

Comparative characteristics of the leaf surface ultrastructure of plants of genus *Populus* L.

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Abstract

The article analyses the ultrastructure and morphometric characters of cells and stomata on the adaxial and abaxial surfaces of leaves in *Populus deltoides* Bartr. ex Marsh., *Populus trichocarpa* Torr. & A. Grey, *Populus suaveolens* Fisch. and *Populus nigra* cv. Italica (Du Roi) Moench (Salicaceae). The aim is to identify species-specific and diagnostically significant features at different taxonomic levels under introduction conditions. For the ultrastructure investigation, the middle part of the leaf blade was fixed on brass stubs, coated with a thin layer of gold and examined using a scanning electron microscope. Most important features are shape, size, nature of the leaf surface and the presence of specific structures. The density of epidermal cells and the number of stomata on the adaxial and abaxial surface of the leaf were determined. The hypostomatous leaf type and collenchymatous ultrastructure type were identified in *P. trichocarpa* and *P. suaveolens*, while the amphistomatous leaf type and stomato-faveolus ultrastructure type are observed on both leaf surfaces of *P. deltoides* and on the adaxial leaf surface of *P. nigra* cv. Italica. Morphometric traits of the leaf surface indicate a higher density of adaxial epidermal cells in *P. nigra* cv. Italica, *P. suaveolens* and *P. trichocarpa* compared to the abaxial surface. Structural organization of the leaf in *P. deltoides*, *P. nigra* cv. Italica, *P. suaveolens* and *P. trichocarpa* allows to identify these taxa on the basis of micromorphological features and suggests their broad ecological plasticity.

Key words: abaxial surface, adaxial surface, cells, epidermis, morphometric features, stomata, stomatal index.

Introduction

The influence of the environment on plants is determined not only by the nature of the

acting factors but also by the genetic specificity of the organism, characterized by its ecological nature. The most flexible organ of plants is the leaf, whose structure re-

flects not only the eco-climatic conditions, in which the species developed, but also the organism's response to the conditions of the external environment in which the plant is currently situated (Ishchuk 2016, Ishchuk and Ishchuk 2018). The study of the anatomical and morphological structure of leaves allows deeper ecological characterization of the plant organism and helps determine the degree of its adaptation to environmental conditions, especially during the process of introduction (Gorlacheva 2010, Brailko 2014). Due to the difficulties that arise in distinguishing species within critical genera of flowering plants based on a series of macro-morphological leaf characteristics, data from other studies are employed, particularly those related to the anatomical structure of leaves (Metcalfe and Chalk 1950, Juniper 1959, Aneli 1975, Carolin, 1980, Chakrabarty and Mukherjee 1986, Shetler and Morin 1986, Barthlott et al. 1998). Waxes are an essential structural element of the surface and of fundamental functional and ecological importance for the interaction between plants and their environment (Barthlott et al. 1998).

Such studies are particularly relevant for the identification of hybrids within genus *Populus*, whose leaves are morphologically very similar. Researchers have attributed crucial importance to the features of the ultrastructure of the leaf surface as diagnostic criteria for distinguishing taxa and understanding the ecological characteristics of species (Chen et al. 2008, Su et al. 2009). Characters, such as shape, size and density of stomatal complexes, were very useful in differentiating *Salix* species. Variation in features of stomatal apparatus in *Salix* is wider than previously known. Moreover, the type of stomatal complex proved to be very helpful in discriminating *Chosenia* Nakai as members

of genus *Salix* (Ghahremaninejad et al. 2012). Leaf ultrastructure is also closely associated with drought resistance of species (Mytyna 2007, Ishchuk 2017, Ishchuk and Ishchuk 2019) and resistance to pollution by dust and heavy metals (Ishchuk et al. 2018, Ishchuk and Ishchuk 2020).

American scientists (Russin and Evert 1984) studied the vascular system and the spatial relationship of various orders of vascular bundles to the mesophyll of *P. deltoides* leaves in field conditions and in special growth chambers. They found that the adaxial and abaxial parenchyma of isolateral leaves grown in growth chambers had thinner lobes, a greater proportion of air space and greater interveinal spacing than in field-grown plants.

Chinese researchers, analysing the anatomical structure of leaves in polyploid hybrids of *P. ussuriensis* Kom., found that tetraploid hybrids were characterized by the thickest leaves, epidermis, columnar parenchyma tissues and the ratio of columnar to spongy parenchyma tissues compared to diploid hybrids of this species (Chuan 2010).

