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RESEARCH ARTICLE
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Adaptive Anatomical Characteristics of Vegetative Organs in *Cynara* L. Varieties under Different Soil Salinity Conditions

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ABSTRACT

This study investigates the anatomical structure of the vegetative organs—leaves, petioles, and stems—of promising artichoke varieties, specifically *Imperial Star* and *Violettto*. A particular focus was placed on the anatomy of the petiole, alongside a comparative analysis of biometric indicators, to explore the relationship between organ strength and plant life forms. The findings revealed distinct structural diagnostic patterns in the morphological characteristics of these artichoke varieties. The insights gained not only facilitate accurate identification of plant specimens but also hold potential applications in botanical systematics. Additionally, the observed anatomical features serve as valuable tools for assessing the presence of biologically active compounds in various organs and tissues, extending their significance beyond taxonomy. Ultimately, this research enhances our understanding of the ecological adaptations of artichokes by illuminating the intricate anatomical structures of their vegetative organs.

Keywords: Anatomical, Stomata, Parenchyma cells, *Imperial Star*, *Violetto*, *Cynara* L.

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INTRODUCTION

The anatomical structure of the vegetative organs of the *Artichoke Green Gold* variety, which is cultivated in the Bukhara region's medium salinity areas, has been examined for the first time. Xeromorphic and meso-xeromorphic characteristics emerged, indicating that cell size in the leaf epidermis decreased, stomatal density increased, stem bark parenchyma thickened, the diameter and number of conducting tubes increased, and lignification intensified (Isomov et al., 2024). Although the appearance and ecological preferences of *Tamarix* species were very similar, their anatomical-hydraulic characteristics differed significantly. These variations, attributed to climatic factors rather than phylogeny, indicate particular regional adaptations to environmental conditions (Akhmedov et al., 2025). Further research provides a groundbreaking analysis of the anatomical makeup of *Ferula tenuisecta* above-ground and underground organs, such as leaves, petioles, peduncles, pedicels, and roots, in their native ecological settings (Duschanova et al., 2023). The local supply of raw materials for pharmaceutical production and the cultivation of medicinal plants is currently one of the most urgent problems. From an economic perspective, it is crucial to identify new medicinal plants, determine their chemical composition, and integrate them into conventional treatment methods (Bobokandov et al., 2024). In the Bukhara region's medium-saline soils, the methodology, formalization, and observed maturation processes of the *Imperial Star* and *Violettto Cynara scolymus L.* cultivars were examined under Uzbekistan's slightly salinized soil conditions. The following characteristics of adaptability were identified (Isomov et al., 2024). Central Asian desert habitats, including those in

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Uzbekistan, are home to distinctive plant communities and rich biodiversity. However, habitat degradation and vegetation cover loss have been exacerbated by high human pressure and prolonged droughts driven by climate change (Bobokandov et al., 2024). Research is required to detect and protect biological diversity due to the increasing effects of human activities and climate change on ecosystems. Significant progress has been made in determining the causes of plant population declines, assessing their dynamics, and creating conservation strategies (Akhmedov et al., 2023). The artichoke *Cynara scolymus* is typically cultivated as perennial in southern regions. However, in the Moscow and Leningrad areas, it is often grown as an annual crop following seedling preparation in greenhouses. In these regions, seedlings are usually transplanted to open ground between late April and early May. Artichoke cultivation began in the Samarkand region under the guidance of Huang, (2011). According to their research, the wet weight of artichokes contains 3.3% protein and 2.9% fat. Additionally, seed yield is notably low, as only half of the flowers in the basket produce viable seeds. In the study area, flowering was observed in only 5-8% of the plant's bushes during the first year of growth. This study also investigated the anatomical composition cotyledon leaf in irrigated and non-irrigated artichoke plants and found that xeromorphic signs such as reduced leaf epidermal cell size, curved cell walls, and increased stomata appeared in plants grown in non-irrigated areas. Abzalov et al. (2016) reported the assimilation and efficiency of nitrogen fertilizers by *Cynara scolymus* L. under varying soil conditions. Their findings revealed that, regardless of phosphorus levels, the application of different nitrogen fertilizers-particularly ammonium sulfate and urea-significantly enhanced the intensity of protein nitrogen biosynthesis in plant tissues. The baskets of artichoke varieties are characterized by their large, multi-flowered, homogamous, and homochromic structure. They are spherical, featuring multiple rows of outer whorls. The lower portion is narrowed and nearly straight, with pinnate edges that taper to form a spine; in some cases, the thornless edges are rounded. The flowers are flat, slightly fleshy, and adorned with long hairs. The seeds are straight and five-lobed, divided into unequal parts that extend to about half the length of the thick tube. The artichoke varieties Imperial Star and Violetto are perennial herbs that reach heights of 0.5 to 2m. They feature a thick, erect stem that is hairy and gray or green, with a slightly ribbed surface. The leaves are large and covered with dense whitish hairs on the underside; those on the lower part of the stem are oblong or broadly lanceolate, doubly pinnately dissected, measuring up to 1 meter long and approximately 50cm wide. The leaves on the middle and upper portions of the stem are smaller and sessile, with the most acute leaves being elongated or oblong, measuring 5-6cm long, transitioning into florets. The baskets of the Imperial Star variety range from 30-38cm, and the Violetto variety measures 28-33cm. These baskets are positioned at the ends of branched stems and are ovoid or nearly spherical. The outer leaves are nearly hairless and smooth, with a relatively fleshy base; the tips of the outermost leaves are slightly bent back or turned, while the tips of the middle and innermost leaves are straight and overlap like tiles. The tips of the middle leaves are relatively narrow but lack thorns, whereas the innermost leaves feature short, blunt-pointed growths. The flowers are abundant, with a blue-black corolla, and bloom in May and June, producing seeds during this period. These varieties thrive in the ceruminous soils of southern regions. In our republic, several studies have been conducted to investigate the bioecological properties and chemical composition of artichokes under introduced conditions. Notably, (Bourgeois et al., 2023) examined the adaptation features of the anatomical structure of *Cynara scolymus* L. under both irrigated and non-irrigated conditions. García Gómez et al. (2024) explored the effect of inorganic and organic substances fertilizers on the absorption of microelements by prickly artichokes focused on the elemental composition and the quantity of biologically active substances in artichoke leaves. In reported results on the standardization of the preparation "Cinaron Bio," derived from the prickly artichoke (Zakharevich et al., 2015). Furthermore, Elena et al. (2019) researched the introduction of various artichoke varieties, while investigated artichoke cultivation, its nutritional properties, and the characteristics of different varieties and hybrids. The paper does not specifically address the adaptive anatomical characteristics of vegetative organs in *Cynara* L. varieties under different soil salinity conditions. It focuses on general mechanisms of salt tolerance in plants and the impact of soil salinity on growth (Hanin et al., 2016). The paper does not specifically address the adaptive anatomical characteristics of vegetative organs in *Cynara* L. varieties under different soil salinity conditions. It focuses on cardoon's response mechanisms to abiotic stresses and secondary metabolite production (Pappalardo et al., 2020). The paper does not specifically address the adaptive anatomical characteristics of vegetative organs in *Cynara* L. varieties under different soil salinity conditions. It focuses on general mechanisms of plant salt tolerance and breeding strategies for salt-tolerant crops (Zhou et al., 2024). The paper does not specifically address the adaptive anatomical characteristics of vegetative organs in *Cynara* L. varieties under different soil salinity conditions. It focuses on general plant responses to salinity stress and genetic engineering for salt tolerance (Muchate et al., 2016). *Cynara* species exhibit salt-secreting structures, such as salt bladders and glands, which help regulate salt accumulation in leaf tissues, enhancing salinity tolerance (Chen et al., 2023). Guard cells in these plants adjust their metabolism to maintain turgor pressure, which is essential for stomatal function under salinity stress (Franzisky et al., 2021). This study focuses on analyzing the anatomical structure of the vegetative organs (cotyledons, true leaves, and leaf sheaths) of artichokes grown under various saline soil conditions and extreme environmental stresses. Specifically, it aims to assess the anatomical features of the leaves and leaf sheaths in the artichoke varieties *Cynara scolymus*, Imperial, and Violettio, as well as their epiphytic characteristics and overall leaf architecture.

