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Morphometric analysis of nuts in the hybrid population of purple-leaved hazelnut (*Corylus avellana* L.)

Abstract. Hazelnut (*Corylus avellana* L.) is a strategically important nut crop with high nutritional value and significant economic potential. While industrial cultivation is primarily based on green-leaved genotypes, interest in purple-leaved forms has been steadily increasing due to the ornamental appeal and elevated antioxidant potential associated with anthocyanin pigmentation. However, information on nut morphometric traits and the variability in hybrid populations of purple-leaved hazelnut remains limited. This study aimed to analyse the morphometric characteristics of nuts in a hybrid population of purple-leaved hazelnut developed at the National University of Life and Environmental Sciences of Ukraine. The experimental material included nuts from 23 mature own-rooted hybrid shrubs derived from a cross between 'Akademik Yablokov' and 'Moskovskij Rubin'. Nut and kernel weight, linear dimensions, shell thickness, kernel percentage, and nut shape index were evaluated using standard morphometric and statistical methods. The results revealed substantial phenotypic variability in nut morphological traits, with average nut weight ranging from 1.4 g to 3.4 g. Based on the aggregate of economic traits, the 'Profesorskyi' genotype was identified as the most promising overall, producing the heaviest nuts (3.4 g) and kernels (1.6 g). Correlation analysis revealed a strong negative relationship between kernel percentage and shell thickness ($r = -0.670$), indicating shell thickness as the primary limiting factor for kernel yield. The studied hybrid

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population represents a valuable genetic resource for hazelnut breeding, enabling the selection of genotypes suitable for both commercial nut production and ornamental use. The combination of high nut quality with pronounced decorative traits associated with stable anthocyanin pigmentation highlights the potential of purple-leaved hazelnut for diversified agricultural production and landscape applications

Keywords: anthocyanin pigmentation; phenotypic variability; nut weight; kernel percentage; shell thickness; breeding

INTRODUCTION

The study of hazelnut genetic diversity, particularly focusing on purple-leaved genotypes, is of paramount importance due to the shifting priorities in global horticulture. As agricultural systems face increasing pressure from climate change and evolving market demands, the reliance on a narrow range of green-leaved cultivars poses a risk to long-term crop resilience and economic stability. Investigating the morphometric characteristics of hybrid populations allows for the identification of genotypes that harmoniously combine high productivity with enhanced biological activity and ornamental appeal. This dual-purpose potential is crucial for the diversification of nut production, providing raw materials for the food industry while simultaneously offering aesthetic value for sustainable urban landscaping. Establishing a robust morphometric database for these hybrids is therefore essential for accelerating the selection process and ensuring the development of superior cultivars that meet modern quality standards.

The global significance of hazelnut as a primary nut crop is underscored by its massive production volumes. According to FA-OSTAT (n.d.), the world production of in-shell hazelnuts exceeds 1.1 million tonnes, reflecting its vital role in the global agricultural economy. Researchers A. Campa Negrillo *et al.* (2021) and M. Rondanelli *et al.* (2023) emphasised that hazelnuts are indispensable in the confectionery industry due to the high nutritional density, whether consumed fresh or processed. Within the Ukrainian market, a marked domestic production deficit exists. Consequently, V. Mezhen-skyj (2022) identifies a significant opportunity for the industrial scaling of hazelnut cultivation. The aesthetic and biological advantages of

anthocyanin-rich genotypes have also gained scientific attention. The genotypes with purple pigmentation in leaves and husks provide significant ornamental value, which led O. Johnson & R. Moore (n.d.) to advocate for the integration of such pigmented mutants into breeding programmes in Europe and North America. I. Kosenko *et al.* (2023) have demonstrated that these genotypes can be effectively utilised to improve specific nut characteristics.

