Received: 03.02.2025; Revised: 02.05.2025; Accepted: 22.05.2025

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

Journal homepage: https://forestscience.com.ua/en
Ukrainian Journal of Forest and Wood Science, 16(2)

UDC 581.15: 581.6: 631.527: 630*232.13: 631.529: 634.54 (477)
DOI: 10.31548/forest/2.2025.08

Introduction and breeding of purple-leaved hazel in the Forest-Steppe of Ukraine

Volodymyr Mezhenskyj*

Doctor of Agricultural Sciences, Senior Researcher
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
http://orcid.org/0000-0002-3154-1120

Vasyl Halinskyi

Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0009-0008-0264-149X

Liudmyla Mezhenska

PhD in Biological Sciences, Associate Professor
Education and Research Institute of Forestry and Landscape-Park Management
of the National University of Life and Environmental Sciences of Ukraine
03041, 19 Horikhuvatskyi Shlyakh Str., Kyiv, Ukraine
http://orcid.org/0000-0002-6520-1853

Volodymyr Krasovskyi

PhD in Biological Sciences, Senior Researcher
Khorol Botanical Garden
37000, 1/79 Kremenchutsjka Str., Khorol, Poltava region, Ukraine
http://orcid.org/0000-0002-8302-6593

Taisiia Cherniak

Postgraduate Student
Khorol Botanical Garden
37000, 1/79 Kremenchutsjka Str., Khorol, Poltava region, Ukraine
http://orcid.org/0000-0001-5463-2642

Abstract. This study was conducted in 2023-2024 to clarify the origin and introduction of purple-leaved hazel, and to examine the morphological and physiological characteristics of the best genotypes developed by the authors. Morphometric analysis of nuts, quantitative and qualitative

Suggested Citation:
Mezhenskyj, V., Halinskyi, V., Mezhenska, L., Krasovskyi, V., & Cherniak, T. (2025). Introduction and breeding of purple-leaved hazel in the Forest-Steppe of Ukraine. *Ukrainian Journal of Forest and Wood Science*, 16(2), 8-24. DOI: 10.31548/forest/2.2025.08.

**Corresponding author*

composition of pigments in leaves in dynamics, and observation of the influence of abiotic and biotic environmental factors were carried out. It was found that there were mutants in *Corylus* with red/purple colouration of the pellicle of kernels and/or leaves. They have been found repeatedly in different places in Europe, belonging to the species *Corylus avellana* and/or *Corylus maxima*. Taxonomists consider these taxa to be distinct; however, molecular studies suggest that *Corylus maxima* should be synonymised with *Corylus avellana*. The best selections of purple-leaved hazel are characterised by high-quality nuts weighing 2.5-3.2 g with a kernel percentage of 48.0-51.7. The content of chlorophyll a, chlorophyll b, carotenoids, and anthocyanins in purple-leaved selections 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi' was generally higher than in green-leaved varieties, although this difference was not statistically significant in most cases, except for anthocyanins. The high anthocyanin content in the leaves (up to 0.69 mg/g in May) and in the fruit involucres gave these genotypes exceptional decorative effect during the first half of the growing season and beyond. These genotypes had high winter hardiness and drought resistance and are well adapted to local soil and climatic conditions. Among the biotic environmental factors, the nut weevil *Curculio nucum* (damaging the nuts), and the powdery fungus *Phyllactinia guttata* (affecting the leaves) had a negative impact. The fungus *Erysiphe corylacearum*, new to Ukraine, was also found on the leaves. These findings support the wider introduction of purple-leaved hazel, as the best genotypes are highly ornamental and also produce nut. The obtained data will be useful for forest restoration, landscaping and amateur gardening

Keywords: *Corylus avellana*; ornamental plants; anthocyanins; nut weigh; kernel percentage; powdery mildew

Introduction

Studying the introduction and breeding of purple-leaved hazel is essential for several practical and scientific reasons. This plant, *Corylus avellana*, is a valuable ornamental species used in landscaping and horticulture. Its unique purple or reddish leaves attract gardeners and landscape architects, leading a significant demand for its cultivation and propagation. Understanding how to introduce new varieties of purple-leaved hazel into different climatic conditions and soil types is crucial for their successful integration into various environments. Additionally, breeding purple-leaved hazel aims to enhance characteristics such as disease resistance, cold hardiness, and productivity. The development of new varieties can improve both the decorative and commercial qualities of the plant, which is important for gardening and agriculture. Furthermore, this research contributes to biodiversity conservation and the advancement of breeding technologies, potentially benefiting forestry and green construction. Overall, studying the introduction and breeding of purple-leaved hazel not only improves its cultivation but also plays a vital role in preserving the ecological balance (Hicks, 2022).

Recent studies have extensively examined anthocyanin pigmentation in various woody plant species, including *Corylus*, emphasising its protective role against abiotic stressors. K.D. Gu *et al*. (2019) explored how anthocyanins contribute to environmental resilience in horticultural crops, particularly in terms of UV protection and oxidative stress resistance. However, while these studies provide a general understanding of anthocyanin functions, they lack specific insights into the performance of purple-leaved hazel under different ecological conditions.

V.M. Mezhenskyj *et al.* (2024) analysed the value of plants with anthocyanin-rich organs and their importance for landscape architecture, fruit cultivation, and nurseries, as well as their nutraceutical value. O. Johnson & R. Moore (2023) focused on breeding advancements in *Corylus avellana*, detailing the development of new cultivars with unique growth forms such as compact, weeping, and contorted varieties. Their study underscored the increasing ornamental value of purple-leaved hazel but did not assess its agronomic performance or physiological traits under local climatic conditions in Ukraine. K. Król & M. Gantner (2020) investigated the economic significance and commercial potential of *Corylus avellana*, emphasising its role in global nut production. Their study examined hazelnut cultivation trends, market demand, and profitability, highlighting the increasing consumer interest in hazelnuts for their nutritional value and industrial applications. However, while their research provided a broad economic perspective, it did not focus on specific morphological or physiological traits of different hazelnut cultivars, particularly purple-leaved genotypes.

