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RESEARCH ARTICLE

Introduction of *Liquidambar styraciflua* L. in Ukraine and its acclimatization success at the M.M. Gryshko National Botanical Garden of the NAS of Ukraine

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Abstract

Liquidambar styraciflua L. plants were screened in all soil and climatic zones of Ukraine in artificial phytocenoses of urban areas, i.e., botanical gardens, parks, squares, green areas, residential areas, and streets.

Considering *L. styraciflua* plants growing in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine (Kyiv) as an example, their introduction success by the acclimatization degree, including the indicators of growth, generative development, winter hardiness, and drought resistance, was calculated. The acclimatization degree of the tested plants reached 90 points, corresponding to a good acclimatization level.

Hence, *L. styraciflua* can be recommended for use in landscape construction to create groups, alleys, or as tapeworms in parks, squares, zoos, in landscaping streets, boulevards, squares, adjacent areas near houses and administrative buildings, private estates. These plants can also be successfully applied in expositions of botanical gardens and arboretums and as objects of topiary art.

Keywords: sweetgum, introduction, acclimatization, woody plants, urban landscape, habitat

Authors' contributions: Nina Smilyanets – conceptualization of the study, writing the manuscript – original draft, editing. Ihor Svitylko – research observations, data analysis, review of literary sources, photographing, preparation of figures and tables, visualization, writing, and editing the manuscript.

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Introduction

Introduction is the deliberate or accidental transfer of organisms beyond their natural range and adaptation to new conditions (Grodzinskyi et al., 2012). Introduction of plants has great theoretical and practical value. Transfer of plants to new conditions accelerates the processes of adaptation and speciation. In a new environment, the factors of evolution and patterns of plant variability become more clearly manifested, and, therefore, the range of used plants can be enriched (Kokhno & Kuznetsov, 2005; Kolesnichenko et al., 2007; Kuznetsov, 2008; Kuznetsov et al., 2013). However, Kokhno (1999)

stated that despite the success in introducing woody plants in Ukraine, only ca. 10% of all introduced species are more or less intensively applied in culture. The rest remain unused, although they form a considerable gene pool for the future introduction.

Liquidambar styraciflua L. (Altingiaceae) is a woody plant from the golden fund of ornamental plants for landscaping (Kokhno, 2002). The prospects of its application for landscaping and medicine are intensively reported (Lebeda, 2009; Minarchenko et al., 2019; Horbenko et al., 2022; Svitylko et al., 2025).

This species is native to the eastern USA, as far north as Connecticut, south to Florida, and west to Texas. It also grows in mountainous regions of Mexico and Central America (POWO, 2025). Seedlings from the northernmost areas show greater cold tolerance than seedlings from the southern parts of the USA, which in turn show greater cold tolerance than seedlings from Mexico or Central America (Williams & McMillan, 1971a, 1971b; McMillan, 1974). Seedlings from the eastern parts of the USA stop annual growth earlier and set dormant buds earlier than plants from Mexican habitats (McMillan & Winstead, 1976). Seedlings from southern locations bud earlier in spring and retain leaves longer in autumn than seedlings from northern sources (Randel & Winstead, 1976).

Liquidambar styraciflua plants prefer the sun and withstand low temperatures down to –23 °C (Brand & Lineberger, 1992). The effect of drought on the main physiological processes of *L. styraciflua*, including studies of photosynthesis, phenological aspects, and the level of hydration, is highlighted by Hinckley et al. (1979), who demonstrated high plasticity of this species.

In Ukraine, sweetgum plants are considered highly decorative with a score of 65 out of 100 (Vlasenko, 2016).

In the 1870s, *L. styraciflua* was acclimatized in the arboretum of the Botanical Garden of the Ukrainian State Forestry University (Lviv) but later lost (Ksendzora & Khomyak, 2023). Its loss was recorded in the 1960s and associated with the thickening of plantings, mismatched forest vegetation conditions, and the harsh influence of negative temperatures.

In the Poltava Dendrological Garden, which was founded at the School of Horticulture, introduction trials of *L. styraciflua* have been conducted since 1904. Significant drawbacks were mainly associated with dense planting, but some sweetgum plants successfully withstood (Panasenko, 2005).

