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Research Article

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Anatomical structure of the leaves and shoots of *Sophora japonica* grown under cultivation in Aktau (Mangistau Region)

Selecting an adaptive plant assortment under conditions of global climate change and increasing aridification is a critical task for modern botanical science. This study focuses on the anatomical structure of young shoots and leaves of *Sophora japonica* to assess its adaptability to the arid conditions in the city of Aktau. Plant samples grown in the Mangyshlak Experimental Botanical Garden were collected for the study. Leaves and shoots were fixed, examined using a freezing microtome, and subsequently described in terms of their anatomical structure, with measurements taken of individual tissues. The results revealed that the leaf of *Sophora japonica* is of the light-type, with a clear division of the mesophyll into palisade and spongy tissues, the presence of a cuticle, and single- and multicellular trichomes on the epidermis; the stomata are of the anomocytic type, and based on their arrangement, the leaf is of the amphistomatic type. The mesophyll contains numerous calcium oxalate druses, localized primarily along the leaf veins. One-year-old shoots have a secondary anatomical structure, featuring a wide zone of chlorenchyma and a narrow zone of parenchyma. Xylem elements are small. The shoot epidermis exhibits a significant cuticle layer and soft trichome pubescence. This set of microscopic characteristics confirms the species' adaptation to the arid conditions of the city of Aktau.

Keywords: Sophora japonica, shoot, leaf, subtropical plant, anatomical study, diagnostic signs, adaptation to arid climate.

Introduction

Kazakhstan, especially its arid regions such as Mangistau, is facing accelerated aridification of the climate [1]. This poses challenges for biodiversity and agriculture, particularly due to the loss of plant species capable of adapting to extreme climatic conditions [2, 3].

Climate change projections indicate increased drought and rising average annual temperatures [4], which necessitate the development of sustainable strategies for the conservation and use of drought-tolerant plants. One promising direction is the introduction of subtropical woody xerophytes, which are well adapted to conditions of water scarcity and high temperatures [5].

Globally, subtropical plants are widely studied in countries with warm climates, such as Greece, Turkey, Spain, and others [6–8]. These studies aim to conserve and utilize subtropical plants under climate change conditions; however, they focus on areas with milder climates compared to the arid regions of Kazakhstan.

In the Republic of Kazakhstan, research related to the introduction of subtropical plants into arid regions is still in its early stages. To date, the mechanisms by which subtropical plants adapt to conditions of extreme drought have not been sufficiently studied, which limits the possibility of their widespread use for landscaping and land restoration. The lack of knowledge regarding the physiological, phenological, morphological, and genetic mechanisms by which these plants adapt to conditions in Mangistau necessitates in-depth research.

Therefore, a promising area of research at this time is the assessment of the degree of adaptation of subtropical plants to the extra-arid climate of Kazakhstan, including the evaluation of physiological, phenological, and anatomical-morphological indicators.

The aim of this study is to assess the characteristics of the anatomical structure of the leaves and shoots of the subtropical plant *Sophora japonica* growing in the conditions of Aktau**.**

Experimental

The study subjects were shoots and leaves of *Sophora japonica* (Fig. 1), collected from the dendrological section of the Mangyshlak Experimental Botanical Garden in May and August 2026.

Figure 1. Flowering (A) and fruiting (B) *Sophora japonica* plants in the Mangyshlak Experimental Botanical Garden

The structural study included microscopic analysis of tissues to identify anatomical changes associated with drought adaptation. This will help us understand how changes in cell and tissue structure contribute to water conservation and ensure plant survival under water-deficient conditions. Anatomical analysis will also be used to assess the condition of generative organs, which is important for understanding the mechanisms of drought tolerance.

Shoots and leaf samples were fixed in Fleming's solution [9], consisting of distilled water, 96 % ethyl alcohol, and glycerin in a 40:40:40 ratio (1:1:1). Transverse sections were prepared on an OMT-2802E freezing microtome, MZP-01 "TEKHNOM" (Russia). The resulting sections were examined and photographed using a Stemi 2000 MA151/35/20 microscope (China) at magnifications of× 60,× 150, and× 240. Photo processing and measurements were performed using the HistoLab software. Specimens were cleared using glycerin [10]. Blue and green light filters were used to ensure image clarity.

