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Comparative analysis of anatomical structures and diagnostic markers in the stem, root, and rhizome of *Valeriana officinalis* L. from Uzbekistan

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Abstract

The anatomical structures of the stem, root, and rhizome of *Valeriana officinalis* L. have not been extensively studied within the context of Uzbekistan, as evidenced by a review of existing literature. Investigating these anatomical features is crucial for enhancing the quality of medicinal raw materials and for a comprehensive understanding of the plant's morphology and anatomy, which can facilitate its broader application in medicine. In Uzbekistan, the anatomical characteristics of these organs remain inadequately documented, indicating a gap in current botanical research. New findings on the anatomical structure of the stem, root, and rhizome will enable more precise identification and analysis of *V. officinalis* raw materials. Furthermore, such research will illuminate the biological processes within the plant, contributing to a deeper understanding of its medicinal properties. This article presents detailed information regarding the anatomical makeup of these plant parts, including the arrangement of organelles and the presence of biologically active substances in their cells. The significance of these substances in both traditional and modern medicinal practices is emphasized. Notably, the study reveals that the stem of *V. officinalis* contains essential oils and calcium oxalate crystals, which may have implications for its therapeutic applications and efficacy. These findings pave the way for further research into the plant's potential benefits in pharmacology and holistic medicine.

1. Introduction

Today, a substantial proportion of medicinal products used in both traditional and modern medicine are derived from medicinal plants, and the demand for these plants continues to grow each year. Consequently, there is a significant emphasis on cultivating and processing these plants, establishing cultivated plantations, and utilizing medicinal plants extensively for disease prevention and treatment. One of the most widely used medicinal plants in medicine and the pharmaceutical industry is *Valeriana officinalis* L., commonly known as “dorivorvaleriana”. This perennial herb belongs to the family Valerianaceae and is distributed across the mountainous regions of North and South America, Europe, and Asia (Atlas of Medicinal Plants of the USSR, 1962; Bach *et al.,* 2014). The plant naturally occurs throughout all regions of the Commonwealth of Independent States (CIS). *V. officinalis* is considered one of the most popular medicinal plants, having been cultivated since ancient times and demonstrating its value as a beneficial crop. The underground parts of the plant are widely utilized, particularly for chronic ailments. Medicinal preparations derived from this plant are recognized as alternative and complementary treatment options for insomnia, a fact reflected in numerous ethnobotanical studies (Baranova, 1981; Barton *et al.,* 2011). *V. officinalis* is highly regarded among medicinal plants for its calming effects on anxiety. It is also employed to prevent nervous tension, treat insomnia, and address various conditions such as cardiac neuroses, vascular spasms, hypertension, migraines, hysteria, and gastrointestinal spasms, as well as kidney and liver diseases. Additionally, it is specifically used to alleviate cerebral congestion, particularly in menopausal women (Barykina*et al.,* 2004; Bernáth, 1997) (Figure 1).

Figure 1: Overall appearance of the *V. officinalis*.

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V. officinalis is renowned for its diverse medicinal applications, particularly in managing mental health conditions. Beyond its traditional use as a sedative, research has explored its potential to enhance cognitive function and improve overall mental clarity. Compounds found in valerian may exert neuroprotective effects, helping to mitigate cognitive decline associated with stress and anxiety (Müller *et al.,* 2019). This is especially relevant in contemporary contexts, where mental health issues are increasingly prevalent, underscoring valerian's role as a natural ally in promoting cognitive wellness. Moreover, *V. officinalis* has shown promise in alleviating physical ailments linked to stress. Its antispasmodic properties can relieve muscle tension and spasms, making it beneficial for conditions such as fibromyalgia and tension headaches (Sarris *et al.,* 2013). By promoting relaxation and alleviating physical discomfort, valerian may effectively manage stress-related disorders, offering a holistic approach to treatment. Additionally, the plant's anti-inflammatory properties have generated interest in its potential applications for inflammatory conditions; further expanding its therapeutic profile (López*et al.,* 2018). In addition to its medicinal uses, *V. officinalis* is cultivated for ornamental purposes, thriving in moist meadows. The plant features stems adorned with umbrella-shaped clusters of flowers, which are pleasantly fragrant and bloom in shades of white, pale pink and light purple during June.