MATERIALS & METHODS

Description of the Study Areas

This study relies on data gathered by the authors from 2020 to 2023. The study area is located in the Gijdivan district of the Bukhara region (N 40°00'57.9", E 64°36'00.7"). Geographically, it falls within the Central Asian dry continental climate province of the Turan subtropical climate region and is characterized by a semi-desert environment. (Fig. 1). Soils. The Bukhara region is situated in a distinctive area characterized by a variety of soil types. It lies at an altitude of 200 to 800 meters above sea level, with approximately 90% of the region composed of dunes and furrowed sands, primarily from the Kyzylkum desert. The primary irrigated soils in the region are detailed below. In the Samarkand region, the most significant factors influencing the growth and development of *Cynara scolymus* are the mechanical and chemical composition of the soil. The soils in the experimental area are relatively low in humus and mobile nutrients. The fertility of these soils is illustrated in the following table:

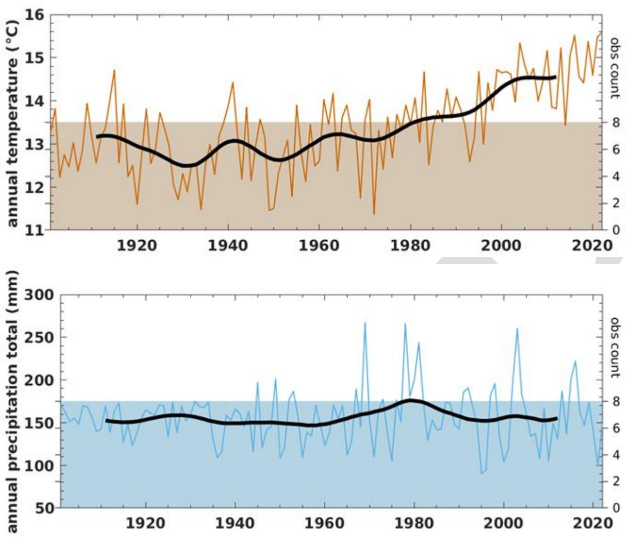


Fig. 1: The study area is integrated with the CRU TS3.10 research section of the climate dataset.

The upper soil layer (0-20cm) contains higher levels of humus and mobile nutrients, with a sharp decline in content observed in deeper layers. Specifically, the humus content in the 0-20cm layer is 0.79%, and mobile phosphorus is 9.1mg/kg of soil. In contrast, at a depth of 20-40cm, these values drop to 0.72% for humus and 6.5mg/kg for mobile phosphorus. Soils with such low levels of humus and nutrients are classified as low-yielding, a characteristic common to the grey soils of the Samarkand region. Meadow-barren soils are present in the upper parts of the Zarafshan and Bukhara deltas, forming among meadow soils in elevated areas with less drainage impact, typically at depths of 3-5m. Under abundant irrigation, runoff waters can temporarily rise to 1-2m. The meadow-barren soils of the Bukhara oasis have been subjected to long-term irrigation and comprise agro-irrigation layers that are 1-2m thick, predominantly medium and light loamy. These soils are less prone to runoff than meadow soils, exhibiting weak salinity and saline-washed characteristics. The salinity type is primarily sulfate, with occasional chloride-sulfate soils. The arable layer contains 0.5-1.1% humus and 0.04-0.12% nitrogen, with gypsum levels ranging from 0.08-0.42% SO_4. The carbonate content varies between 7.4 and 9.2% (Ortikov et al., 2020).

To investigate the anatomical structure of the artichoke varieties *Imperial Star*, and *Violetto*, vegetative organs were fixed in 70% ethyl alcohol. The epidermis of the leaves was examined through paradermal and transverse sections, while the leaf mesophyll, leaf sheath, stem, and roots were analyzed using transverse sections.

Anatomical preparations were made from the middle part of the leaf, leaf sheath, stem, and basal regions of the root to study the leaf mesophyll structure. The main tissues and cell structures were described following the methods of Esau (1969) and Kiseleva (1971) and the epidermis (Zakharevich, 1954). Preparations were stained with methylene blue and mounted in glycerin-gelatin. Photomicrographs were captured using a Canon A123 digital camera attached to a Motic B1-220A-3 microscope.

RESULTS & DISCUSSION

Drought is one of the foremost environmental factors limiting plant growth. Leaf thickness (LT) is an essential quantitative trait in plant physiology. The experiment was carried out in a controlled growth environment, dividing plants into well-watered and drought-stressed groups (Khan et al., 2023). Salt stress directly affects plant growth. The limitation of leaf expansion is among the earliest visible effects of salt stress (Yao et al., 2023). This is a significant challenge in agriculture and crop production, influencing global food security. Mitigation strategies through agronomic practices can help manage this issue (Mady et al., 2023).

The cotyledon leaves of *Cynara scolymus* are obovate, fleshy, and measure 4.5–5.0cm in length and 2.0–2.5cm in width. The epidermis consists of a single layer of large cells, with wavier abaxial cell walls compared to the adaxial epidermis. Cuticle thickness varies between 4.2±0.1µm (adaxial) and 6.8±0.1µm (abaxial). Stomatal density is higher in the abaxial epidermis (94.8±2.4 per mm^2) than in the adaxial epidermis (56.3±1.2), with stomata being flush with the epidermal surface. The stomatal types include anomocyte, anisocyte, and hemiparacytic (Fig. 2 d, e).

The mesophyll is dorsoventral in cross-section, featuring 4-5 rows of columnar palisade cells at the base of the adaxial epidermis, which are longer than wide. This is followed by cloud-like tissue with 9-10 rows of wide cell spaces. The dimensions of the columnar tissue are 92.4±2.8µm in height and 31.6±0.6µm in width, while the cloud-like tissue measures 70.8±0.9µm in height and 60.3±1.5µm in width. All mesophyll cells contain large chloroplasts. The main vein consists of a single collateral bundle surrounded by sclerenchyma tissue on both adaxial and abaxial sides (Fig. 2a). Plant leaves are highly sensitive to environmental factors, particularly during the early stages of ontogenesis when growth conditions significantly influence development. *Cynara scolymus* exhibits morphological and anatomical adaptations in its vegetative organs in response to water scarcity, displaying xeromorphic traits from the initial stages of cotyledon leaf development.

