Agrobiodiversity for Improving Nutrition, Health and Life Quality

Research Article OPEN ACCESS

Morphological Structure of Infructescence, Fruits, and Seeds of Some Species of the Genus *Liquidambar* L. in Species Identification

Nina Smilyanets*, Tetyana Vakulenko, Igor Svitylko

M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

Nina Smilyanets: https://orcid.org/0009-0002-8471-263X
Tetiana Vakulenko: https://orcid.org/0009-0002-9541-4462
Igor Svitylko: https://orcid.org/0009-0002-6112-8019

Article Details:
Received: 2024-04-28
Accepted: 2024-05-26
Available online: 2024-05-31

DOI: https://doi.org/10.15414/ainhlq.2024.0012

To improve the human living space in an urbanized environment, there is a growing need to use new species and forms of ornamental trees and shrubs in urban landscaping. Plants of the genus *Liquidambar* L. are increasingly used in the landscapes of large cities and industrial centers. The genus *Liquidambar* includes 15 species, 3 of which are found in Ukraine: *Liquidambar formosana* Hance, *L. orientalis* Mill., *L. styraciflua* L. In the M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine National Botanic Garden (NBG), studies of the distribution of these species were carried out, but the most urgent task of these studies is to determine the species belonging to plants, which is extremely important for botanical institutions that have a significant assortment of trees and shrubs that are the most ecologically stable and tested. The morphological structure of fruits and seeds is one of the most important in determining the species. Morphological studies of infructescences, fruits, and seeds of the plants of *Liquidambar* species were conducted at the NBG, and its species affiliation was determined. The following characteristics were studied: the shape and structure of the infructescence, peduncle, fruit, seed, and wing; features of the location of the fruits; form of extrafloral structures; shape and size of cells of the seed coat. By comparing the obtained data with the morphological descriptions of *L. orientalis* and *L. styraciflua*, it was possible to determine the species belonging to the plants of the *Liquidambar* genus growing in the NBG. Based on these features, it was determined that an unidentified species, collected in NBG, belong to the species *L. styraciflua*. Identifying the species of the genus *Liquidambar* for the botanical institution provides an opportunity to conduct research and recommend *L. styraciflua* for wider use in Ukraine.

Keywords: sweetgum plant, ornamental woody plants, morphological studies, infructescence, fruit, seed, species identification

Introduction

With the development of the urbanized environment, the need for a balanced living space for human existence increases. Highly productive and viable green spaces can provide people with more comfortable living conditions, reducing the anthropogenic influence on the environment (Levon, 2008). This encourages the new plant species used to improve the environment, which would meet the complex requirements for sustainability in megacities. Improvement

***Corresponding Author:** Nina Smilyanets, M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, 1 Sadovo-Botanichna str., 01014 Kyiv, Ukraine
n.smilyanets@nas.gov.ua

of landscaping techniques and enrichment of the species composition of urban green spaces, enrichment of their taxonomic composition with new plant species and forms is a strategic direction in the development of the landscape construction industry (Kohno and Kuznetsov, 2005; Kucheriavyi and Kucheriavyi, 2020).

Botanical institutions play an extraordinary role in this process as centers of plant introduction and conservation (Zaimenko et al., 2022). The collections of botanical gardens and arboretums in Ukraine now have an extremely large assortment of trees and shrubs that are the most tested, decorative, and environmentally sustainable (Kuznetsov et al., 2013; Kucheriavyi and Kucheriavyi, 2020).

Determining the species affiliation of plants is essential for botanical institutions that have collections of living plants or herbaria. The collections of plants of the M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (NBG) and the Botanical Garden of Yuriy Fedkovych Chernivtsi National University contain plants of the genus *Liquidambar* L. that require species identification.

Traditionally, the genus *Liquidambar* was considered such as part of the subfamily Altingioideae of the family Hamamelidaceae (Endress, 1989; Li, 1997; Li and Donoghue, 1999; Mosyakin and Fedoronchuk, 1999; Zhiyun et al., 2003) or was distinguished as part of the subfamily Liquidambaroideae (Bogle, 1986; Ickert-Bond and Wen, 2006). Some authors, emphasizing the similarity between *Liquidambar* and *Altingia*, have separated them into a separate family Altingiaceae (Shi et al., 2001; Ickert-Bond and Wen, 2006). To date, the unification of these genera into a special taxonomic group of generic rank based on several morphological characters is considered quite reasonable and supported by most researchers (Ickert-Bond et al., 2005; Ickert-Bond and Wen, 2013).

The genus *Liquidambar* in the world flora is represented by several species that are relics of the Tertiary and Cretaceous flora such as *L. formosana* and L. acalycina Hung T. Chang. They are distributed in East Asia (central, southern and southwestern China, Taiwan). Plants of *L. styraciflua* are distributed in North America (east coast), and *L. orientalis* in West Asia (southwest Asia Minor, Cyprus) (Li and Donoghue, 1999; Kokhno et al., 2002; Ickert-Bond et al, 2005; Bilous, 2020; Bulgakova, 2020). Some researchers recognize only 4 species belonging to the genus *Liquidambar* (Kokhno et al., 2002; Ouyang et al., 2016).

According to the modern classification, the genus *Liquidambar* belongs to class Equisetopsida, subclass Magnoliidae, order Saxifragales, family Altingiaceae, and is represented by 15 species: *Liquidambar acalycina* H.T.Chang, *L. cambodiana* (Lecomte) Ickert-Bond & J.Wen, *L. caudata* (H.T.Chang) Ickert-Bond & J.Wen, *L. chinensis* Champ. ex Benth., *L. chingii* (F.P.Metcalf) Ickert-Bond & J.Wen, *L. excelsa* (Noronha) Oken, *L. formosana* Hance, *L. gracilipes* (Hemsl.) Ickert-Bond & J.Wen, *L. multinervis* (W.C.Cheng) Ickert-Bond & J.Wen, *L. obovata* (Merr. & Chun) Ickert-Bond & J.Wen, *L. orientalis* Mill., *L. poilanei* (Tardieu) Ickert-Bond & J.Wen, *L. siamensis* (Craib) Ickert-Bond & J.Wen, *L. styraciflua* L., *L. yunnanensis* (Rehder & E.H.Wilson) Ickert-Bond & J.Wen. These species have native and introduced distribution.

In Ukraine, scientific studies of individual species of the genus *Liquidambar* have only recently been carried out: *L. formosana*, *L. orientalis*, and *L. styraciflua*. Thus, the distribution, species composition, form diversity, decorative properties, morphological features, invasion, and pharmacological properties are studied (Svitylko, 2023; Svitylko, and Smilyanets, 2023; Svitylko, and Smilyanets, 2024).

To obtain data on all possible species of the *Liquidambar* genus that grew in the NBG during its existence, we conducted a series of archival data studies. Here are the names of the plants that were obtained from other botanical gardens and planted on NBG sites.