The experiments were conducted at the Scientific Research Institute of Forestry, "Darkhon" Scientific Experimental Farm in the Tashkent region. The study aimed to investigate various aspects of *V. officinalis* including its distribution, medicinal properties, economic significance, introduction, growth and development, bioecology, morphology, and anatomy under the diverse soil and climate conditions of Uzbekistan. Additionally, the research focused on the cultivation technology of this important medicinal plant (Figure 2).

A key objective of this study was to examine the anatomical structure and diagnostic traits of the stem, root, and rhizome of *V. officinalis* in Uzbekistan. This examination aimed to identify the adaptation characteristics of the introduced plant, as well as the anatomical features and diagnostic traits that are specific to the species.

Figure 2: *V. officinalis* cultivated in the experimental field.

2. Materials and Methods

The stem, root, and rhizome of the medicinal plant *V. officinalis* were preserved in 70% ethanol during the flowering phase of its generative period. Transverse sections of these plant organs were prepared using the hand-cutting method. The sections were stained with safranin and mounted in glycerin-gelatin (Bressler *et al.,* 2017). The primary tissues and cells of the plant organs were described based on the methodologies of Esau (1969) and Kiseleva (1971). The epidermal characteristics were assessed according to Zakharevich (1954), while the types of stomata were classified following Baranova (1981). Microphotographs were captured using a Canon A123 digital camera in conjunction with a Motic B1-220A-3 microscope.

3. Results

The transverse sections of the stem, root, and rhizome of *V. officinalis* display a distinct star-shaped morphology, which is a key identifying feature of the plant. This characteristic star shape is complemented by a vibrant dark pink coloration, which enhances the visibility of the anatomical structures within these plant organs(Figure 3).