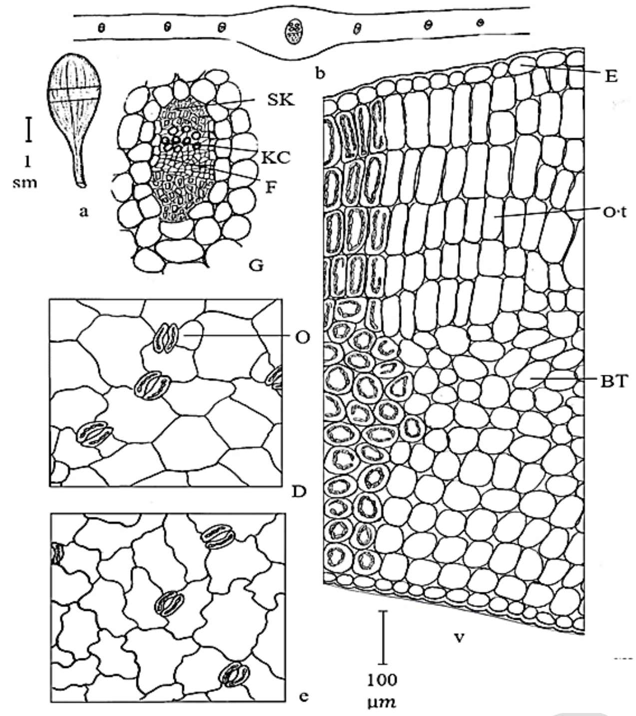


Fig. 2: Structure of the cotyledon leaf of *Cynara scolymus* L. in a low-salinity area. a) General view of the cotyledon leaf; b) part of a cross section; v) cross-section of the mesophyll part; g) appearance of the conducting tubule bundles in the main vessel; d) adaxial epidermis, e) abaxial epidermis. E– epidermis, UT– columnar tissue, BT– cloud-like tissue, SK– sclerenchyma, KS– xylem, F– phloem, O— stomata.

The leaves of *Cynara scolymus* are simple, broadly lanceolate, with serrated margins, measuring 50-55cm in length and 15-20cm in width. The main vein is prominent on the abaxial side. The epidermis consists of a single layer of thin-walled, multifaceted isodiametric cells, with adaxial cells averaging 25.8±0.5µm in size and abaxial cells averaging 23.8±0.3µm. Adaxial cell walls are linear, while abaxial walls are faintly wavy.

The stomatal apparatus is anomalous and hemiparasitic, with stomata mostly grouped in pairs or threes, totaling 50.6±2.4 in the adaxial and 36.9±1.7 in the abaxial epidermis. Some epidermal cells develop 1-3-celled simple hairs and glandular structures.

The mesophyll is dorsoventral, featuring 2-3 rows of columnar tissue on the adaxial side and 3-4 rows of cloud-like tissue with wide intercellular spaces on the abaxial side (Fig. 3, c). Columnar tissue measures 49.0±0.3µm in height and 18.7±0.5µm in width, while cloud-like tissue has a height of 16.7±0.3µm and a width of 25.7±0.4µm. The main veins consist of one median and 5-6 lateral collateral bundles, surrounded by sclerenchyma on both sides (Fig. 3 a-d).

The leaf blade is multi-ribbed, with a slightly concave adaxial side. The concave edge measures 0.2cm in width and 0.1cm in depth, with 8-10 ribs present. The thin epidermis consists of relatively large cells, under which lies a hypodermis followed by 3-4 rows of palisade parenchyma and on the lower side, 4-5 rows of cloud-like tissue with intercellular spaces. The leaf blade surface is covered with sparse single-celled hairs, and it contains a high number of conducting tubes (14-15), which may be solitary or grouped in clusters of 5-6 among parenchyma tissues.

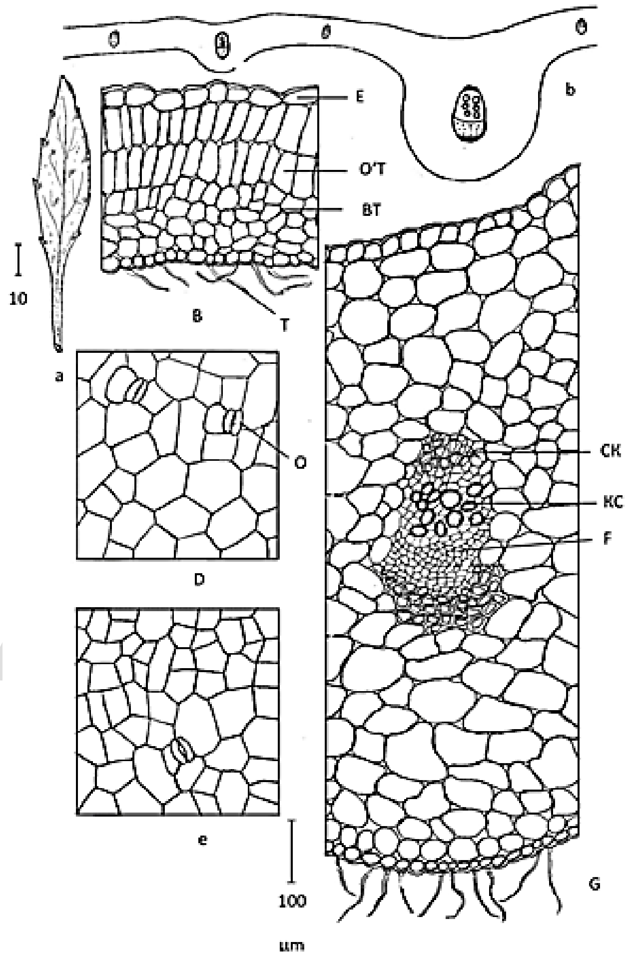


Fig. 3: Internal structure of a *Cynara scolymus* L. leaf blade in a low-salinity area. a) leaf appearance; b) vascular bundles in the main vein of a leaf; v) leaf mesophyll tissues; g) location of vascular bundles in a leaf; d) adaxial epidermis; ye) abaxial epidermis; E– epidermis, UT– columnar tissue, BT– cloud-like tissue, T– trichome, O– stomata., SK– sclerenchyma, KS– xylem, F– phloem.

In the paradermal section of the Imperial leaf, the adaxial epidermal cell walls are linear, while the abaxial cell walls are wavy with multifaceted projections. Adaxial epidermal cells measure 32.5±0.34µm, significantly larger than the smaller abaxial cells, which average 11.76±0.09µm. Both epidermal layers contain numerous unicellular and multicellular trichomes, including glandular types (Fig. 4).

The leaves of the *Imperial* variety exhibit an amphistomatic structure, with stomata present in both the adaxial and abaxial epidermis. Stomata are oval, measuring 32.14±0.35µm in length and 25.11±0.26µm in width on the adaxial side, and 18.42±0.21µm in length and 15.79±0.09µm in width on the abaxial side. The connecting cells of the stomata have similar lengths. Stomatal density is higher in the adaxial epidermis (334.83±3.47/mm^2) compared to the *Violettio* varieties, while the abaxial epidermis has a density of 669.64±7.51/mm^2.