The data of the NBG Archive were analyzed, namely: inventory lists of plants of scientific sites, documents on the organization of the construction of the Botanical Garden, and stages of development of research on plants of the genus *Liquidambar* according to the publications of scientists. In different years, 2 species of the *Liquidambar* genus were planted on the NBG sites: *L. styraciflua* and *L. orientalis*. Thus, it is stated that in 1951, more than 300 one-year-old seedlings of *L. styraciflua* were grown in the NBG, which were planted on the plots of the dendrology department, but in the inventory lists of plants of the scientific plots of the NBG for 1959, plantings of *L. orientalis* were recorded, the plants of which were obtained from the Sukhum Botanical Garden. As indicated in the materials of the inventory of 1959, they grow well and develop for 9 years in the conditions of the NBG. 10 plants, 9 years old, about 5 m tall, with a crown diameter of 315 cm and a trunk diameter at the base from 6.5 cm to 12.0 cm were recorded. Later (1962, 1964, 1965) these plants are also recorded in NBG's inventory lists of green spaces (Smilyanets and Svitylko, 2020; Svitylko and Smilyanets, 2023; Svitylko and Smilyanets, 2024).

The results of these studies confirmed that the species existing in the NBG may belong to *L. styraciflua* or *L. orientalis*, but they are very similar in the structure of leaves (Ickert-Bond et al., 2005). Therefore, some morphological differences can be used to identify the species.

The morphological structure of the seed is certainly a reliable diagnostic feature, which, with studies of the structure of other organs, can help in determining of the species (Serbin et al., 2015).

Thus, the purpose of the research was to study the main morphological characteristics of the infructescence, fruit, and seed and to determine the species of the unidentified plant *Liquidambar* genus growing in the NBG based on their characteristics.

Material and methodology

Study region, weather, and climate conditions

The study was conducted in 2021–2023 in the M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (NBG) in Kyiv (50° 27' N; 30° 31' E). The entire area is 130 hectares and altitudes vary from 100 to 190 m above sea level. The NBG lies on the right bank of the river Dnipro. High hills are cut with many valleys and provide suitable conditions for many introduced plants. The climate of Kyiv is temperate continental. The average yearly temperature is +7.4 °C. Mean temperatures in Kyiv are +20.5 °C for the hottest month (July) and –3.5 °C for the coldest month (January). The highest recorded temperature was +39.9 °C and the lowest was –32.2 °C. The yearly precipitation is about 550–650 mm and the average total solar radiation is 97–100 kcal·cm^{-2} per year (Index Seminum, 2019).

Research objects

For the research, an unidentified species of the genus *Liquidambar* was used, which is in the area of medicinal plants of the NBG. According to archival documents, it may belong to *L. styraciflua* or *L. orientalis*.

Genotypes of *L. styraciflua* were grown in NBG from seeds of unknown origin in 1951. Genotypes of *L. orientalis* were grown from seeds obtained from the Sukhum Botanical Garden in 1951.

For research descriptive and morphological methods, micromorphological methods, and photo fixation were used. Transverse sections of dry seeds were made in the medial part with a blade by hand without further staining (Panyuta and Olhovich, 2019). We studied the dry infructescences, fruits, and mature seeds of plant collected at the medicinal plant site of the NBG in 2021–2023. The objects were photographed using a Canon A 640 camera on a Stemmi-2000 microscope, Carl Zeiss (Germany) at magnifications from × 6 to × 50. The descriptions are given according to the generally accepted scheme and terminology (Ziman et al., 2004; Bojnanský and Fargašová, 2007; Slovnyk, 2012; Pererva, 2019).

Statistical analysis

The results are expressed as mean values of three replications ± standard deviation (SD). Data were analyzed with the ANOVA test.

Results and discussion

The species composition of the *Liquidambar* genus was revised and supplemented in connection with new phylogenetic and archaeological research. Taxonomic aspects and phylogenetic analysis of the *Liquidambar* genus are covered in detail in the works of scientists (Endress, 1989; Li, 1997; Li and Donoghue, 1999; Mosyakin and Fedoronchuk, 1999; Shi et al., 2001; Zhiyun et al., 2003; Ickert-Bond et al., 2005; Ickert-Bond and Wen, 2006; Ickert-Bond and Wen, 2013).

According to the modern classification, the *Liquidambar* genus has 15 species in the world. These species have native and introduced distribution (Li and Donoghue, 1999; Kokhno et al., 2002; Ickert-Bond et al., 2005; Smilyanets and Svitylko, 2021; *Liquidambar*, 2024) (Table 1).

Some of these species are used in gardening as decorative plants, as the leaves are green in spring and summer, and red in autumn, in ecology and agriculture – to improve the soil structure. Also, species of the genus *Liquidambar* are used for medical and cosmetology purposes, for the extraction of a pigment substance used in the food industry, and for obtaining wood in the carpentry and furniture industry. They have good potential for development due to their medicinal, economic, ecological, and decorative value (Ouyang et al., 2016; El-Readi et al., 2013; Pozzobon et al., 2023; Mancarz et al., 2019).

In Ukraine, there is no distribution of *Liquidambar* species in nature, but some introduced species are cultivated in parks and botanical gardens (Kolesnichenko, 2011). These are species: *L. formosana*, *L. orientalis*, *L. styraciflua* (Table 2).

These species are used in landscape construction to create groups, alleys, or solitaires in parks, squares,

Table 1 Species composition and the distribution of species of *Liquidambar* L. in the world

Species	Native distribution	Introduced distribution
L. acalycina	China South-Central, China Southeast	–
L. cambodiana	Cambodia	–
L. caudata	China Southeast	–
L. chinensis	China South-Central, China Southeast, Hainan, Vietnam	–
L. chingii	China South-Central, China Southeast, Vietnam	–
L. excelsa	Assam, Bangladesh, Cambodia, China South-Central, East Himalaya, Jawa, Laos, Lesser Sunda Is., Malaya, Myanmar, Sumatera, Thailand, Tibet, Vietnam	–
L. formosana	China North-Central, China South-Central, China Southeast, Hainan, Korea, Laos, Taiwan, Vietnam	Assam, East Himalaya, India, Ukraine
L. gracilipes	China Southeast	–
L. multinervis	China South-Central	–
L. obovata	Hainan	–
L. orientalis	East Aegean Islands, Turkey	Ukraine
L. poilanei	Vietnam	–
L. siamensis	Cambodia, China South-Central, China Southeast, Laos, Thailand, Vietnam	–
L. styraciflua	Alabama, Arkansas, Belize, Connecticut, El Salvador, Florida, Georgia, Guatemala, Honduras, Illinois, Indiana, Kentucky, Louisiana, Maryland, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Mississippi, Missouri, Nicaragua, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, West Virginia	Belgium, Italy, New York, Spain, Ukraine
L. yunnanensis	China South-Central, Vietnam	–