Microscopic preparations were described according to methodological guidelines [11, 12].

All measurements were performed in 10 replicates. Data are presented as mean ± standard deviation (SD). Differences between treatments were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test at a significance level of $p < 0.05$.

Results and Discussion

The leaf *of Sophora japonica* is compound, imparipinnate, consisting of 6–15 pairs of leaflets. The leaves are dark green, almost smooth, and glossy on the adaxial side; on the abaxial side, they are light green and sparsely pubescent.

Microscopically, the leaf is of the light-type, flat, and dorsoventral in structure (Figs. 2, 3). The surface on both sides is covered by a single-layered epidermis; the thickness on the upper side is 1.46 μm, and on the lower side, 1.23 μm (Tab. 1). On the lower side, long, sparse, simple trichomes are noted, the length of which may exceed the thickness of the mesophyll. On the upper side of the leaf, the trichomes are small, unicellular, and pressed against the surface. The trichomes are unicellular and multicellular, with thin walls, straight or sickle-shaped. The cells on the adaxial side are larger and oval-shaped; the cuticle layer is thicker. On the abaxial side, the cells are clearly defined, and the cuticle layer is thin.

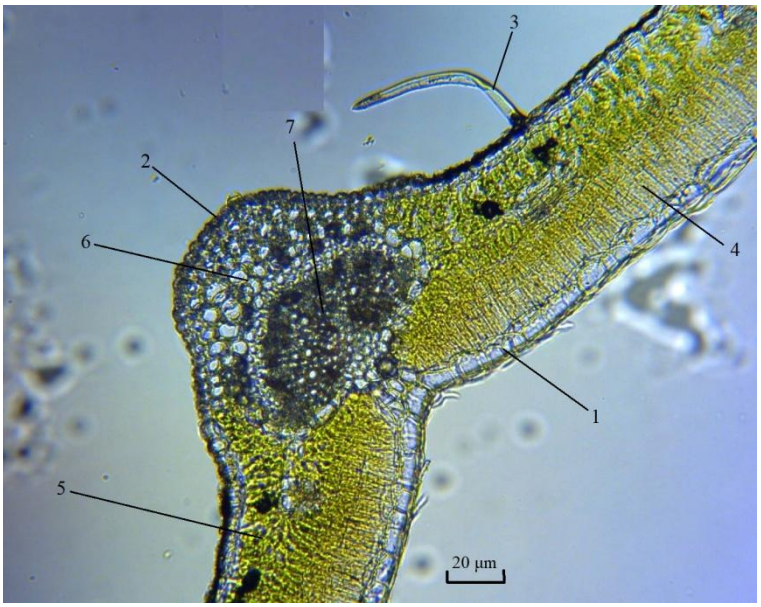

Figure 2. Cross-section of a *Sophora japonica* leaf, fragment in the region of the midrib
1 — upper epidermis, 2 — lower epidermis, 3 — trichome, 4 — palisade mesophyll,
5 — spongy mesophyll, 6 — loose collenchyma, 7 — vascular bundle

Figure 3. Cross-section of a *Sophora japonica* leaf, lateral fragment
1 — upper epidermis, 2 — lower epidermis, 3 — trichome, 4 — palisade mesophyll, 5 — spongy mesophyll

T a b l e 1

Dimensions of certain leaf tissues of *Sophora japonica*

No.	Tissues	Parameters
1	Epidermal cell size, µm	
1.1	Upper side	1.46±0.008
1.2	Lower side	1.23±0.10

Continuation of Table 1

No.	Tissues	Parameters
2	Mesophyll thickness, μm	18.69±0.43
3	Columnar mesophyll	
3.1	Number of rows, pieces	1–2
3.2	Row thickness, μm	7.78±0.29
4	Spongy mesophyll	
4.1	Number of rows, pieces	3
4.2	Row thickness, μm	8.94±0.13

The mesophyll has a thickness of 18.69 μm in the lateral part of the leaf and is well divided into palisade and spongy tissues. The palisade tissues are 1-layered, rarely 2-layered, with a thickness of 7.78 μm. The spongy tissues form up to 3 layers, and the thickness of this zone is 8.94 μm. The central bundle is oval, slightly curved, collateral, of the closed type, surrounded by areas of loose collenchyma, the zones of which are thicker on the lower side. The phloem occupies an extremely small area, whereas the xylem occupies the main part. Under the epidermis, rare calcium oxalate crystals are noted, located primarily along the leaf veins (Fig. 4).