Researchers D. Shataer *et al.* (2021) analysed the chemical composition of *Corylus avellana* kernels and evaluated their biological properties, including anti-inflammatory, antimicrobial, and antioxidant activities. Their findings demonstrated the significant health benefits of hazelnuts due to their rich polyphenolic content and bioactive compounds. The study primarily addressed kernel composition without considering the potential effects of leaf pigmentation on the plant's biochemical and physiological processes. Additionally, no differentiation was made between green- and purple-leaved hazelnut selections.

A. Allegrini *et al.* (2022) explored *Corylus avellana* as a multipurpose species within the framework of the circular economy, emphasising its role in sustainable agriculture, agroforestry, and landscape management. Their research highlighted the diverse applications of hazelnut cultivation beyond nut production, including its potential for erosion control, carbon sequestration, and biodiversity enhancement. However, the study did not address the ornamental value of purple-leaved hazelnuts or their adaptation to different environmental conditions, leaving a gap in understanding their role in ecological and urban green spaces in Ukraine. Meanwhile, purple-leaved hazel varieties have been included in Ukraine's State Register of Varieties Suitable for Distribution (Ministry..., 2024), but research evaluating their adaptation to the country's environmental conditions remains insufficient.

The purpose of this study was to evaluate the best selections of purple-leaved hazel of their own breeding in terms of morphological characteristics and physiological properties for their introduction as ornamental and nut plants for agroforestry, landscaping architecture and amateur growing.

Materials and Methods

Plant Materials. The seedlings of 'Akademik Yablokov' and 'Moskovskij Rubin' were planted in the orchard of the Educational, Research and Production Laboratory "Genetic Resources, Introduction and Breeding of Rare Fruits and Ornamental Plants" of prof. V.L. Symyrenko Department of Horticulture. This orchard is located at the Agronomic Research Station of the National University of Life and Environmental Sciences of Ukraine (NULESU) in Pshenychne village, Bila Tserkva district, Kyiv region which is part of the forest-steppe natural zone. The purpose of establishing and maintaining trees and shrubs in NULESU was to preserve the gene pool and breeding work with fruit and ornamental plants. The collection also had an educational value. Three best selections of *Corylus avellana* named 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi' were used. The adult multi-stemmed shrubs were grown at a planting distance of 5 × 4 m. Standard cultural practices were applied, except irrigation. To compare the pigment content of purple-leaved and green-leaved hazel, leaves of the green-leaved cultivars 'Mortarella', 'Tonda Gentile delle Langhe', and 'Yamhill' were used. The study was conducted in accordance with the ethical standards of the Convention on Biological Diversity (June 1992), which ensures the conservation and sustainable use of biological diversity.

Morphometric analyses. A sample of 20 nuts per genotype collected in 2023-2024 was randomly used for nut traits. In the prof. V.L. Symyrenko Department of Horticulture laboratory, nut samples were dried to constant mass prior to analyses and measurements. Only two linear dimensions of the nut, length and diameter, were measured using a mechanical calliper. It was because these nuts had virtually no difference in nut thickness and nut diameter, and the shell thickness was assessed after manual cracking of the nuts. All measurements were taken in mm. For each sample, the nut and kernel weight (in grams) were measured using an Adventurer™ (Ohaus, China, 2010) electronic laboratory balance. The percentage of kernel was calculated by the following equation: kernel weight / nut weight. Nut shape index was calculated by the following equation: nut length (mm) / nut diameter (mm).

Determination of pigments. Biochemical analyses of hazel leaves were carried out in the Laboratory of Breeding and Technology of Growing Small Fruit Crops of the Institute of Horticulture of the National Academy of Sciences and in independent laboratories for assessing the quality of fruits. The pigments content was determined by the spectrophotometric method using ULAB 102UV (China) spectrophotometer, according to the relevant methods (Kryventsov, 1982; Lichtenthaler, 1987; Hrynenko & Zhuravel, 2017). The data was expressed as mg/g of fresh weight. To determine the pigments, the second and third fully expanded leaves of the shoots of the current year were used.

Impact of environmental factors. Winter hardiness and drought tolerance were assessed in the field by observing plant condition. Pests and pathogens that damage and infect leaves and fruit were identified.

Statistical analysis. The acclimatisation score was calculated using the appropriate formula (Kokhno & Kurdyuk, 1994). Analysis of variance (ANOVA) was performed using Microsoft Excel software (Microsoft Corporation, Roselle, IL, USA). Fisher's least significant difference (LSD) test was used to determine significant differences between means at a 95% confidence level ($P \leq 0.05$). Results are presented as the mean ± standard deviation.

Results and Discussion

Ecological, economic, and ornamental significance of Corylus avellana L. *Corylus avellana* L. (*Betulaceae*) is a component of nemoralis vegetation, which began to form in the Mesozoic era. During the post-glacial period of the early Holocene, it grew only in the western part of the modern territory of Ukraine, subsequently migrating eastward. In pine stands, hazel had only pine and sometimes birch as competitors. Here it formed dense thickets and replaced forests with hazel groves. In contrast, there was little hazel in spruce forests. In the Middle Holocene, hazel occupied most of the territory of Ukraine, except for the steppe regions (Nejshtadt, 1957). At present, according to V.P. Tkach *et al.* (2024) *Corylus avellana* is included in the undergrowth of oak-birch and oak-hornbeam forests. H.P. Ishchuk (2007) points out that it is dominant in the undergrowth of forest cultures of *Juglans nigra* L. According to V.Ye. Sliusarchuk (2006) *Corylus avellana* performs protective functions in steppe forestry, in phytomelioration plantations it protects soil from water erosion, improves hydrological regime, and soil fertility. As a pioneer species it is useful for forest restoration and forest succession.

The hazel is one of the five most important nut crops after cashew, walnut, almond, and chestnut. In Ukraine, the area of hazelnut plantations increased from 100 to 300 hectares (a 66.7% increase), and gross production rose from 20 tons to 210 tons (a 90.5% increase). In the next ten years it is planned to increase the total area of hazelnut plantations to 15 thousand hectares (Mezhenskyj, 2022). Hazelnuts are very nutritious. They are consumed fresh, dry and roasted, used in cooking for various dishes and in the confectionery industry. The oil from the kernels is of nutritional and technical importance and is also used in painting and perfumery. The oil cake is used to make halva and as a substitute for coffee. Young leaves are used in cabbage rolls, soups, and as a tea substitute. Leaves and shoots are fodder for wild and domestic animals (Molnar, 2011).