In Eastern Europe, the latest advancements in variety registration and testing have been highlighted by the official entry of the 'Barbakan BSI' and 'Bahrianyi' cultivars into the State Register of Plant Varieties of Ukraine (Vishtak *et al.*, 2021; Vishtak *et al.*, 2022; Ministry of Economy, Environment, and Agriculture of Ukraine, 2025). Meanwhile, G. Hodun & S. Pluta (2024, pers. commun.) have noted the increasing inclusion of such forms in Polish breeding efforts. Despite the promising results, at the National University of Life and Environmental Sciences of Ukraine, a critical challenge remains. Breeding programmes in hazelnut are exceptionally time-consuming, often requiring 15-20 years from the initial cross to the release of a new cultivar. This long duration necessitates the use of advanced morphometric analysis at early stages to identify the most promising material. This is particularly relevant when evaluating offspring from crosses of highly productive cultivars such as 'Akademik Yablokov' and 'Moskovskij Rubin', which serve as the genetic foundation for many purple-leaved hybrids in the region.

Furthermore, the introduction of new crops and cultivars better adapted to climate change is relevant for many countries, including Ukraine, as established by R. Kızılkaya *et al.* (2022) and

M. Nazarenko & O. Simchenko (2023). Hybrid populations derived from purple-leaved forms represent a valuable source of phenotypic variability, particularly in nut size, shape, and shell characteristics. Understanding the correlation between shell thickness and kernel yield is vital for selecting genotypes that meet the industrial requirement for high-efficiency processing. Modern standards demand thin-shelled nuts with a kernel percentage exceeding 45%, a threshold that requires rigorous selection within hybrid populations.

The aim of this study was to analyse nut morphological traits in hybrid population genotypes of purple-leaved hazelnut developed at the National University of Life and Environmental Sciences of Ukraine (NULES).

MATERIALS AND METHODS

Purple-leaved hazelnut cultivars 'Akademik Yablokov' and 'Moskovskij Rubin' were cultivated at a separate site. Nuts from 'Akademik Yablokov' were used to generate a hybrid seedling population, from which purple-leaved genotypes were selected and planted in a breeding orchard at the Educational, Research and Production Laboratory of Genetic Resources, Introduction, and Breeding of Rare Fruit and Ornamental Plants (NULES of Ukraine), located at the Agro-economic Research Station in Pshenychne village, Bila Tserkva district, Kyiv region (50°05'20.1" N 30°12'54.9" E). The experimental material comprised nuts collected from 23 mature shrubs of the hybrid population. Seedlings were planted in 2014 at a spacing of 5 × 4 m and maintained under rainfed conditions using standard horticultural practices. Nuts were harvested at full physiological maturity in mid-August 2025. All procedures complied with the Convention on Biological Diversity (1992) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

Nut length, width, thickness, and shell thickness (all in mm) were measured using a mechanical calliper with a resolution of 0.1 mm. Nut and kernel weights were determined with an Adventurer™ electronic laboratory balance (China) with a precision of 0.01 g. Kernel percentage was calculated as the ratio of kernel

weight to nut weight. Nut shape index was expressed as the length-to-width ratio. Nut and kernel traits were evaluated according to the International Board for Plant Genetic Resources Descriptors (Bioversity, FAO & CIHEAM, 2008). Statistical analysis included descriptive statistics (mean, standard deviation (SD), and coefficient of variation (CV%)) and correlation analysis. All calculations were performed using Microsoft Excel Office 2019. One-way analysis of variance (ANOVA) was used to compare genotypes for each morphometric trait, and differences were considered significant at the 95% confidence level ($p \leq 0.05$) using R. Fisher's least significant difference (LSD) test. Skewness and kurtosis were calculated using standard Excel statistical functions. K. Pearson correlation coefficients were calculated, and the statistical significance was assessed using Student's t-test at $p \leq 0.05$.

RESULTS AND DISCUSSION

In 2003, nuts of the purple-leaved hazelnut cultivars 'Moskovskij Rubin' and 'Akademik Yablokov' from the collection of the Bakhmut Experimental Station of Nursery Cultivation were evaluated. 'Moskovskij Rubin' had a higher nut weight (4.4 g) but a lower kernel percentage (38.0%) compared with 'Akademik Yablokov', which produced smaller nuts (2.8 g) with a higher kernel percentage (49.7%). The relatively low kernel content of 'Moskovskij Rubin' was associated with poor kernel filling, presumably due to cultivation under rainfed conditions; in addition, approximately half of the nuts were damaged by the hazelnut weevil (*Curculio nucum* L.).