Therefore, the goal of our study was to establish the features of the ultrastructure of leaf epidermis in introduced species and hybrids of *Populus deltoides* Bartr. ex Marsh., *Populus trichocarpa* Torr. & A. Grey, *Populus suaveolens* Fisch. and *Populus nigra* cv. *Italica* (Du Roi) Moench., and to identify the species-specific and diagnostic significance of these characteristics at various taxonomic levels under introduction conditions.

Materials and Methods

The material for the study consisted of leaves from the middle part of the crown of young 8–10-year-old plants of *Popu-*

lus deltoides, *Populus nigra* cv. Italica, *Populus suaveolens* and *Populus trichocarpa* from the collection of the Botanical Garden of Bila Tserkva National Agrarian University. The studied species come from different regions of the globe. The natural range of *P. deltoides* occupies the eastern regions of North America, *P. trichocarpa* – the western part of North America, *P. suaveolens* – Eastern Siberia, Mongolia and Northern China, *P. nigra* cv. Italica is the territory of Central and Asia Minor (Ishchuk 2019). For the ultrastructure investigation, the middle part of the leaf blade was fixed on brass stubs and coated with a thin layer of gold. The surface ultrastructure was examined using a scanning electron microscope (SEM) JSM-6060 LA. Digital images were captured with an AxioCam MRC-5 camera and processed using the Axio Vision 4.8 software. The study was conducted with five replicates. The ultrastructure of the leaves was described using the commonly accepted methodology and terminology (Aneli 1975). Among the external characteristics, most important were shape, size, surface characteristics of the leaf and the presence of specific structures. According to Barthlott and Wollenweber (1981), primary and secondary structures of the leaf epidermis are distinguished.

The primary structure is determined by:

- General outlines of cells in the paradermal plane (isodiametric or elongated);
- Shape of the external periclinal wall (convex, concave, flat);
- Shape of anticlinal walls (straight, wavy, thickened, not thickened);
- Outlines of visible cell boundaries on the surface.

The secondary structure is primarily determined by the morphological features of the cuticle (Barthlott and Wollenweber

1981). Following the widely accepted botanical terminology (Stern and Morris 1992), in cells of elongated shape, the anticlinal walls farthest from the cell centre are referred to as distal, while those closer to the cell centre and perpendicular to the distal walls are termed proximal.

The quantity of cells per 1 mm² of the adaxial and abaxial epidermis of the leaf was determined. If the quantity of cells on the adaxial surface is less than 400 and on the abaxial surface is less than 600 per 1 mm², they are considered very large. If the quantity of cells on the adaxial surface of the epidermis is between 401–900, and on the abaxial surface is between 601–1350 per 1 mm², these cells are classified as large according to the author's classification. Cells of medium size on the adaxial surface may be present in quantities of 901–1600 per 1 mm² on the adaxial surface and 1351–2400 on the abaxial surface. Conversely, cells in quantities of 1601–2500 on the adaxial surface and 2401–3750 per 1 mm² are considered small, and if their quantity is even greater, the author considers them very small.

If the quantity of stomata per 1 mm² on the adaxial surface of the leaf is less than 10, they are classified as solitary; if they are between 11 and 100, it is considered small quantity; 101–150 is an average quantity; 151–250 is a large quantity, and above 251 is considered very large. For the abaxial surface, if the quantity of stomata is less than 100 per 1 mm², their sizes are classified as very small; 101–160 as small; 161–250 as medium; 251–360 as large; 361–490 as very large, and above 491 as extremely large stomatal quantity.

The quantity of stomata was determined in the microscope field by counting per 1 mm² of the epidermal surface. The stomatal index was expressed as the ratio

of the quantity of guard cells of stomata to the total quantity of epidermal cells, including both guard cells and other epidermal cells, on the same area, expressed as a percentage by formula (1)

$$I = \frac{100 \cdot 2n}{2n + m}, \quad (1)$$

where: I is stomatal index, %; n is quantity of guard cells of stomata per 1 mm²; m is total quantity of epidermal cells per 1 mm² (including guard cells and other epidermal cells).

The statistical analysis of the obtained data was performed using the Microsoft Excel software application.

Results

Among the species of genus *Populus*, we investigated the ultrastructure of the leaf surfaces of four species: *P. deltoides*, *P. nigra* cv. Italica, *P. suaveolens* and *P. trichocarpa*, the descriptions are provided below.

The projections and outlines of epidermal cells vary: in the region of vascular bundles, cells with elongated projections

and straight outlines are observed, while above the moesophyll, cells are angular (four- to five-sided) with straight, uniformly thickened anticlinal walls. The external periclinal walls are characterized by a granular texture. The surface relief is reticulate, and the subtype is reticulate-comminuted. The cuticle is well-developed, and the epicuticular wax is represented by flakes.