Hazel wood is thin, white with a reddish tinge, not heavy, soft and easy to split. It is used for hoops, rivets, bent furniture, turnery and carpentry, fencing, wattle and daub, canes and poles; thin branches are used for baskets. The wood burns well and gives off a lot of heat. Charcoal is used to make gunpowder and is good for filtering and drawing. Hazel sawdust clarifies vinegar and clears cloudy wine. The bark can be used as a tanning agent to make the hide yellow. Hazel fruits, bark, leaves, pollen and roots are used in folk medicine. The use of drugs is indicated for dilated veins, periphlebitis, ulcers, capillary hemorrhages. They are used in prostatitis, liver and kidney diseases, anemia, diabetes, hypertension, atherosclerosis, etc. *Corylus avellana* belongs to the taxol-producing angiosperms. Taxol is used to treat breast, ovarian, and non-small cell lung cancer (Goktepe-Atilgan *et al.*, 2023).

The "waste" (leaves, skins, shells, hulls, and pruning material) from hazelnut cultivation is interesting to be valorised as a source of chemical compounds for human health, even more than as a biomass fuel or for biochar applications. *Corylus avellana* can be used for the production of hazelnuts and truffles because its roots form a symbiosis with black and summer truffles.

Hazel is important as an ornamental. Plants with purple leaves are particularly attractive, with anthocyanin colouration dominating in the first half of the growing season. In spring, purple spikes are also attractive. Red pigmentation is also seen in dormant buds, female flowers, husks, and nuts. Many popular ornamental hazelnut cultivars with purple leaves have now been developed in Europe and North America (Johnson & Moore, 2023).

Thus, *Corylus avellana* is a valuable multi-purpose species that plays an important role in forestry, agriculture, industry, and medicine. Its ecological significance in afforestation, erosion control, and phytomelioration, combined with its economic potential in nut production, wood processing, and pharmaceutical applications, highlights its relevance for sustainable resource utilisation. The growing interest in hazel cultivation and the diversification of its applications further emphasise its importance in both ecological restoration and commercial production.

Introduction and breeding of purple-leaved hazel in Ukraine. For a long time cultivated varieties of filbert were attributed to separate species *Corylus maxima* Mill., separating them from the common hazel – *Corylus avellana,* but according to molecular and structural analyses, *Corylus maxima* belongs to the large polymorphic species *Corylus avellana* (Bassil *et al.*, 2013). In *Corylus avellana* populations, red colouration of leaves, buds, female and male flowers occurs. Purple-leaved hazel was introduced to Kyiv in the early 20th century (Dubovyk, 1934). Currently, *Corylus maxima* 'Purpurea' occurs in the botanical gardens and parks of Askania-Nova, Dnipro, Bila Tserkva, Zhytomyr, Ichnia, Kyiv, Lviv, Nikita, Odesa, Uzhhorod, Uman, Kharkiv, Chernivtsi, Kamianets-Podilskyi and *Corylus avellana* 'Atroprpurea/Purpurea' and 'Fuscorubra' – in Bila Tserkva, Kyiv, Lviv, Uman, Kharkiv (Kosenko, 2002).

In 2021, for the first time, the purple-leaved hazelnut variety 'Barbacan BS 1' was registered in the State Register of Varieties of Ukraine. It was selected by Ihor Tsybenko (pers. comm., 2024) in plantations in Poland, with subsequent selection in vegetative progeny. In 1979, Mykola Matvienko (pers. comm., 2024) at the Institute of Horticulture of the NAAS of Ukraine received offspring from the pollination of 'Karamanovskij' × 'Moskovskij Rubin' (Kosenko *et al.*, 2016). From this he selected a number of promising purple-leaved hybrids, which he named 'Bahrianyi', 'Bahriana Bulava', 'Bahriana Bochka', 'Bahriana Kulia' and 'Bahriane Sontse'. In 2022, the cultivar 'Bahrianyi' was included in the State Register of Plant Varieties of Ukraine. In 1991, a collection of hazelnut varieties obtained from the Lozovatskyi Nursery was planted at the Bakhmut Experimental Station of Nurseries Cultivation. The collection included purple-leaved varieties such as 'Akademik Yablokov', 'Moskovskij Rubin', and 'Pushkinskij Krasnyj'. Subsequently, the grafted specimens of 'Akademik Yablokov' and 'Moskovskij Rubin' onto *Corylus colurna* L. were planted in a separate, isolated area for the purpose of harvesting them for hybrid seedlings. In the spring of 2014, the hybrid seedlings were planted in the experimental garden of the National University of Life and Environmental Sciences of Ukraine, located near Kyiv. There is considerable variability among the seedlings, particularly with regard to nut size and nut shape, kernel percentage, time for fruit ripening, and yield. Three best hybrids, selected for a set of economically valuable traits, were designated 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi'. Today, breeding work with the offspring of these hybrids continues at the Khorol Botanical Garden.

Content of pigments. While most trees and shrubs including *Corylus* species have green leaves, there are purple leaves as well. The popularity of purple-leaved hazel is due to the natural colour of its leaves. For this reason, it has undoubted advantages in ornamental gardening over most plants with green leaves. The purple-leaved hazel is cultivated for its functional and ornamental uses as a street and park plant. The use of purple-leaved hazel allows specialists to solve many problems in landscaping and to create highly decorative and effective compositions of woody plants (Fig. 1).

Figure 1. Purple-leaved and green-leaved hazel plants
Source: authors'photo

The intense anthocyanin colour of the leaves is characteristic of purple-leaved hazel in the first half of the growing season. As time goes by, the anthocyanin intensity decreases and the leaves turn green, at which point the beautiful colour of the nut involucre comes to the fore as a decorative feature (Fig. 2).

Figure 2. Attractive appearance of the purple-leaved hazel husk
Source: authors'photo

In the process of photosynthesis, chlorophylls play a crucial role in light absorption, energy transfer and electron transfer. The main pigment is chlorophyll a. The proportion of chlorophyll b is about one third of the total chlorophyll. The amount of chlorophyll in the plant changes during the vegetative period, gradually increasing until the flowering phase and decreasing from flowering to the end of the vegetative period.