These two cultivars, grafted onto Turkish hazel (*Corylus colurna* L.), were established at a separate site. Given that hazelnut is a self-incompatible species, it is highly probable that 'Akademik Yablokov' was cross-pollinated by 'Moskovskij Rubin'. Nuts collected from 'Akademik Yablokov' trees were characterised by an average nut weight of 2.6 g and a kernel percentage of 48.6%. An analysis of the hybrid population of purple-leaved seedlings derived from 'Akademik Yablokov' nuts revealed a variation in average nut weight ranging from 1.4 g to 3.4 g (Table 1).

Table 1. Morphometric indicators of nuts ($\bar{x} \pm SD$, $n=20$), 2025

Genotype	Nut weight, g	Nut length, mm	Nut width, mm	Nut thickness, mm	Kernel weight, g	Kernel percentage, %	Shell thickness, mm
'Profesorskiy'	3.4 ± 0.29	25.1 ± 1.29	19.6 ± 0.70	18.8 ± 1.32	1.6 ± 0.02	47.4 ± 3.46	1.1 ± 0.08
'Aspirantskiy'	2.9 ± 0.29	22.6 ± 0.97	17.9 ± 0.88	16.7 ± 0.95	1.1 ± 0.02	37.1 ± 6.23	1.4 ± 0.18
#58	2.7 ± 0.39	27.5 ± 1.27	18.8 ± 1.14	16.7 ± 0.67	1.3 ± 0.03	48.1 ± 3.79	1.0 ± 0.11
#34	2.6 ± 0.29	25.7 ± 1.42	17.2 ± 0.92	15.8 ± 0.92	0.7 ± 0.02	27.8 ± 3.57	1.3 ± 0.07
#66	2.5 ± 0.25	19.5 ± 0.85	18.6 ± 0.84	15.4 ± 0.70	1.1 ± 0.01	46.5 ± 3.24	1.2 ± 0.08
#61	2.5 ± 0.23	26.2 ± 0.63	19.9 ± 0.32	18.7 ± 0.67	0.6 ± 0.03	25.3 ± 5.95	1.1 ± 0.12
#60	2.5 ± 0.40	29.4 ± 1.26	17.8 ± 1.39	16.8 ± 0.92	1.2 ± 0.05	47.9 ± 3.92	1.1 ± 0.07
'Akademichnyi'	2.5 ± 0.16	21.8 ± 0.42	17.5 ± 0.53	16.6 ± 0.52	1.2 ± 0.01	48.1 ± 2.85	1.1 ± 0.06
#68	2.4 ± 0.19	24.8 ± 0.42	16.7 ± 0.48	15.4 ± 0.70	1.1 ± 0.02	44.7 ± 3.56	1.1 ± 0.08
#65	2.4 ± 0.19	22.8 ± 0.63	16.7 ± 0.67	15.7 ± 0.48	0.9 ± 0.01	38.0 ± 2.17	1.2 ± 0.05
#57	2.3 ± 0.22	21.1 ± 0.74	16.5 ± 0.71	15.9 ± 0.74	1.1 ± 0.02	46.6 ± 2.60	1.2 ± 0.09
#36	2.3 ± 0.18	26.7 ± 0.95	15.6 ± 0.52	14.5 ± 0.85	0.9 ± 0.01	39.0 ± 3.32	1.2 ± 0.04
#54	2.3 ± 0.15	24.4 ± 0.84	16.0 ± 0.82	15.1 ± 0.57	0.8 ± 0.03	37.3 ± 8.23	1.1 ± 0.08
#64	2.1 ± 0.14	22.4 ± 0.70	16.9 ± 0.74	13.5 ± 0.53	1.1 ± 0.00	54.3 ± 2.14	0.8 ± 0.28
#56	1.9 ± 0.17	19.8 ± 0.42	16.6 ± 0.84	13.4 ± 0.70	0.9 ± 0.07	46.2 ± 9.45	1.0 ± 0.07
#38	1.8 ± 0.17	20.3 ± 0.67	15.9 ± 0.74	12.6 ± 0.52	0.8 ± 0.00	43.7 ± 2.64	1.1 ± 0.09
#42	1.7 ± 0.21	22.5 ± 0.53	15.1 ± 0.32	14.8 ± 0.42	0.8 ± 0.02	44.5 ± 3.71	0.8 ± 0.13
#45	1.7 ± 0.20	22.0 ± 0.47	15.6 ± 0.52	14.3 ± 0.67	0.6 ± 0.03	34.4 ± 6.83	1.1 ± 0.13
#52	1.7 ± 0.14	19.6 ± 0.70	15.2 ± 0.42	13.2 ± 0.42	0.8 ± 0.01	44.0 ± 2.59	1.1 ± 0.11
#62	1.6 ± 0.10	18.7 ± 0.67	15.4 ± 0.70	13.3 ± 0.67	0.9 ± 0.01	54.6 ± 2.52	0.8 ± 0.13
#49	1.5 ± 0.12	21.7 ± 0.67	13.1 ± 0.57	12.1 ± 0.57	0.8 ± 0.01	55.3 ± 1.77	0.9 ± 0.14
#44	1.5 ± 0.11	20.1 ± 0.32	14.1 ± 0.74	12.3 ± 0.48	0.6 ± 0.00	41.7 ± 1.58	1.1 ± 0.05
#37	1.4 ± 0.14	20.2 ± 0.63	12.6 ± 0.52	11.4 ± 0.52	0.7 ± 0.01	47.9 ± 2.83	1.0 ± 0.03
LS _{0.05}	0.19	0.72	0.64	0.62	0.12	3.85	0.10
Lim	1.4-3.4	18.7-27.5	12.6-19.6	11.4-18.8	0.6-1.6	25.3-55.3	0.8-1.4
CV, %	23.6	12.7	11.3	13.4	29.9	17.7	13.9

