species leaf: *S. virgaurea* – A (10×); B (40×); *S. canadensis* – C (40×); D (40×); 1 – multicellular protective trichomes, 2 – protective trichome with the broken apical cell, 3 – basal cells of the trichome filled with a brownish-red content, 4 – flabelliform trichome

cells, the apical one can be elongated to the filiform, because of this, these trichomes are also found in the literature review [20, 21] as flabelliform, moniliform or flagellate trichomes. This type of trichomes is more common on the lower epidermis of *S. virgaurea* middle leaves (fig. 5 B). There are fewer such flabelliform trichomes only on *S. canadensis* leaves (fig. 5 C).

3. Secretory trichomes, being short, with a stalk formed of 1-2 cells and a unicellular head, representing the apical secretory cell. The unicellular foot secretory trichomes were found more on leaves of *S. virgaurea*, and the multicellular (2 cells) foot secretory trichomes – on leaves of *S. canadensis*. The secretory trichomes are less numerous compared to the covering ones for both *Solidago* species.

The comparative microscopic study of *S. virgaurea* and *S. canadensis* leaf in cross-section view demonstrates that leaf of *S. virgaurea* has a dorsoventral (bifacial) structure, but leaf of *S. canadensis* – equifacial structure. For *S. virgaurea* leaf it was distinguished the upper and lower epidermis, including well developed mesophyll, differentiated into palisade parenchyma – occurred in two rows in the upper part of the leaf blade, and spongy parenchyma – located in

the lower part of the leaf blade (fig. 6). The mesophyll structure of *S. canadensis* differed from that of *S. virgaurea*: the palisade cells occurred in two layers: upper (near adaxial epidermis), composed of two rows, and lower, with one row of palisade cells. Spongy cells formed a clearly differentiated thin layer between the palisade layers.

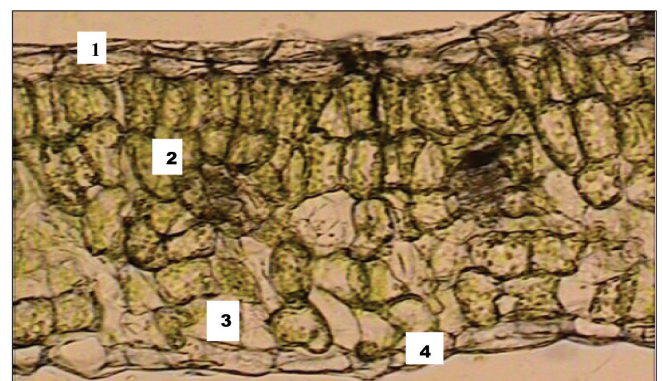


Fig. 6. Cross-section view of *S. virgaurea* leaf (10×): 1 – upper epidermis, 2 – palisade parenchyma, 3 – spongy parenchyma, 4 – lower epidermis

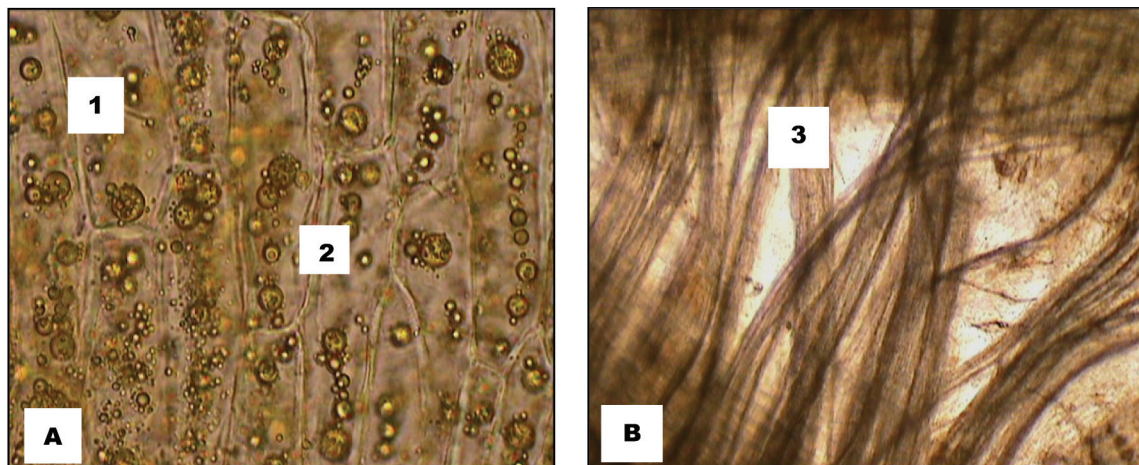


Fig. 7. Superficial view of *S. virgaurea* florets: A – ligulate floret (40x); B – tubular floret (4x); 1 – spherical chromoplasts, 2 – ligulate floret epidermis cells, 3 – pappus at the base of tubular floret