The maximum chlorophyll a content was observed in early July, with values of 2.49 mg/g and 2.39 mg/g recorded in green-leaved and purple-leaved hazel samples, respectively. Subsequently, during the month of July, the chlorophyll a content declined by 1.7 and 1.3 times in green- and purple-leaved hazels, respectively (Fig. 3).

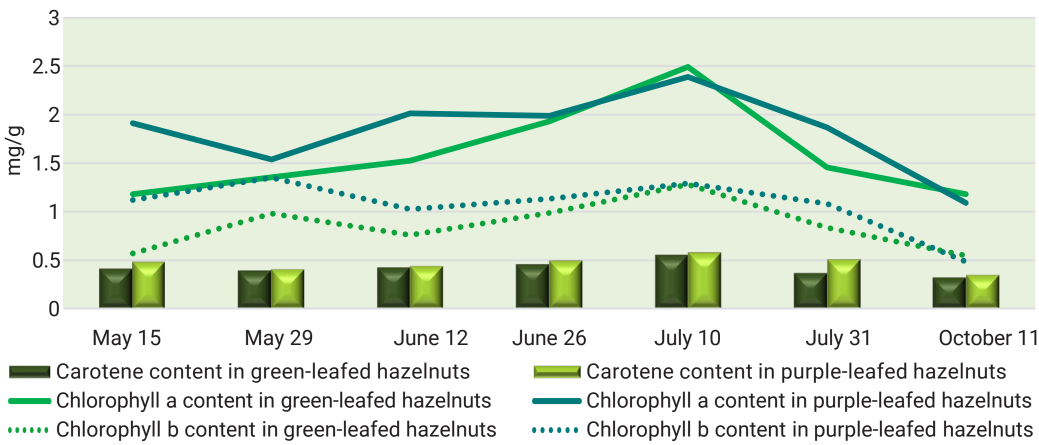

Figure 3. Dynamics of carotene, chlorophyll a, chlorophyll b contents in hazel leaves during the growing season, 2023
Source: compiled by the authors

Throughout the growing season, leaves of red-leaved hazel generally contained more chlorophyll a, except at the end of the growing season. However, this difference was not statistically significant until the first determination in mid-May, when the chlorophyll a content was 1.90 mg/g and 1.44 mg/g for purple- and green-leaved hazel, respectively. Furthermore, a higher chlorophyll b content was observed in the leaves of purple-leaved hazel compared to green-leaved hazel during the growing season. However, these differences did not reach statistical significance. Concurrently, the chlorophyll a/chlorophyll b ratio demonstrated higher levels in green-leaved hazel, though this increase also lacked statistical significance. It should be noted that there is no direct relationship between chlorophyll content and the intensity of photosynthesis, as the latter is determined by the complex interaction of light intensity, its spectral composition, and temperature. The dynamics of carotenoids in hazel leaves is similar to the changes in chlorophyll content, reaching the highest values in early July, 0.55 mg/g and 0.58 mg/g in green- and purple-leaved hazels, respectively. More carotenoids were found in purple-leaved hazel during the growing season, but the difference was not statistically significant.

Anthocyanins, which give tissues their specific colours, are also present in hazel leaves. Anthocyanins are important protective substances that help plants resist stresses such as low temperatures and radiation. Anthocyanins absorb radiation that is poorly absorbed by chlorophyll. The influx of anthocyanins into the leaves is observed in spring and fall, i.e. during cold periods of vegetation. Plants rich in anthocyanins are more resistant to adverse environmental conditions. This is probably due to the fact that anthocyanins activate enzymes of the oxidase class. Together with other plant phenols, flavonoids may be involved in the formation of plant resistance to disease. Anthocyanin plant organs may also have an anti-herbivory function. In addition, both the defensive and physiological functions of anthocyanins may occur simultaneously in plants. It is possible that anthocyanins play a role in plant defence. Anthocyanin pigments absorb UV light as well as visible light and have been proposed to act as UV protectants. J.-H.B. Hatier & K.S. Gould (2008) reviewed three major functional hypotheses for anthocyanins, namely: protection of chloroplasts from the deleterious effects of excess light; attenuation of UV-B radiation; and antioxidant activity, and concluded that none of these hypotheses adequately explains the variation in the spatial and temporal patterns of anthocyanin production because the degree to which each of these processes is affected by anthocyanins varies greatly among plant species. Therefore, anthocyanins may have a more indirect role as modulators of reactive oxygen signalling cascades involved in plant growth and development, responses to stress, and gene expression. In addition, the prevalence of anthocyanin-coloured clones in ornamental horticulture and landscaping is explained by the attention of gardeners, who pay special attention to them for their exceptional decorative value. In a typical hazel, trace amounts of anthocyanins were detected on May 15 (0.01 mg/g), June 12 and July 10 (0.003 mg/g each), and July 31 (0.02 mg/g) (Fig. 4). At this stage, the tips of young shoots with leaves exhibited a slight anthocyanin tint, similar to many other green-leaved species, which fades over time.

In contrast, the leaves of the 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi' selections (Fig. 4) contained high amounts of anthocyanins, 0.62 mg/g, 0.69 mg/g, and 0.45 mg/6, respectively, on May 15. Their number gradually decreased and was halved by the end of May. A month later, there were three to four times fewer of them (Fig. 5, 6). As a result, the photosynthetic apparatus of the purple hazel is protected more reliably and for a longer period of time from excessive solar radiation.

As the leaves matured, they became greener, with only the apical leaves retaining some pigmentation, although their anthocyanin content was significantly lower than at the beginning of the season. From the end of June until the end of the growing season, they anthocyanin content was low (0.01-0.05 mg/g), but still higher than in the green-leaved cultivars. A certain difference in colour intensity in the studied selections at the beginning of the growing season was later diminished.