Note: $\bar{x}$ – mean; SD – standard deviation; n – number of replications; LSD0.05 – least significant difference ($p \leq 0.05$); lim – range of variation (min–max); CV – coefficient of variation

Source: compiled by the authors

In the course of evaluating the hybrid population, the distribution of genotypes by nut weight was found to be fairly symmetrical and close to normal. The observed slight positive skewness (0.305) indicates a predominance of individuals with nut weights below the arithmetic mean of 2.2 g, while a few variants are characterised by significantly higher nut weights. This is further supported by the negative kurtosis value (-0.195), suggesting a platykurtic distribution where values are spread relatively evenly across the range (1.4–3.4 g) without a sharp concentration around the centre. These distributional patterns are analogous to the findings of N. Valentini *et al.* (2025), who reported skewness values of 0.355–0.512 and kurtosis of -0.086 to 0.018 in F_1 populations from crosses between two European cultivars.

In the research, the average nut weight of the parental forms ranged from 2.3–2.4 g and 3.1–3.5 g, respectively, while the nut weight range in the F_1 population fluctuated between 1.3 g and 3.9 g across different years.

The phenotypic superiority of specific genotypes within the studied material is noteworthy. Significantly, the heaviest nuts were produced by the 'Profesorskiy' genotype (3.4 ± 0.29 g), which surpasses its maternal cultivar, 'Akademik Yablokov'. 'Aspirantskiy' genotype also significantly outperforms others in kernel weight (2.9 ± 0.29 g). Both 'Profesorskiy' and 'Aspirantskiy' produce "very large" nuts, placing these genotypes among the top tier of the population, where 43.5% of genotypes are categorised as "large" or "very large". When comparing these results to international commercial standards,

