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Leaf structure of species of the Brassicaceae Burnett family in Southwestern Kyzylkum, Uzbekistan

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ABSTRACT

Leaf species of the family Brassicaceae have been studied, diagnostic features have been identified. Omitted by various types of trichomes: stellate, dendroid stomata are randomly arranged, numerous, non-submerged, mostly anomatid hemiparacytic anisocytic.

Keywords: Trichome, Stomata, Epidermis, Heterophilia, Dorsoventral, Isolaterally Palisade, Idioblast, Venation, Abaxial, Adaxial.
Article type: Research Article.

INTRODUCTION

There are many reports about plant biology in the world (Anar *et al.* 2023; Duschanova 2023; Wang *et al.* 2023). The leaf organs of ephemera attract the attention of researchers due to their lability to environmental conditions. The study of their structure in plant ontogenesis determines the strategy of plant adaptation, that is, the path of adaptation in the transition from germinal leaf organs (cotyledons) to the leaf. There are data on the structure of the leaf of several species of ephemera from different habitats: Karakum, foothills of the western Tien Shan and Kopet-Dag. The type of leaf mesophyll of some types of Kyzylkum ephemera and the ratio of palisade and spongy tissues are reflected in the works of Butnik *et al.* (1987), Ploch *et al.* (2016), Andryakov *et al.* (2019), Tkacz *et al.* (2020), Tripathi Sharma (2023), Nkeiruka *et al.* (2024) & Wagh *et al.* (2024).

MATERIALS AND METHODS

The material was collected within a radius of 50 km around the Kyzylkum desert station, which is located 160 km northwest of Bukhara at 40°45′ N latitude and 63°45′ E at an altitude of 375 m a.s.l. on the basis of the springs of Ayak-Guzhumdy. The depth of groundwater is 20-30 m, water salinity -0.65-1.95 g L^{-1}, in some places - 4-5 g L^{-1}. Salinity is chloride-sulfate. Soil with an admixture of gypsum (10-50%). The soils are diverse: gray-brown gypsum, solonchaks, takyrs, semi-fixed sands, sandy loamy, variegated, rocky slopes of remnant mountains, which determines the diversity of vegetation, including ephemera. Leaves were collected in 3-5 pieces. from the lower, middle and upper tiers of shoots of I and II orders in natural habitats and in crops in the budding phase - the beginning of flowering. Quantitative

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measurements of the leaves were carried out in the middle part of the organ on 3 leaves from 3 plants according to the method of Barykina & Chubatova (2005). The arithmetic mean was derived from 90 measurements.

RESULTS AND DISCUSSION

In the capital summary of Metcalfe & Chalk (1957) it was noted that the leaf species of the family Brassicaceae is predominantly dorsiventral, but isolateral-palisade is also found. Trichomes are very diverse. Stomata are anisocytic on both sides of the leaf. In all organs there are idioblasts with myrosin, which turns red or purple when coagulated, which can be used as a diagnostic sign. Volkova (1960) studied the structure of 10 ephemeral species, including Brassicaceae species, under the conditions of the Kopetdag and the Moscow region. She noted the diversity of leaf types and an increase in mesomorphism under the conditions of introduction in the Moscow region. Rao & Inamdar (1983) described the morphology and leaf venation of 35 species of Brassicaceae, including species of the genus Alyssum: the leaves are simple, alternate, but the blade shape is very diverse. The venation is predominantly craspedromous. Begbaeva (1995) described the type of leaf mesophyll in 2 species of Isatis. Species of Isatis are nutritionally valuable plants, containing all the essential amino acids and a significant amount of carbohydrates (Karimov *et al.* 1965). Thus, information on the leaf structure of the desert Brassicaceae species is few.

Alyssum dasycarpum. The leaf is simple, broadly lanceolate, entire-extreme, smoothly turning into a petiole. Leaf blade is 6-8 mm long, 4-6 mm wide, evenly pubescent on both sides with 5-8 ray stellate hairs. The epidermis is single-row, on the paradermal section the cells are 4- and 5-coal with slightly sinuous walls. Their outer walls are slightly thickened. On the abaxial side, the epidermal cells are smaller and lower than on the adaxial side in cross section. The leaf is amphistomatic. Stomata are not submerged oval, hemiparacytic and anisocytic, less frequently anomocytic (Table 1). Mesophyll is isolateral-palisade, loose. The palisade fabric is single-row on both sides, spongy 3-row. The vascular bundles are sclerified, 25–30 in cross section (Fig. 1).

A. turkestanicum. The leaf is simple, oblong, almost sessile. Lamina is 9-11 mm long, 2-3 mm wide, entire. It is pubescent with 16-ray stellate hairs denser on the adaxial side. The epidermis is single row. On paradermal sections, its cells are 4-5-angled with slightly sinuous walls on the adaxial side of the leaf and sinuous on the abaxial. Their outer wall is slightly thickened. On the adaxial side, epidermal cells are larger and higher than on the abaxial side. Leaves are amphistomatic. Stomata are oblong-oval, anisocytic and tetracytic. The mesophyll is isolateral-palisade, with 2-3 rows of palisade cells on the adaxial side and with 1 row on the abaxial side. The palisade tissue occupies most of the volume of the entire mesophyll; the height of the palisade cells is 2 times greater than the width. Sponge fabric 4-6 row. Conductive bundles numerous, 19–21 in transverse section, sclerified (Table 2; Fig. 2).

A. szovitsianum. Simple Leaf, oblong-pointed blade 7-9 mm long, 4-6 mm wide, entire, pubescent on both sides with eight-sixteen-ray hairs (on the upper side of the leaf, the hairs are predominantly eight-rayed, and on the lower side sixteen). The epidermis is single row. Leaves are amphistomatic. On the paradermal section, the walls of the adaxial epidermis are slightly wavy, while the abaxial section is sinuous. Stomata of anomocytic, hemiparacytic types is larger, but in smaller numbers on the adaxial side of the leaf. The mesophyll is isolateral-palisade, with 2-3 rows of palisade cells on the adaxial side and 1-2 on the abaxial side. There are 3-4 rows of loose spongy cells between them. Intercellular spaces are large throughout the mesophyll. The vascular bundles are small, lateral non-sclerified, central with several sclerenchyma cells on the abaxial side and a parenchymal lining (Fig. 3).

The leaves of *A. szovitsianum, A. turkestanicum,* and *A. dasycarpum* have the following common features: pubescent with stellate hairs, amphistomatic, stomata not submerged, adaxial epidermal cells larger than abaxial, mesophyll type isolateral-palisade. However, the leaf of species of the genus *Alyssum* differs in the following diagnostic features: *A. szovitsianum* is characterized by a lanceolate leaf shape, a thick mesophyll; *A. turkestanicum* - oblong leaf shape, thin leaf, more pronounced palisade (palisade coefficient - 63%); *A. dasycarpum* is a broadly lanceolate leaf form. In plant ontogeny, xero- and heliomorphism of the structure of assimilating organs increases: from dorsiventral cotyledons to isolateral-palisade leaves.

Diptychocarpus strictus. The leaf is simple, oblong-linear, sharp-toothed, pubescent with simple and capitate glandular hairs on a 4-celled stalk. The epidermis is single row. From the surface the cells are flattened, on the adaxial side the cell walls are wavy, on the abaxial side they are sinuous. Stomata are numerous, especially on the abaxial side, anomocytic, hemiparacytic, anisocytic, nonsubmerged (Fig. 4).

Goldbachia laevigata. The leaf is lamellar, heart-shaped petiolate at the base, rarely toothed along the edges, 8-10 mm long, 1.5-2 mm wide. Tapered at the top. It is pubescent with simple unicellular hairs on a 2-cell base (Fig. 5).

Table 1. Indicators of the structure of the epidermis of the middle sheet of ephemera.

Kind	Height (μm)		Outer wall thickness (μm)		Stomata length (μm)		Stomata width (μm)		Number of stomata (per 1 mm^2)	
	Adax.	**Abax.**	**Adax.**	**Abax.**	**Adax.**	**Abax.**	**Adax.**	**Abax.**	**Adax.**	**Abax.**
Asteraceae										
Amberboa turanica	16.8 ± 1.5	11.9 ± 1.0	7.7 ± 0.7	6.2 ± 0.6	–	–	–	–	20.0 ± 11.9	139 ± 13.0
Epilasia hemilasia	20.9 ± 2.0	20.6 ± 1.9	7.1 ± 0.68	8.2 ± 0.8	38.9 ± 3.5	39.0 ± 3.8	25.9 ± 2.0	26.9 ± 2.1	75.0 ± 7.3	84.0 ± 0.79
Brassicaceae										
Alyssum dasycarpum	13.9 ± 1.2	17.2 ± 1.5	2.6 ± 0.2	2.6 ± 0.21	21.9 ± 2.0	21.7 ± 1.9	15.8 ± 1.4	16.2 ± 1.5	129.0 ± 12.0	208.0 ± 20.0
A. szovitsianum	21.0 ± 2.0	16.3 ± 1.5	1.8 ± 0.9	1.7 ± 0.8	19.8 ± 1.9	22.6 ± 2.1	16.2 ± 1.5	16.2 ± 1.6	155.0 ± 15.0	200 ± 19.0
Hymenolobus procumbus	19.2 ± 1.8	15.6 ± 1.5	4.7 ± 0.4	4.4 ± 0.38	16.4 ± 1.6	17.6 ± 1.7	–	–	–	–
Goldbachia laeviata	23.6 ± 2.3	20.1 ± 2.0	4.6 ± 0.4	5.0 ± 0.45	19.8 ± 1.9	21.2 ± 2.0	–	–	290.1 ± 128.3	259.9 ± 24.7
Lachnoloma lechmanii	16.0 ± 1.5	19.7 ± 1.85	4.3 ± 0.4	4.4 ± 0.4	31.8 ± 3.0	32.5 ± 3.1	–	–	–	–
Strigosella africana	21.9 ± 2.1	19.8 ± 1.8	3.6 ± 0.3	4.0 ± 0.4	33.0 ± 3.1	32.1 ± 3.0	–	–	136.3 ± 13.0	121.9 ± 12.2
Isatis minima	14.2 ± 1.2	13.7 ± 1.3	5.6 ± 0.5	5.1 ± 0.49	23.4 ± 2.0	25.0 ± 2.3	171 ± 1.6	18.1 ± 1.7	137.0 ± 13.0	133.0 ± 12.9
I. viollascens	19.9 ± 1.8	15.5 ± 1.4	2.7 ± 0.2	2.5 ± 0.19	21.1 ± 2.0	22.4 ± 2.1	18.7 ± 1.8	19.1 ± 1.85	152.0 ± 15.0	143.0 ± 13.9
Chenopodiaceae										
Londesia eriantha	54.7 ± 5.0	50.1 ± 4.9	2.7 ± 0.2	2.9 ± 0.2	26.0 ± 2.6	24.0 ± 2.3	19.0 ± 1.8	17.0 ± 1.6	16.0 ± 1.6	18 ± 1.8
Fabaceae										
Astragalus ammophilus	20.2 ± 2.0	17.4 ± 1.5	3.0 ± 0.25	3.4 ± 0.3	20.9 ± 1.9	21.5 ± 2.0	18.5 ± 1.7	19.6 ± 1.8	252 ± 20.1	170 ± 15.0