For *P. deltoides*, the leaf is characterized by an amphistomatous structure, with paracytic and anomocytic stomata evenly distributed on both surfaces of the leaf blade at the same level as the main epidermal cells. The adaxial surface of the leaf blade of this species is reticulate (Fig. 1).

In *P. deltoides*, the abaxial surface is structurally similar to the adaxial one (Fig. 2) but differs primarily in a more pronounced wrinkling of the cuticle compared to the adaxial surface.

For *P. nigra* cv. Italica, the leaf is characterized by an amphistomatous type, with anomocytic and paracytic stomata evenly distributed on both upper and lower epidermis of the leaf blade, at the same level as the main epidermal cells. The ad-

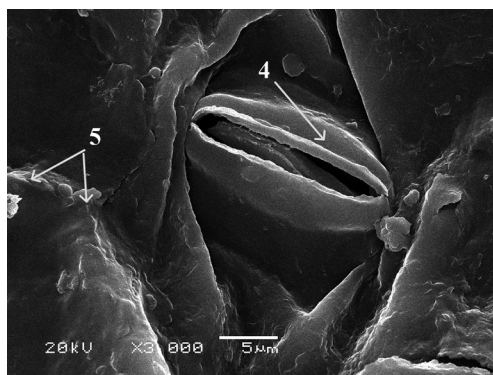
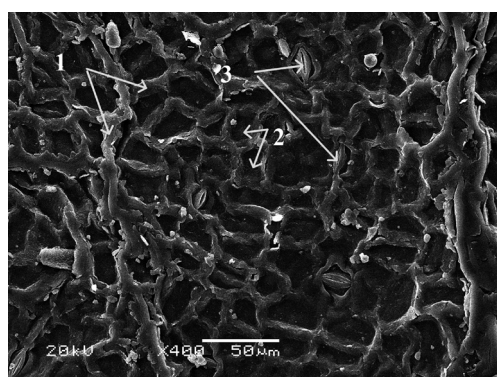


Fig. 1. Ultrastructure of the adaxial epidermis of the leaf blade of *P. deltoides*: 1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells, 3 – stomata, 4 – stoma, 5 – epicuticular wax.

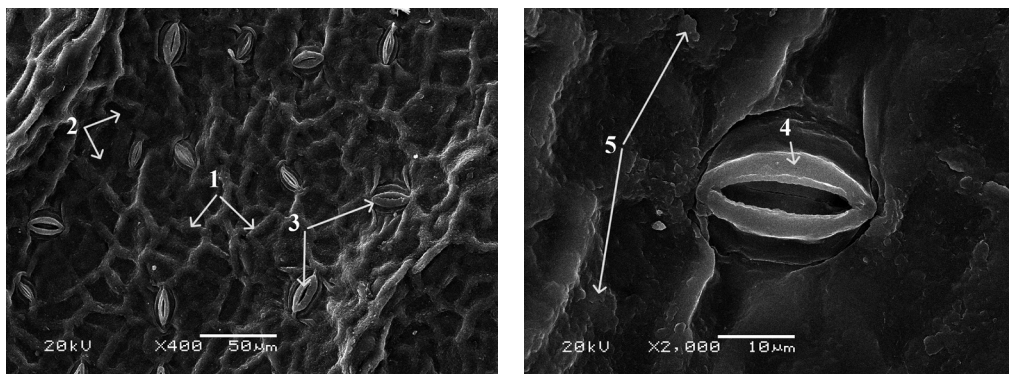


Fig. 2. Ultrastructure of the abaxial epidermis of the leaf blade of *P. deltoides*:
1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells,
3 – stomata, 4 – stoma, 5 – epicuticular wax.

axial epidermis of the investigated hybrid is characterized by a reticulate-communited subtype of relief with deeply concave periclinal walls of cells and a granular ultrasculpture (Fig. 3).

The cell boundaries are on the adaxial surface of *P. nigra* cv. *Italica* distinct. Projections and outlines of epidermal cells vary: in the area of vascular bundles, cells with elongated projections and straight outlines are observed, while above the mesophyll, cells are angular (triangular, quadrangular) with straight, thickened anticlinal walls. The cuticle is well-devel-

oped. Epicuticular wax is represented by wax flakes and wax plates.