the hybrid population demonstrates high competitive potential. In a review by K. Król & M. Gantner (2020), commercial hazelnut cultivars typically exhibit nut weights between 1.4 g and 3.8 g, kernel weights between 0.5 g and 2.0 g, and kernel content from 33.2 to 49.5%. Genotypes with nut weights between 1.2 g and 5.4 g, kernel weights between 0.5 g and 2.0 g, and kernel content from 39 to 57% were involved in the American breeding programmes (Yao & Mehlenbacher, 2000). As noted by Q. Yao & S. Mehlenbacher (2001), nut weight is a function of shell thickness and kernel weight. Most crosses in the investigations exhibited transgressive segregation toward lighter nuts.

The analysis of shell thickness revealed it to be one of the most stable traits in the hybrid population, with a coefficient of variation of 13.9% and an average value of 1.1 mm. The distribution of this trait is characterised by a moderate negative skewness (-0.64) and a positive kurtosis (0.39), indicating a slight predominance of genotypes with a thicker shell. The biological significance of this parameter is directly confirmed by its correlation with kernel yield. In particular, the genotypes that demonstrated the highest kernel content (exceeding the 54.0% threshold), namely #49, #62, and #64, were found to possess the thinnest shells (0.8 mm) in the entire population. This aligns with the breeding objectives for commercial hazelnut cultivars, where a thin shell is a primary indicator of high technological quality. In comparison, the 'Profesorskyj' genotype, while having the largest nut weight,

possesses a shell of medium thickness, which results in an average kernel content of 47.4%. These observations highlight the importance of shell thickness as a limiting factor for kernel productivity in the studied hybrid material. It should be noted that in the current study, the genotype 'Aspirantskyj' exhibited the thickest shell (1.4 mm), which harmed its kernel percentage. According to previous observations over two seasons, nuts of 'Aspirantskyj' had an average shell thickness of 1.1 mm and a mean kernel percentage of 51.0% (Mezhenskyj et al., 2025). In contrast, for top-performing genotypes such as 'Profesorskyj' and 'Akademichnyi', shell thickness and kernel percentage remained stable without significant fluctuations.

Finally, the observed higher variability in weight indicators (CV = 23.6-29.9%) compared to linear parameters of nuts (CV = 11.3-13.4%) aligns with the biological patterns established by D. Falconer (1995), confirming that weight-based traits offer the greatest scope for further clonal selection. The distribution of width was found to be the most symmetrical and closest to the theoretical normal curve (skewness = -0.17; kurtosis = 0.00), while height and thickness showed slight deviations. Specifically, the height of the nuts exhibited a moderate positive skewness (0.61), indicating a predominance of genotypes with below-average height (22.8 mm) alongside individual tall specimens. The correlation analysis revealed significant relationships between the morphological and weight-based traits of the studied hybrids (Table 2).

Table 2. Pearson correlation coefficients between traits (*r*)

Trait	Nut weight	Nut length	Nut width	Nut thickness	Kernel weight	Kernel percentage	Shell thickness
Nut weight	1						
Nut length	0.611	1					
Nut width	0.858	0.498	1				
Nut thickness	0.890	0.644	0.891	1			
Kernel weight	0.743	0.334	0.599	0.560	1		
Kernel percentage	-0.250	-0.333	-0.290	-0.386	0.450	1	
Shell thickness	0.481	0.178	0.319	0.385	-0.011	-0.670	1

Note: significant coefficients ($p \leq 0.05$) are shown in bold ($n = 23$)