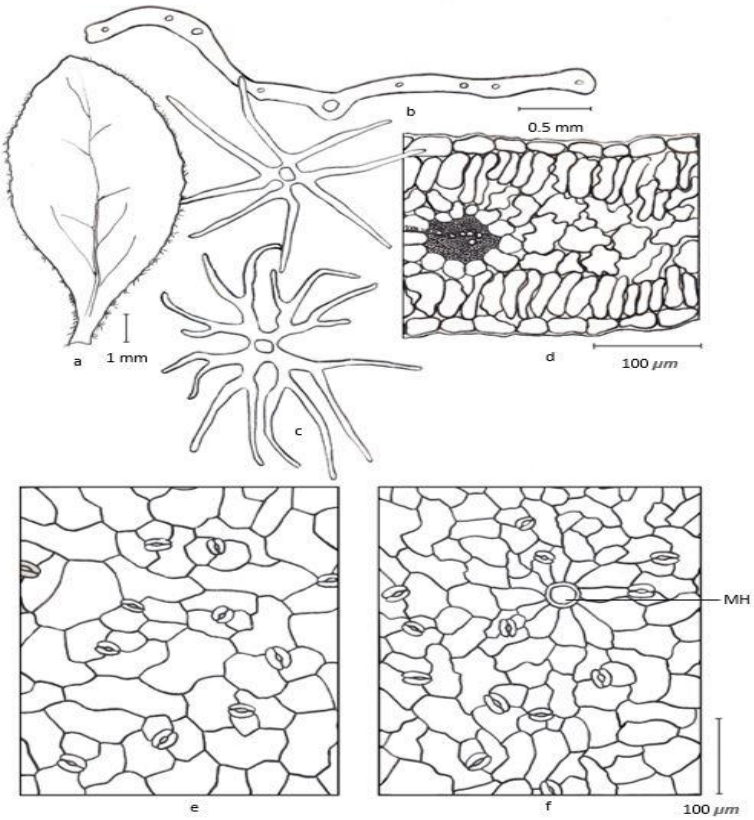

Fig. 1. Leaf structure of *Alyssum dasycarpum*: a – appearance; b - diagram of the cross section; c - dendroid trichomes; d – mesophyll detail; e - adaxial epidermis; f - abaxial.

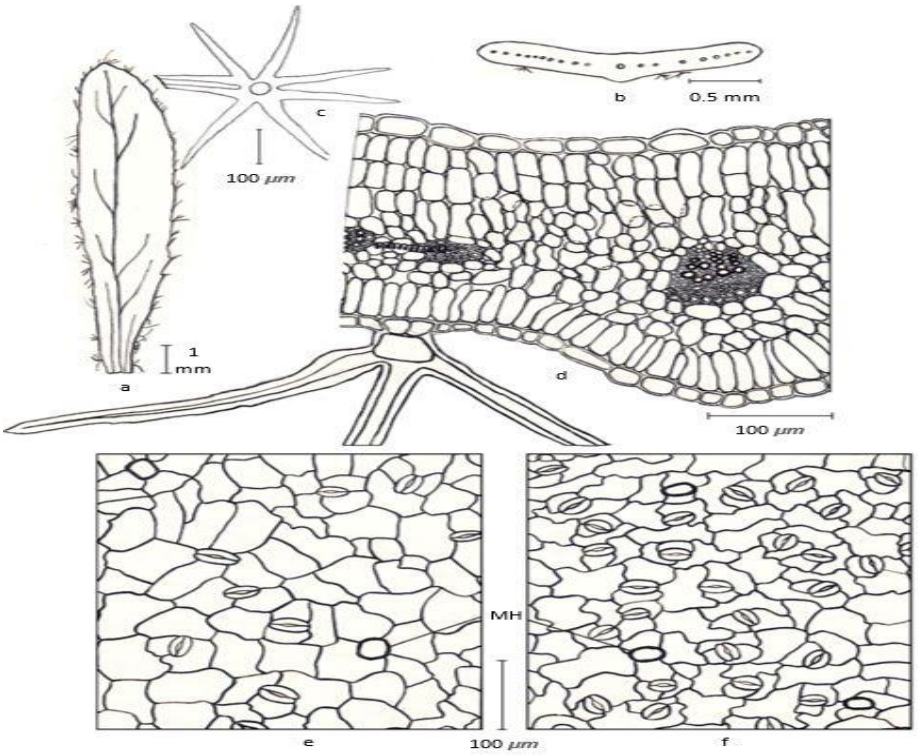

Fig. 2. Leaf structure of *Alyssum turkestanicum*: a – appearance; b - diagram of the cross section; c - trichomes; d – mesophyll detail; e - adaxial epidermis; e - abaxial.

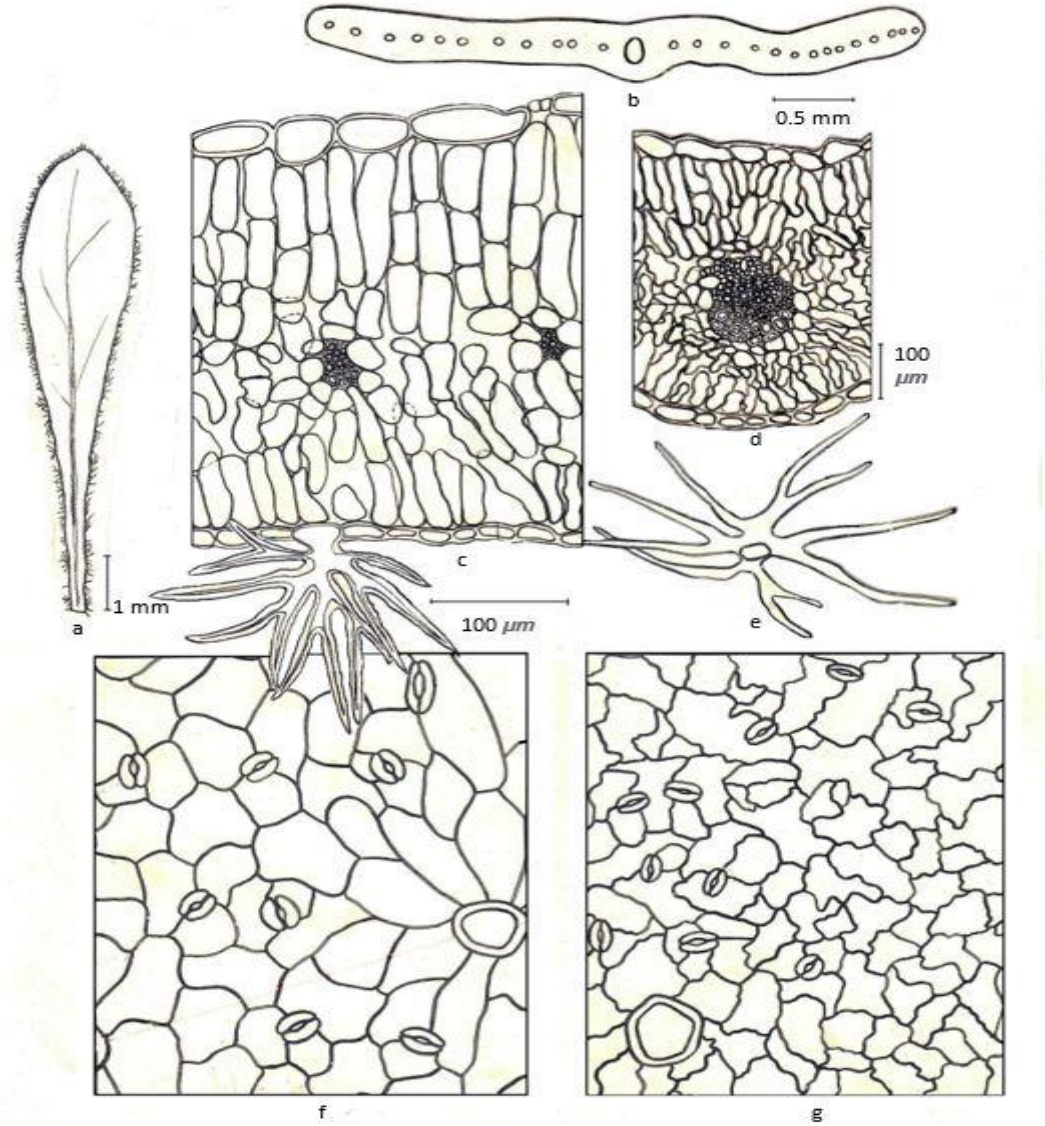

Fig. 3. Leaf structure of *Alyssum szovitsianum*: a – appearance; b - diagram of the cross section; (c) mesophyll detail; d - main vein; e - dendroid trichome; (f) adaxial epidermis; g – abaxial.