In the studied hybrid *P. nigra* cv. *Italica*, the abaxial surface differs from the adaxial one. On the abaxial surface there are stomata of the paracytic type. On the abaxial surface of the leaf, epidermal cells are not clearly visible. Abaxial epidermal cells have sinuous outlines and spread projections above the mesophyll, with sinuous outlines and elongated projections in the region of the midvein. The surface relief is colloquially ostiate (Fig. 4). The wax is represented by wax flakes.

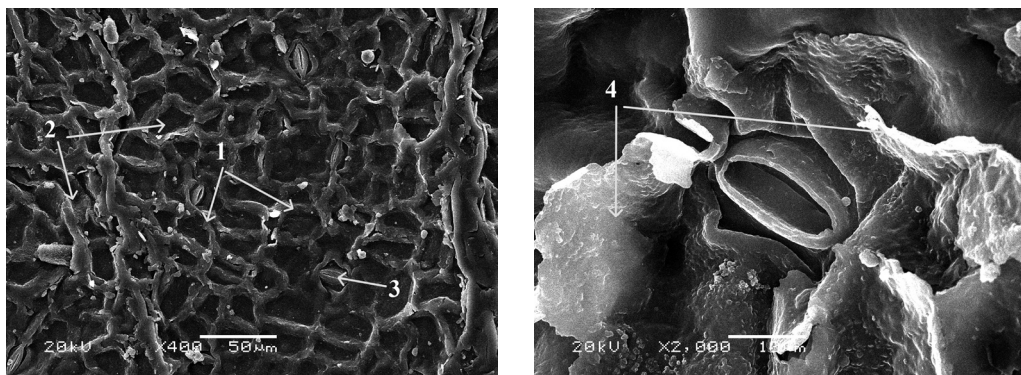


Fig. 3. Ultrastructure of the adaxial epidermis of the leaf blade of *P. nigra* cv. *Italica*:
1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells, 3 – stomata,
4 – epicuticular wax.

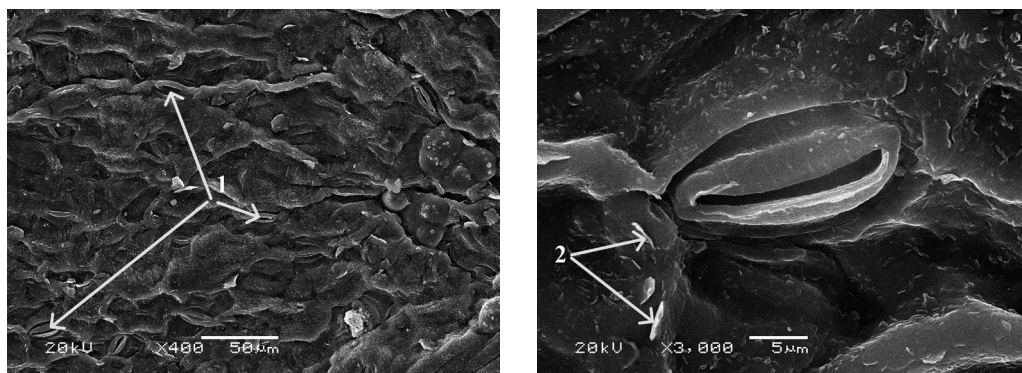


Fig. 4. Ultrastructure of the abaxial epidermis of the leaf blade of *P. nigra* cv. *Italica*: 1 – stomata, 2 – wax.

Leaf of *P. suaveolens* is hypostomatic, with paracytic stomata evenly distributed on the abaxial surface of the leaf blade, at the same level as the main epidermal cells. The adaxial surface of the leaf blade of the studied species is collicular. Cell boundaries are clear (Fig. 5).

Projections and outlines of epidermal cells vary: in the area of vascular bundles, cells with elongated projections and straight outlines are observed, while above the moesophyll, cells are angular (triangular, quadrangular) with straight, non-thickened anticlinal walls. External periclinal walls are convex, thin, charac-

terized by smooth texture. The cuticle is well-developed. Epicuticular wax is represented by wax plates.