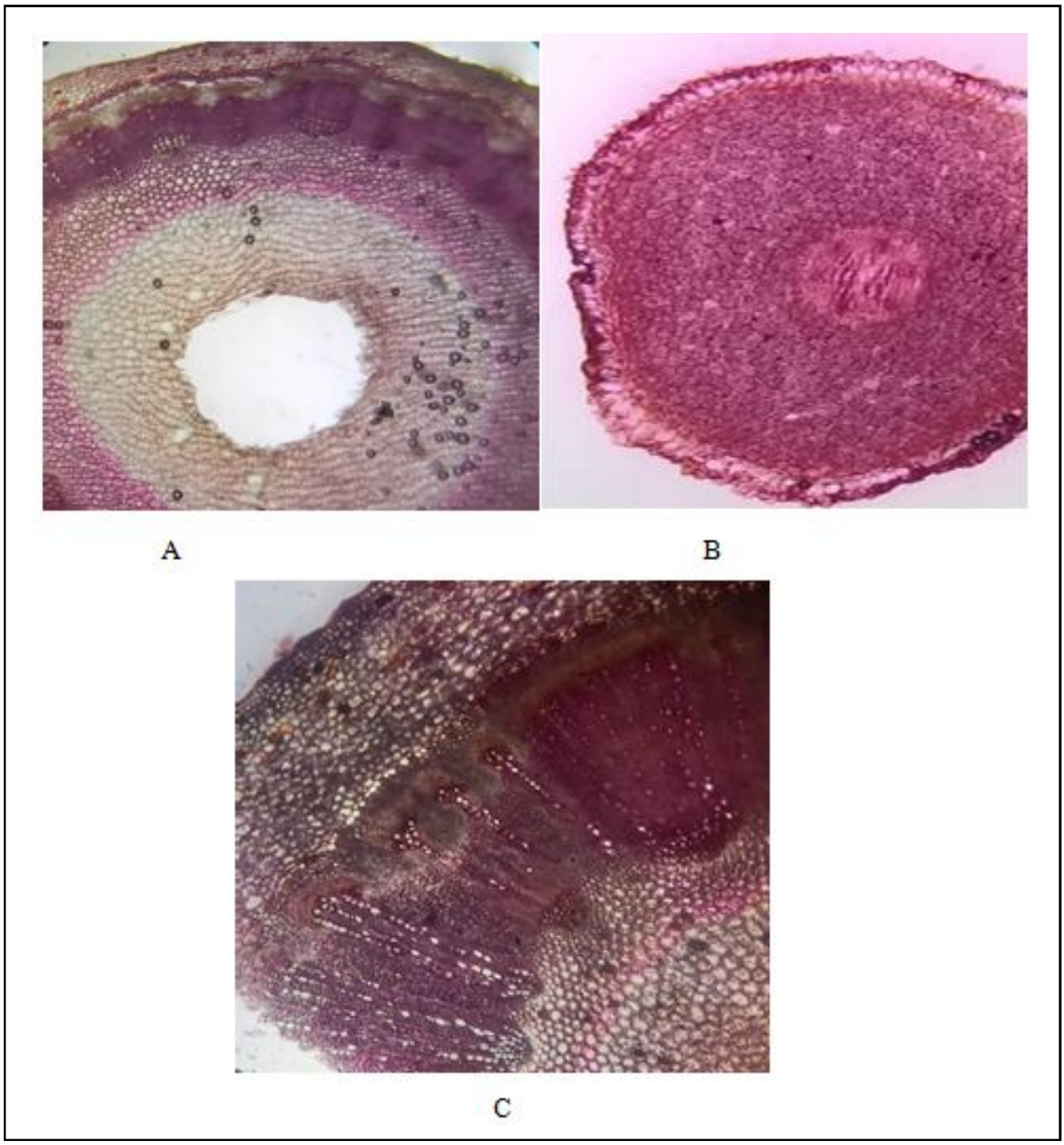

Figure 3: Overall appearance of the *V. officinalis*. (A) Stem, (B) Root and (C) Rhizome.

The transverse section of the stem of *V. officinalis* exhibits a round shape and a pink coloration. Anatomical studies revealed that the stem is covered externally by a single layer of uniseriate epidermis, which serves a protective function and is further coated with a thick cuticle. Beneath the epidermis, multiple layers of parenchyma cells are present (Figure 4).

The width of the epidermal cells is 15 µm, and their length is 10 µm (Table 1). The thickness of the outer wall of the epidermis measures 2.0 µm. The endodermis has a length of 12.2 µm and a width of 6.2 µm. The parenchyma cells have a length of 0.2 µm and a width of 0.1 µm. Mechanical tissues, such as collenchyma and sclerenchyma, provide structural support to the stem, with a 2-3 layered brownish collenchyma located beneath the epidermis. The chlorenchymal parenchyma cells, which contain intercellular spaces, are situated after the collenchyma. Cambial cells allow for clear visibility of the collateral vascular bundles. These vascular bundles are surrounded

by well-developed parenchymal (endodermal) cells that contain starch. The endodermis consists of a layer of cells with thicker walls, positioned between the epidermis and the central cylinder.The central cylinder (stele) comprises the pericycle, vascular tissues, and cambium. The pericycle consists of a single layer of cells encircling the vascular bundles. The vascular tissues consist of a phloem and xylem, with the phloem transporting organic substances and xylem transporting water and minerals. The cambium layer, located between the phloem and xylem, contributes to stem growth. A large cavity is observed at the center of the cross-section (Figure 3A). The parenchymal tissues in the stem serve storage or protective functions, containing essential oils and calcium oxalate crystals. These anatomical features highlight the medicinal properties of the plant and its adaptation to various growing conditions.