The mesophyll is dorsiventral, with 3 rows of wide palisade cells on the adaxial side, palisade-like, loose on the abaxial side. Spongy cells form 5-6 rows. Conductive bundles (main and 20-22 lateral) sclerified. Epidermal cells on the paradermal section are flattened, slightly wavy, swollen on the transverse section with a thickened outer wall. The leaf is amphistomatic. Stomata are small, numerous, anomocytic and hemiparacytic, not submerged. The mesophyll is isolateral-palisade, with 2-(3) rows of palisade cells on both sides, 6-7 rows of spongy cells in the center. The median vascular bundle is larger than the lateral ones and is surrounded by a sclerenchymal sheath (see Table 2; Fig. 5).

***Hymenolobus procumbens*.** Leaves with homoblastic heterophylls. Basal leaves alternate, 3-5, up to 1.5 cm long, 0.8 cm wide, lyre-pinnately divided with 5-8 lobes. Lower stem - 1.5-1.8 cm long, 0.5 cm wide, dissected, with 4-5 lobes. Medium - 1.2-1.5 cm long, 0.4-0.5 cm wide, less dissected, oblong, with an elongated slightly pointed apex and a retracted base, short-petiolate or sessile. Upper leaves 0.5-1 cm long, 0.1-0.3 cm wide, entire, sessile. On a transverse section of a leaf of the middle tier, the epidermis is single-row, its outer walls are thickened (4.7 microns).

On the paradermal section, the epidermal cells are oblong, their walls are sinuous on both sides of the leaf. Stomata are anisocytic and hemiparacytic, rarely anomocytic, non-immersed, randomly oriented. The mesophyll is isolateral-palisade, 277.9 μm thick. On the adaxial side there are 3 rows of palisade cells, on the abaxial side there are 2 rows with large intercellular spaces and 6 rows of spongy cells between them. Palisade coefficient 45%, cell palisade index - 2. Median vascular bundle with 10-15 vessels, small lateral bundles - 10-12. All bundles are sclerified due to the thickening of the walls of the phloem parenchyma (Table 2; Fig. 6).

Table 2. Signs of the mesophyll of the leaf of species of the Brassicaceae family.

Kind	Thickness (µm)		Coefficient palisade (%)	Palisade cells adaxial (µm)			Palisade cells abaxial (µm)		
	mesophyll	palisade layer		height	width	Palisade index	height	width	Palisade index
Alyssum dasycarpum	267.4 ± 21.6	93.9 ± 8.2	35.1	38.6 ± 3.2	18.5 ± 1.6	2.1	–	–	–
Alyssum szovitsianum	311.5 ± 23.5	156.2 ± 12.3	56.5	40.6 ± 4.0	12.6 ± 1.1	3.2	–	–	–
Alyssum turkestanicum	158.6 ± 12.1	100.8 ± 9.3	63.6	26.9 ± 2.1	12.1 ± 0.9	2.2	–	–	–
Hymenolobus procumbens	277.9 ± 26.3	124.0 ± 11.2	44.6	39.0 ± 3.8	19.0 ± 1.8	2.0	–	–	–
Goldbachia laevigata	399.7 ± 32.5	ad.174.0 ± 17.0 ab. 124.8 ± 11.2	74.7	55.0 ± 5.3	25.0 ± 2.3	2.2	48.5 ± 4.4	23.4 ± 2.1	2.0
Lachnoloma lechmanii	291.9 ± 28.8	ad. 117.5 ± 10.3 ab. 97.5 ± 9.0	73.6	64.5 ± 6.3	21.9 ± 2.0	2.9	57.3 ± 5.1	18.5 ± 1.7	3.1
Stigozella africana	286.5 ± 27.3	ad. 133.5 ± 13.0 ab. 42.4 ± 4.2	61.4	68.1 ± 6.3	22.5 ± 2.1	3.0	43.9 ± 4.2	22.8 ± 2.2	1.9

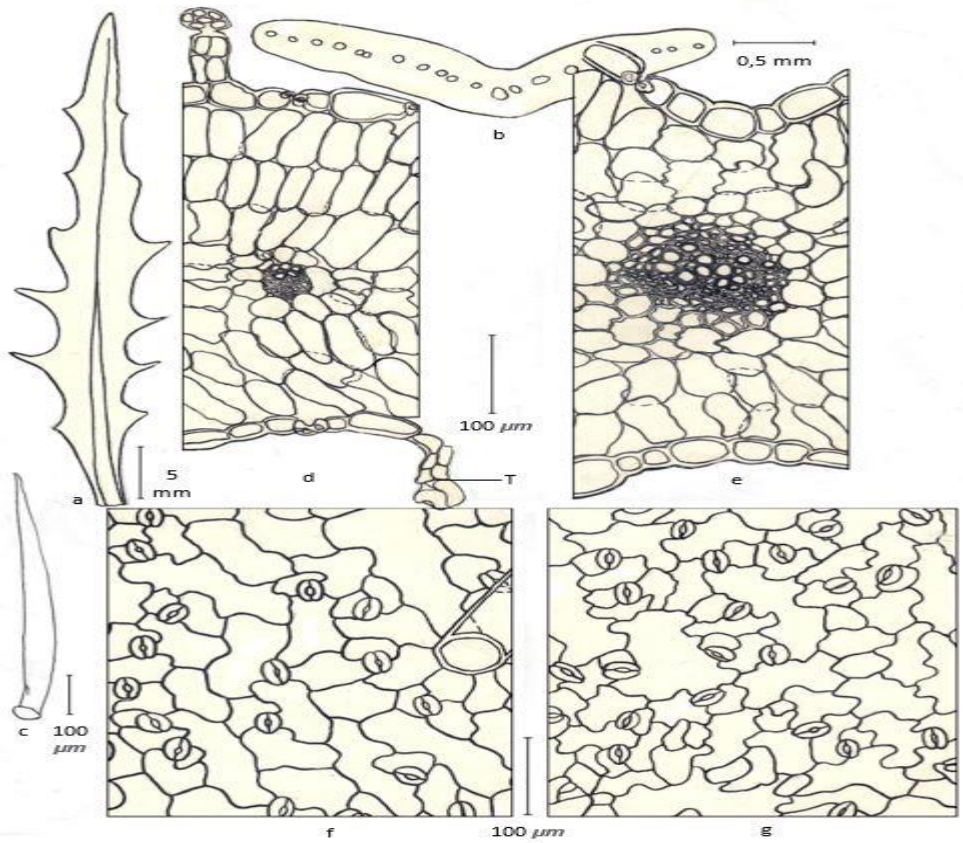

Fig. 4. Leaf structure of *Diptychocarpus strictus*: a – appearance; b - diagram of the cross section; c - trichome; d – mesophyll detail; e - main vein; f- adaxial

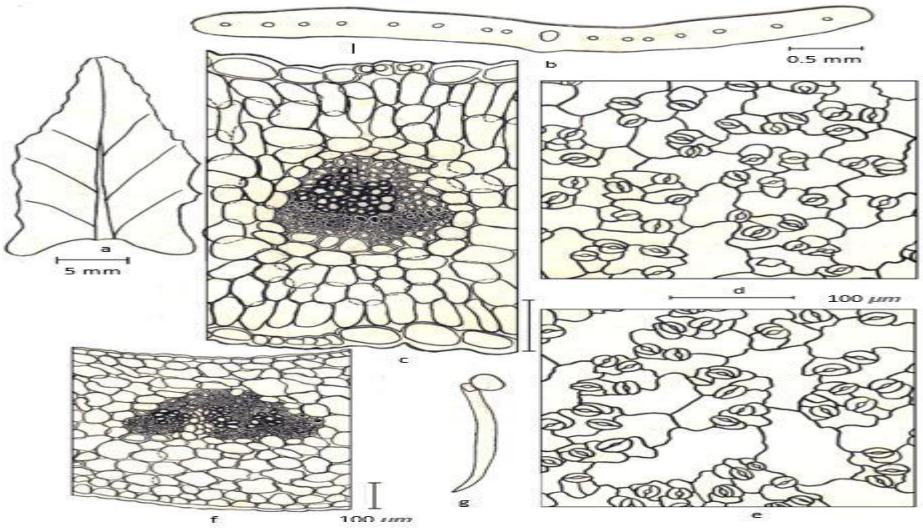

Fig. 5. structure of leaf *Goldbachia laevigata*: a – appearance; b - diagram of the cross section; c-mesophyll detail; d – adaxial epidermis; e - abaxial; e - main vein; g - trichomes.

In ontogenesis, *H. procumbens* undergoes a change in the adaptation of assimilating organs towards an increase in the degree of helio- and xeromorphism, expressed in the transition from the dorsiventral mesophyll of cotyledons to the isolateral-palisade of leaves. However, the structure of vegetative organs also bears mesomorphic features: tortuosity of epidermal cells, large intercellular spaces in the leaf mesophyll, non-submerged small numerous stomata.