Table 1: Quantitative indices of leaf anatomical characteristics of promising artichoke varieties (n=30)

Character indicators		Imperial	Violettio
Leaf: mesophyll thickness, µm		229.17±22.12	311.11±32.28
Epidermis: thickness of the outer wall cuticle (µm)	A	7.51±0.08	12.51±0.09
	B	2.91±0.02	3.13±0.04
Epidermal cell height (µm)	A	32.5±0.34	40.51±0.37
	B	11.76±0.09	16.63±0.21
Number of stomata/mm^2 of epidermis	A	334.83±3.47	210.84±2.11
	B	669.64±7.51	223.21±2.31
Leaf apical length (µm)	A	32.14±0.35	37.04±0.47
	B	18.42±0.21	34.62±0.41
Leaf margin width (µm)	A	25.11±0.26	29.63±0.33
	B	15.79±0.09	30.77±0.30
Depth of the stomata in the epidermal cell (µm)		10.12±0.09	–
Columnar cell (µm):			
Height		41.67±0.45	50.13±0.51
Width		10.41±0.08	13.8±0.15
Palisading Index		4	3.6
Number of Rows		3	3
Porous cell:			
Diameter (µm)		14.71±0.11	21.88±0.24
Number of Rows		4-5	4-5
The number of vascular bundles on the main vein of a leaf		8	8
Diameter of xylem in the vascular bundle (µm)		60.11±0.57	87.5±0.91
Parenchyma cell diameter (µm)		35.13±0.37	44.26±0.53
Number of collenchyma cell rows		5-6	2-3

A=Adaxial; B=Abaxial.

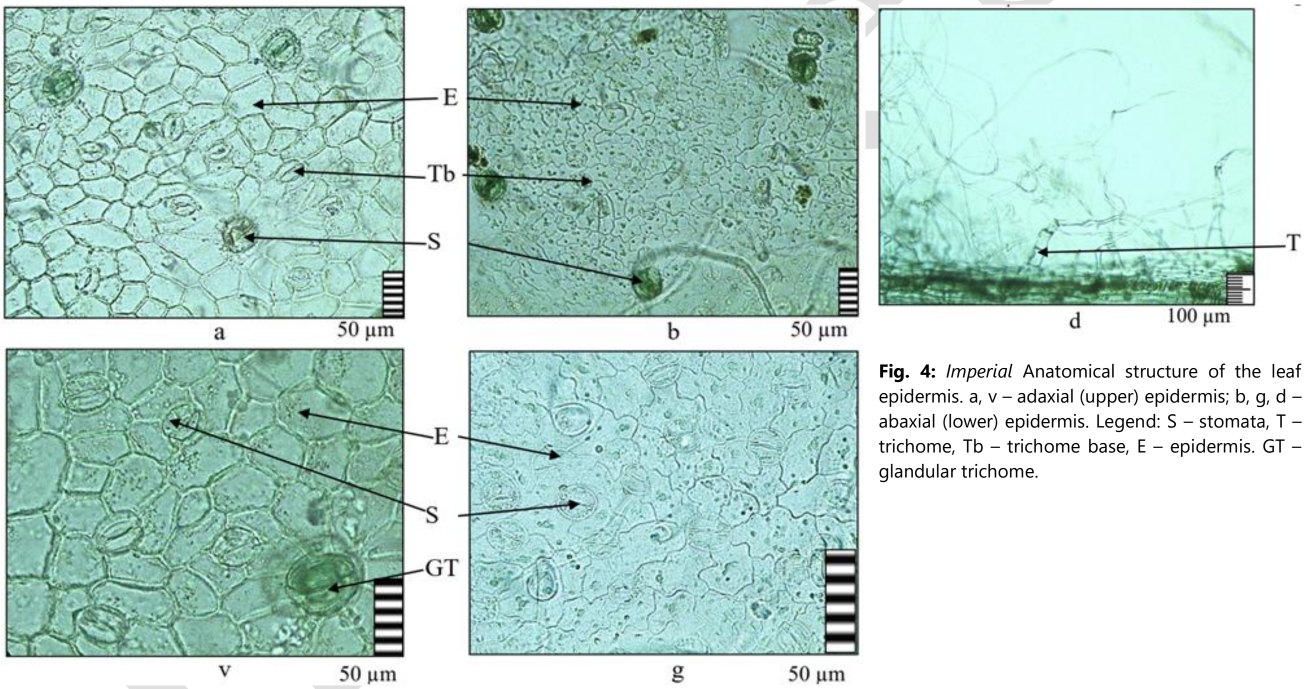


Fig. 4: *Imperial* Anatomical structure of the leaf epidermis. a, v – adaxial (upper) epidermis; b, g, d – abaxial (lower) epidermis. Legend: S – stomata, T – trichome, Tb – trichome base, E – epidermis. GT – glandular trichome.

The mesophyll of the *Imperial* variety is dorsiventral, with a thickness of 229.17±22.12µm, smaller than that of the *Violettio* varieties. Columnar cells are situated on the adaxial side, while spongy cells are on the abaxial side. Adaxial epidermal cells are larger than abaxial cells and feature numerous unicellular and multicellular trichomes, including glandular types (Fig. 4, Table 1). The assimilating tissue between the epidermal layers consists of closely spaced columnar and spongy parenchyma cells. The columnar parenchyma cells, containing chlorophyll grains, measure 41.67±0.45µm in height and 10.41±0.08µm in width, and are smaller than those in the *Violettio* varieties (Fig. 5, Table 1).

Porous parenchyma cells, which contain chlorophyll grains, consist of 4-5 rows with an average diameter of 14.71±0.11µm, located between the columnar and abaxial epidermal cells in the leaf mesophyll. Numerous laterals conducting ligaments are present between the columnar and porous cells (Fig. 5).

The main vein bulges towards the abaxial side and is centrally positioned within the mesophyll. The epidermis comprises thin-walled cells, with the abaxial epidermal cells containing various unicellular and multicellular trichomes, including glandular types. Beneath the abaxial epidermis are 5-6 rows of angular collenchyma. The central part of the main vein features 6 large and 2 small closed bicollateral vascular bundles composed of xylem and phloem. The diameter of the thin-walled, round-isodiametric parenchyma cells in the main vein measures 35.13±0.37µm, smaller than those in the *Violettio* varieties, with hydrocytic cells also present (Fig. 5, Table 1).