The leaf epidermis on both sides consists of cells with slightly curved lateral walls (Fig. 4); the walls are thickened. Stomata are numerous, of the anomocytic type, and located on both sides (amphistomatic type). Above the leaf veins, the epidermis consists of prosenchyma cells with straight walls. Numerous druses are visible through the epidermis.

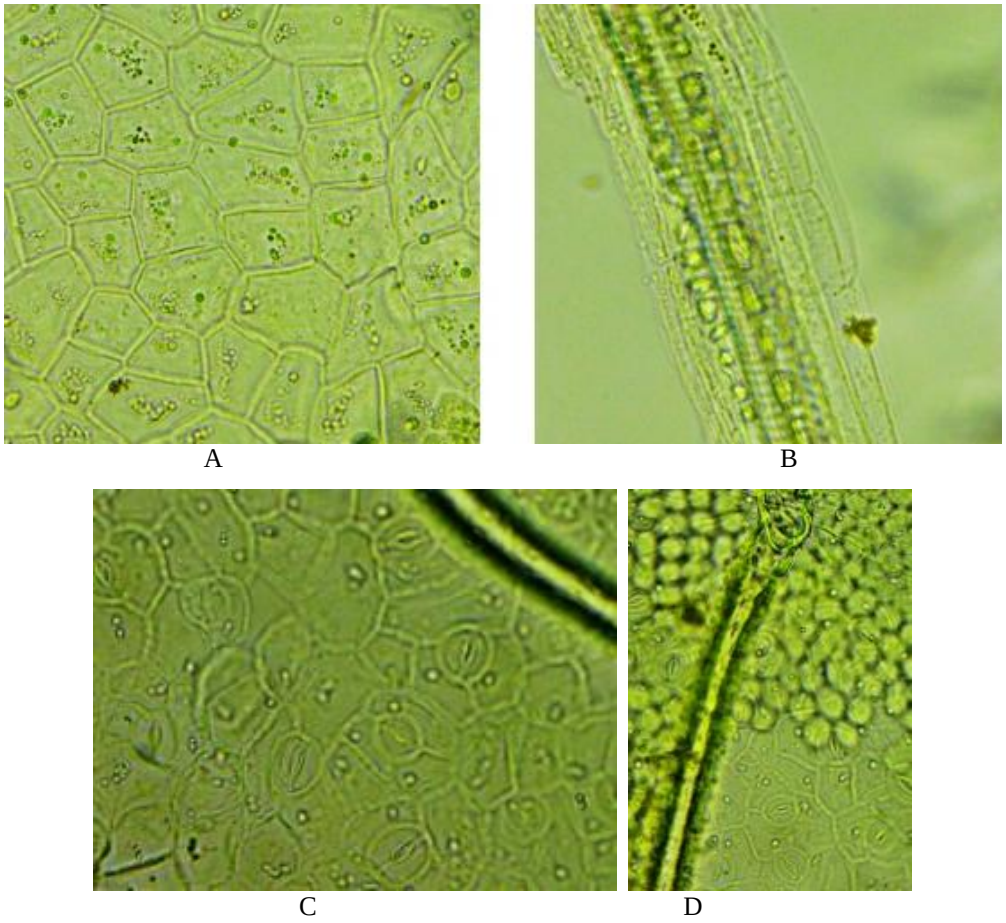

Figure 4. Surface preparation *of Sophora japonica*:
A — epidermis, B — crystalline inclusions along the leaf vein; C — anomocytic stomata, D — trichome

Trichomes are simple multicellular hairs consisting of a short base and long cells with a thick cuticle layer and warty walls.

Leaf tissues are characterized by large-celled structures, a well-developed cuticle on the upper surface, and pubescence on the lower surface, which is an adaptive trait for solar activity. The differentiated mesophyll indicates a light-demanding leaf type, and the presence of calcium oxalate druses indicates tolerance to growth on saline soils.