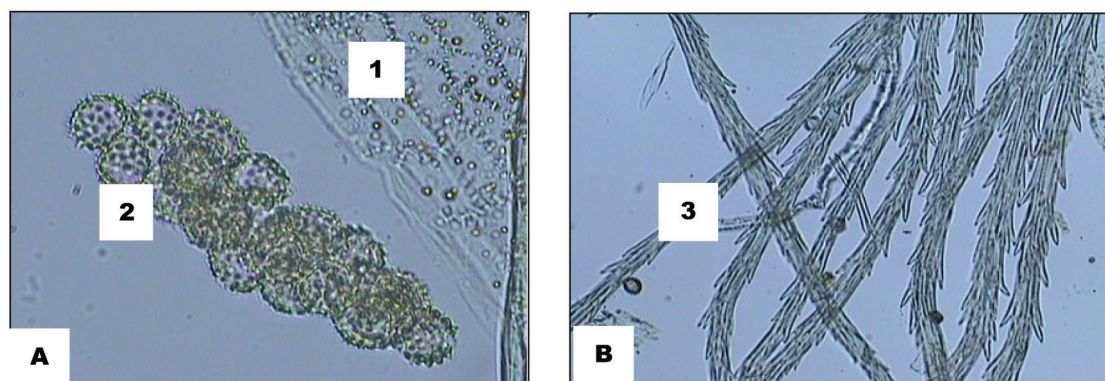


Fig. 8. Superficial view of *S. canadensis* florets: A – ligulate floret (40x); B – tubular floret (40x); 1 – spherical chromoplasts, 2 – spherical pollen grains with irregular surface, 3 – multiserrate pappus bristles, branched on the outside

Microscopy of S. virgaurea and S. canadensis flower (superficial view). The anatomical structure of the ligulate and tubular florets has a lot of common features for *Solidago* species, with only a few small differences. For the ligulate ray florets of *Solidago* species, it is characteristic the epidermis consisting of rectangular-shaped cells with thin cell walls without intercellular spaces. The cells are rich in spherical, globular chromoplasts (fig. 7 A). The epidermis of tubular floret is formed from cells of the same shape as those of the ray floret epidermis, although, we mention the elongation of the cells and thickening of their walls as well as the formation of cuticle strips. Chromoplasts are present in abundance and usually form conglomerates (fig. 7 A, fig. 8 A).

On the stigma of the tubular floret, there are numerous pollen grains of spherical shape with irregular surface, a common feature for plant species from Asteraceae family (fig. 8 A). At the base of the floret there is attached the pappus, made up of numerous bristles. The pappus is abundant, being composed of multiserrate bristles (fig. 7 B). The pappus bristles from *S. canadensis* florets are much more branched on the outside, compared to those from *S. virgaurea* (fig. 8 B).

Conclusions

The main anatomical indices with diagnostic role for *S. virgaurea* and *S. canadensis* species from the flora of the Republic of Moldova were highlighted: the presence of secretory channels in rhizome and stem (both species); the contour of stem in cross-section (polygonal outline – *S. virgaurea*, circular outline – *S. canadensis*); the mesophyll structure of leaf (dorsoventral mesophyll for *S. virgaurea* and equifacial mesophyll – *S. Canadensis*); anomocytic type of stomata (both species); multicellular protective conical trichomes and flabelliform ones (both species); secretory trichomes (with unicellular foot for *S. virgaurea*, and with multicellular one – *S. canadensis*); abundant pappus composed of multiserrate bristles (both species, but with some specifications for *S. canadensis* – pappus bristles from florets are much more branched on the outside); numerous pollen grains of spherical shape with irregular surface (both species).

As a result of this anatomical study, there have been determined specific structural indices that have an important diagnostic role for the identification of *S. virgaurea* and *S. canadensis* species from the Republic of Moldova flora.

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Authors' contribution

CF collected and processed the plant material, performed the microscopic study, drafted the first manuscript; TC designed the study, conducted the laboratory work, interpreted the data, revised the manuscript; LU conducted the laboratory work, revised the manuscript. All the authors revised and approved the final version of the manuscript.

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Ethics approval and consent to participate

No approval was required for this study.

Conflict of Interests

No competing interests were disclosed.