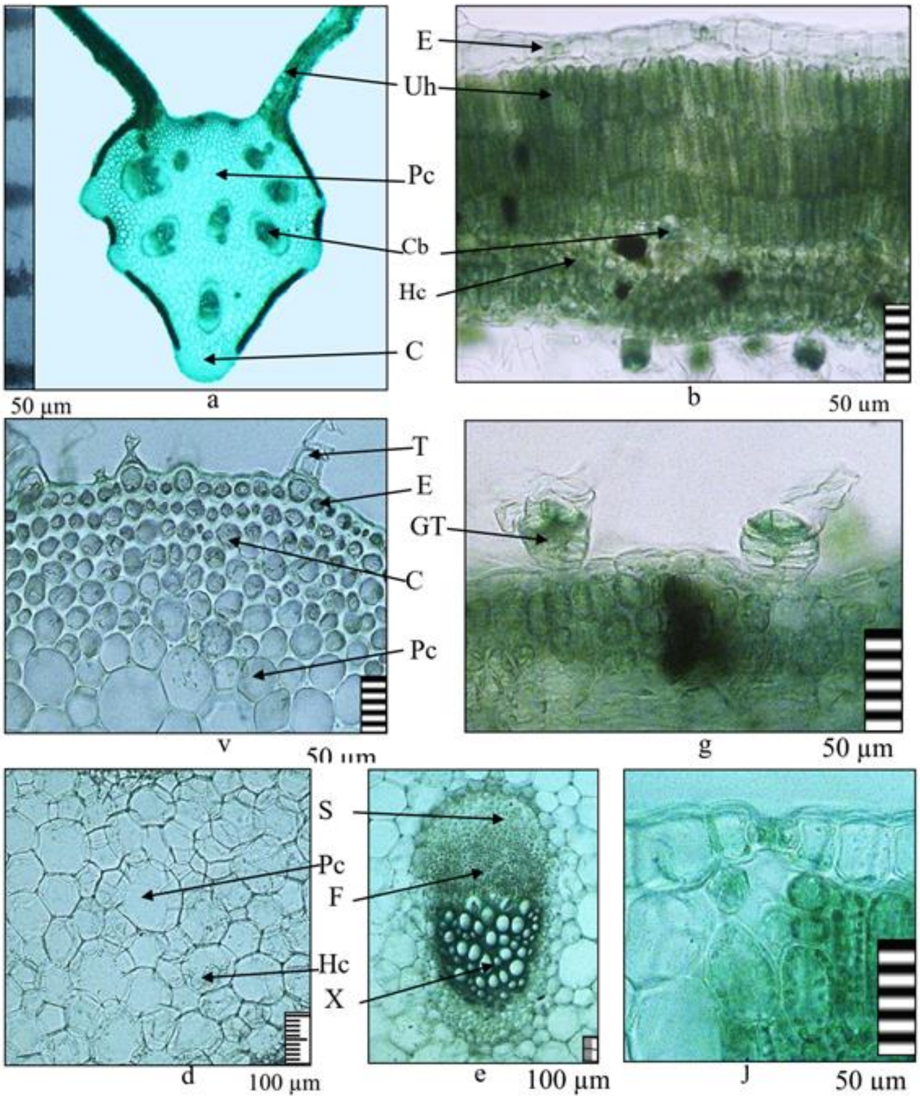


Fig. 5: Anatomical structure of *imperial* fresh leaf mesophyll. a - general view of leaf base vein; b – detailed leaf mesophyll; v – epidermis and collenchyma; g – epidermis and glandular trichome; d – parenchyma and hydrocytic cells; e - supporting link; j – epidermis and leaf mouth. Legend: GT – glandular trichome, Hc– hydrocytic cells, C – collenchyma, X – xylem, Pc – parenchyma cells, S– sclerenchyma, T – trichome, Cc– columnar cell, F– phloem, E – epidermis, Cb – conductive band, Pc– porous cell.

The transverse section of the leaf sheath of the Imperial variety displays a parenchyma-vascular structure, consisting of epidermis, collenchyma, parenchyma, and vascular bundles. The sheath bulges towards the abaxial side, with rib-like regions containing mechanical collenchyma tissue and vascular bundles. Epidermal cells have smaller diameters (5.56±0.05 – 22.22±0.18µm) and thinner walls compared to the Violettio varieties. Each rib-like protrusion contains more than 12-13 rows of angular collenchyma cells and one closed bicollateral vascular bundle beneath the epidermis (Fig. 5, Table 2).

The main portion of the leaf sheath consists of parenchyma cells with a diameter of 121.43±1.32µm, smaller than those in the Violettio varieties. These cells accumulate biologically active substances and contain hydrocytic cells. Between the parenchyma cells are 6 large and 10 small vascular bundles composed of phloem and xylem, with xylem cells in the large bundles averaging 44.45±0.52µm in diameter, smaller than in the Violettio varieties (Fig. 6, Table 2).

In the paradermal section of the *Violettio* leaf, the adaxial and abaxial epidermal cell walls are straight with multifaceted projections. Adaxial cells average 40.51±0.37µm in size, while abaxial cells are smaller at 16.63±0.21µm. Both cell types contain numerous unicellular and multicellular trichomes, including glandular spherical trichomes (Fig. 7, Table 1).

The leaves of the *Violettio* variety have an amphistomatic structure, with stomata present in both the adaxial and abaxial epidermis. Stomatal dimensions are larger than those in the *Imperial* varieties, measuring 37.04±0.47µm (adaxial) and 34.62±0.41µm (abaxial) in length, and 29.63±0.33µm (adaxial) and 30.77±0.30µm (abaxial) in width. The number of stomata is lower in the adaxial epidermis (210.84±2.11/mm²) compared to the *Imperial* varieties, while the abaxial epidermis has a higher density (223.21±2.31/mm²). The stomata are of anomocytic type and located relatively shallowly within the epidermal cells (Fig. 7-8, Table 2).

The leaf mesophyll of the *Violettio* variety has a dorsiventral structure, measuring 311.11±32.28µm in thickness, which is greater than that of the *Imperial* varieties. The epidermal cells are round oval with thicker walls, measuring 12.51±0.09µm in the adaxial epidermis and 3.13±0.04µm in the abaxial epidermis. Adaxial cells average 40.51±0.37µm, while abaxial cells are 16.63±0.21µm. Both layers contain numerous unicellular and multicellular trichomes, including glandular and spherical types (Fig. 7-8, Table 1).