Notes: – there is no information

Table 2 Species composition and the distribution of introduced species of *Liquidambar* L. in Ukraine

Species	Distribution of species in the cities of Ukraine
L. formosana	Yalta, Chernivtsi
L. orientalis	Kyiv
L. styraciflua	Lviv, Uzhgorod, Chernivtsi, Kyiv, Simferopol, Yalta, Uman, Kremenets, Kharkiv, Kryvyi Rih, Dnipro, Kramatorsk, Bucha, Boryspil, Berezinka, Zhukin

zoos, forest parks, when landscaping streets, boulevards, squares, residential areas, administrative buildings, memorial parks, private estates, in expositions of botanical gardens and arboretums (Kohno and Kuznetsov, 2005; Kuznetsov et al., 2013; Kucheriavyi and Kucheriavyi, 2020; Smilyanets and Svitylko, 2020). Recently, studies of species of *Liquidambar* as medicinal raw materials have been conducted (Lebeda, 2009; Oliinyk et al., 2020; Oliinyk et al., 2021; Minarchenko et al., 2021; Svitylko, 2023) and the possibility of plantation cultivation of these plants to obtain raw resources is even being considered (Zayachuk et al., 2022).

A study of the distribution of plants of the genus *Liquidambar* in the NBG was conducted and unidentified individuals were found. These are old trees that are over 70 years old. They have a height of 18 m and a crown diameter of 6 m, which blooms well, forms fruits, and seeds. Morphological description of the studied species *Liquidambar* genus consisted in studying the infructescences, fruits and seeds structure.

The infructescence of the studied species is characterized by a spherical shape with outgrowths formed from the styles. At a young age, they are green and fleshy, when they mature, they become dry and woody (Figure 1). The length of infructescences was 23.69–39.88 mm ($\bar{x}$ = 34.23 mm) and the width was 26.55–42.98 mm ($\bar{x}$ = 35.76 mm). The ratio of length and width ranged from 0.89–1.05 ($\bar{x}$ = 0.95). The length of peduncles was 35.20–70.01 mm ($\bar{x}$ = 51.84 mm), and the width was 0.94–2.20 mm ($\bar{x}$ = 1.33) (Figure 2). The number of infructescences was from 28 to 49 ($\bar{x}$ = 30) in individual bilocular fruits. Extrafloral hilly structures are located between the fruits, which often break off when drying (Figure 3).

Figure 1 General appearance of the infructescence of the studied species of the genus *Liquidambar* L.

The fruits are dry bilocular that open with longitudinal slits when ripe. They are spindle-shaped with 20.2 mm of height and 7.0 mm of width. The ratio of length and width ranged 2.8:1. They have a spindle-shaped and fused for ~2/3 of their total length, and free distally (Figures 4, 5, and 6). Fruit walls are relatively thin.

The fruit is inlaid with the remains of styles of various shapes and configurations (hooked, curved, spirally twisted), which remain on the top of the fruit, eventually sclerotize, become brittle, and easily break off. In addition to the sclerotized styles, the fruit contains the remains of extrafloral structures (8 to 12), located mainly on the dorsal side of the capsules in the form of various spines, filmy or cone-shaped outgrowths, and tubercles (Ickert-Bond et al., 2005). Their interpretation is ambiguous – as brachythera, staminodes, calyx lobes or rudimentary styles of sterile flowers (Bogle, 1986; Pigg et al., 2004; Meyer, 2024).

The seeds are spindle-shaped with a length of 5.36–8.77 mm ($\bar{x}$ = 7.06 mm) and a width of 1.81–2.35 mm ($\bar{x}$ = 2.11 mm). The ratio and length to width ranged from 2.82 to 4.38 ($\bar{x}$ = 3.37). Has a translucent leathery fragile wing in the upper part of the seed. The tip of the wing is obliquely truncated or rounded, sometimes barely wider than the seed. The seed is flattened in the dorsal-ventral plane, 0.63–0.91 mm thick (Figure 7).

The wing is lighter, brownish-straw, translucent, fragile. Epidermal cells are rectangular or polygonal, often prosenchymous, with straight or slightly curved

Figure 2 Infructescence and peduncles of the studied species of the genus *Liquidambar* L.

Figure 3 Infructescence and extrafloral hilly structures are located between the fruits of the studied species of the genus *Liquidambar* L. (scale bar: 10 mm)

Figure 4 Transverse section of the infructescence, and fruits with capitate extrafloral structures between adjacent capsules of the studied species of the genus *Liquidambar* L.

Figure 5 Infructescence, and fruits of the studied species of the genus *Liquidambar* L. (Scale bar: 10 mm)

Figure 6 Fruits, seeds, and extrafloral structures of the studied species of the genus *Liquidambar* L.

tangential anticlinal walls, end walls mostly straight. Wing had 2.03–3.23 mm ($\bar{X}$ = 2.66 mm) of length, 1.90–2.76 mm ($\bar{x}$ = 2.35 mm) of width, and L/W ratio was 0.84–1.36 ($\bar{x}$ = 1.14) (Figure 8).

Along the edge of the wing, the thickened outer periclinal walls of the epidermal cells are dome-shaped and convex, forming a thin transparent border that is visible at high magnifications (from ×40). This feature is characteristic of the structure of seeds of *L. styraciflua* (Ickert-Bond et al., 2005). The border can be expressed only on the apical part of the wing in the form of a crown (Figure 9A), or it can encircle the wing from the sides, but rarely extends to the endosperm (Figure 9B).

Rows of epidermal cells are oriented differently in different parts of the seed. Above the endosperm, they are usually oriented along a larger axis, in the wing area on the ventral side they are arcuate, on the dorsal side they are fan-shaped, and on the basal part around the chalazal area they are radially converging.

Figure 7 Seeds from the dorsal (D) and ventral (V) sides of the studied species of the genus *Liquidambar* L.

Figure 8 Seed from the lateral side of the studied species of the genus *Liquidambar* L.

Seeds with endosperm, formed from anatropic tenuinucellate seed embryos with two integuments (Ziman et al., 2004). The dorsal side of the seed is usually convex, sometimes with wide grooves, and its outline is broadly wavy in the transverse section (Figure 10). The ventral side is often concave in the distal part, tuberculate, elevated in the proximal part, and bluntly carinated in the transverse section.

Raphe (seed scar) ventral, slit-like, located on a bumpy elevation almost in the center of the seed, lighter in color. On the basal part, a spot of chalazion is visible, as a rule, in the form of a rounded depressed impression formed by small, darkly colored cells. The basal part of the seed is often horseshoe-shaped along the edge (Figure 11).