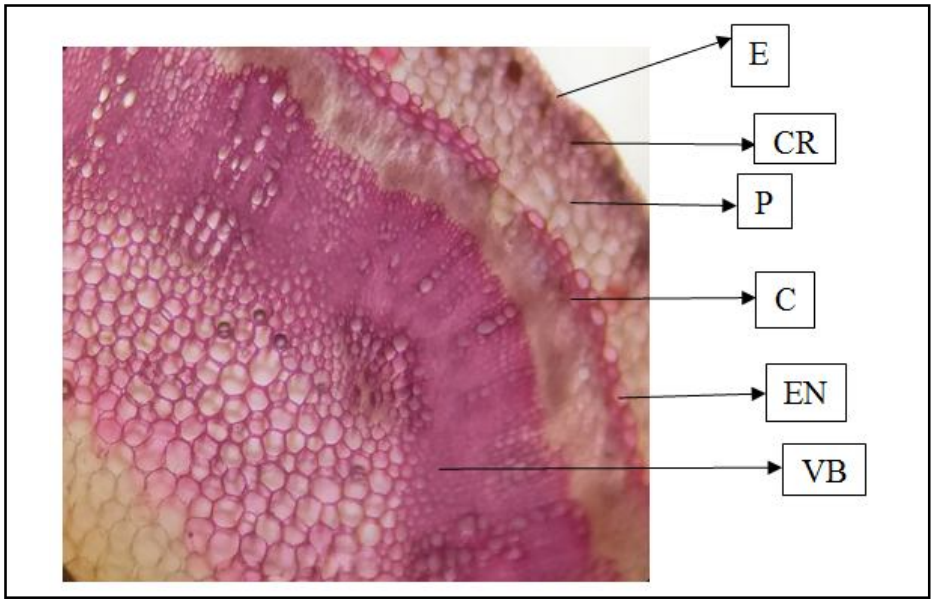

Figure 4: Transverse section of the stem of the *V. officinalis.*
E-Epidermis, CR-Crystal, C-Collenchyma, P-Parenchyma, EN-Endodermis, VB-Vascular bundles.

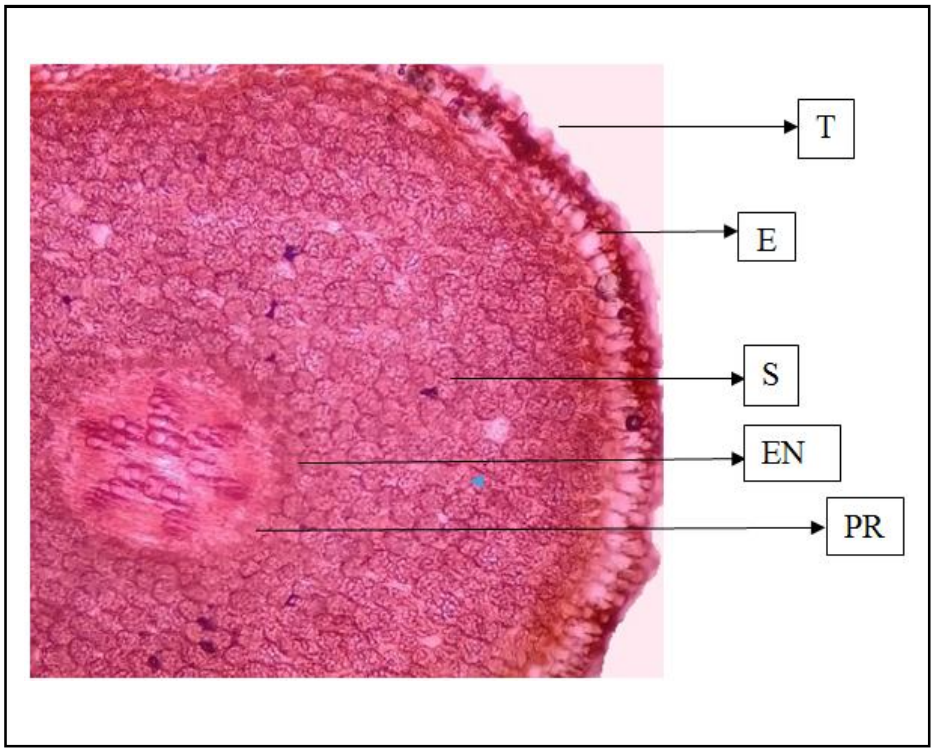

Figure 5: Cross-section of the root of the medicinal plant *V. officinalis.*
T-Trichomes, E-Epidermis, S-Starch, EN-Endodermis, PR-Pericycle.