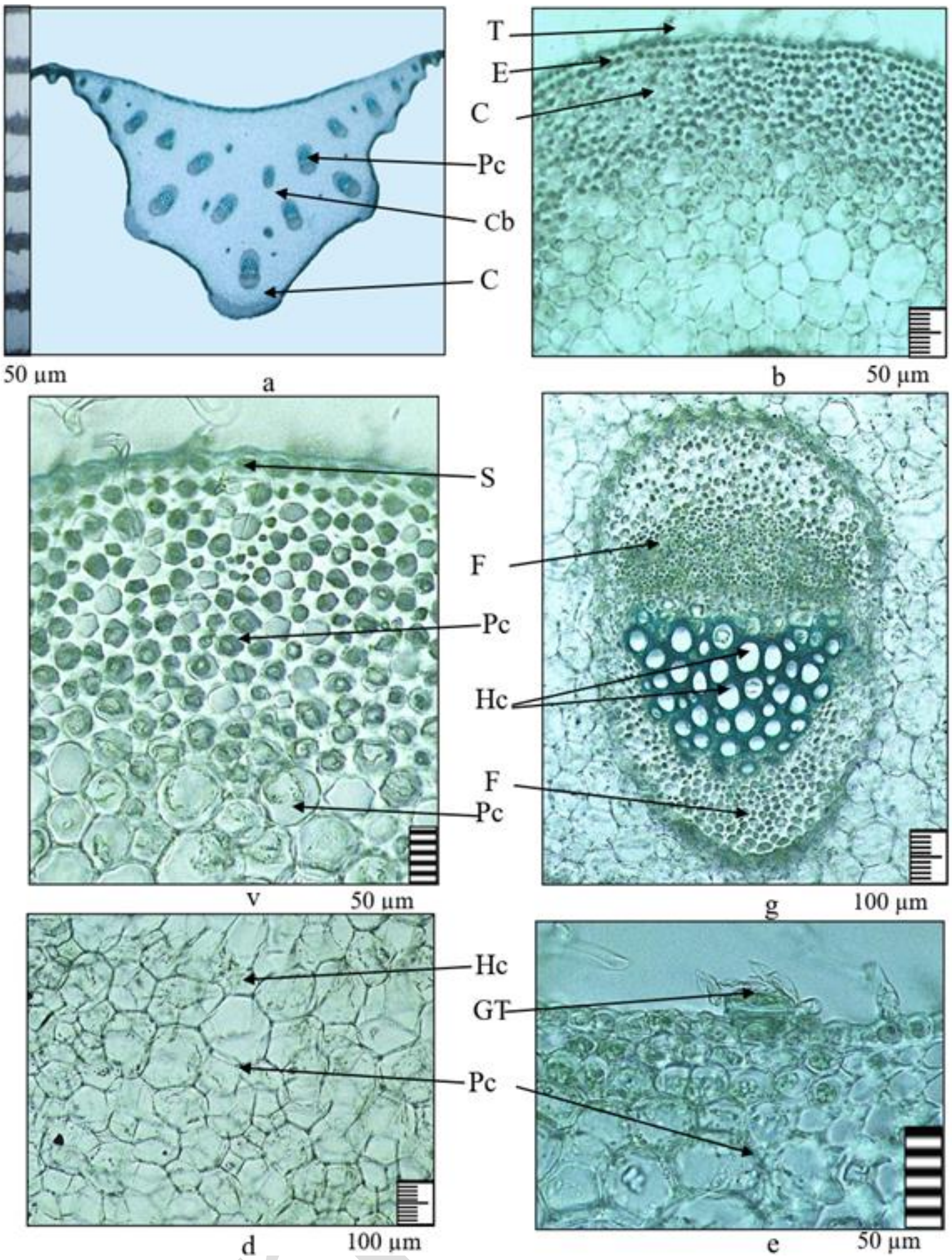
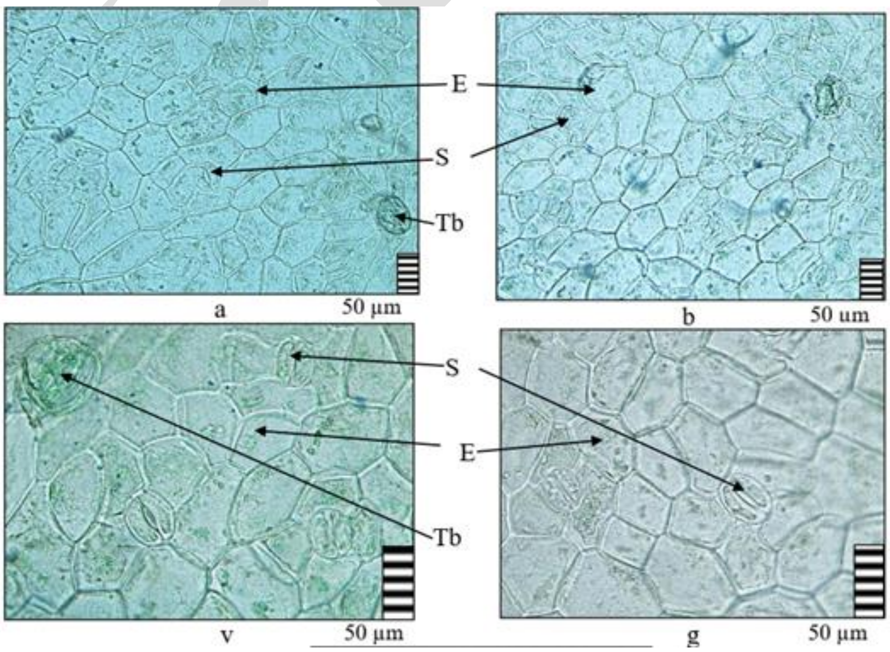


Fig. 6: Anatomical structure of the leaf band of the imperial variety. a – general view of a leaf band; b, v – epidermis and collenchyma; r – conductive link; d – parenchyma and hydrocytic cells, e – epidermis and glandular trichome. Legend: GT – glandular trichome, Hc– hydrocytic cells, C – collenchyma, Kc – X – xylem, Пх – Pc– parenchyma cells, T – trichome, F– phloem, E – epidermis, Cb – conductive band.



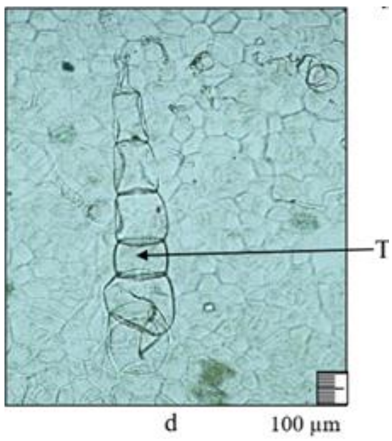


Fig. 7: Anatomical structure of the leaf epidermis of Violettio variety. a, v - adaxial (upper) epidermis; b, g, d - abaxial (lower) epidermis. Legend: S – stomata, T – trichome, Tb – trichome base, E – epidermis.

Table 2: Quantitative indicators of anatomical characteristics of the leaf blade of promising artichoke varieties (n=30)

Character indicators	*Imperial*	*Violettio*
Epidermis:		
Cuticle thickness (µm)	5.56±0.05	8.82±0.09
Cell height (µm)	22.22±0.18	20.59±0.24
Number of conducting ligaments in the leaf bundle	16	15
Diameter of xylem in the vascular bundle (µm)	44.45±0.52	83.33±0.92
Parenchyma cell diameter (µm)	121.43±1.32	230.23±2.35
Number of collenchyma cell rows	12-13	9-10