Young shoots *of Sophora japonica* are green or greenish-gray in color, often sparsely pubescent with short, simple hairs, and less frequently glabrous. The one-year-old shoot is rounded-lobed and non-fasciculate in structure (Fig. 5). The general pattern of microscopic structure is characteristic of secondary thickening.

The epidermis forms the outermost layer, with a thickness of 1.89 μm (Tab. 2); it consists of small, nearly rectangular cells. A fairly thick layer of cuticle is visible on the surface. The epidermis is reinforced by a ring of collenchyma cells lying beneath it. The chlorenchyma is 16.8 μm thick. The cortical parenchyma is also thick, with cells of a sinuous shape.

The sclerenchyma ring occupies a significant portion of the internal tissues and consists of small cells with barely visible intercellular spaces. The vascular system itself is of the non-bundled type, although clusters of fused bundles can be observed. The sclerenchyma ring is separated from the parenchyma by a layer of endoderm consisting of oval cells with straight walls.

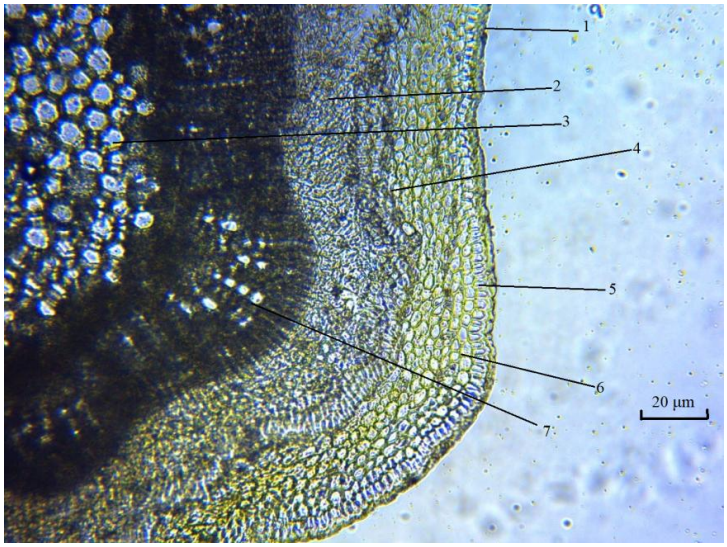

Figure 5. Cross-section of a one-year-old shoot of *Sophora japonica*, fragment
1 — epidermis, 2 — cork parenchyma, 3 — pith, 4 — endodermis,
5 — collenchyma, 6 — chlorenchyma, 7 — xylem

Table 2

Dimensions of some tissues of a one-year-old shoot of *Sophora japonica*

No.	Tissues	Parameters
1	Epidermis thickness, μm	1.89±0.04
2	Thickness of the parenchyma layer, μm	16.80 ± 0.72
3	Diameter of xylem vessels, μm	2.30±0.13
4	Area of xylem vessels, $\times 10^{\wedge -3 mm^2}$	4.76±0.11
5	Diameter of heartwood parenchyma cells, μm	4.28±0.53

The phloem layer is thin, while the xylem layer is substantial. The average diameter of xylem vessels is 2.3 μm, and their area is 4.76 μm². The central part is occupied by loose cells of the medullary parenchyma, with a cell diameter of 4.28 μm.

The formation of a wide zone of cortex and chlorenchyma, the absence of a thick cuticle layer on the stem epidermis, and the development of mechanical tissues on the young shoot confirm the species' adaptability to arid conditions. These changes help conserve moisture, provide rigidity to cells when turgor is lost, and the development of pubescence allows for the dissipation of excess sunlight.

Conclusion

Microscopic examination of *Sophora japonica* grown in the Mangistau region revealed diagnostic features such as amphistomatic leaf type, an epidermis consisting of isodiametric cells with slightly curved walls, the presence of long, multicellular, coarse, wart-like hairs, a thick cuticle layer, and the presence of calcium oxalate crystals in the leaf mesophyll; a secondary anatomical structure of the stem with a well-defined zone of chlorenchyma and medullary parenchyma, a single-layered collenchyma, pubescence, and a cuticle on the stem epidermis.