Source: compiled by the authors

A very strong positive correlation was observed between nut weight and its transverse

dimensions: thickness ($r = 0.890$) and width ($r = 0.858$). Nut weight also showed a strong

correlation with nut length ($r = 0.611$), although to a lesser extent than with width and thickness. The nearly perfect correlation between nut width and nut thickness ($r = 0.891$) suggests that these two dimensions develop proportionally in the studied population. Kernel weight is strongly and positively correlated with total nut weight ($r = 0.743$), confirming that selection for heavier nuts will likely lead to heavier kernels. Among linear parameters, nut width ($r = 0.599$) and thickness ($r = 0.560$) have a greater influence on kernel weight than nut length ($r = 0.334$). Interestingly, there is virtually no correlation between kernel weight and shell thickness ($r = -0.011$), indicating that these two traits vary independently. The most critical findings for breeding concern the kernel percentage. A strong negative correlation was found between kernel percentage and shell thickness ($r = -0.670$), identifying shell thickness as the primary limiting factor for productivity. Furthermore, kernel percentage showed negative correlations with all nut dimensions, most notably with nut thickness ($r = -0.386$) and nut length ($r = -0.333$), as well as with total nut weight ($r = -0.250$). This suggests a potential “trade-off” in selection: while selecting for larger or heavier nuts, there is a risk of decreasing the relative kernel yield if the shell mass increases disproportionately. These results confirm that for the evaluated *Corylus avellana* purple-leaved hybrids,

the most effective breeding strategy for high productivity should prioritise genotypes that combine a large nut volume (width and thickness) with a thin shell. The positive correlation between kernel weight and kernel percentage ($r = 0.450$) further supports the possibility of selecting for both high absolute weight and high relative yield. As noted by Q. Yao & S. Mehlenbacher (2001), nut dimensions represent a critical parameter for both the in-shell and kernel sectors of the industry. This is due to the inherent relationship where nut volume serves as a reliable proxy for kernel size, provided that significant kernel shrinkage is absent. Correlation analysis further supports this.

The parental cultivars ‘Akademik Yablokov’ and ‘Moskovskij Rubin’ produce elongated nuts, with shape indices of 1.6 and 1.3, respectively, according to measurements from 2003. Significant variation in nut shape was observed among the progeny. Specifically, the shape index ranges from 1.1 to 1.7, with 39.1% of the genotypes producing elongated fruits with a shape index of 1.5 or higher. This range is wider than that reported by A. Ferrão *et al.* (2021), who studied industrial cultivars and reported shape index fluctuations ranging from 0.9 to 1.5. Genotype #66 is characterised by oblate nuts with globular kernels. Four other genotypes: #61 (with ovate nuts), as well as #62, #57, and #38 (all with obovate nuts), also possess globular kernels (Figs. 1-2, Table 3).