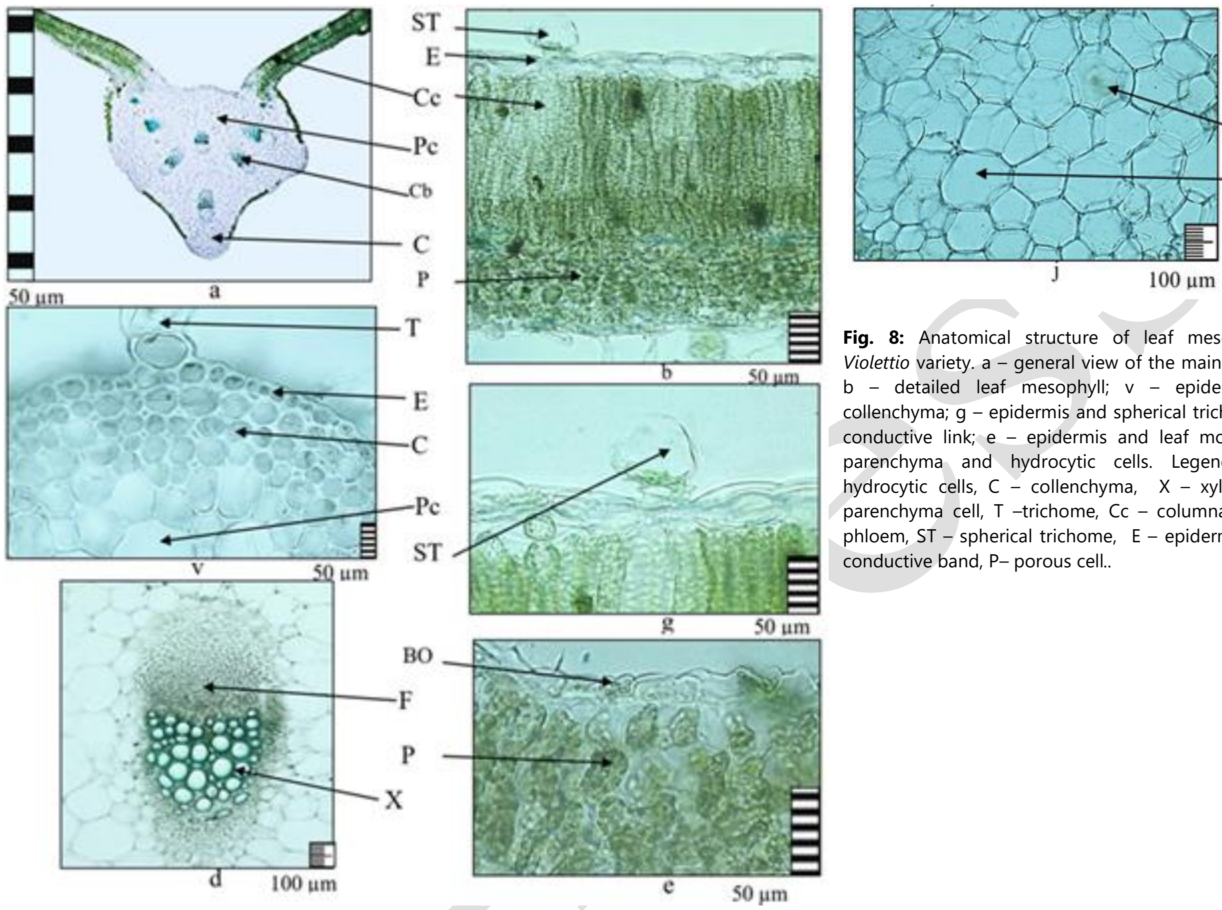


Fig. 8: Anatomical structure of leaf mesophyll of *Violettio* variety. a – general view of the main leaf vein; b – detailed leaf mesophyll; v – epidermis and collenchyma; g – epidermis and spherical trichome; d – conductive link; e – epidermis and leaf mouth; j – parenchyma and hydrocytic cells. Legend: Hc – hydrocytic cells, C – collenchyma, X – xylem, Pc – parenchyma cell, T –trichome, Cc – columnar cell, F– phloem, ST – spherical trichome, E – epidermis, Cb – conductive band, P– porous cell..

The assimilative tissue between the epidermal layers comprises columnar and spongy parenchyma cells. Columnar cells are densely arranged in three rows, measuring 50.13±0.51 µm in length and 13.8±0.15µm in width, longer than those in the Imperial variety. Spongy parenchyma cells, which contain chlorophyll grains, consist of 4-5 rows and have a diameter of 21.88±0.24µm, larger than those in the *Imperial* varieties, with substantial intercellular spaces. Numerous lateral conducting ligaments are present between the columnar and spongy cells. The main vein bulges towards the abaxial side and is centrally located within the mesophyll. The epidermal layer consists of thin-walled cells, with the abaxial epidermis containing various unicellular and multicellular trichomes, including glandular types (Fig. 8, Table 1).

Within the leaf's abaxial epidermis, two to three rows of angulatory chyma are seen. Comprising xylem and phloem, the central portion of the main vein has two small, closed bicyclic vesculature bundles and six large ones. The size of the xylem cells in the average bundles is 87.5±0.91µm, which is smaller than in the inferior varieties. In the main vein, the diameter of the thin-walled, round-isometric perirenchyma cells is 44.26±0.53µm, and hydrocytic cells are also visible. (Fig. 8, Table 1).

The leaf sheath of the *Violettio* variety exhibits a parenchymal-ligamentous structure in cross section, comprising epidermis, collenchyma, parenchyma, and vascular bundles. The sheath is convex towards the abaxial side, with rib-like regions containing mechanical tissue, including collenchyma and vascular bundles (Fig. 9, Table 2).

Epidermal cells are small and round-oval in shape, with thicker walls and a diameter ranging from 8.82±0.09 to 20.59±0.2µm, smaller than those in the *Imperial* varieties. Each rib-like bulge beneath the epidermis contains fewer rows of angular collenchyma cells (9-10) and one closed bicollateral conducting ligament compared to the *Imperial* variety. The main portion of the leaf sheath consists of parenchyma cells with a larger diameter of 230.23±2.35µm, which accumulate biologically active substances and contain hydrocytic cells. Between these parenchyma cells, there are 6 large and 9 small conducting ligaments. The xylem cells in the large vascular bundles measure 83.33±0.92µm in diameter, larger than those in the *Imperial* varieties (Fig. 9, Table 2). Based on the anatomical examination of the stem across various studied plant varieties, the stem is categorized into three primary regions - epidermis, primary bark parenchyma and central cylinders (Fig. 7-9, Table 2).

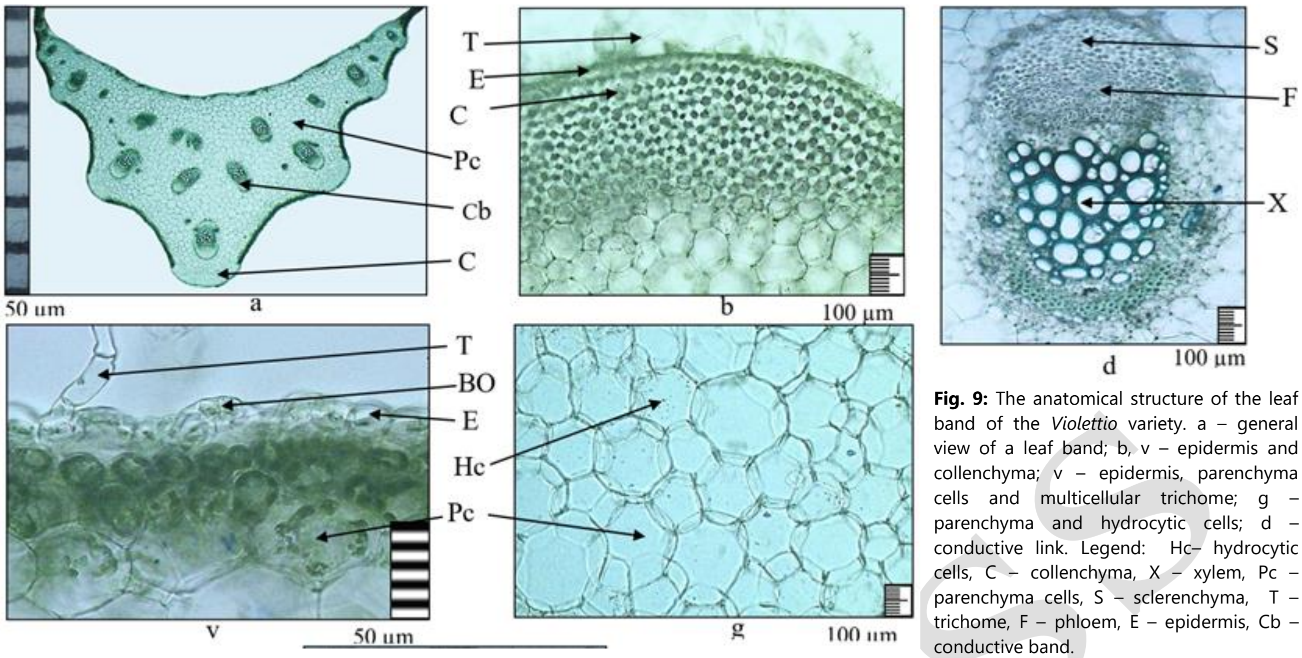


Fig. 9: The anatomical structure of the leaf band of the *Violettio* variety. a – general view of a leaf band; b, v – epidermis and collenchyma; v – epidermis, parenchyma cells and multicellular trichome; g – parenchyma and hydrocytic cells; d – conductive link. Legend: Hc– hydrocytic cells, C – collenchyma, X – xylem, Pc – parenchyma cells, S – sclerenchyma, T – trichome, F – phloem, E – epidermis, Cb – conductive band.