In *P. suaveolens*, abaxial surface of the leaf differs from the adaxial one. Cells of the abaxial epidermis are characterized by winding outlines and spread projections over the moesophyll, while in the area of the midrib, they have winding outlines and elongated projections. Stomata are of the paracytic type. Closing cells of stomata are characterized by a distinctly striate cuticle, whereas the periclinal walls of the main epidermal cells are characterized by a smooth cuticle (Fig. 6). The relief

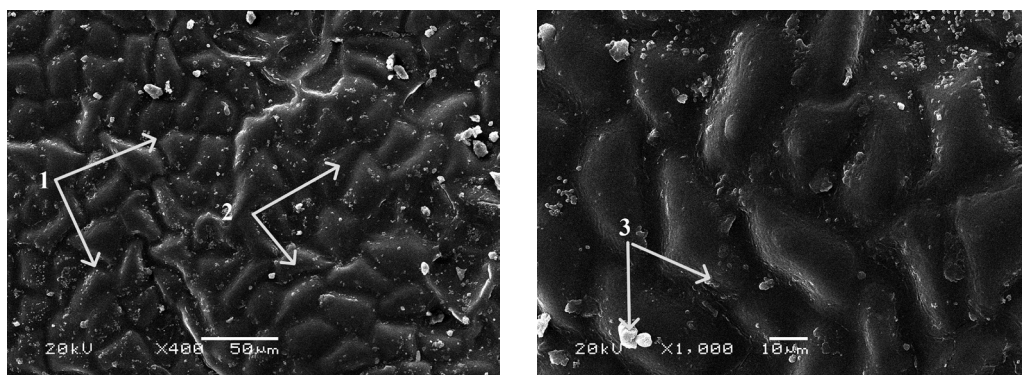


Fig. 5. Ultrastructure of the adaxial epidermis of the leaf blade of *P. suaveolens*: 1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells, 3 – epicuticular wax.

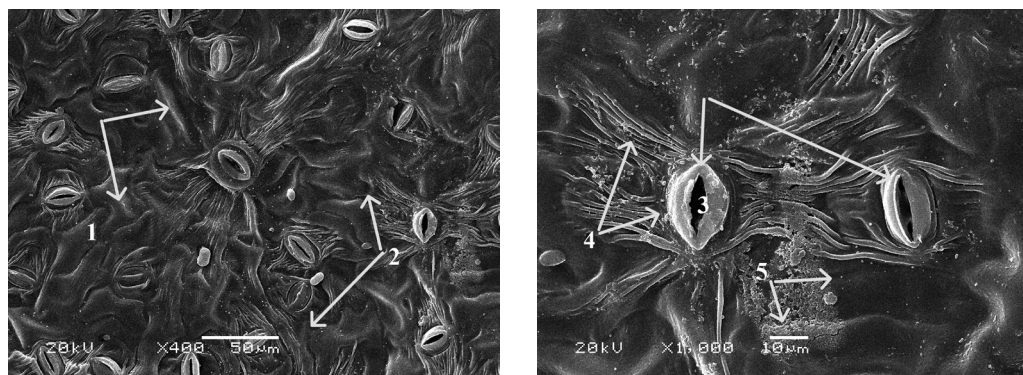


Fig. 6. Ultrastructure of the abaxial epidermis of the leaf blade of *P. suaveolens*:
 1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells,
 3 – stomata, 4 – cuticle, 5 – wax.

of the surface is colloquial. The periclinal walls of the cells are characterized by a smooth texture. Epicuticular wax is represented by wax granules and wax plates.

The leaf of *P. trichocarpa* is hypostomatic, with paracytic stomata (socio-vate-like according to Aneli 1975), evenly distributed on the abaxial surface of the leaf blade, at the same level as the main epidermal cells. The adaxial surface of the leaf blade of this species is collicular. Cell boundaries are clear (Fig. 7). Projections and outlines of epidermal cells vary: in the

region of vascular bundles, there are cells with elongated projections and straight outlines, while above the moesophyll, cells are angular (triangular, quadrangular) with straight, non-thickened anticlinal walls.

The external periclinal walls of *P. trichocarpa* cells are convex, thin and characterized by a smooth texture. The cuticle is well-developed. The relief is collicular. The periclinal walls of epidermal cells have a smooth texture, and the anticlinal walls are not raised or thickened. The epicuticular

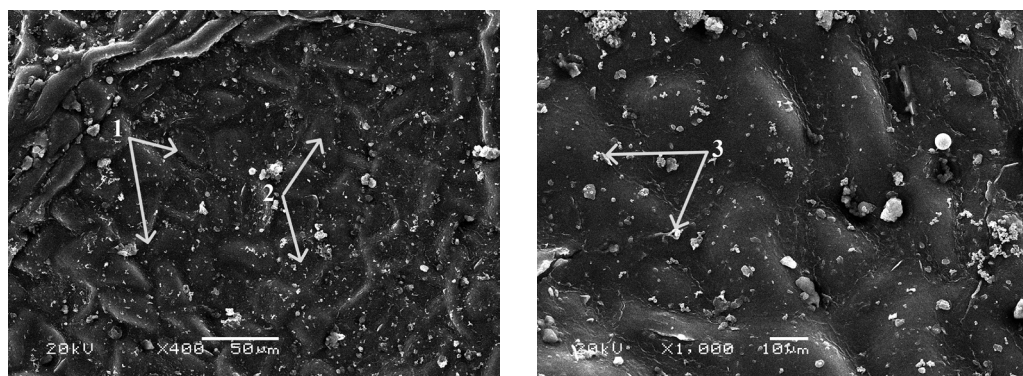


Fig. 7. Ultrastructure of the adaxial epidermis of the leaf blade of *P. trichocarpa*:
 1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells,
 3 – epicuticular wax.