Next to the raphe is a dot-shaped micropyle, in the area in which exotestinal cells sometimes grow. Along the ventral side of the raphaeus, several pointed folds sometimes extend in different directions, the longest of which, the middle one, can reach the wing and often enters it; in some places, it is less pronounced; sometimes the folds are smoothed. The same fold is occasionally visible on the dorsal side, but only above the wing. The surface is matte, almost smooth on the dorsum, and

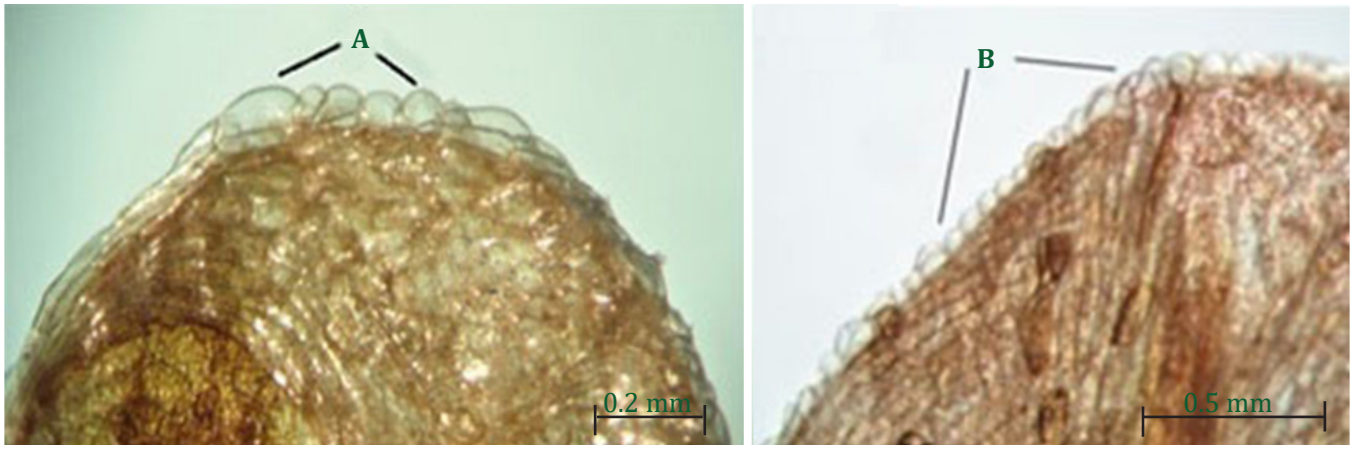

Figure 9 Wing with border on apical part (A) and lateral part (B) of the studied species of the genus *Liquidambar* L.

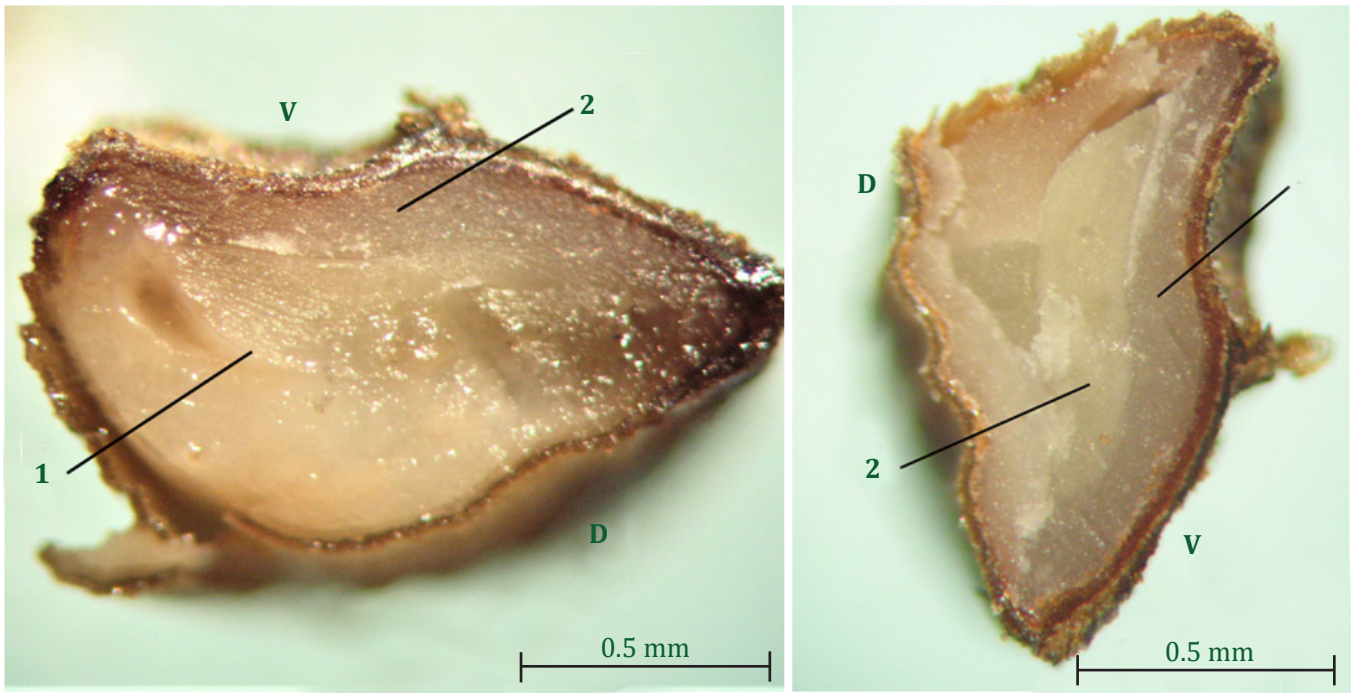

Figure 10 Transverse (axial) section of the studied species of the genus *Liquidambar* L. seeds: ventral side (V), dorsal side (D), endosperm (1), embryo (2)