The acclimatization of *L. styraciflua* was also investigated at the Botanical Garden of the Yuriy Fedkovych Chernivtsi National University. In particular, it was noted that adult plants are completely frost-resistant, while the young plants in the first years freeze up to half, and with age, only the tops of annual shoots freeze (Kostevich, 1966). When young plants grow from seeds, some die yearly, but the most resistant of them remain after wintering. Kostevich (1966) concluded that seed sowing allows selection of the most frost-resistant individuals, which, with age, under the influence of new growing conditions, become even more frost-resistant.

Winter hardiness, drought resistance, and the resistance of *L. styraciflua* to pests and diseases were also analyzed in arboretums and botanical gardens of the Kherson region. The plants had no visible damage after wintering in these conditions and were therefore classified as winter-hardy. These plants were relatively drought-resistant, requiring maintenance irrigation in the driest periods (Boyko et al., 2022).

The introduction of plants of North American origin, including sweetgum, was studied in Northern Bukovina. It was found that its flowering duration depends on the temperature and air humidity deficit during the flowering period (Litvinenko, 2000).

Kolesnichenko et al. (2011) studied the success of introducing 26-year-old *L. styraciflua* plants in the Botanical Garden of the National University of Life and Environmental Sciences of Ukraine. The authors pointed out a low adaptation level of these plants in general. Their winter hardiness corresponded to two or three out of five points (half or a quarter of the length of the apical shoot is damaged). Drought resistance corresponded to four or five out of six points (during the day, leaves lose turgor, but at night it is restored, or the plant does not suffer from drought). Reproductive ability corresponded to only one out of six points, meaning plants did not form generative organs.

In the M.M. Gryshko National Botanical Garden of the NAS of Ukraine (NBG), studies on

the genus *Liquidambar* have been conducted for many years and comprise two species – *L. styraciflua* and *L. orientalis* Mill. (Smilyanets & Svitylko, 2021; Smilyanets et al., 2024; Svitylko, 2024; Svitylko & Smilyanets, 2024). Based on archival data, seeds of *L. styraciflua* were obtained from Washington in 1939. The seeds germinated well, and seedlings were planted in plots at the NBG (Inventory..., 1939). However, there are no further references regarding these plants. In 1944, a Botanical Garden Landscaping Project was developed. The Explanatory Note to it justified the creation of a section 'North America', where *L. styraciflua* was expected to be planted in a special protected location (Documents..., 1944). In 1956, the NBG, together with the Forest Institute, developed recommendations, which argued the application of *L. styraciflua* and *L. orientalis* for the Carpathian region, the Right-Bank Forest-Steppe (western part), the Right-Bank Steppe (near the water), Seaboard (on rich soils), in alley plantings (boulevards), groups in squares, parks, forest parks, solitary and parterre plantings (Planting..., 1956).

Figure 1. *Liquidambar styraciflua* in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Material and methods

The study was conducted during 2020–2024 using plants over 60 years old growing in the NBG. *Liquidambar styraciflua* trees at the NBG belong to first magnitude (Fig. 1).

NBG is located in the north of Ukraine, in Kyiv, on the right bank of the Dnipro River. The total area of NBG is 130 ha, and the elevation ranges from 100 to 190 m a.s.l.

The climate in Kyiv is temperate continental (Vakulenko et al., 2019). During the research in 2020–2024, it was relatively warm. The average annual temperature in this period was +10.4 °C, which is 1.4 °C warmer than the multi-year average temperature (+9.0 °C). In all months, except April and May, the average temperature during the observation period was higher than the multi-year average (Table 1). The atmospheric precipitations during the observation period tended to decrease and were unevenly distributed over the months (Table 2). Over five years (2020–2024), three years (2020, 2021, 2022) had less precipitation than the long-term average, and two years (2023, 2024) had more precipitation than the long-term average. 2020 was the driest year (140 mm), and 2023 was the wettest (673 mm).

Liquidambar styraciflua distribution in Ukraine was screened based on literary sources and own surveys.

To assess the success of the introduction, we applied the method of evaluating the success of the introduction and the degree of acclimatization of woody plants by Kokhno (1968) and Kokhno & Kuznetsov (2005), which is characterized by the acclimatization degree. The acclimatization degree is the sum of the indicators of growth, generative development, winter hardiness, and drought resistance of plants. These indicators were assessed visually using a five-point scale. The acclimation number was calculated using the formula:

$$A = G \times i + Gd \times i + Wh \times i + Dr \times i,$$ where:

A – acclimatization degree;
G – growth;
Gd – generative development;
Wh – winter hardiness;
Dr – drought resistance;
i – importance coefficient of the trait.