The study of the anatomical characteristics of the stem of *V.officinalis* identified the following diagnostic features: the single-layer epidermal cells are tightly interconnected and covered with a thick cuticle that protects against water evaporation; the bark comprises several layers of parenchymal and collenchyma cells that enhance stem strength; the endodermis has thickened cell walls; the vascular bundles consist of phloem tubes, with xylem arranged in a ring shape and surrounded by parenchymal cells, indicating the presence of cambium; the pith parenchyma is well-developed, composed of large parenchymal cells; and the hollow or perforated central part of the stem is a characteristic feature. Additionally, secretion channels located in the bark and central cylinder of the stem, essential oil secretory structures, and the yellowish or green color of the stem when cut transversely were also observed. These features are utilized for microscopic diagnostics to confirm that the sample belongs to the *Valeriana* species. The cross-section of the root of *V.officinalis* is round or oval in shape (Figure 3B). The root is covered by a single-layered and densely hairy epiblema (rhizodermis), which functions to protect and absorb water and minerals. The width of the epidermal cells is 11 µm, and their length is 12 µm (Table). The thickness of the outer wall of the epidermis is 2.0 µm. The endodermis has a length of 12.6 µm and a width of 8.2 µm, while the parenchyma measures 0.1 µm in length and 0.2 µm in width. Beneath the epidermis lies the bark, which consists of several layers of parenchymal cells. The bark functions to store nutrients and facilitate the transfer of water from the rhizodermis to the central cylinder.The endodermis represents the inner layer of the bark, with cells that often exhibit thickened walls (Figure 5).

The pericycle is situated beneath the endodermis and consists of one or more layers of cells that can contribute to the formation of lateral roots. The xylem is centrally located within the root, forming radial strands. Xylem vessels are large with thick walls, facilitating the transport of water and minerals, while the phloem is responsible for the transportation of organic substances. The cambium, located between the xylem and phloem, plays a crucial role in the growth of the root.The diagnostic characteristics of the root of *V. officinalis* include the presence of an epiblema covered with root trichomes, a well-developed cortex featuring a distinct endodermis, and the presence of starch grains within the parenchymal cells. Additionally, the typical radial arrangement of xylem and phloem is noted, along with the cambium, which contributes to root thickening and the development of secondary tissues. Essential oils are also present in the parenchymal cells.The rhizome of *V. officinalis* exhibits a complex anatomical structure characteristic of perennial plants. Its outer layer consists of thick-walled epidermal cells (Figure 6).