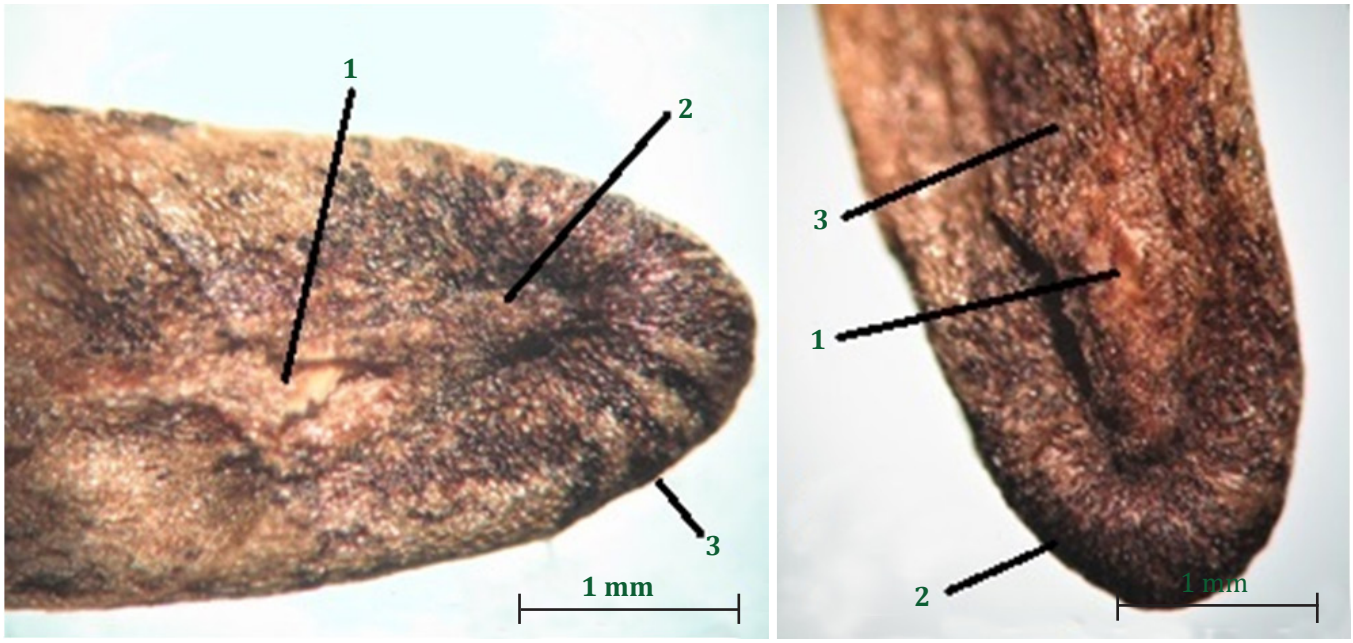

Figure 11 Basal part of *Liquidambar* L. seed: raphe (1), basal thickening (2), chalazal site (3) of the studied species of the genus *Liquidambar*

slightly wavy on the abdomen. The microrelief is finely tuberculate, formed by epidermal cells of different sizes and shapes of exotheca. The color is light brown, grayish brown, with dark brown spots or strokes, which are most concentrated at the base of the seed. Such spotting is due to the presence of a subepidermal layer of thin-walled cells filled with darkly colored flobaphenes under the epidermis (Foo, and Karchesy, 1989). Obviously, the same flobaphenes can be found in the epidermal cells, where we found stained cells (Figure 12).

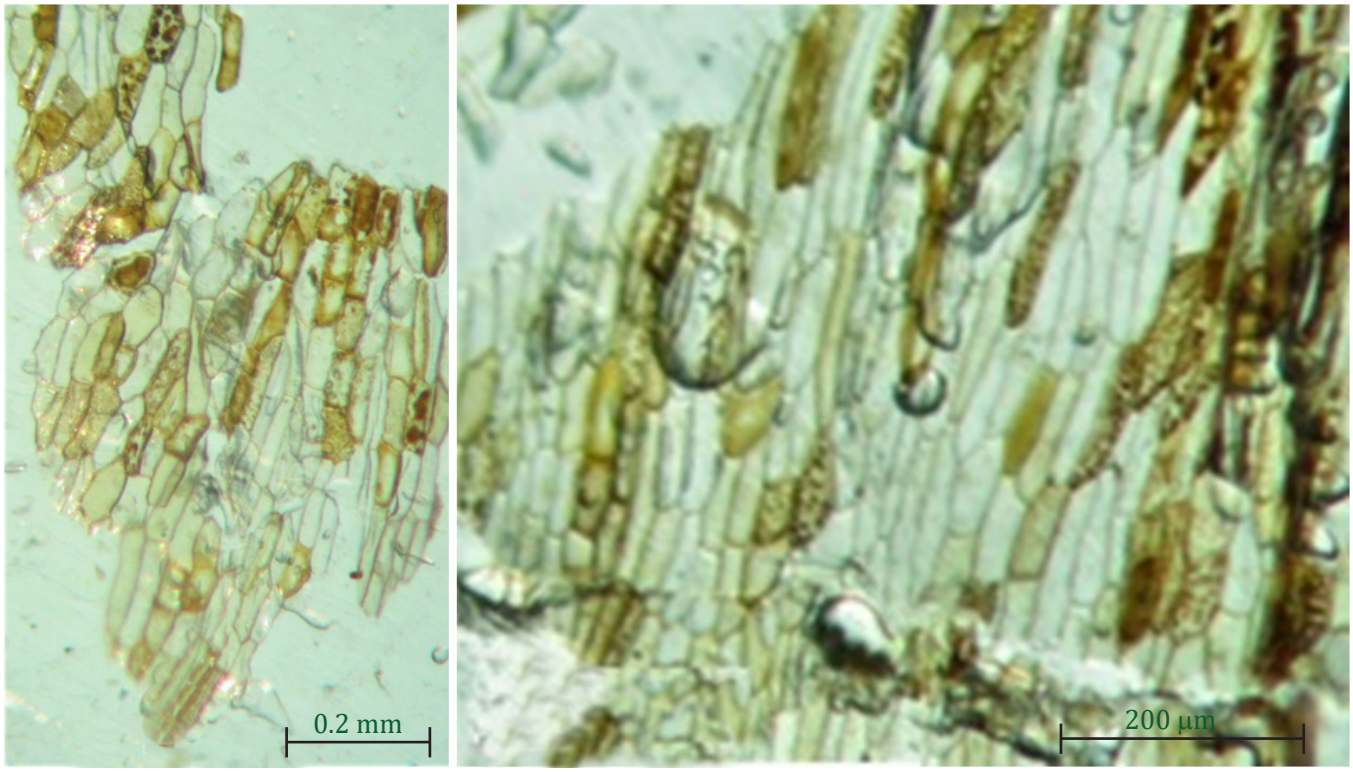

Figure 12 Epidermal cells of the seed with flobaphenes of the studied species of the genus *Liquidambar* L.

The comparative morphological features of the studied plants of *L. orientalis* and *L. styraciflua* are represented in Table 3.

Our research has established that the infructescence of the studied species are spherical with a size of 34.23 × 35.76 mm (Figures 1, 2, 3). According to descriptions of infructescence (Kokhno et al., 1991; Kokhno et al., 2002; Ickert-Bond et al., 2005) in the species *L. styraciflua* (30.34 × 35.76 mm in size), they are larger than in *L. orientalis* (17.92 × 17.43 mm), which gives grounds to characterize the infructescence of the studied species as *L. styraciflua*. Also, many researchers (Pigg, Ickert-Bond & Wen, 2004) claim that the infructescence of *L. styraciflua* has larger sizes than *L. orientalis*.