It has been determined that the anatomical structure of the leaf and shoot indicates the plant's adaptability to the extra-arid conditions of the city of Aktau, which confirms the possibility of its widespread use in the region's green construction.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Imanbayeva A.A.** — conceptualization, laboratory experiments, investigation; **Tuyakova A.T**. — anatomical study, data description, draft writing; **Duysenova N.I.** — data analysis, data collection, draft writing.

Conflict of Interest

The authors declare no conflict of interest.

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А.А. Иманбаева, А.Т. Туякова, Н.И. Дуйсенова

Ақтау (Маңғыстау облысы) дақылдарында өсірілген *Sophora japonica* жапырағы мен өркендерінің анатомиялық құрылымы

Климаттың жаһандық өзгеруі және аридизацияны күшейту жағдайында өсімдіктердің бейімделген ассортиментін таңдау қазіргі заманғы ботаникалық ғылымның маңызды міндеті. Жұмыстың мақсаты — Ақтау қаласының құрғақ жағдайларына бейімделуді бағалау үшін *Sophora japonica* жас өскіні мен жапырағының анатомиялық құрылымын бағалау. Зерттеу үшін Маңғышлақ экспериментальды ботаникалық бағында өсірілген өсімдіктердің үлгілері алынды. Жапырақтары мен өркендері іріктеліп, мұздатқыш микротомды қолдана отырып, микроскопия жасалды және анатомиялық құрылымды әрі қарай сипаттап, жеке тіндердің параметрлері өлшенді. Нәтижесінде *Sophora japonica* жапырағының жарқырауық типте екендігі, мезофиллдің палисадты және кеуек тәрізді тіндерге анық бөлінуі, эпидермисте кутикуланың, бір және көп жасушалы трихомалардың болуы; саңылауы аномоцитарлы типке, ал орналасуына қарай жапырақ амфистоматикалық типке жатады. Мезофиллде кальций оксалатының көптеген друздері бар, олар негізінен жапырақ тамырлары бойымен оқшауланған. Жылдық өркендер қайталама анатомиялық құрылымға ие, хлоренхима мен қабық паренхимасының кең аймағына ие. Ксилема элементтері ұсақ. Өркеннің эпидермисінде кутикуланың едәуір қабаты және жұмсақ трихомалардың түкті болуы байқалады. Микроскопиялық белгілер кешені түрдің Ақтау қаласының құрғақ жағдайларына бейімделуін растайды.

Кілт сөздер: Sophora japonica, өркен, жапырақ, субтропикалық өсімдік, анатомиялық зерттеу, диагностикалық белгілер, аридті климатқа бейімделу.

А.А. Иманбаева, А.Т. Туякова, Н.И. Дуйсенова

Анатомическое строение листа и побега *Sophora japonica* выращенного в культуры в Актау (Мангистауская область)

Подбор адаптивного ассортимента растений в условиях глобального изменения климата и усиления аридизации является важной задачей современной ботанической науки. Цель настоящей работы заключалась в оценке анатомического строения молодого побега и листа *Sophora japonica* для оценки адаптивности к аридным условиям города Актау. Для исследования были взяты образцы растений, выращенных в Мангышлакском экспериментальном ботаническом саду. Листья и побеги фиксировали, выполняли микроскопирование с использованием замораживающего микротома и дальнейшим описанием анатомического строения и измерением параметров отдельных тканей. Результаты позволили выявить, что лист *Sophora japonica* светового типа, с четким делением мезофилла на палисадную и губчатую ткани, наличием кутикулы, одно- и многоклеточных трихом на эпидермисе; устьица аномоцитного типа, по их размещению — лист амфистоматического типа. В мезофилле присутствуют многочисленные друзы оксалата кальция, локализованные преимущественно вдоль жилок листа. Годичные побеги имеют вторичное анатомическое строение, обладают широкой зоной хлоренхимы и коровой паренхимы. Ксилемные элементы мелкие. На эпидермисе побега отмечен значительный слой кутикулы и присутствие опушения из мягких трихом. Комплекс микроскопических признаков подтверждает адаптацию вида к засушливым условиям города Актау.

Ключевые слова: Sophora japonica, побег, лист, субтропическое растение, анатомическое исследование, диагностические признаки, адаптация к аридному климату.

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