wax is represented by wax granules.

In *P. trichocarpa*, the abaxial surface differs from the adaxial one. The cells of the abaxial epidermis are characterized

by wavy outlines and projections spread over the moesophyll, with wavy outlines and elongated projections in the region of the midvein (Fig. 8).

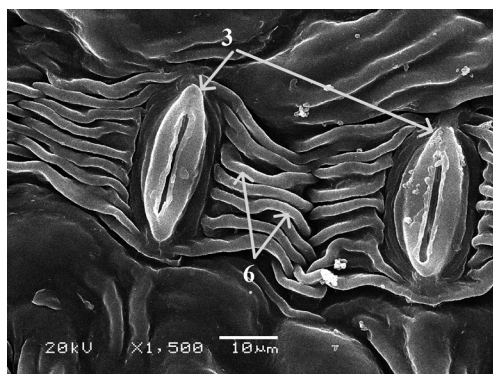
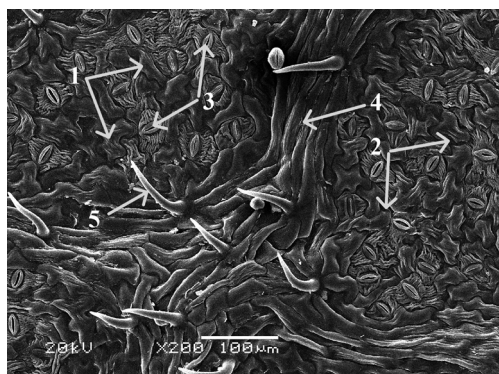


Fig. 8. Ultrastructure of the abaxial epidermis of the leaf blade of *P. trichocarpa*:
1 – anticlinal walls of epidermal cells, 2 – periclinal walls of epidermal cells, 3 – stomata,
4 – epidermal cells in the area of the central vein, 5 – trichomes, 6 – cuticle.

The stomata in *P. trichocarpa* are of the paracytic type. The closing cells of the stomata are characterized by a distinctly striate cuticle, while the periclinal walls of the main epidermal cells are characterized by a smooth cuticle. Leaf veins are covered with trichomes. The “hooks” are two-celled, formed by an isodiametric basal cell and a

long distal cell. The surface relief is collicular, and the periclinal walls of the cells are characterized by a smooth texture.

Thus, the ultrastructure of the adaxial surface in *P. suaveolens* and *P. trichocarpa* is of the collicular type, while in *P. deltoides* and *P. nigra* cv. *Italica*, it is of the reticulate type (Table 1).

Table 1. Characteristics of the ultrastructure of the leaf surface of species and hybrids of the genus *Populus*.

Species	The type or sub-type of the ultra-structure of the surface	Cell shape	Anticlinal walls		Periclinal walls	
			nature of thickening	level	level	ultra-sculpture
Adaxial epidermis						
<i>P. deltoides</i>	reticulate type reticulate-faveolus subtype	polygonal	uniformly thickened	considerably elevated	concave	granular
<i>P. nigra</i> cv. <i>Italica</i>	reticulate-faveolus	angular	uniformly thickened	raised	deeply concave	granular
<i>P. suaveolens</i>	collenchymatous	spreading	uniformly thickened	below peri- clinal walls	convex	granular
<i>P. trichocarpa</i>	collenchymatous	angular	not thick- ened	below peri- clinal walls	convex	smooth

Species	The type or sub-type of the ultra-structure of the surface	Cell shape	Anticlinal walls		Periclinal walls	
			nature of thickening	level	level	ultra-sculpture
Abaxial epidermis						
<i>P. deltoides</i>	reticulate type reticulate-faveolus subtype	polygonal	uniformly thickened	considerably elevated	concave	granular
<i>P. nigra</i> cv. <i>Italica</i>	collenchymatous-coriaceous	elongated-spread-ing	uniformly thickened	below periclinal walls	convex	granular
<i>P. suaveolens</i>	collenchymatous	spreading	uniformly thickened	below periclinal walls	convex	smooth, stream-wise-wrinkled
<i>P. trichocarpa</i>	collenchymatous	spreading	not thickened	below periclinal walls	convex	stream-wise-wrinkled, smooth