The peduncles of *L. orientalis* and *L. styraciflua* also differ in size. The significant differences was found in

Table 3 Morphological characteristics of the studied species grown in the NBG of the species Liquidamba orientalis, *L. styraciflua* (in mm)

Characters	*L. orientalis* min-max ($\bar{x}$)	*L. styraciflua* min-max ($\bar{x}$)	The studied species min-max ($\bar{x}$)
Infructescence			
Length (L)	12.20–26.62 (17.92)	19.00–34.62 (30.34)	23.69–39.88 (34.23)
Width (W)	14.45–26.96 (17.43)	20.25–40.87 (31.60)	26.55–42.98 (35.76)
L/W ratio	0.78–1.08 : 1 (0.90 : 1)	0.84–1.09 : 1 (0.97:1)	0.89–1.05 : 1 (0.95 : 1)
No. of fruits/ infructescence	33–48	34–40	28–49
Peduncle length	13.98–47.48 (29.89)	36.71–55.89 (42.75)	35.20–70.01 (51.84)
Peduncle width	0.88–1.45 (1.20)	0.73–1.10 (0.95)	0.94–2.20 (1.33)
Extrafloral structures	smooth rim	bumpy rim	bumpy rim
Fruit			
Length	6.0	12.4	20.2
Width	2.5	4.3	7.0
L/W ratio	2.4 : 1	2.9 : 1	2.8 : 1
Shape	cylindrical to slightly wedge-shaped	cylindrical to spindle-shaped	spindle-shaped
Features of the location	fused for ~2/3–3/4 of their total length, and free distally	fused for ~2/3–3/4 of their total length, and free distally	fused for ~2/3 of their total length, and free distally
Fruits are held	together fairly tightly	together tightly	together tightly
Fruit walls	relatively thin	relatively thin	relatively thin
Seed			
Length	4.55–4.85 (4.73)	7.79–8.51 (7.98)	5.36–8.77 (7.06)
Width	1.82–1.87 (1.85)	1.86–2.79 (2.33)	1.81–2.35 (2.11)
L/W ratio	2.43–2.66 : 1 (2.55 : 1)	2.90–4.24 : 1 (3.43 : 1)	2.82–4.38 : 1 (3.37 : 1)
Shape	longate	elongate	elongate
Cells of the seed coat	tangentially elongated, rectangular with thickened anticlinal walls, and oblique-end walls	tangentially elongated, rectangular to polygonal with thickened anticlinal walls and mostly straight-end walls	tangentially elongated, rectangular to polygonal with thickened anticlinal walls and mostly straight-end walls
Wind	distal, relatively short	distal, relatively long	distal, relatively long; length 2.03–3.23 (2.66); width 1.90–2.76 (2.35); L/W ratio 0.84–1.36 : 1 (1.14 : 1)
The othe features			
Characteristic features	thick, relatively smooth areas between individual fruits	numerous knob-like extrafloral structures that have a "braided" appearance	numerous knob-like structures that have a "braided" appearance

Note: min, max – minimal and maximal measured values; $\bar{x}$ – arithmetic mean; L/W ratio – length/width ratio

the length of the peduncles of *L. orientalis* – 42.75 mm and *L. styraciflua* – 29.89 mm (Ickert-Bond et al., 2005). The studied species has a peduncle length an average of 51.84 mm (Figure 2), which also allows its identification as *L. styraciflua*.

Extrafloral structures of *L. styraciflua* had a twisted shape and therefore the area between adjacent fruits is bumpy. In *L. orientalis*, this area is smooth (Ickert-Bond et al., 2005; Ickert-Bond and Wen, 2013). The studied species has a bumpy area between adjacent fruits (Figure 3), which leads us to think it is *L. styraciflua*.

The morphological characteristics of the fruit of *L. orientalis* and *L. styraciflua* are very similar: this is the location, and the thickness of the walls, but some significant differences will also help to identify the studied species. So, the sizes of the fruit differ significantly: *L. styraciflua* has fruits two times larger (12.4 × 4.3 mm) than *L. orientalis* (6.0 × 2.5 mm) (Ickert-Bond et al., 2005). The fruits of the studied species are even larger (20.2 × 7.0 mm), which can be explained by the considerable age of the tree and its massiveness. Therefore, this sign can be interpreted in favor of *L. styraciflua*. The ratio of L/W of the fruit shows that the fruits of *L. styraciflua* (2.9 : 1) are more elongated compared to the fruits of *L. orientalis* (2.4 : 1). The studied species has a ratio L/W of 2.8 : 1 (Figure 6), which can identify it as an *L. styraciflua*.

Seeds of species of species *Liquidambar* are similar in structure, shape, and color, but there are significant differences in the size of the seed, wing, and micromorphology of the seed epidermis (Ickert-Bond et al., 2005). *L. orientalis* seed size was 4.73 × 1.85 mm, *L. styraciflua* was 7.79 × 2.33 mm, the studied species – 7.06 × 2.11 mm (Figures 7, 8). The L/W ratio shows that the seed *L. styraciflua* is more elongated in length (3.43 : 1) than seeds of *L. orientalis* (2.55 : 1), which can also be interpreted as the belonging of the studied species to the *L. styraciflua*.

The seed coat cells in *L. orientalis* are tangentially elongated and rectangular with thickened anticlinal walls, and oblique end walls (Ickert-Bond et al., 2005). The seed coat cells of *L. styraciflua* are tangentially elongated, rectangular to polygonal with thickened anticlinal walls and mostly straight end walls. The studied species have the same cells of the seed coat as *L. styraciflua* (Figure 11).

The wing of the seed hp. relatively long (Ickert-Bond et al., 2005.), which we observed in the studied species: length 2.03–3.23 ($\bar{X}$ = 2.66), width 1.90–2.76 ($\bar{X}$ = 2.35), L/W ratio 0.84–1.36:1 ($\bar{X}$ = 1.14:1) (Figures 7, 8).

Thus, the common features in all three species (*L. orientalis*, *L. styraciflua*, and the studied species) are the structure of the infructescence, peduncle, fruit, seed, and wing; and features of the location of the fruits. Significant differences between *L. orientalis* and *L. styraciflua* this is the size of the infructescence, peduncle, fruit, seed, and wing; shape and size of cells of the seed coat; the presence of extrafloral twisted structures in *L. styraciflua*. According to these features, the species under study coincides with *L. styraciflua*.