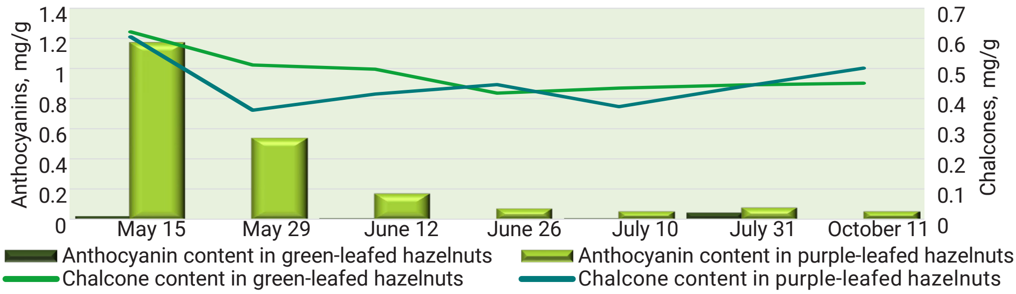

Figure 4. Dynamics of anthocyanin and chalcone contents in hazel leaves during the growing season, 2023

Source: compiled by the authors

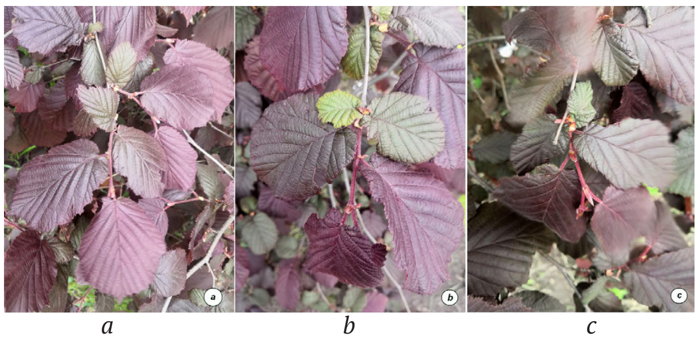

Figure 5. Leaves of young shoots of purple-leaved hazels, May 15, 2023

Note: a – 'Profesorskyi', b – 'Aspirantskyi', c – 'Akademichnyi'

Source: authors' photo

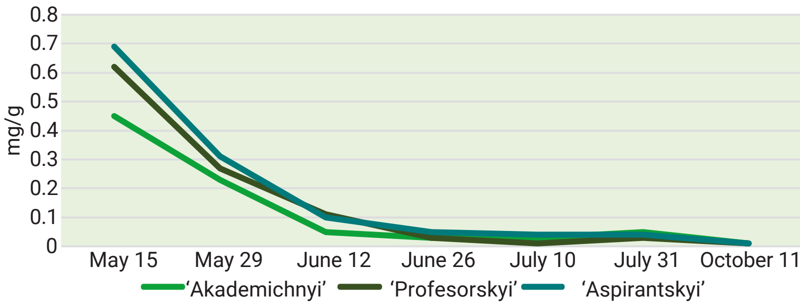

Figure 6. Dynamics of anthocyanin content in leaves of the best hazel genotypes during the growing season, 2023

Source: compiled by the authors

Chalcones, which belong to the class of flavonoids along with anthocyanis, are substances involved in the secondary metabolism of plants. As pointed out by Y.N. Nayak *et al.* (2022), chalcones have low biological activity. However, they exhibit antibacterial, antifungal, antitumor, and anti-inflammatory properties. According to L.M. Shevchuk (2019), chalcones, along with anthocyanins are components of the polyphenol complex in the fruits of many crops. Similar to other pigments, the highest chalcone content in leaves was observed at the beginning of the growing season, with values of 1.24 mg/g in green-leaved and 1.21 mg/g in purple-leaved hazel, respectively (Fig. 5). It then decreased but remained at about the same level throughout the growing season. No statistically significant difference in chalcones content was found between the two groups of hazel studied.

Morphometric characteristic of the best selections. The aim of introduction and breeding effort is to select well-adapted forms exhibiting a complex of economically valuable characteristics. In the population of hybrid purple-leaved hazel seedlings exhibits significant variability in yield, ripening time and fruit quality. Thus, the nuts display a wide range of characteristics. Their shape varies from very elongated and almost cylindrical to ovoid and conical. They also differ in size (from small to large), ripening time (from early to late), shell thickness, and degree to which the fiber develops around the kernels. Based on a comprehensive evaluation of their characteristics, varietal names were assigned to the three best seedlings (Fig. 7).

Morphometric data of nuts from these best genotypes are presented in Table 1.

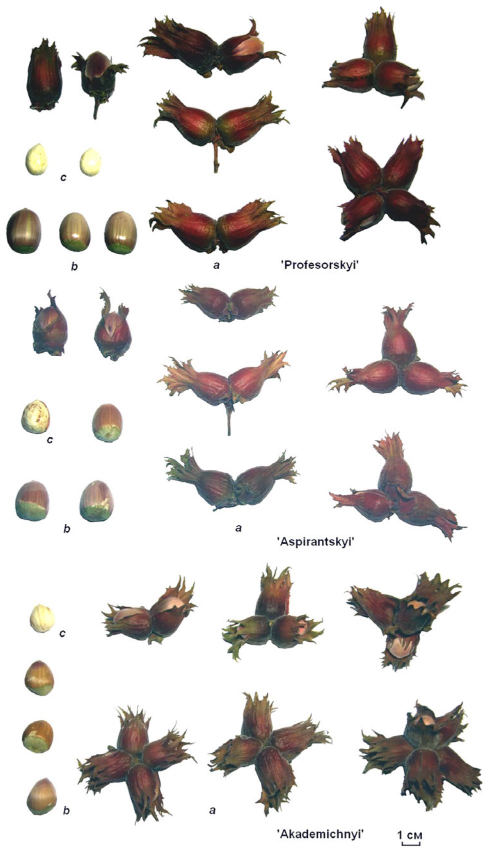

Figure 7. Fruits of the best hazel genotypes

Note: a – fruits with involucre; b – nuts; c – kernel without pelicula
Source: authors' photo

Table 1. The morphometric characteristics of the best hazel genotypes nuts, 2023-2024 (x ± SD, n = 20)

Traits	'Profesorskyi'	'Aspirantskyi'	'Akademichnyi'
Average weight, g	3.20 ± 0.35 a	2.75 ± 0.28b	2.47 ± 0.25c
Kernel percentage, %	47.96 ± 3.39b	50.99 ± 3.77a	51.74 ± 2.98a
Shell thickness, mm	1.13 ± 0.11a	1.09 ± 0.06a	1.12 ± 0.10a
Nut height, mm	25.60 ± 0.98a	23.23 ± 1.28b	22.28 ± 1.04c
Nut diameter, mm	18.65 ± 1.44a	17.50 ± 0.93c	16.52 ± 1.04c
Shape index	1.38 ± 0.09a	1.33 ± 0.09b	1.35 ± 0.08ab