Morphometric characteristics of the ultrastructure of leaf surfaces in species and hybrids of *Populus* indicate a higher density of adaxial epidermal cells in *P. nigra* cv. *Italica*, *P. suaveolens*, *P. trichocarpa* compared to the abaxial surface

(Table 2). The stomatal index values in *P. deltoides* and *P. nigra* cv. *Italica*, with an amphistomatous leaf type, indicate that the number of stomata on the adaxial surface is less than on the abaxial surface.

Table 2. Morphometric characteristics of the ultrastructure of leaf surfaces in species and hybrids of the genus *Populus*.

Species, hybrid	Adaxial epidermis		Abaxial epidermis		Stomatal index, %	
	number of cells per 1 mm ²	number of stomata per 1 mm ²	number of cells per 1 mm ²	number of stomata per 1 mm ²	adaxial epidermis	abaxial epidermis
<i>P. deltoides</i>	1561.1 ±11.8	109.1 ±0.45	1918.1 ±21.42	191.8 ±0.65	12.3	16.7
<i>P. nigra</i> cv. <i>Italica</i>	2123.0 ±23.1	68.5 ±0.65	1850.2 ±13.2	219.0 ±0.54	6.1	19.14
<i>P. suaveolens</i>	1438.0 ±0.74	-	1023.0 ±4.8	167.0 ±0.48	-	24.61
<i>P. trichocarpa</i>	1315.0 ±2.78	-	1000.0 ±1.43	100.0 ±0.46	-	16.7

Note: Columns 2–5 represents mean ±standard error.

The adaxial surface of the leaves of *P. deltoides*, *P. suaveolens* and *P. trichocarpa* is characterized by cells of medium size, while for *P. nigra* cv. *Italica* small cells are typical (Table 3). On the abaxial surface, large cells are characteristic for the leaves of *P. suaveolens* and *P. trichocarpa*, and medium-sized cells are typical for *P. deltoides* and *P. nigra* cv. *Italica*.

Discussion

The results of the ultrastructural studies of the leaves of *P. deltoides*, *P. nigra* cv. *Italica*, *P. suaveolens* and *P. trichocarpa* show that, overall, they are characterized by plasticity. This is supported by studies on the ultrastructure of *P. alba* L. leaves, where parenchymal cells were elongated

Table 3. Morphometric characteristics (mean $\pm$ standard error) of epidermal cells and stomata of leaves of *Populus* species and hybrids, μm .

Species, hybrid	Epidermis		Stomata	
	cell length	cell width	stomatal length	stomatal width
Adaxial epidermis				
<i>P. deltoides</i>	34.2 $\pm$ 1.3	30.1 $\pm$ 2.5	28.5 $\pm$ 0.62	30.85 $\pm$ 0.85
<i>P. nigra</i> cv. Italica	42.55 $\pm$ 2.25	36.42 $\pm$ 0.26	24.83 $\pm$ 0.7	20.11 $\pm$ 0.22
<i>P. suaveolens</i>	48.75 $\pm$ 2.45	25.67 $\pm$ 0.65	-	-
<i>P. trichocarpa</i>	52.65 $\pm$ 1.25	31.75 $\pm$ 0.88	-	-
Abaxial epidermis				
<i>P. deltoides</i>	26.2 $\pm$ 3.1	21.3 $\pm$ 1.1	37.5 $\pm$ 1.15	28.65 $\pm$ 1.12
<i>P. nigra</i> cv. Italica	28 $\pm$ 1.15	25.15 $\pm$ 0.50	48.35 $\pm$ 2.08	36.85 $\pm$ 0.45
<i>P. suaveolens</i>	36.42 $\pm$ 0.75	19.45 $\pm$ 0.42	24.0 $\pm$ 0.925	20.15 $\pm$ 0.75
<i>P. trichocarpa</i>	40.44 $\pm$ 0.92	15.67 $\pm$ 0.66	21.45 $\pm$ 0.35	18.23 $\pm$ 0.38

in plants taken from field conditions, enhancing intercellular CO₂ exchange and increasing photosynthetic capacity compared to leaves taken from an artificial phytotron (Lin et al. 2022). The plasticity of leaves is also supported by the conclusions of Redko (1966), who, based on moisture requirements, classified all species of genus *Populus* growing in Ukraine into three groups: xeromoesophytes (*P. alba*, *P. × canescens*, *P. suaveolens*, *P. tremula*, *P. trichocarpa*), moesophytes (*P. nigra* cv. Italica, *P. bolleana*, *P. balsamifera*, *P. × euramericana* cv. 'Serotina'), moesohygrophytes (all other Euro-American hybrids).