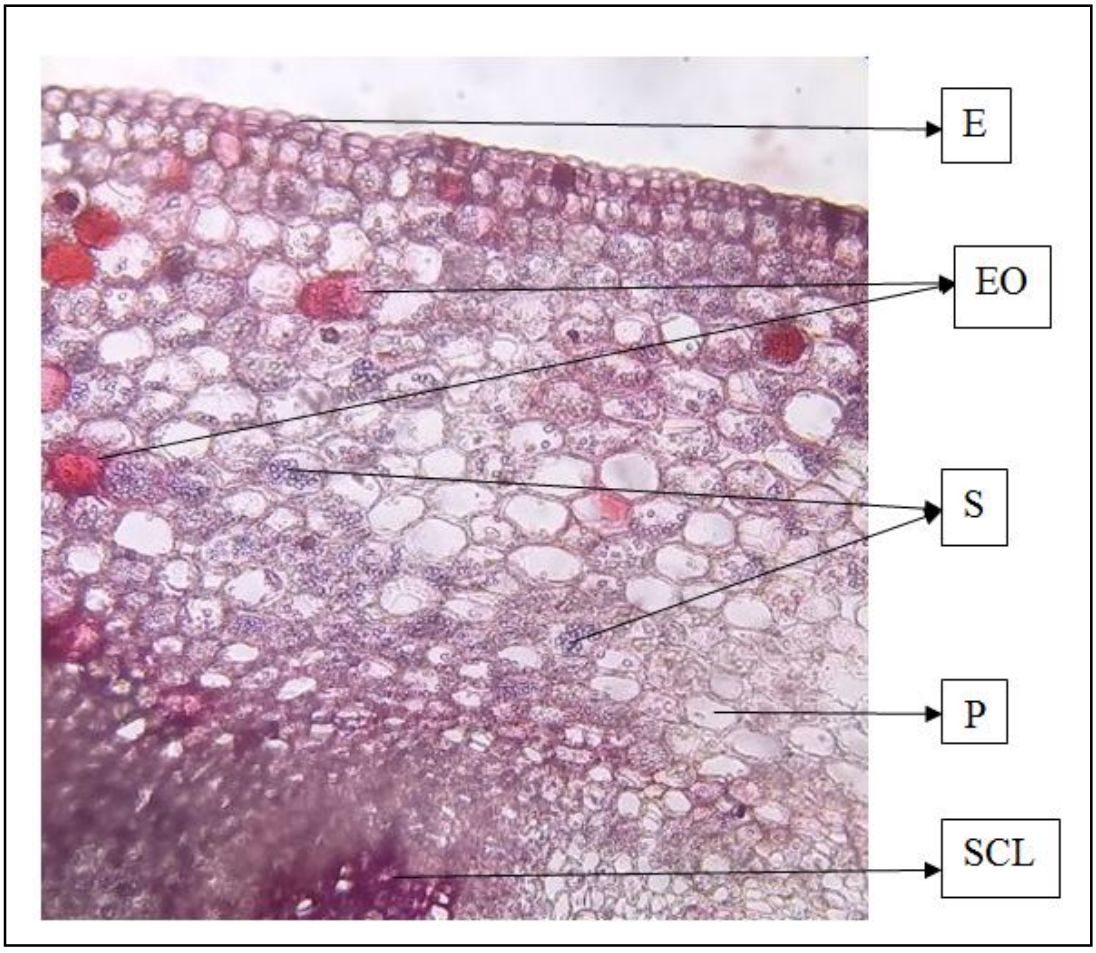

Figure 6: Cross-section of the rhizome of the *V. officinalis*.
E-Epidermis, EO-Essential oil, S-Starch, P-Parenchyma, SCL-Sclerenchyma.

The anatomical structure of the root of *V. officinalis* has been extensively studied through various botanical and pharmacological research efforts. Given its medicinal and pharmacological applications, the organs of this plant have garnered considerable interest within society.The measurements of the anatomical features of the root include an epidermal cell width of 13 µm and a length of 17 µm. The thickness of the outer wall of the epidermis measures 2.5 µm. The endodermis has a length of 14.3 µm and a width of 7.8 µm, while the parenchyma cells exhibit a length of 0.3 µm and a width of 0.2 µm (Table 1).

Table 1:Anatomical characteristics of the stem, root, and rhizome of the medicinal plant *V. officinalis*

S.No.	Parameters	Indicators of the stem, µm	Indicators of the root, µm	Indicators of the rhizome, µm
1	Epidermis length	10,2 ± 0,3	11,3 ± 0,3	13,3 ± 0,3
2	Epidermis width	15,6 ± 0,2	12,7 ± 0,2	17,7 ± 0,2
3	Thickness of the outer wall of the epidermis	2,0 ± 0,1	2,3 ± 0,1	2,5 ± 0,1
4	Length of the endodermis	12,2 ± 0,4	12,6 ± 0,4	14,3 ± 0,4
5	Width of the endodermis	6,2 ± 0,2	8,2 ± 0,2	7,8 ± 0,3
6	Length of the parenchyma	0,2 ± 0,1	0,1 ± 0,1	0,3 ± 0,1
7	Width of the parenchyma	0,1 ± 0,1	0,2 ± 0,1	0,2 ± 0,1

The epidermis of the rhizome serves a protective role by shielding it from injury and preventing moisture loss. The bark is composed of multiple layers of parenchymal cells, which store starch, inulin, and other nutrients, fulfilling a storage function. Beneath the bark lies the endodermis, an inner layer consisting of thick-walled cells that encircle the central cylinder of the rhizome. The endodermis acts as a barrier, regulating the transport of substances between the bark and the central cylinder. The pericycle, located beneath the endodermis, is a layer of cells involved in the formation of lateral roots and the synthesis of secondary metabolites. The vascular bundles consist of xylem and phloem. Within the central cylinder, the xylem (wood) and phloem are responsible for transporting water, minerals, and organic compounds. The rhizome also contains essential oils and other biologically active compounds stored in specialized secretory cells or intercellular spaces. These components are crucial for the rhizome's ability to store nutrients, facilitate vegetative reproduction, and resist unfavorable environmental conditions. The diagnostic features of the rhizome of *V. officinalis* enable the identification of raw materials, differentiation from other plants, and quality control. The primary diagnostic characteristics include:

- The rhizome is cylindrical, tuberous, dark brown, short, and grows horizontally.
- It contains intercellular spaces filled with secretory cells and essential oils.
- The bark features sclerenchyma fibers that provide mechanical strength.
- The xylem vessels exhibit large, clearly visible openings.
- The rhizome has a distinctive, strong odor that intensifies when rubbed, accompanied by a bitter taste.
- When iodine solution is applied to the rhizome, the starch grains turn a deep blue color, confirming the presence of starch.

The valerian rhizome is widely used in both folk and official medicine due to its pharmacological activity, making it a subject of intensive study in scientific and medical fields. Research has identified several key aspects regarding its composition:

- **Essential oils** (0.5-2.0%): The main components include borneol, valerenic acid, isovalerenic acid, and their derivatives, which exhibit calming and antispasmodic effects.
- **Valepotriates**: Compounds such as valtrate, isovaltrate, and acetovaltrate, known for their antispasmodic properties.
- **Alkaloids**: This category includes compounds like actinidine and valerianine.
- **Flavonoids**: These compounds possess antioxidant properties and contribute to the strengthening of blood vessels.

The valerian rhizome is renowned for its calming properties, commonly used to treat neurological disorders such as insomnia, anxiety, and stress. Its mechanisms of action involve modulating GABA (gamma-aminobutyric acid) receptors, which influence the central nervous system and lead to a tranquilizing effect.

4. Discussion

In the 19th and 20th centuries, extensive research was conducted on the anatomy of the valerian rhizome, documenting the primary tissues and structures of the stem, including the epidermis, cortex, central cylinder, vascular tissues, and their characteristics (B¹czek*et al.,* 2022; Davydov, 2023; Jerome *et al.,* 2011). Detailed studies focused on structural features such as the arrangement and composition of tissues within the vascular bundles (xylem and phloem), as well as the presence of cambium, which is crucial for the secondary growth of the stem. Contemporary microscopy methods have enabled comprehensive analyses of the cellular structure of the valerian rhizome, focusing on aspects such as cell morphology, the properties of the cuticle, xylem, and phloem, along with the identification and localization of secretory glands. Investigating the anatomy of the stem also includes exploring physiological processes like water and nutrient transport and understanding how mechanical tissues contribute to the plant's ability to withstand external influences. Regarding the root, primary anatomical investigations were similarly carried out in the 19th and 20th centuries. These studies examined all layers of the root, from the epiblema to the central cylinder, as well

as the structural features of the conductive tissues and cortex. The diagnostic characteristics of the valerian root, including the presence of starch grains, structural characteristics of the endodermis, and the arrangement of the conductive tissues, have been extensively researched and documented in pharmacopoeia monographs (Khojimatov, 2021; Kostrakiewicz-Giera³t, 2018). Special attention has been given to the presence of secretory cells that store essential oils, which contribute to the root's distinctive aroma. The anatomical structure of valerian has also been examined in pharmacognostic studies focused on verifying the authenticity of plant materials and evaluating their quality (Nikolova*et al.,* 2017; Özdemir, 2022). These studies underscore the importance of microscopic analysis in determining the quality of medicinal raw materials.

5. Conclusion

In conclusion, *V. officinalis* (valerian) stands out as one of the most renowned and widely utilized medicinal plants globally. Its therapeutic properties stem from the complex array of biologically active compounds found in its stems, roots, and rhizomes. However, the anatomical structure of the stem, root, and rhizome of *V. officinalis* has been insufficiently studied in Uzbekistan. Understanding the anatomical structure of these organs is essential for comprehensively grasping the morphology and anatomy of this medicinal raw material, which is crucial for ensuring its quality. This, in turn, facilitates the broader application of medicinal valerian in healthcare settings.This article presents a detailed analysis of the anatomical structure of the stem, root, and rhizome of medicinal valerian in the context of Uzbekistan. The new findings contribute to the identification and evaluation of raw materials, enhancing our understanding of the biological processes occurring within the plant.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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