Conclusion

A study of the morphological structure of an unidentified species of the *Liquidambar* genus, which grows in the area of medicinal plants of the NBG, was carried out, namely: the shape and structure of the infructescence, peduncle, fruit, seed, and wing; features of the location of the fruits; form of extrafloral structures; shape and size of cells of the seed coat. It has been established that it has all the common features of *L. styraciflua*. It also differs from *L. orientalis* by the size and shape of the infructescence, the peduncle size, and the shape size of the fruit, seeds, and wings. Therefore, it can be concluded that the species under study is *L. styraciflua*. Thus, the following characteristics: the size of the infructescence, peduncle, fruit, seed, and wing; form of extrafloral structures; the shape and size of the cells of the seed coat can be used to identify some species of *Liquidambar* genus.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical statement

This article doesn't contain any studies that would require an ethical statement.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

Bilous, L.F. 2020. Biogeografiia. Pidruchnyk [Biogeography. Tutorial.] Kyiv: Taras Shevchenko KNU, 54–55. https://geo.knu.ua/wp-content/uploads/2021/06/bilous_biogeography_posibn.pdf

Bogle, A.L. 1986. The floral morphology and vascular anatomy of the Hamamelidaceae: subfamily Liquidambaroideae. In *Annals of the Missouri Botanical Garden*, 73, 325–347. https://doi.org/10.2307/2399116

Bojnanský, V., & Fargašová, A. 2007. Taxonomy and Morphology of Seeds. Atlas of seeds and fruits of Central and East-European flora. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-5362-7_1

Bulgakova, N.A. 2020 Opyt introduktsii predstavitelei roda Likvidambar (*Liquidambar* L.) v Abhazii [The experience of the introduction of *Liquidambar* L. in Abkhazia]. In SNBG Bulletin, 134, 50–53. https://doi.org/10.36305/0513-1634-2020-134-50-53

El-Readi, M.Z., Eid, H.H., Ashour, M.L., Eid, S.Y., Labib, R.M., Sporer, F. & Wink M. 2013. Variations of the chemical composition and bioactivity of essential oils from leaves and stems of *Liquidambar styraciflua* (Altingiaceae). In *Journal of Pharmacy and Pharmacology*, 65(11), 1653–1663. https://doi.org/10.1111/jphp.12142

Endress, P.K. 1989. A Suprageneric Taxonomic Classification of the Hamamelidaceae. In Taxon, 38(3), 371–376. https://doi.org/10.2307/1222267

Foo, L.Y. & Karchesy, J.J. 1989. Chemical Nature of Phlobaphenes. Chemistry and Significance of Condensed Tannins. Springer, Boston, MA. https://doi.org/10.1007/978-1-4684-7511-1_6

Ickert-Bond, S., & Wen, J. 2013. A taxonomic synopsis of Altingiaceae with nine new combinations. In PhytoKeys, 31, 21–61. https://doi.org/10.3897/phytokeys.31.6251

Ickert-Bond, S.M., & Wen, J. 2006. Phylogeny and biogeography of Altingiaceae: Evidence from combined analysis of five non-coding chloroplast regions. In Molecular Phylogenetics and Evolution, 39, 512–528. http://people.iab.uaf.edu/stefanie_bond/Publications_files/Ickert-Bond_MPE2006.pdf

Ickert-Bond, S.M., Pigg, K.B., & Wen, J. 2005. Comparative infructescence morphology in *Liquidambar* (Altingiaceae) and its evolutionary significance. In *American Journal of Botany*, 2(8), 1234–1255. https://doi.org/10.3732/ajb.92.8.1234

Index seminum M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine. 2019. https://doi.org/10.5281/zenodo.2648464

Kohno, M.A., & Kuznetsov, S.I. 2005. *Metodychni rekomendatsii shchodo doboru derev ta kushchiv dlia introduktsii v Ukraini* [*Methodological recommendations for the selection of trees and shrubs for introduction in Ukraine*]. Kyiv. Publishing House of the Ukrainian Phytosociological Center. 48 p. [In Ukrainian]

Kokhno, M.A., Parkhomenko, L.I., & Zarubenko, A.U. 2002. Rid *Liquidambar* L. [The genus *Liquidambar* L.]. In *Dendroflora of Ukraine*. Wild and cultivated trees and shrubs. Part I. Handbook. Kyiv. Phytosociocentr, (1). 123–124. [In Ukrainian]

Kokhno, N.A., Kurdyuk, A.M., & Dudik N.M. 1991. *Plody i semena dereviev i kustarnikov, kultiviruiemykh v Ukrainskoi SSR* [*Fruits and seeds of trees and shrubs cultivated in the Ukrainian SSR*]. Kyiv: Nauk. Dumka, 320 p. [In Russian]

Kolesnichenko, O.V., Yakubenko, B.Y., & Slyusar, C.I. 2011. *Kataloh roslyn Botanichnoho sadu NUBiP Ukrainy*. [*Catalog of plants of the Botanical Garden of the National University of Bioresources and Nature Utilization of Ukraine*]. Kyiv. 130 p. [In Ukrainian]

Kucheriavyi, V.P., & Kucheriavyi, V.S. 2020. *Ozelenennia naselenykh mists. Pidruchnyk dlia studentiv vyshchykh navchalnykh zakladiv* [*Landscaping of populated areas*]. The textbook for university students. Lviv. Vydavnytstvo Novyi Svit. 666 p. [In Ukrainian]

Kuznetsov, S.I., Pushkar, V.V. & Levon F.M. 2013. *Asortyment derev, kushchiv ta lian dlia ozelenennia v Ukraini* [*Assortment of trees, bushes and vines for landscaping in Ukraine*]. Kyiv. Komprynt, 256 p. [In Ukrainian]

Lebeda, F.P. 2009. *Kataloh likarskykh roslyn botanichnykh sadiv i dendroparkiv Ukrainy* [*Catalog of medicinal plants of botanical gardens and arboretums of Ukraine*]. Kyiv: Akademperiodyka, P.64 [In Ukrainian]

Levon, F.M. 2008. *Zeleni nasadzhennia v antropohenno transformovanomu seredovyshchi* [*Green plantations in an anthropogenically transformed environment:* monograph]. Kyiv. National Scientific Center Institute of Agrarian Economy. 364 p. [In Ukrainian]

Li, J. 1997. *Systematics of the Hamamelidaceae based on morphological and molecular evidence*. dissertation theses. https://scholars.unh.edu/dissertation/1997

Li, J., & Donoghue, M.J. 1999. More molecular evidence for interspecific relationships in *Liquidambar* (Hamamelidaceae). In *Rhodora*, 101(905), 87–91.

Liquidambar styraciflua L. *Plants of the World Online*. Kew Science. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:30008300-2 (Accessed 15 May 2024).

Mancarz, G.F.F., Laba, L.C., da Silva, E.C.P., Prado, M.R.M, de Souza, L.M, de Souza, D., Nakashima, T. & Mello, R.G. 2019. *Liquidambar styraciflua* L.: a new potential source for therapeutic uses. In *Journal of Pharmaceutical and Biomedical Analysis*, 174, 422–431. https://doi.org/10.1016/j.jpba.2019.06.003

Meyer, F.G. 1753. *Liquidambar styraciflua* Linnaeus. In *Flora of North America*, 2, 999. http://floranorthamerica.org/Liquidambar_styraciflua (date of access: 22/04/2024)

Minarchenko, V.M., Lysiuk, R.M., & Kovalska, N.P. 2019. *Medicinal plant resources*. Kyiv. 240 p.

Mosyakin, S.L. & Fedoronchuk, M.M. 1999. *Vascular Plants of Ukraine*. A Nomenclatural Checklist. Kiev. 346 p.