The article presents the results of an ecological and anatomical study of plants from coastal shallows of rivers and lakes in the Lower Amur region to identify their resistance and adaptability to the conditions of existence. Seven stenotopic species were studied (Tsyrenova, 2024a). This study the metamorphosed stems of both species share a similar structure, with assimilating tissue beneath the epidermis and colorless tissue in the central part. However, R. hypoglossum has fewer, larger cells in the central tissue, while R. aculeatus has more, but smaller, cells (Timuc and Gostin 2024). The results of the ecological and anatomical study of plants in the coastal shallows of rivers and lakes of the Lower Amur region are presented to identify their resistance and adaptability to the habitat conditions (Tsyrenova, 2024b). Plants growing in arid environments developed structural adaptations to reduce water loss and dissipate excessive light energy (Almabek et al., 2024). It was found that: C.rotundus has typical characteristics for adaption to an amphibious environment, including tissue air cavities and an apoplastic barrier in roots (Zheng et al., 2024). In taxonomic studies, structural characteristics of vegetative organs, in addition to floral traits, contribute significantly to species identification and classification. To provide insights into these characteristics within the genus (Brechú-Franco et al., 2024), our findings revealed that *P. sinensis* leaves from forests experiencing mild to moderate rocky desertification exhibited higher specific leaf area (SLA) and magnesium concentrations. In contrast, these leaves had lower leaf dry matter content (LDMC), as well as reduced abaxial and adaxial epidermis thickness, compared to those from forests with severe to extremely severe desertification (Li et al., 2025). Dioecious tree species may be more vulnerable to climate warming if sex-related sensitivity to drought occurs since lower performance of one sex may drive differential stress tolerance and sex-related mortality rates (Rodríguez-Ramírez et al., 2025). Plants deploy different strategies to optimize the N uptake by roots, based on a complicated regulatory network that controls root phenotype and physiology (Rouina et al., 2025). The diaspores of Asteraceae have three structures that can contain sticky substances: exocarp epidermal cells, exocarp trichomes, and viscid pappus. The South American species Adenostemma brasilianum (Asteraceae) has all three features (Dosil Hiriart et al., 2024). This study provides new insight into the plastid genome evolution and phylogenetic relationships. Moreover, it would be fundamental to formulate potential conservation and management strategies for the enigmatic species in the Himalaya (Yu et al., 2022). A set of the anatomical and carpological characters indicates a possible relationship of *Gymnarrhena* with the basal subtribes Cardopatiinae and Carlininae of the tribe Cardueae. The morphophysiological adaptation of *G. micrantha* and *Cousiniopsis atractyloides* cypselae to dissemination in desert conditions, similar in structural details, apparently suggests a close relationship between the subfamilies Gymnarrhenoideae and Carduoideae (Kravtsova, 2024). In terms of the structure of the leaf sheath of *Cynara scolymus*, the *Imperial* and *Violettio* varieties differ from the leaf sheath, the size of the epidermal cells is relatively small, the wall is thickened, under it there is a row of hypodermis, then 2-3 rows of oval multi-faceted smaller palisade parenchyma cells. The parenchyma cells of the *Imperial* and *Violettio* varieties are composed of 10-13 layers of cells, slightly elongated in length and much smaller in width than those of the *Cynara scolymus* leaf sheath. The conducting tubes are arranged in groups. The walls of the parenchyma tissue located in the center are thickened. The parenchyma cells in the center of the *Imperial* and *Violettio* varieties are oval in shape, most of them elongated in length, unlike those of *Cynara scolymus*.

Therefore, the anatomical structure of the leaf sheath of the *Imperial* and *Violettio* varieties of *Cynara scolymus* differs slightly from that of the *Imperial* and *Violettio* varieties. The outer side of the leaf blade has more ribs, 10-12, but the interribbed spaces are concave, 0.1-0.2cm wide and up to 0.1 cm deep, covered with short unicellular hairs. The vascular tubes are joined together in radial rows of 9-12. Between them is a single- or two- or three-celled mechanical tissue. Anatomical structure of leaves and leaf sheaths in the promising artichoke varieties *Imperial*, and *Violettio* identified several key anatomical features. All varieties exhibited large, rectilinear polygonal adaxial epidermal cells and relatively small, wavy polygonal abaxial epidermal cells. The leaves have an amphistomatic structure, with stomata present on both surfaces. Anomocytic stomata were observed in the *Violettio* varieties, while both anomocytic and paracytic stomata were found in the *Imperial* variety, located deeper within the epidermis. The *Imperial* variety exhibited a higher stomatal density compared to the *Violettio* variety. The mesophyll of all varieties was identified as dorsiventral. Both epidermal layers contained numerous unicellular and multicellular simple trichomes, along with multicellular glandular and spherical trichomes. Under the abaxial epidermis of the main vein, multi-rowed collenchyma cells were observed, with the *Imperial* varieties having more rows (5-6) compared to the *Violettio* variety (2-3).

The leaf sheath exhibited a parenchymal-ligamentous structure, with the largest diameter of parenchyma cells found in the *Violettio* variety (230.23±2.35 µm), followed by the *Imperial* varieties (121.43±1.32 µm). Conducting bundles in the assimilating organs were of the closed bicollateral type, with the largest xylem tubes in the *Violettio* (83.33±0.92 µm) varieties, and the smallest in the *Imperial* variety (44.45±0.52 µm) (Fig. 2-9, Table 1).

Conclusion

This study successfully identified diagnostic anatomical traits in the assimilating organs of the promising artichoke varieties *Cynara scolymus*, Imperial, and Violettio under introduced conditions. Compared to *Cynara scolymus*, the Imperial and Violettio varieties exhibited pronounced xeromorphic adaptations, including a reduction in leaf epidermal cell size, an increased number of stomata, thickening of the stem bark parenchyma, an increase in both the diameter and number of conducting tubes, and enhanced lignification. It was also determined that the localization of biologically active substances is due to the absence of internal separating tissue in the leaves, leaf sheaths and stems, but rather the release of biologically active substances due to the presence of unicellular and multicellular simple trichomes, glandular trichomes with a round head and essential oil trichomes. Also, based on a comparative analysis of anatomical characters in vegetative organs, structural and adaptive characters specific to the conditions of introduction of Imperial and *Violettio* varieties were identified compared to *Cynara scolymus*. It was found that the *Violettio* variety has a predominance of meso-xeromorphic characters in assimilating and shooting organs, while the *Imperial* variety has a predominance of xeromorphic characters, indicating good adaptation to arid conditions.

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