Table 1. Air temperature indicators in Kyiv, °C (CGO, 2024).

Period	Months												Average annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2020	0.8	2.5	6.5	9.9	12.4	21.7	21.9	21.4	18.4	12.5	3.8	−0.5	10.9
2021	−2.5	−4.5	2.7	8.0	14.3	21.3	24.6	21.1	13.5	8.4	4.8	−1.5	9.2
2022	−1.3	1.8	2.6	8.1	14.6	21.7	20.8	22.3	12.7	10.6	3.1	−0.7	9.7
2023	−0.3	−0.2	4.8	9.6	16.0	19.6	21.5	23.8	18.8	11.4	4.1	0.7	10.8
2024	−2.6	2.9	4.8	12.8	16.3	21.5	24.3	23.1	20.6	10.9	2.7	0.0	11.4
Average for 2020–2024	−1.2	0.5	5.1	9.7	14.7	21.2	22.6	22.3	16.8	10.8	3.7	−0.4	10.4
Long-term average (1991–2020)	−3.2	−2.3	2.5	10.0	15.8	19.5	21.3	20.4	14.9	8.6	2.6	−1.9	9.0

Table 2. Precipitation indicators in Kyiv, mm (CGO, 2024).

Period	Months												Total annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2020	10	9	6	5	26	14	23	9	8	15	6	9	140
2021	63	62	17	45	74	24	63	65	23	2	29	66	533
2022	52	17	9	42	33	42	40	60	63	44	99	58	559
2023	19	30	42	102	1	87	136	19	8	66	98	65	673
2024	48	48	55	78	15	135	52	24	21	63	51	52	642
Average for 2020–2024	38	33	26	54	30	60	63	35	25	38	57	50	509
Long-term average (1991–2020)	37	39	40	42	65	74	68	56	58	46	46	47	618

Results and discussion

Liquidambar styraciflua was registered for all soil and climatic zones of Ukraine (Fig. 2). Positive experience of *L. styraciflua* application has been recorded in the following regions: Lviv, Ivano-Frankivsk, Zakarpattia, Ternopil, Chernivtsi, Dnipropetrovsk, Kyiv, Cherkasy, Chernihiv, Kharkiv, Donetsk, Odessa, Kherson, Vinnytsia, and Autonomous Republic of Crimea.

Sweetgum has recently gained popularity in the landscaping of megalopolises. It is more often applied in reconstructing old and creating new parks (Kovalchuk, 2021). In Kyiv, sweetgum is registered in six districts: Obolonskyi, Shevchenkivskyi, Pecherskyi, Holosiivskyi, Dniprovskyi, and Darnytskyi (Fig. 3).

Generally, sweetgum in Ukraine is used in landscape construction to create groups, alleys, or as tapeworms in parks, squares, zoos, in landscaping streets, boulevards, squares, surrounding areas near administrative buildings and houses, memorial parks, private estates, in expositions of botanical gardens and arboretums (Fig. 4). In Kyiv, this plant is increasingly found in parks, botanical gardens, and on the streets of Kyiv (Fig. 5).

Analyzing *L. styraciflua* plants located in the NBG, it was found that their shoots increase annually, and the plants grow and develop well. They also bloom and produce fruits and seeds with high germination rate (98%). The

Figure 2. Occurrence of *Liquidambar styraciflua* in Ukraine. **Red dots** indicate confirmed localities. Climatic zones of Ukraine: **I** – Polissya; **II** – Forest-Steppe; **III** – Northern and Central Steppe; **IV** – Southern Steppe; **V** – foothill and mountainous regions of Crimea; **VI** – Southern coast of Crimea; **VII** – foothill and mountainous regions of the Carpathians; **VIII** – Transcarpathia.

Figure 3. Occurrence of *Liquidambar styraciflua* in Kyiv. **Red dots** indicate confirmed localities.

Figure 4. *Liquidambar styraciflua* in landscaping: **A** – Botanical Garden of Yuriy Fedkovych Chernivtsi National University (Chernivtsi); **B** – Urban greening of Uzhgorod (Transcarpathian region); **C** – Fantasy Park "Nova Sofiivka" (Uman, Cherkasy region); **D** – Botanical Garden of Odessa I.I. Mechnikov National University; **E** – Private estate in Zhukyn village (Vyshgorod district, Kyiv region).