***Isatis minima*.** The leaf is simple, finely indented, with a prominent vein on the abaxial side. The epidermis is single row. Epidermal cells are flattened, their walls are wavy, higher on the adaxial side, sinuous and large on the abaxial side. The leaf is amphistomatic. Stomata are numerous, small, anomocytic, rarely hemiparacytic and

anisocytic, not submerged. The mesophyll is isolateral-palisade, with 2-(3) rows of palisade cells on the adaxial side and 1 on the abaxial side. Spongy tissue 6-7-row, loose, with large intercellular spaces. The median conducting bundle protrudes from the adaxial and even more so from the abaxial side. There are 10 lateral vascular bundles in a transverse section. All bundles are sclerified (Fig. 7).

I. viollascens. The leaf of the middle tier of the shoot is flat, widened at the base and narrowed towards the apex, with a prominent midrib, pubescent with thin filiform and thick short hooked trichomes. Epidermal cells of a flattened shape with sinuous and wavy walls, on the abaxial side contain anthocyanin, which protects against insolation. The leaf is amphistomatic. Stomata numerous, large and small, anomocytic, hemiparacytic, anisocytic, nonsubmerged. Mesophyll dorsiventral, loose. Palisade parenchyma 2-row, spongy 7-8-row with large intercellular spaces. The median bundle is strongly sclerified on all sides. Lateral vascular bundles 24-26 in transverse section, small, but also sclerified. At the base of the leaf, the entire mesophyll tissue is parenchymal; the main vein is large and sclerified (Fig. 8).

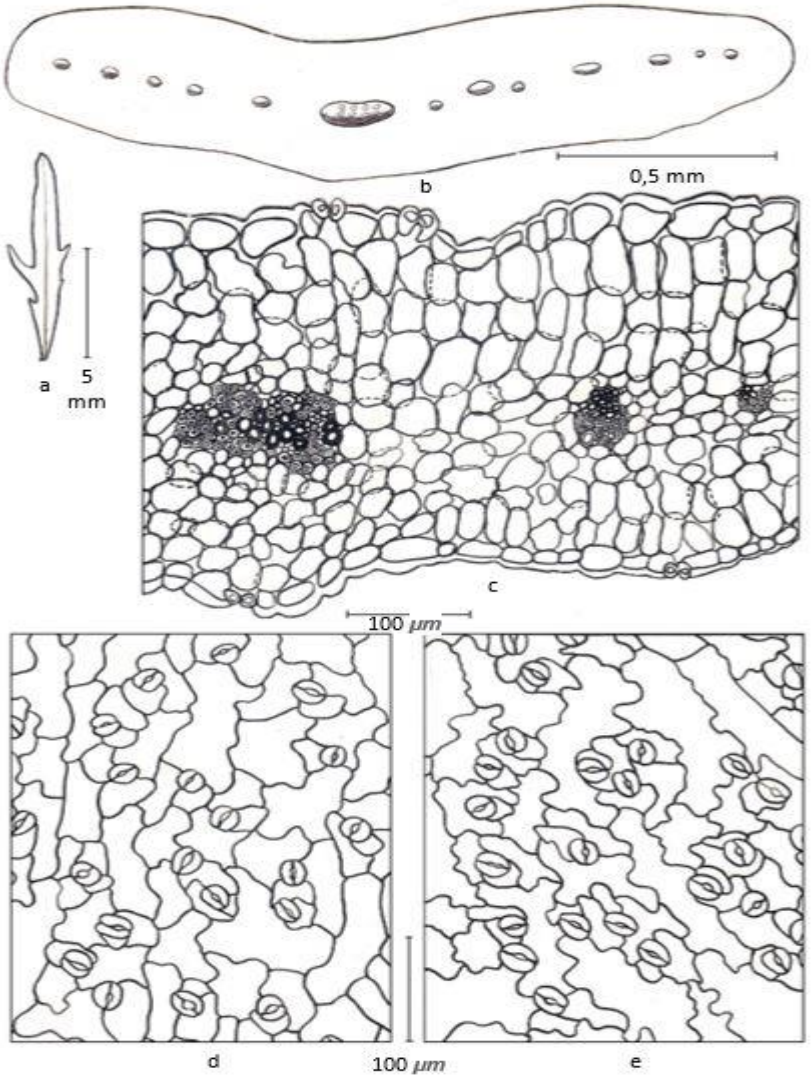

Fig. 6. The structure of the middle leaf of *Hymenolobus procumbens*: a – appearance; b - diagram of the cross section; c- mesophyll detail; d – adaxial epidermis; e - abaxial

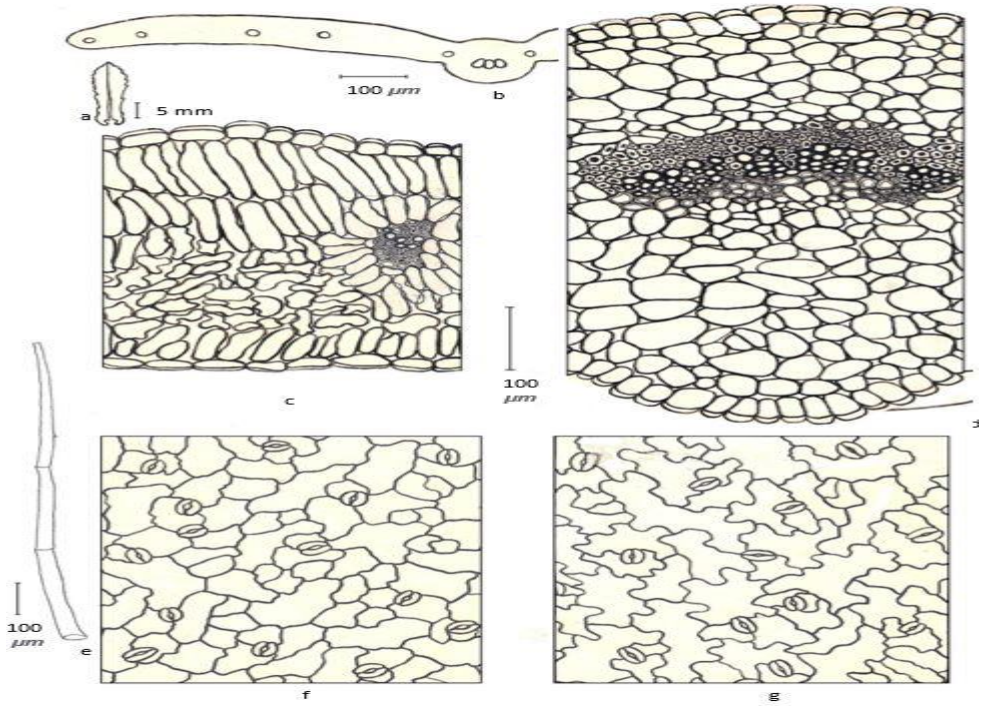

Fig. 7. Structure of the middle leaf of *Isatis minima*: a – appearance of the leaf; b - diagram of the cross section; (c) mesophyll detail; d - main vein; e - trichome; f- adaxial epidermis; g - abaxial.

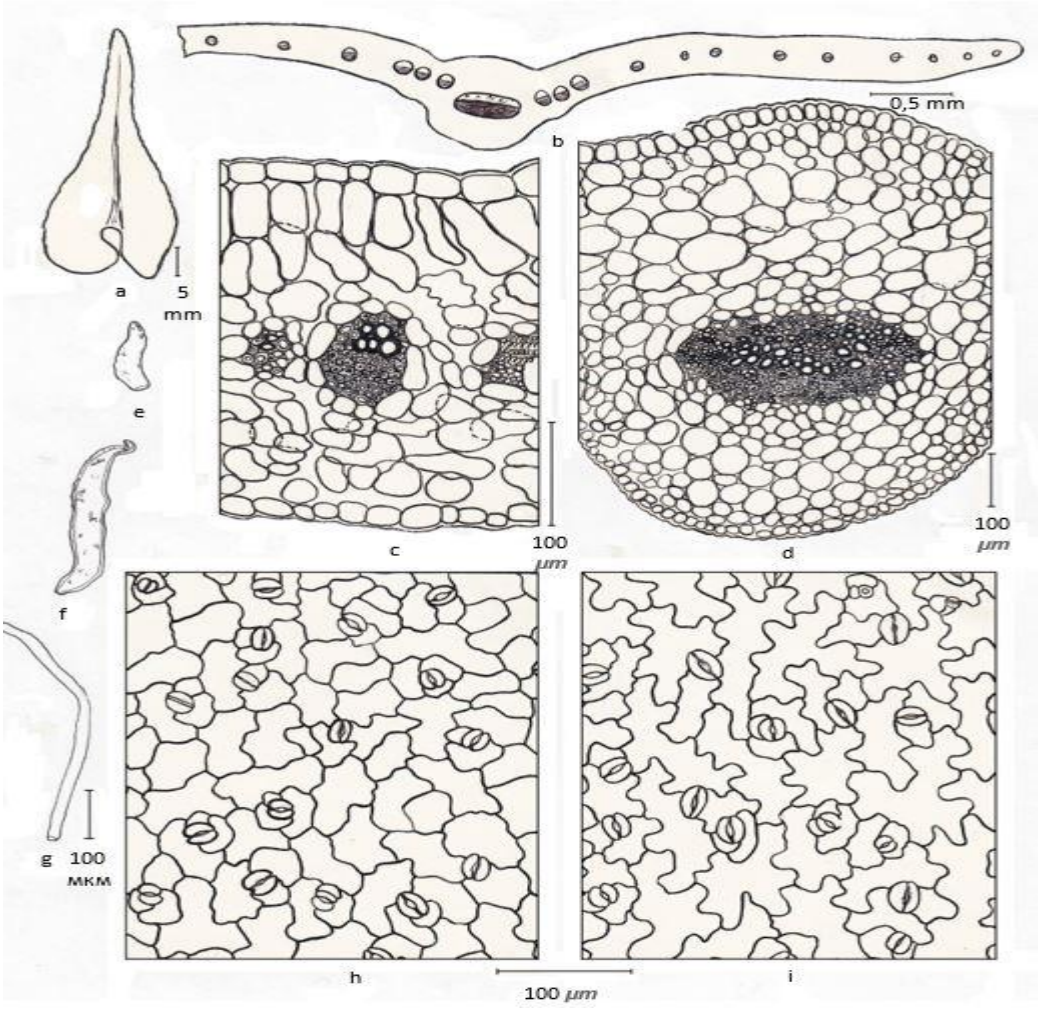

Fig. 8. Structure of the middle leaf of *Isatis violascens*: a – appearance; b - diagram of the cross section; (c) mesophyll detail; d - main vein; e, f, g - trichomes; h- adaxial epidermis; and is abaxial.