For *P. suaveolens* and *P. trichocarpa*, hypostomatous leaf type is characteristic, while for *P. deltoides* and *P. nigra* cv. Italica it is amphistomatous. The exclusive presence of stomata on the adaxial surface of the leaf might suggest adaptation to growth in arid habitats. Nitrogen-enriched anatomical changes in the leaves and adjustments of stomatal behaviour during drought stress in *Populus* species lead to reduced water loss and improved plant growth during dry periods (Lu et al. 2019). Positive correlations between biomass production and abaxi-

al stomatal density were observed in the leaves during the third growing season of the second rotation of high-density *P. deltoides* and *P. nigra* coppice (Al Afas et al. 2007). Researchers also note that in *P. deltoides* and *P. nigra* plants, the spongy parenchyma layer was thinner than the palisade layer, indicating their resilience to drought. Regarding stomatal density on the abaxial surface of the leaf epidermis, there is a pattern where species with a more southern origin tend to have fewer stomata per unit area of leaf epidermis. According to the stomatal density scale on the adaxial surface of leaves in *P. nigra* cv. Italica has low stomatal density, while *P. deltoides* has medium stomatal density. On the abaxial surface of the leaves in *P. trichocarpa*, the density of stomata is low, while the rest of the studied species have an average density of stomata. Studying the anatomical structure of *P. deltoides* hybrids in the southern mountainous regions of China, scientists found that the stomatal density of maternal and parental individuals in the upper and lower parts of the leaf epidermis varied in proportions ranging from 0.08 to 0.55 (Liu et al. 2018). Our studies on leaves of the parental individual *P. deltoides* showed a stomatal den-

sity of 0.12 on the adaxial side and 0.16 on the abaxial side, which coincides with research conducted in China. Analysis of quantitative characters of leaf surface ultrastructure suggests that species originating from a warmer climate (*P. trichocarpa*, *P. suaveolens*, *P. nigra* cv. *Italica*) exhibit higher density of adaxial epidermal cells compared to the abaxial ones.

All these patterns, in our opinion, indicate the adaptation of species of more southern origin (*P. nigra* cv. *Italica*, *P. suaveolens* and *P. trichocarpa*) to reduce transpiration, enhancing their drought resistance. At the same time, species like *P. deltoides* and *P. nigra* cv. *Italica*, with an amphistomatous leaf type, appear to be more environmentally flexible and occupy a much broader range, both in nature and in cultivation in Ukraine.

Conclusions

Leaves of *Populus* species are morphologically very similar and, therefore, it is quite difficult to identify them. It has been observed that *P. nigra* cv. *Italica* and *P. deltoides* exhibit an amphistomatous leaf type, while *P. trichocarpa* and *P. suaveolens* have a hypostomatous leaf type. The ultrastructural type is collicular in *P. suaveolens* and *P. trichocarpa*, while it is reticulate-complex in *P. nigra* cv. *Italica* and *P. deltoides*. The shape of cells on the adaxial surface is similar in *P. trichocarpa* and *P. nigra* cv. *Italica*. Periclinal walls of leaf cells in *P. nigra* cv. *Italica*, *P. suaveolens* and *P. deltoides* on the abaxial surface are granular, while in *P. trichocarpa* they are smooth. Trichomes are characteristic only for the veins of *P. trichocarpa* leaves on the abaxial surface, in the rest of the studied species, trichomes are absent on both leaf surfaces.

In all examined samples, except for *P. trichocarpa*, the epidermal cells of the adaxial surface of the leaf and, in the case of *P. nigra* cv. *Italica* and *P. deltoides*, the abaxial surface of the leaf, are of medium size. Medium-sized epidermal cells are characteristic of the adaxial surface of *P. trichocarpa*. Large epidermal cells are typical for *P. suaveolens* and *P. trichocarpa*.

The structural organization of elements, including number of cells, their sizes, number and arrangement of stomata and covering tissues of the leaves of *P. deltoides*, *P. nigra* cv. *Italica*, *P. suaveolens* and *P. trichocarpa*, helps identify these species based on morphometric features. It demonstrates their wide ecological plasticity and ability to adapt to various changing environmental conditions, including those encountered during introduction or cultivation.

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