Figure 5. *Liquidambar styraciflua* in Kyiv: **A** – Natalka Park (Obolonskyi district); **B** – Plot of medicinal plants of the M.M. Gryshko National Botanical Garden of the NAS of Ukraine (Pecherskyi district); **C** – Kyiv Zoo (Shevchenkivskyi district); **D** – Recreation zone near Khvylya Bridge (Obolonskyi district); **E** – Heydar Aliyev Park (Shevchenkivskyi district); **F** – Budivelnykiv str. (Dniprovskyi district).

Table 3. Success rates of *Liquidambar styraciflua* introduction at the M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Growth		Generative development		Winter hardiness		Drought resistance	
Indicator characteristics	Score	Indicator characteristics	Score	Indicator characteristics	Score	Indicator characteristics	Score
Less intense than in natural conditions, but relatively good	4	Fruiting is not constant, few similar seeds are formed	4	Good winter hardiness (shoots do not freeze)	5	Leaves lose turgor during drought, but then restore it	4

plants are also characterized by good winter hardiness: shoots do not freeze (Table 3). In dry years (2020, 2021), in July, when there were hot and rainless days, the leaves of *L. styraciflua* lost turgor but restored it without damaging or shedding.

The acclimatization degree (Kokhno & Kuznetsov, 2005) allows to assess the success of *L. styraciflua* introduction at the NBG. Following the proposed formula, the indicators of growth, generative development, winter hardiness, and drought resistance should be multiplied by an importance coefficient of the trait. For *L. styraciflua* plants growing at the NBG, winter hardiness, importance coefficient of the trait was ascertained at the level 10, for generative development – 5, for drought resistance – 3, and for growth – 2. Hence, considering discovered success rates (Table 3) and importance coefficients, the acclimatization degree of *L. styraciflua* plants growing at the NBG is: $A = 4 \times 2 + 4 \times 5 + 5 \times 10 + 4 \times 3 = 90$. This corresponds to a good level of acclimatization.

Conclusions

Liquidambar styraciflua has been recorded in all soil and climatic zones of Ukraine, namely in the following regions: Lviv, Ivano-Frankivsk, Zakarpattia, Ternopil, Chernivtsi, Dnipropetrovsk, Kyiv, Cherkasy, Chernihiv, Kharkiv, Donetsk, Odessa, Kherson, and the Autonomous Republic of Crimea.

It was found that *L. styraciflua* plants at the NBG annually produce young shoots, bloom, and form fruits and seeds with high germination rate. They winter well, and withstand drought.

The assessment of the introduction success of *L. styraciflua* at the NBG was calculated based on growth indicators, generative development, winter hardiness, and drought resistance. The acclimatization of these plants was found to be at good level (90 points).

Hence, *L. styraciflua* can be recommended for landscape construction to create groups, alleys, or tapeworms in parks, squares, zoos, streets, boulevards, squares, areas near houses and administrative buildings, and private estates. It can also be applied in expositions of botanical gardens and arboretums and in topiary art to form complex and straightforward geometric figures, clipped high hedges (living walls), arches, etc.

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Інтродукція *Liquidambar styraciflua* L. в Україні та успішність його акліматизації в Національному ботанічному саду імені М.М. Гришка НАН України

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Проведено скринінг рослин *Liquidambar styraciflua* L. в усіх ґрунтово-кліматичних зонах України у штучних фітоценозах урбанізованих територій, що включають ботанічні сади, парки, сквери, зелені зони, прибудинкові території, вулиці, площі.

На прикладі рослин *L. styraciflua*, що ростуть у Національному ботанічному саду імені М.М. Гришка НАН України (м. Київ), розраховано оцінку успішності інтродукції цих рослин за акліматизаційним числом, що включає показники росту, генеративного розвитку, зимостійкості, посухостійкості. Ступінь акліматизації становить 90 балів, що відповідає добрій акліматизації.

Таким чином, *L. styraciflua* може бути рекомендованим для використання у ландшафтному будівництві для створення груп, алей або в якості солітерів у парках, скверах, зоопарках, а також при озелененні вулиць, бульварів, площ, територій біля будинків та адміністративних будівель, приватних садиб. Ці рослини також можуть бути успішно застосовані в експозиціях ботанічних садів та дендропарків і в якості об'єктів топіарного мистецтва.

Ключові слова: ліквідамбар, інтродукція, акліматизація, деревні рослини, міський ландшафт, середовище існування