Lachnoloma lehmanii. The leaf of the middle tier is lamellar, coarsely toothed on a wide petiole, pubescent with branched hairs. The epidermis is single-row, adaxial, 16.3 μm high, abaxial, 19.7 μm, flattened from the surface, slightly wavy. The adaxial cells are larger than the abaxial ones, with an outer wall thickness of 4.3–4.4 μm. The leaf is amphistomatic. Stomata are not submerged, predominantly anomocytic, oval, 31.8 (adaxial) and 32.9 (abaxial) μm long, 26.5 and 27.7 μm wide, respectively. The mesophyll is isolateral-palisade, with 2 rows of palisade cells on the adaxial side and 2-3 on the abaxial side. The height of the palisade cells is 64.5 and 57.3 μm. Spongy parenchyma 4-5 row. Mesophyll loose with large intercellular spaces. The median bundle is larger than the lateral bundles (16 per transverse section), surrounded on all sides by sclerenchyma, the lateral bundles are weakly sclerified (Fig. 9). The petiole is pubescent, flattened, under the epidermis with 1 row of palisade-like cells and stomata on the adaxial side, the rest of the cells are spongy parenchyma. The median bundle is large, consisting of 3 fused bundles, sclerified.

***Leptaleum filifolium*.** Leaf 3-3.5 cm long, divided into 5-6 narrow (1-1.5 mm wide) lobes, pubescent with 1-2 ray hairs with curved hook-shaped ends of the rays. On the adaxial side above the vein, a depression is noticeable, on the abaxial side, a protrusion. The epidermis is single row. On the adaxial side, the cell walls are slightly wavy; on the abaxial side, they are sinuous; the outer walls of the cells are thickened. The leaf is amphistomatic. Stomata are small, numerous, anomocytic, rarely hemiparacytic, not submerged. There are no stomata on the adaxial side above and below the main vein. In cross section, the lobe of the leaf is in the shape of a crescent with blunt ends. The mesophyll is isolateral-palisade with 3 rows of palisade cells on both sides of the plate, between them there are 4-5 rows of spongy cells. Intercellular spaces are large. On the transverse section of the leaf lobes, 4 large conductive bundles and 5-6 small ones pass. The main and large lateral vascular bundles with 15–20 vessels are surrounded by a sclerenchymal sheath (Fig. 10). The leaf is xeromorphic due to the reduction of the evaporative surface (narrow lobes), thickened outer walls of the epidermis, isolateral-palisade mesophyll (3 rows of cells on both sides), and sclerification of vascular bundles.

***Meniocus linifolius*.** The leaf is linear, entire, 3-3.5 cm long, 3-4 mm wide, pubescent with stellate hairs. The epidermis is single-row, with a surface of flattened cells with slightly wavy, often straight walls. Stomata are small, numerous, unsubmerged, anomocytic, hemiparacytic and paracytic, arranged randomly.

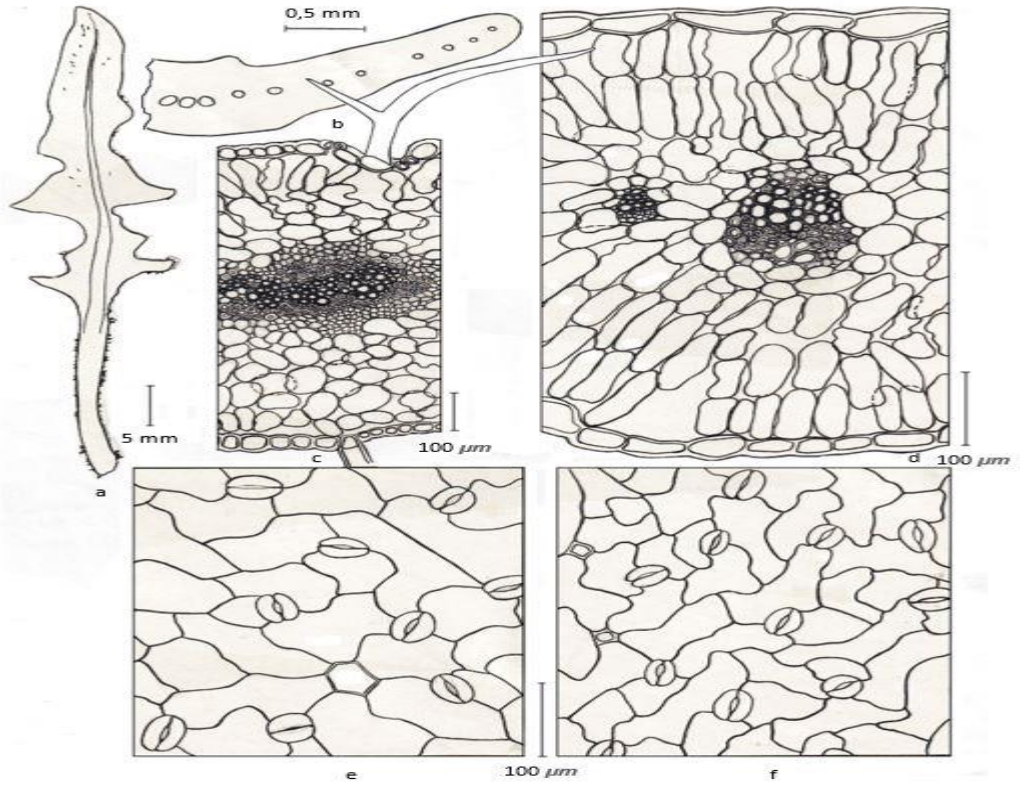

Fig. 9. Structure of the middle leaf of *Lachnoloma lehmanii*: a – appearance; b - diagram of the cross section; c- mesophyll detail; d - main vein; e - adaxial epidermis; f - abaxial.

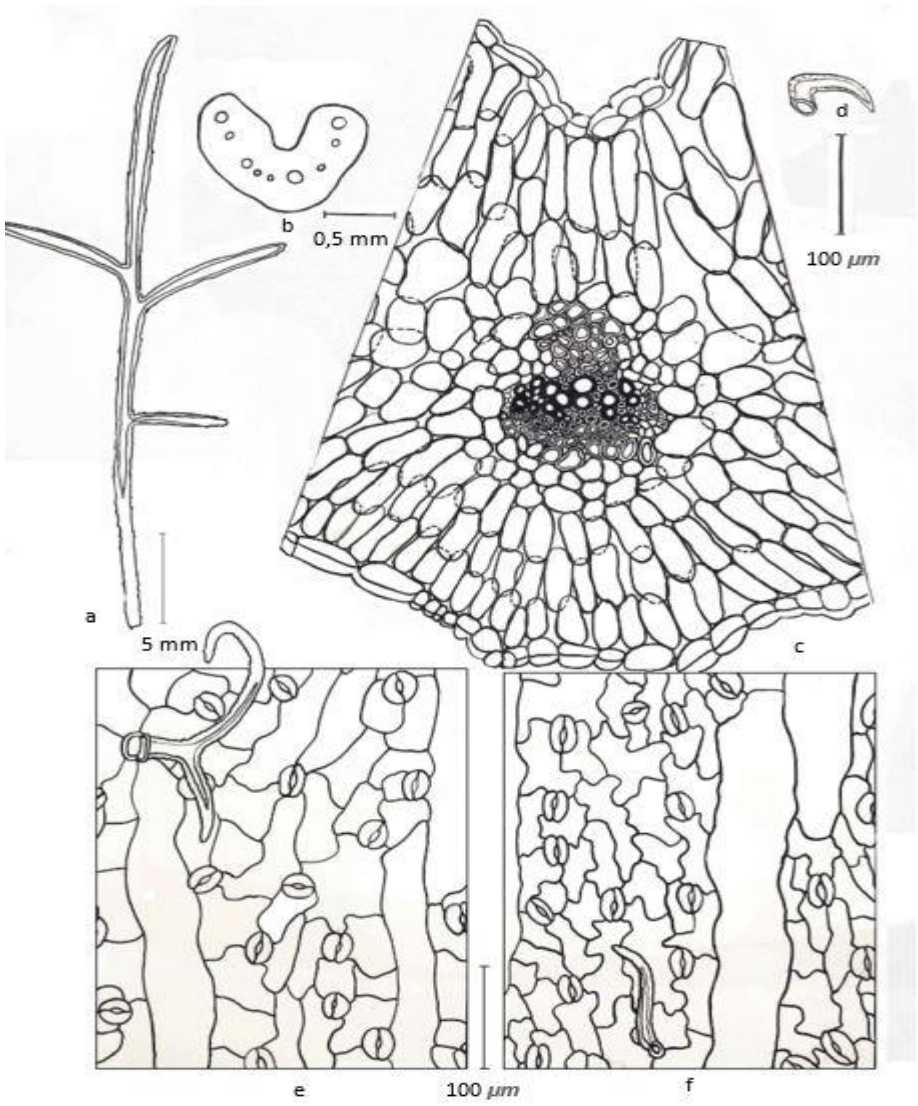

Fig. 10. Structure of the middle leaf of *Leptaleum filifolium*: a – appearance; b - diagram of the cross section; c- mesophyll detail; d - hooked trichome; e - adaxial epidermis; f - abaxial.