Note: different letters indicate values that are significantly different within one row according to results of the Tukey's test ($P \leqslant 0.05$)
Source: compiled by the authors

'Profesorskyi' has the largest nuts, weighing more than 3 g. 'Aspirantskyi' and 'Akademichnyi' have nut weights of 2.7-2.8 g and 2.3-2.6 g, respectively. The purple-leaved hazelnut cultivars 'Bahrianyi' and 'Barbakan' registered in Ukraine have an average nut weight of 4.60 g (Bahrianyi, 2022) and 2.43 g (Barbakan, 2021), respectively. However, despite its large nuts, 'Bahrianyi'exhibited a lower kernel percentage compared to all three best-selected genotypes. Similarly, 'Barbakan' demonstrated a lower kernel percentage than the selected genotypes. The shells are thin and easily split in these best genotypes. The kernels of 'Profesorskyi' and 'Aspirantskyi' exhibit an absence or only a very weak presence of the fiber. Based on the weight, length, and diameter of the nuts, the selections are arranged in descending order: 'Profesorskyi' > 'Aspirantskyi' > 'Akademichnyi'. In all these genotypes, the nut length exceeds the nut diameter.

Environmental factors. Over 10 years of observation, purple-leaved hazel plants showed no damage from winter frost or spring frosts. During prolonged summer droughts with no precipitation and high air temperatures, adult hazel bushes grown on rainfed soils showed no obvious signs of leaf damage. The plants exhibit excellent growth, and self-seeding occurs under the bushes. Taking into account all these indicators, the degree of acclimatisation is determined as 100% (Kokhno & Kurdyuk, 1994). Aphids, some caterpillars, and true weevils were observed on the leaves. However, these phytophagous pests did not exceed the economic damage threshold. The percentage of nuts affected by the hazel weevil (*Curculio nucum* L.) in the absence of chemical control of the pest reaches 10-12%.

Powdery mildew negatively affects the appearance of hazel leaves (Fig. 8a). *Phyllactinia suffulta* is the type species of the genus causing this disease and is considered a synonym of *Phyllactinia guttata* (Wallr.) Lév. (Cooke, 1952). *Phyllactinia guttata* (*Helotiales, Ascomycota*) is considered a species complex that requires a comprehensive morphological and molecular revision. The fungus parasitizes a wide range of deciduous trees and a smaller number of herbaceous plants. In addition to hazel, this powdery mildew fungus affects fruit crops such as quince, grape, pear, cornelain cherry, kiwi, pistachio, mulberry, and forest trees such as birch, beech, alder, elm, and robinia (Hartney *et al.*, 2005). In Ukraine, common hazel is often affected by powdery mildew caused by *Phyllactinia guttata.* The mycelium of this fungus initially develops endophytically, in the mesophyll of the leaf. Only in late summer does it grow through the stomata to the lower surface of the leaf. Here the mycelium forms the conidial stage of the fungus and later produces fruiting bodies called chasmothecia. During these two stages, the fungus is easy to spot because it forms large, grayish patches that can coalesce into a continuous mycelial layer. Apparently, this disease does not cause significant damage to the host, as it only develops intensively in the fall, at the end of the plant's growing season (Heluta *et al.*, 2019). However, the appearance of the leaves affected by the disease has an adverse effect on the overall decorative effect.

a

b

Figure 8. Hazel leaf lesions

Note: a – Phyllactinia guttata (upper side of the leaf blade), b – Erysiphe corylacearum (lower side of the leaf blade), 2024

Source: authors' photo

A recently discovered species of powdery mildew fungus, *Erysiphe corylacearum* U. Braun & S. Takam. (*Erysiphales, Ascomycota*), has been identified in Ukraine. This species, native to East Asian and North America, has already been documented in Kyiv, Prykarpattia, and Crimea. It is postulated that the fungus migrated from the east or southeast, traversing the Caucasus. Given the epiphytic nature of *Erysiphe corylacearum* in Iran and Turkey, its widespread distribution in Ukraine is anticipated. This has the potential to cause significant damage to ornamental plantations and result in substantial losses in hazelnut farms (Heluta *et al.*, 2019; Heluta & Fokshei, 2020). Hazel leaves damaged by this species of powdery mildew are shown in Figure 8b.

V.P. Heluta *et al.* (2019) and V.P. Heluta & A.I. Fokshei (2020) reported the first occurrences of *Erysiphe corylacearum* in Ukraine, describing its spread as an invasive species affecting hazel trees. Their findings indicated that this alien fungus posed a threat to hazel plantations due to its rapid adaptation to local climatic conditions and its ability to cause extensive powdery mildew infections on leaves. These results highlighted the critical need for continuous monitoring of hazel plantations in Ukraine. S. Hartney *et al.* (2005) identified significant fungal pathogen *Phyllactinia guttata*, which was as the causal agent of powdery mildew in *Corylus avellana* in Washington State. Their study emphasised the importance of early detection and control strategies due to the negative impacts or this pathogen on the growth and physiological functions of infected trees. The presence of *Phyllactinia guttata* in North America suggests its potential expansion to other regions, making it a relevant concern for global hazelnut cultivation.

These studies provide a foundation for understanding the phytopathological risks associated with hazel cultivation and the nutritional significance of its fruits. However, further research is needed to explore the resistance mechanisms of hazel trees against fungal pathogens and the impact of environmental stressors on their biochemical composition. This study aims to address these issues by analysing the introduction of purple-leaved hazel in the Forest-Steppe of Ukraine and evaluating its morphological, physiological, and resistance characteristics.

The research showed that the visual difference between green- and purple-leaved hazelnuts was due to the accumulation of a significant amount of anthocyanidins in the latter. Concurrently, there was no significant difference in the content of other pigments. Among the hybrid population, three genotypes with high-quality nuts, competitive with registered varieties, were selected. Their adaptability to the growing region provides a good basis for wider testing and introduction into forest restoration, ornamental, and orchard plantations.