Oliinyk, P., Voronenko, D. & Lysiuk, R. 2020. Radioprotektorni vlastyvosti polifenolnykh spoluk kharchovykh i priano-aromatychnykh roslyn. [Radioprotective properties of polyphenolic compounds of edible and aromatic plants]. In *Food science and technolog*, 14(3), 62–72. https://doi.org/10.15673/fst.v14i3.1797 [In Ukrainian]

Oliinyk, P., Voronenko, D., Lysiuk, R., Oliinyk, A. & Oliinyk, S. 2021. Geroprotective properties of polyphenolic compounds of food plants. In *Food science and technology,* 15(3), 4–14. https://doi.org/10.15673/fst.v15i3.2115

Ouyang, X.L., Yi, Sh., Lu, H.Y., Wu, Sh.M. & Qiong H. 2016. *Liquidambar formosana* Hance: A mini-review of chemical constituents and pharmacology. In *European Journal of Medicinal Plants*, 17(1), 1–11. https://doi.org/10.9734/EJMP/2016/29440

Panyuta, O.O. & Olhovich, O.P. 2019. *Anatomiia roclyn* [*Anatomy of* plants]. Kyiv. 280 p. [In Ukrainian]

Pererva, V.V. 2019. *Iliustrovanyi terminolohichnyi slovnyk z botaniky* (*heneratyvni orhany roslyn*) [*Illustrated terminology dictionary of botany* (*generative organs of plants*)]. Kryvyi Rih. 71 p.

Pigg, K.B., Ickert-Bond, S.M., & Wen, J. 2004. Anatomically Preserved *Liquidambar* (Altingiaceae) from the Middle Miocene of Yakima Canyon. In *American Journal of Botany*, 3(91), 499–509.

Pozzobon, R.G., Rutckeviski, R., Carlotto, J., Schneider, V.S., Cordeiro, L.M.C., Mancarz, G.F.F., M de Souza, L., Mello, R.G. & Smiderle, F.R. 2023. Chemical Evaluation of *Liquidambar styraciflua* L. Fruits Extracts and Their Potential as Anticancer Drugs. In *Molecules*, 28(1), 360. https://doi.org/10.3390/molecules28010360

Serbin, A.G., Syra, L.M., & Slobodyaniuk, T.O. 2015. *Farmatsevtychna botanika* [*Pharmaceutical botany*]. Vinnytsia. New book, 118–123.

Shi, S., Huang, Y., Zhong, Y., Du, Y., Zhang, Q., Chang, H., & Boufford, D.E. 2001. Phylogeny of the Altingiaceae based on cpDNA matK, PY-IGS and nrDNA ITS sequences. In *Plant Systematics and Evolution*, 230(1/2), 13–24.

Slovnyk ukrainskoi biolohichnoi terminolohii. 2012. [*Dictionary of Ukrainian biological terminology*]. Kyiv: KMM, 744 p. http://www.komm.ltd.ua/images/slovnykBIO.pdf [In Ukrainian]

Smilyanets, N.M., & Svitylko, I.M. 2020. Teoretychni ta praktychni peredumovy doslidzhen rodu *Liquidambar* L. u Natsionalnomu botanichnomu sadu imeni M.M.Hryshka Natsionalnoi akademii nauk Ukrainy [Theoretical and practical prerequisites for research of the genus *Liquidambar* L. in the M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine]. In *Fundamental and applied aspects of plant introduction in conditions of global environmental changes*. Kyiv: Lira-K. 172–175. [In Ukrainian]

Smilyanets, N.M., & Svitylko, I.M. 2021. Vydovyi sklad ta poshyrennia rodu *Liquidambar* L. (Altingiaceae) v Ukraini [Species composition and distribution of the genus *Liquidambar* L. (Altingiaceae) in Ukraine]. In *Journal of Native and Alien Plant Studies*, 274–277. https://doi.org/10.37555/2707-3114.1.2021.247728 [In Ukrainian]

Svitylko, I. 2023. Farmakolohichni vlastyvosti roslyn rodu *Liquidambar* L. [Pharmacological properties of the genus *Liquidambar* L.]. In *Chemical and Biopharmaceutikal Technologies: collection of scientific papers.* Tallinn: Nordic Sci Publisher, 84–86. [In Ukrainian]

Svitylko, I., & Smilyanets, N. 2023. Ziasuvannia invaziinosti predstavnykiv rodu *Liquidambar* L. u zviazku z introduktsiieiu v Ukrainu [Elucidation of the invasiveness of representatives of the genus *Liquidambar* L. in connection with the introduction into Ukraine]. In *Objects of the nature reserve fund of Ukraine: current state and ways to ensure their effective operation. Collection of materials of the All-Ukrainian scientific and practical conference, on the occasion of the 10th anniversary of the National Nature Park Male Polissya*. Slavuta, 293–294. https://doi.org/10.61584/3-4-08-2023 [In Ukrainian]

Svitylko, I., & Smilyanets, N. 2024. Istorychnyi aspekt doslidzhennia *Liquidambar* L.: periodyzatsiia ta perspektyvy. [Historical aspect of *Liquidambar* L. research: periodization and perspectives]. In *Biota. Human. Technology,* 1, 73–80. https://doi.org/10.58407/bht.1.24.7 [In Ukrainian]

Zaimenko, N.V., Rakhmetov, D.B., Gaponenko, M.B., & Shumyk, M.I. 2022. *Fundamentalni ta prykladni aspekty introduktsii i zberezhennia roslyn v Natsionalnomu botanichnomu sadu imeni M.M.Hryshka NAN Ukrainy* [*Fundamental and applied aspects of the introduction and preservation of plants in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine*]. Monograph. Kyiv. Publishing Lira-K, 110, 406–421. [In Ukrainian]

Zayachuk, V.Ya., Genyk, Y.V., & Lysyuk, O.M. 2022. Vydy rodu Likvidambar (*Liquidambar* L.) flory Ukrainy yak tsinni introdutsenty – aktualnyi stan ta perspektyvy vykorystannia [Species of the genus *Liquidambar* (*Liquidambar* L.) flora of Ukraine as valuable introductors – current state and prospects of use]. Basic, less common and nontraditional plant species – from study to implementation (agricultural and biological sciences). In *6th International scientific and practical conference*. March 3, 2022, p. Kruty village, Chernihiv region, Ukraine, 2, 122–127. [In Ukrainian]

Zhiyun, Zh., Hongda, Zh. (Hung-ta Chang), & Endress, P.K. 2003. Hamamelidaceae. In *Flora of China*, 9, 18–42. http://flora.huh.harvard.edu/china/mss/volume09/Hamamelidaceae.PDF

Ziman, I.M., Mosyakin, S.L., Bulak, O.V., Tsarenko, O.M., & Felbaba-Klushina, L.M. 2004. *Iliustrovanyi dovidnyk z morfolohii kvitkovykh roslyn* [*Illustrated handbook on the morphology of flowering plants*]. Uzhhorod. Medium, 156 p. [In Ukrainian]