Mesophyll isolateral-palisade. From the adaxial side it is represented by 3 rows of palisade cells, from the abaxial side by 1-2. Between them there are 4-5 rows of spongy cells. Intercellular spaces are small. The median bundle is large, with numerous vessels, strongly sclerified, surrounded by a parenchymal sheath. The lateral bundles (15–16 in transverse section) are also sclerified, and there are few vessels in them (Fig. 11). The leaf is xeromorphic due to pubescence of stellate trichomes, small intercellular spaces, and sclerification of vascular bundles.

Strigosella africana. The leaf is large, 33-35 mm long, 10-12 wide, oblong-oval, serrated along the edges, on a wide petiole, pubescent with single- and double-rayed hairs with small spines. The main vein protrudes from the underside of the leaf. The epidermis is single-row, cells flattened from the surface, slightly wavy on the adaxial side, sinuous on the abaxial side. Stomata numerous non-submerged, anomocytic, rarely hemiparacytic and anisocytic, randomly arranged. The mesophyll is dorsiventral, loose, with 2-3 rows of large wide palisade cells located on the adaxial side and 6-8 rows of spongy cells on the abaxial side. Median vein large, with numerous vessels, sclerified on all sides. The lateral veins are also sclerified and surrounded by a parenchymal sheath (Fig. 12).

***S. grandiflora*.** The lower rosette leaves are oblong, petiolate, finely toothed, pubescent along the edge with simple flask-shaped and two-celled hairs. The epidermis is single row. From the surface, the cells of the adaxial epidermis are 4-5-sided with straight walls, while the cells of the abaxial epidermis are flattened with wavy walls. Stomata are numerous, small, anomocytic, hemiparacytic, anisocytic, arranged randomly, not submerged. The outer cell wall is strongly thickened. The mesophyll is dorsiventral: on the adaxial side there are 2 rows of palisade cells,

the spongy parenchyma is 5-6 rows, loose with large intercellular spaces. There are no palisade cells in the region of the median vein. The vein protrudes on the abaxial side and consists of 2–4 contiguous sclerified bundles. Lateral vascular bundles are small, 15–17 in cross section, with several vessels, sclerified (Fig. 13).

S. scorpioides. The leaf is elongated-spatulate, entire, sometimes finely dentate, oval-elongated, pubescent with unicellular branched and bifid hairs, with an extended petiole. The epidermis is single-row, the cell shape is flattened from the surface, the cell walls are wavy on the adaxial side, and sinuous on the abaxial side. Stomata numerous, anomocytic, rarely hemiparacytic and anisocytic, non-submerged, randomly arranged.

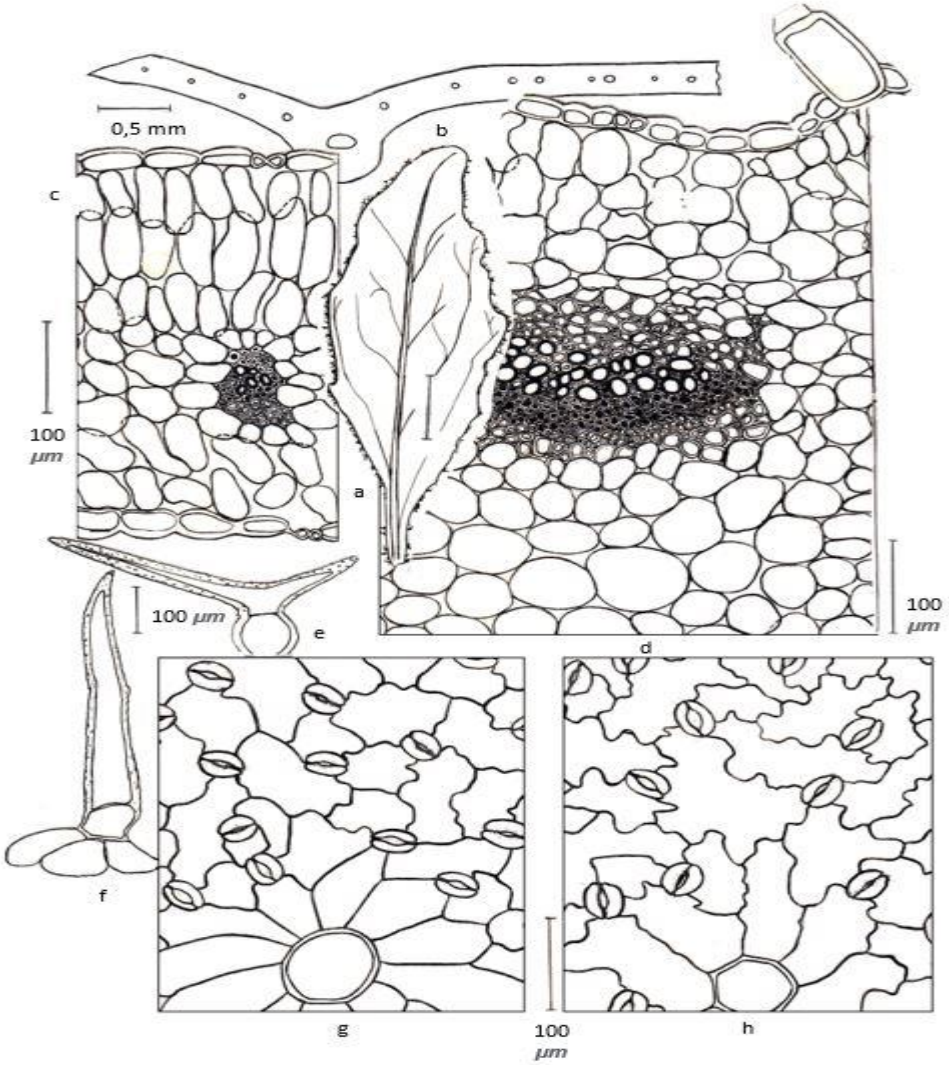

Fig. 12. The structure of the leaf of the middle layer of *Strigosella africana*: a - appearance; b - diagram of the cross section; c- mesophyll detail; d - main vein; e - multibeam trichome; f - glandular trichome; (g) adaxial epidermis; h – abaxial.

The leaf mesophyll is dorsiventral. The palisade parenchyma is 2-row on the adaxial side, the spongy parenchyma is 5-7 rows. Intercellular spaces are small. Median vein protrudes from abaxial side, sclerified on all sides. Lateral veins in cross section 16-18, they are small, with 1-3 vessels, sclerified (Fig. 14).

Streptoloma desertorum. The leaf of the middle tier is lyre-shaped, coarsely and finely toothed, with a blade 0.5-1.0 cm long and 10 mm wide of the teeth, on a flattened petiole. It is pubescent with simple and branched trichomes with spines. Epidermal cells are large, flattened, with slightly wavy walls. Stomata are oval, anomocytic and rarely hemiparacytic, not submerged. The outer wall of the epidermal cells is slightly thickened. The mesophyll is isolateral-palisade with 3 rows of palisade cells on the adaxial side and 2 rows of palisade-like cells on the abaxial side. Between them there are 3-4 rows of loose spongy cells, large intercellular spaces. The main vein smoothly protrudes from the abaxial side and consists of 3 contiguous sclerified vascular bundles. Lateral fascicles in transverse section (Mohammed *et al.* 2024) are small - non-sclerified, large - sclerified (Fig. 15).

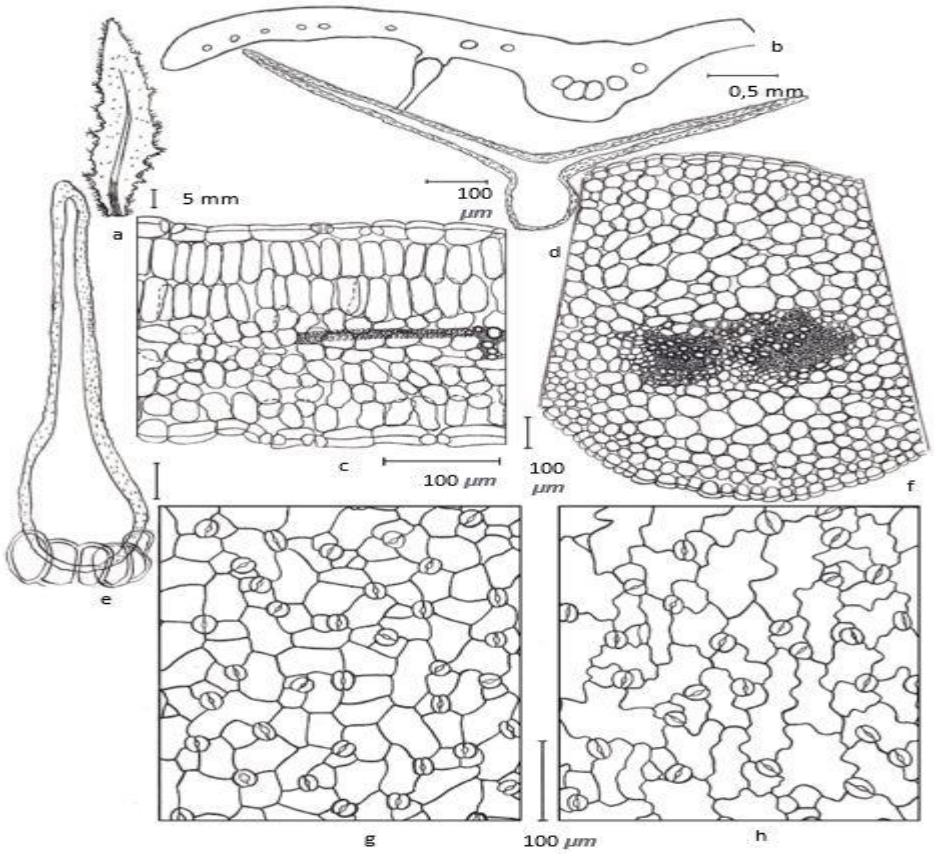

Fig. 13. *Strigosella grandiflora* leaf structure: a – appearance; b - diagram of the cross section; c-mesophyll detail; d - multibeam trichome; e - glandular flask-shaped trichome; g- adaxial epidermis; h – abaxial.