Conclusions

This study was conducted to highlight the characteristics of a new purple-leaved hazel selections developed at the National University of Life and Environmental Sciences of Ukraine. The purple-leaved hazels have been cultivated in the Ukraine for ornamental purposes on a limited scale for over a century, and two nut varieties have been registered in recent years. The three new best genotypes exhibit certain morphological and physiological differences from the typical green-leaved hazel and characterised by high ornamental value due to their intensely coloured leaves in the first half of the growing season, followed by beautifully coloured fruit shells. The highest content of anthocyanins (average of 0.59 mg/g) and chalcones (average 1.21 mg/g) in leaves was found in mid-May. The highest content of chlorophyll a (average 2.39 mg/g), chlorophyll b (average 1.29 mg/g), and carotenoids (average 0.58 mg/g) was found in early July. The varieties 'Profesorskyi', 'Aspirantskyi' and 'Akademichnyi have large nuts with an average weight of 3.2 g, 2.8 g and 2.5 g, with a high kernel percentage of 48.0%, 51.0% and 51.7%, respectively. Based on these indicators, their performance is comparable to or exceeds that of registered purple-leaf hazelnut cultivars in Ukraine. A new species of powdery mildew fungus was detected, which has recently begun to spread in Ukraine. The varieties are well adapted to the soil and climatic conditions of the Forest-Steppe of Ukraine and can be used in forest restoration plantations, landscaping and gardening. The genotypes developed are valuable for further breeding work and will be the subject of a wider range of studies, including reproduction and fruit biochemical composition.

Acknowledgements

Authors are grateful to Doctor of Biological Sciences Vasyl Heluta, Institute of Botany of NAS of Ukraine for the identification of the pathogenic fungal species.

Funding

None.

Conflict of Interest

None.

References

[1] Allegrini, A., Salvaneschi, P., Schirone, B., Cianfaglione, K., & Di Michele, A. (2022). Multipurpose plant species and circular economy: *Corylus avellana* L. as a study case. *Frontiers in Bioscience-Landmark*, 27(1), article number 11. doi: 10.31083/j.fbl2701011.

[2] Bahrianyi. (2022). In *Protection of plant variety rights* (Vol. 1, p. 553). Vinnytsia: LLC "Tvory".

[3] Barbakan. (2021). In *Protection of plant variety rights* (Vol. 6, p. 820). Vinnytsia: LLC "Tvory".

[4] Bassil, N., Boccacci, P., Botta, R., Postman, J., & Mehlenbacher, S. (2013). Nuclear and chloroplast microsatellite markers to assess genetic diversity and evolution in hazelnut species, hybrids and cultivars. *Genetic Resources and Crop Evolution*, 60, 543-568. doi: 10.1007/s10722-012-9857-z.

[5] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[6] Cooke, W.B. (1952). Nomenclatural notes on the *Erysiphaceae*. *Mycologia*, 44(4), 570-574. doi: 10.1080/00275514.1952.12024218.

[7] Dubovyk, M.V. (1934). *Corylus maxima* Mill. var. *purpurea* Hort. from the Kyiv Botanical Garden as an example of a periclinal chimera. *Bulletin Kyiv Botanical Garden*, 17, 19-21.

[8] Goktepe-Atilgan, I., Dogan, A., & Ari, S. (2023). Enhancement of taxane production in cell suspension culture of *Corylus avellana* L. Kalınkara by elicitation and precursor feeding. *Biotechnology & Biotechnological Equipment*, 37(1), article number 2255703. doi: 10.1080/13102818.2023.2255703.

[9] Gu, K.-D., Wang, C.-K., Hu, D.-G., & Hao, Y.-J. (2019). How do anthocyanins paint our horticultural products? *Scientia Horticulturae*, 249, 257-262. doi: 10.1016/J.SCIENTA.2019.01.034.

[10] Hartney, S., Glawe, D. A., Dugan, F. M., & Ammirati, J. (2005). First report of powdery mildew on *Corylus avellana* caused by *Phyllactinia guttata* in Washington state. *Plant Health Progress*, 6(1). doi: 10.1094/PHP-2005-1121-01-BR.

[11] Hatier, J.-H. B., & Gould, K. S. (2008). Anthocyanin function in vegetative organs. In C. Winefield, K. Davies & K. Gould (Eds.), *Anthocyanins: Biosynthesis, functions, and applications* (pp. 1-19). doi: 10.1007/978-0-387-77335-3_1.

[12] Heluta, V.P., & Fokshei, S.I. (2020). New records of an alien fungus *Erysiphe corylacearum* (Erysiphales, Ascomycota) in Ukraine. *Plant & Fungal Research*, 3(1), 11-17. doi: 10.29228/plantfungalres.64.

[13] Heluta, V.P., Makarenko, N.V., & Al-Maali, G.A. (2019). First records of *Erysiphe corylacearum* (*Erysiphales, Ascomycota*) on *Corylus avellana* in Ukraine. *Ukrainian Botanical Journal*, 76(3), 252-259. doi: 10.15407/ukrbotj76.03.252.

[14] Hicks, D. (2022). Biological flora of Britain and Ireland: *Corylus avellana*. *Journal of Ecology*, 110(12), 3053-3089. doi: 10.1111/1365-2745.14008.

[15] Hrynenko, U.V., & Zhuravel, I.O. (2017). Determination of chlorophyll and carotenoid content in spinach leaves (*Spinacia oleracea* L.). *Collection of Scientific Works of Employees of the P.L. Shupyk National Medical Academy of Physical Education and Sports*, 28, 29-33.

[16] Ishchuk, H.P. (2007). Establishment of forest cultures *Juglans nigra* L. in forestry's of Uman state-run forest enterprise. *Scientific Bulletin of UNFU*, 17.6, 25-31.

[17] Johnson, O., & Moore, R. (2023). *Corylus avellana* L. Retrieved from. https://surli.cc/dssgee

[18] Kokhno, N.A., & Kurdyuk, A.M. (1994). *Theoretical foundations and experience of introduction of woody plants in Ukraine*. Kyiv: Naukova dumka.

[19] Kosenko, I.S. (2002). Family *Corylaceae* – hazel and related trees. In M.A. Kokhno (Ed.), *Wild and cultivated trees and shrubs. Angiosperms. Part I.* (pp. 204-315). Kyiv: Fitosotsiotsentr.

[20] Kosenko, I.S., Opalko, A.I., Balabak, O.A., & Shulga, S.M. (2016). Corylus spp. genetic collection use in hazelnut *Corylus domestica* Kos. et Opal. improvement. *Journal of Native and Alien Plant Studies*, 12, 120-136.