The upper leaf is entire, with an expanded apex and a narrowed base, pubescent with 1-2-celled trichomes. Its structure is more xeromorphic. Stomata are numerous, especially on the abaxial side. The leaf blade is thinner, the mesophyll is denser. On the adaxial side, there are 3 rows of palisade cells with a palisade index of 3.0-3.5, and on the abaxial side - 1.5-2.0. There are 3-5 sclerified vascular bundles in the median vein, 8 lateral bundles; heterophylly and heteromorphism of the structure are clearly expressed.

Tauscheria lasiocarpa. The middle leaf is lamellar with a heart-shaped base, sessile, with a prominent main vein. The epidermis is single-row, flattened from the surface of the cell, their walls are sinuous, on a transverse section with a thickened outer wall. The leaf is amphistomatic. Stomata numerous, small anomocytic and hemiparacytic, not submerged. Mesophyll isolateral-palisade. There are 2 rows of large palisade cells on the adaxial side, and 1 row on the abaxial side. Between them there are 4-5 rows of loose spongy parenchyma. Intercellular spaces are large throughout the mesophyll. The median bundle is sclerified on the abaxial side, the vessels are few (Fig. 16).

Tetracme recurvata. The middle leaf is elongated, pinnatipartite with rounded lobes on a long wide petiole, pubescent with numerous numerous branched trichomes. The epidermis is single-row, small-celled, cells from the surface on the adaxial side are 4-5-sided with straight walls, on the abaxial side they are flattened, with slightly wavy walls. Stomata are small, numerous, anomocytic, hemiparacytic, rarely anisocytic, not submerged.

The mesophyll is isolateral-palisade: on the adaxial side there are 2 rows of palisade cells, on the abaxial side - 1-2. Between them there are 3-4 rows of loose spongy cells, elongated tangentially. The median bundle is small, protruding from the abaxial side, with a few vessels, sclerified. Lateral bundles are small, 11-12 in cross section (Fig. 17).

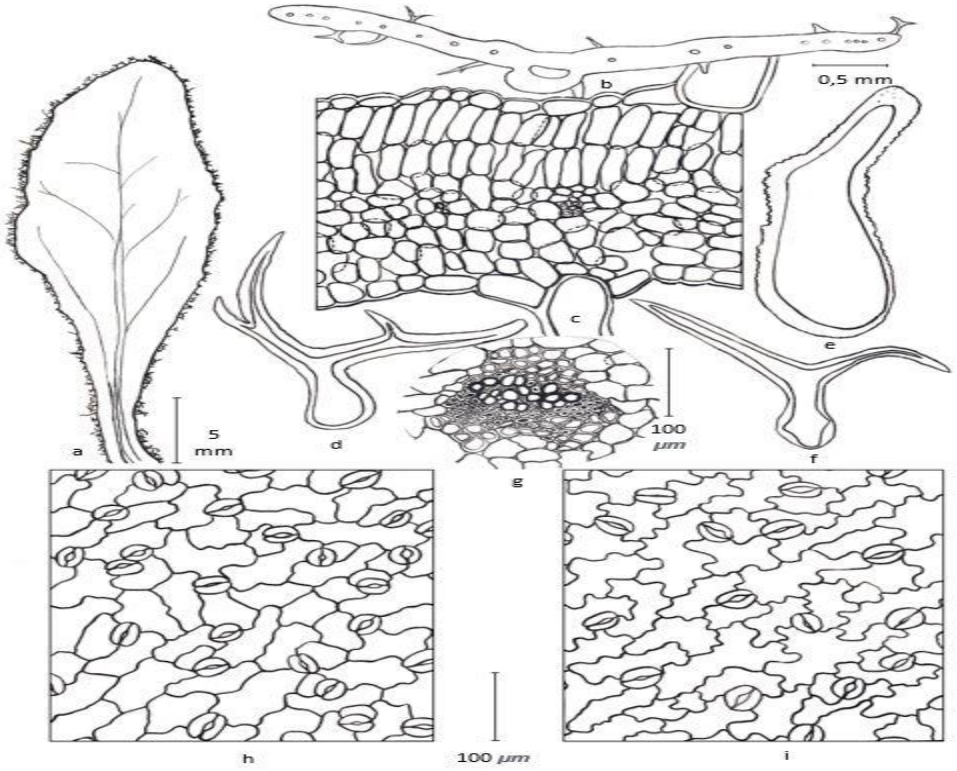

Fig. 14. The structure of the middle leaf of *Strigosella scorpioides*: a – appearance; b - diagram of the cross section; c- mesophyll detail; d, e, f – multibeam trichomes; g - main vein; h-adaxial epidermis; i-abaxial.

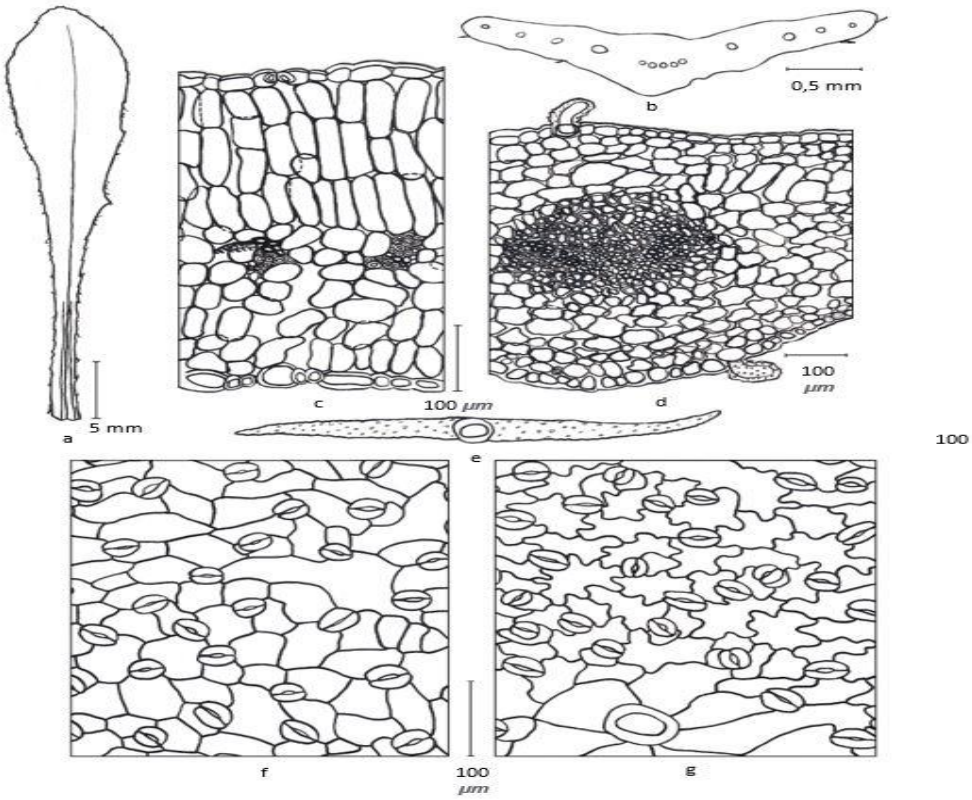

Fig. 15. Structure of the middle leaf of *Streptoloma desertorum*: a – appearance; b - diagram of the cross section; (c) mesophyll detail; d - main vein; e - two-beam trichome; f- adaxial epidermis; g - abaxial.

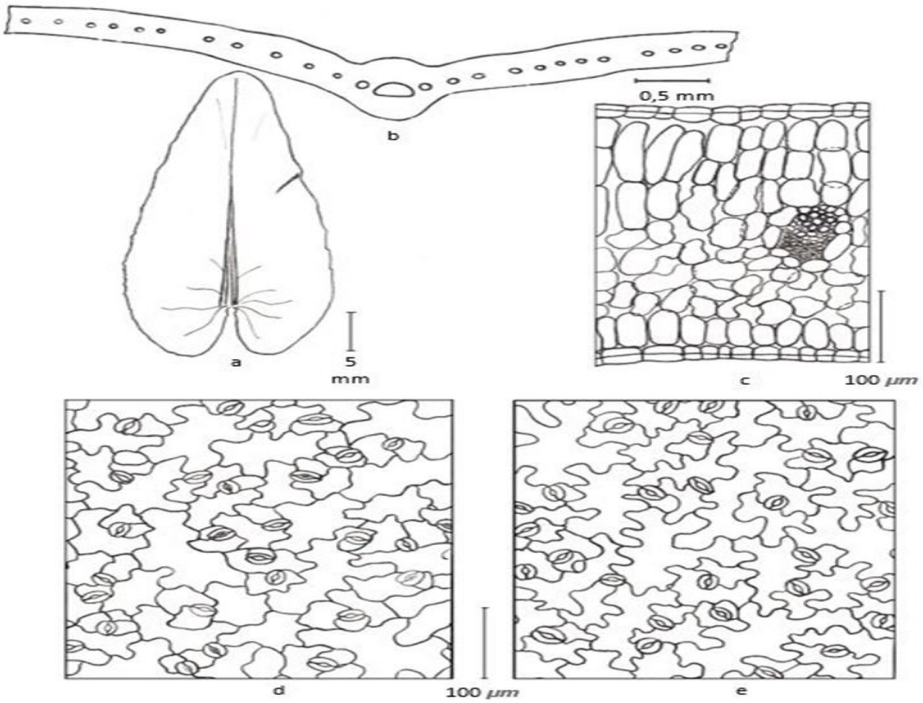

Fig. 16. The structure of the middle leaf of *Tauscheria lasiocarpa*: a - appearance; b - diagram of the cross section; c-mesophyll detail; d – adaxial epidermis; e - abaxial.

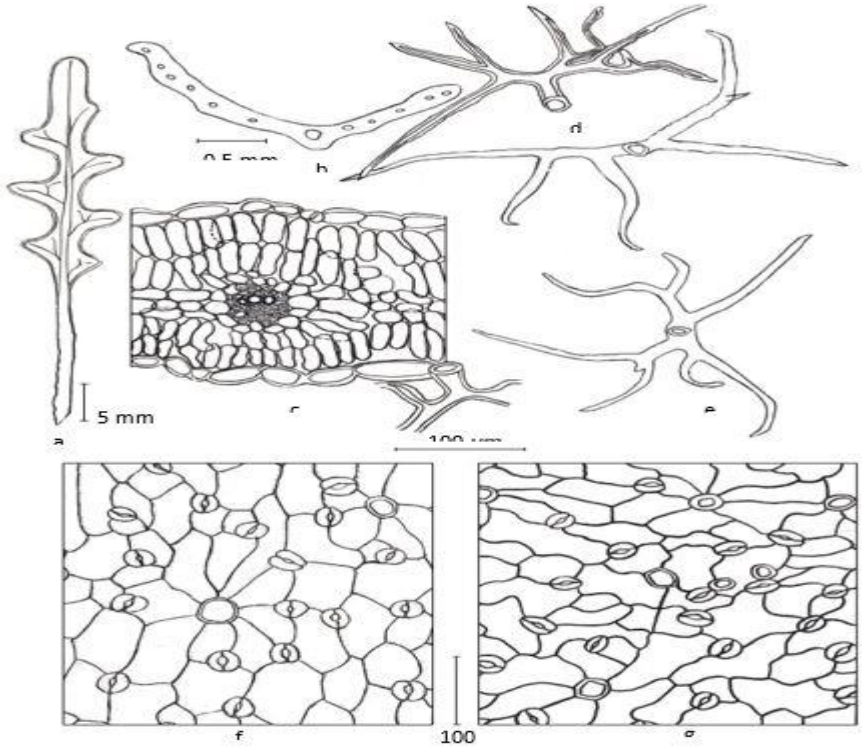

Fig. 17. Structure of a *Tetracme recurvata* leaf: a – appearance; b - diagram of the cross section; c-mesophyll detail; d, e - trichomes; f- adaxial epidermis; g - abaxial.

CONCLUSION

Thus, the leaves of species of the family Brassicaceae are lamellar, serrated (*Diptychocarpus strictus, Tetracme recurvata*) and terete only in *Leptaleum filifolium*. It is pubescent with trichomes of various types: stellate, dendroid (Alyssum, *Meniocus linifolius* species), equal-beam (*Streptoloma desertorum*), unequal-beam (*Strigosella, Leptaleum filifolium* species), unicellular hooked (*Alyssum turkestanicum, Leptaleum filifolium*). The density of pubescence is inversely correlated with the thickness of the outer wall of the epidermis. In densely pubescent species, the outer wall of the epidermis is thin. Epidermal cells are flattened with wavy or tortuous walls. Almost straight cell walls of the adaxial epidermis in *Strigosella* and *Tetracme* species. Stomata are arranged randomly, numerous, not submerged, mostly anomocytic, hemiparacytic, anisocytic. Isolateral-palisade (80% of species) mesophyll prevails with a different ratio of palisade cells 1-1; 3-1, 2-2, 2-3, 3-2. The spongy parenchyma is 4-7 rows with intercellular spaces, especially large in the species *Alyssum, Isatis, Lachnoloma, Strigosella*. Conductive bundles of all types are sclerified. The main protective features of the leaf of species of the family Brassicaceae are pubescence and sclerification of vascular bundles. Other indicators: numerous non-immersed stomata, large intercellular spaces, a thin wall of epidermal cells are signs of mesomorphism. A.F. Ilyinskaya (1986) considers ephemera of the family Brassicaceae (genus *Alyssum*) to be a reduction line of development, in contrast to perennial advanced xeromorphic species. We consider the mesomorphic and xeromorphic lines of development.

REFERENCES

Anar, M, Ainur, S, Manar, T, Saule, M, Zhumagul, MZ, Zheksenbaevna, NA, Bekbolatovna, BA, Zharakovich, MM 2023, Morphological variability of the rare species *Linaria cretacea* in the conditions of the chalk hills in North-Western Kazakhstan. *Caspian Journal of Environmental Sciences*, 21: 1273-1278.

Andryakov, AA, Egamberdievich, SS, Sattorivich, RO, Rustamovna, AM & Xojimuratovna, AD 2019, Ways of Improving Marketing Communications. In 2019 International Conference on Information Science and Communications Technologies (ICISCT), pp. 1-5. IEEE.

Butnik, AA & Timchenko, OV 1987, The structure of the epidermis of leaves of species of the family Chenopodiaceae. *Botanical Journal*, 72: 1021-1030.

Duschanova, GM, Fakhriddinova, DK, Abdinazarov, SK, Aliyeva, NK 2023, Structural and adaptive features of the

vegetative organs of Lophanthus anisatus Benth. in the conditions of the introduction of Uzbekistan. *Caspian Journal of Environmental Sciences*, 21: 921-930.

Mohammed, AF, Ali, ShU & Adamu, IA 2024, Coagulation potentials of the leaves of desert dates, guiera, jujube tree, kamel's foot and mahogany. *International Journal of Innovations in Engineering Research and Technology*, 11: 68-73, https://doi.org/10.26662/ijiert.v11i1.pp68-73

Nkeiruka, NCh, Chukwudi, NI & Ebuka, ChCh 2024, Bleaching of crude palm oil by activated nise clay: process kinetics, isotherm and thermodynamic studies. *International Journal of Innovations in Engineering Research and Technology*, 11: 55-71, https://doi.org/10.26662/ijiert.v11i2.pp55-71

Ploch, S, Rose, LE, Bass, D & Bonkowski, M 2016, High diversity revealed in leaf-associated protists (rhizaria: cercozoa) of brassicaceae. *The Journal of Eukaryotic Microbiology*, 63:| 635–641. https://doi.org/10.1111/jeu.12314

Tkacz, A, Bestion, E, Bo, Z, Hortala, M & Poole, PS 2020, Influence of plant fraction, soil, and plant species on microbiota: A multikingdom comparison. *MBio*, 11. https://doi.org/10.1128/mBio.02785-19

Tripathi Sharma, ShT 2023, Reflections on cross-cultural association in half of a yellow sun. *International Journal of Innovations in Engineering Research and Technology*, 10: 101-103. https://doi.org/10.17605/OSF.IO/HNYTU

Wagh, MKH, Hipparge, T, Mali, A, Kamble, S & Shaikh, S 2024, Tech savvy: smart trolley 2.0 innovation system. *International Journal of Innovations in Engineering Research and Technology*, 11: 104-107. https://doi.org/10.26662/ijiert.v11i2.pp104-107

Wang, W, Jiang, H, Shoukat, A & Usmanovich, BA 2023, Quantifying the impact of green growth and digital transformation on health: new insights from Asian economies. *Environmental Science and Pollution Research*, 30: 107624-107633.

Xidirberdiyevich, AE, Ilkhomovich, SE, Azizbek, K & Dostonbek, R 2020, Investment activities of insurance companies: The role of insurance companies in the financial market. *Journal of Advanced Research in Dynamical and Control Systems*, 12: 719-725.

Xidirberdiyevich, AE, Ilkhomovich, SE, Azizbek, K & Dostonbek, R 2020, Investment activities of insurance companies: The role of insurance companies in the financial market. *Journal of Advanced Research in Dynamical and Control Systems*, 12: 719-725.

Xu, P, Adebayo, TS, Khan, KA, Özkan, O & Shukurullaevich, K 2024, United States' 2050 carbon neutrality: Myth or reality? Evaluating the impact of high-tech industries and green electricity consumption. *Journal of Cleaner Production*, 140855.

Xu, P, Adebayo, TS, Khan, KA, Özkan, O & Shukurullaevich, NK 2024, United States' 2050 carbon neutrality: Myth or reality? Evaluating the impact of high-tech industries and green electricity. *Journal of Cleaner Production*, 440: 140855.

Yu, Z, Farooq, U, Shukurullaevich, NK, Alam, MM & Dai, J 2024, How does inflation rate influence the resource utilization policy? New empirical evidence from OPEC countries. *Resources Policy*, 91: 104862.

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