[21] Król, K., & Gantner, M. (2020). Morphological traits and chemical composition of hazelnut from different geographical origins: A review. *Agriculture*, 10(9), article number 375. doi: 10.3390/agriculture10090375.

[22] Kryventsov, V.Y. (1982). *Methodical recommendations for the analysis of fruits for biochemical composition*. Yalta: State Nikita Botanical Garden.

[23] Lichtenthaler, H.K. (1987). Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. *Methods in Enzymology*, 148, 350-382. doi: 10.1016/0076-6879(87)48036-1.

[24] Mezhenskyj, V. (2022). Rare fruits in Ukraine. *Chronica Horticulturae*, 62(3), 40-44.

[25] Mezhenskyj, V.M., Pyshcholka, D.V., Mezhenska, L.O., & Havryliuk, O.S. (2024). An overview of the red-fleshed apple: History and its importance for horticulturists, gardeners, nurserymen, and consumers. *Biosystems Diversity*, 32(1), 158-167. doi: 10.15421/012416.

[26] Ministry of Agrarian Policy and Food of Ukraine. (2024). *State register of plant varieties suitable for distribution in Ukraine*. Retrieved from https://minagro.gov.ua/file-storage/reyestr-sortiv-roslin.

[27] Molnar, T.J. (2011). *Corylus*. In C. Kole (Ed.), *Wild crop relatives: Genomic and breeding resources, forest trees* (pp. 15-48). Berlin; Heidelberg: Springer-Verlag. doi: 10.1007/978-3-642-21250-5_2.

[28] Nayak, Y.N., Gaonkar, S.L., & Sabu, M. (2022). Chalcones: Versatile intermediates in heterocyclic synthesis. *Journal of Heterocyclic Chemistry*, 60(8), 1301-1325. doi: 10.1002/jhet.4617.

[29] Nejshtadt, M.I. (1957). *History of forests and paleography of the USSR in the Holocene*.

[30] Shataer, D., Li, J., Duan, X.-M., Liu, L., Xin, X.-L., & Aisa, H.A. (2021). Chemical composition of the hazelnut kernel (*Corylus avellana* L.) and its anti-inflammatory, antimicrobial, and antioxidant activities. *Journal of Agricultural and Food Chemistry*, 69, 4111-4119. doi: 10.1021/acs.jafc.1c00297.

[31] Shevchuk, L.M. (2019). The content of biologically active substances in the fruits of traditional and less common cultivated fruit crops. *Bulletin of Agricultural Science*, 97(1), 81-88. doi: 10.31073/agrovisnyk201911-12.

[32] Sliusarchuk, V.Ye. (2006). Biodiversity of filbert and hazelnut: Conservation and improvement. *Scientific Bulletin of UNFU*, 16.6, 11-18.

[33] Tkach, V.P., Tarnopilska, O.M., & Orlov, O.O. (2024). *Types of forest formations of Ukraine in the system of European classifications*. Kharkiv: LLC Typography Madrid. doi: 10.33220/2024.978-617-8254-23-0.

Інтродукція і селекція пурпуролисткової ліщини в Лісостепу України

Володимир Меженський

Доктор сільськогосподарських наук, старший науковий співробітник
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
http://orcid.org/0000-0002-3154-1120

Василь Галінський

Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0009-0008-0264-149X

Людмила Меженська

Кандидат біологічних наук, доцент
Навчально-науковий інститут лісового і садово-паркового господарства
Національного університету біоресурсів і природокористування України
03041, вул. Горіхуватський шлях, 19, м. Київ, Україна
http://orcid.org/0000-0002-6520-185

Володимир Красовський

Кандидат біологічних наук, старший науковий співробітник
Хорольський ботанічний сад
37800, вул. Кременчуцька, 1/79, м. Хорол, Полтавська обл., Україна
http://orcid.org/0000-0002-8302-6593

Таїсія Черняк

Аспірант
Хорольський ботанічний сад
37800, вул. Кременчуцька, 1/79, м. Хорол, Полтавська обл., Україна
http://orcid.org/0000-0001-5463-2642

Анотація. Дане дослідження проведено в 2023-2024 рр. з метою з'ясування походження та інтродукції пурпуроволисткової ліщини, а також вивчення морфологічних і фізіологічних особливостей кращих генотипів, створених авторами. Було проведено морфометричний аналіз горіхів, кількісний та якісний склад пігментів в листках в динаміці та спостереження за впливом абіотичних та біотичних чинників довкілля. Виявлено, що у *Corylus* існують мутанти з червоним/фіолетовим забарвленням оболонки ядра та/або листків. Їх неодноразово знаходили в різних місцях Європи, відносячи до видів *Corylus avellana* та/або *Corylus maxima*. Систематики вважають ці таксони окремими, проте молекулярні дослідження свідчать, що *Corylus maxima* слід синонімізувати з *Corylus avellana*. Найкращі селекційні зразки пурпуроволисткової ліщини характеризувалися високоякісними горіхами масою 2,5-3,2 г та з виходом ядра 48,0-51,7 %. Встановлено, що за вмістом хлорофілу a, хлорофілу b, каротиноїдів та антоціанів пурпуроволисткові добори 'Професорський', 'Аспірантський' і 'Академічний' перевищують зеленолисткові сорти, хоча ця різниця не є статистично значущою у більшості випадків, за винятком антоціанів. Високий вміст антоціанів у листках (до 0,69 мг/г у травні) та у плюсках надавав цим генотипам виняткової декоративності протягом першої половини вегетації та пізніше. Ці генотипи мали високу зимостійкість та посухостійкість і добре адаптовані до місцевих ґрунтово-кліматичних умов. Серед біотичних факторів довкілля негативний вплив мали ліщиновий довгоносик *Curculio nucum* (пошкоджував горіхи) та борошнистий гриб *Phyllactinia guttata* (вражав листки). На листках також було виявлено новий для України борошнисторосяний гриб *Erysiphe corylacearum*. Ці результати підтримують ширшу інтродукцію пурпуроволисткової ліщини, оскільки найкращі генотипи мають високу декоративність, а також дають горіхи. Отримані дані будуть корисними для лісомеліорації, декоративного та аматорського садівництва

Ключові слова: *Corylus avellana;* декоративні рослини; антоціани; маса горіха; відсоток ядра; борошниста роса