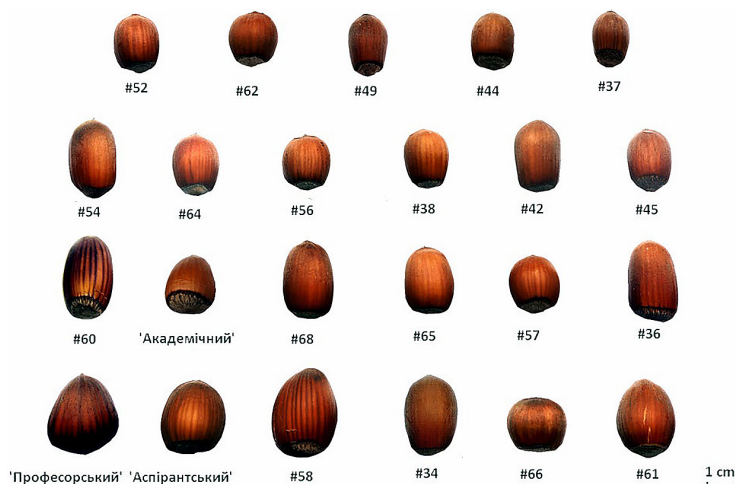


Figure 1. Nuts of genotypes tested

Source: compiled by the authors

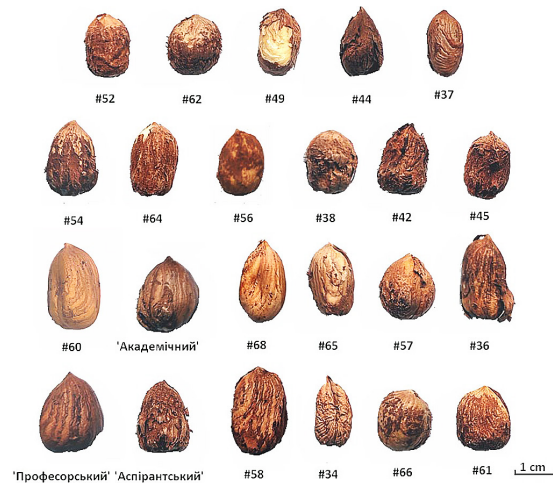


Figure 2. Kernels of genotypes tested

Source: compiled by the authors

Table 3. The characteristics of the nuts and kernels

Genotype	Shape index	Nut shape	Kernel shape	Kernel: Presence of fibre
#66	1.1	oblate	globular	weak
'Akademichnyi'	1.2	conical	ovoid	medium
#56	1.2	obovoid	ovoid	medium
#62	1.2	obovoid	globular	strong
'Profesorskyi'	1.3	ovoid	ovoid	absent
'Aspirantskyi'	1.3	ovoid	ovoid	medium
#61	1.3	ovoid	globular	weak
#57	1.3	obovoid	globular	medium
#64	1.3	obovoid	obovoid	medium
#52	1.3	obovoid	obovoid	very strong
#38	1.3	obovoid	globular	very strong
#65	1.4	ovoid	obovoid	strong
#45	1.4	obovoid	obovoid	very strong
#44	1.4	obovoid	ovoid	very strong
#58	1.5	ovoid	subcylindrical	strong
#34	1.5	subcylindrical	obovoid-subcylindrical	weak
#68	1.5	subcylindrical	obovoid-subcylindrical	weak
#54	1.5	subcylindrical	ovoid	strong
#42	1.5	obovoid-subcylindrical	ovoid	very strong
#60	1.6	subcylindrical	obovoid-subcylindrical	absent
#37	1.6	obovoid-subcylindrical	subcylindrical	medium
#36	1.7	ovoid-subcylindrical	subcylindrical	strong
#49	1.7	obovoid-subcylindrical	obovoid	very strong

Source: compiled by the authors

The observed inheritance patterns in the study are consistent with the findings of Q. Yao & S. Mehlenbacher (2001), who noted that

when parents with long nuts are crossed, long nuts predominate in the offspring, and oblate nuts are seldom observed. In this context, the

appearance of genotype #66 in the progeny of the 'Akademik Yablokov' × 'Moskovskij Rubin' cross represents a rare exception to this trend. This occurrence highlights the presence of transgressive segregation for fruit shape within this specific hybrid combination, suggesting that even with elongated parental forms, the genetic potential for diverse morphotypes remains accessible. According to Q. Yao & S. Mehlenbacher (2000), the world kernel market needs globular kernels. The amount of fibre on the kernel is a critical trait for both the unblanched kernel and in-shell markets. As noted by Q. Yao & S. Mehlenbacher (2001), transgressive segregation for this trait was observed in most crosses, with a high overall frequency of very fibrous kernels. Many progenies exhibited mean values exceeding those of the higher parent, while only two progenies showed means lower than the lower parent.

In the studied hybrid population, genotypes with "strong" and "very strong" presence of fibre account for 52.2% of all seedlings. In contrast, only two genotypes, 'Profesorskiy' and #60, produce kernels that are virtually free of fibre. While fibre can be removed during industrial processing through high-temperature blanching, kernels intended for the fresh market (direct consumption) must be naturally free of fibre to ensure high consumer attractiveness. It should be noted that breeding requirements vary significantly depending on whether a cultivar is intended primarily for direct consumption (the in-shell market) or for dual-purpose use (both processing and the fresh market) (Valentini *et al.*, 2006). Within the hybrid population, the segregation of traits allows for selection in both directions. Genotypes with large nuts (e.g., 'Profesorskiy') align with the requirements for direct consumption, while those with globular kernels are more suited for the processing sector. This diversity highlights the potential of the 'Akademik Yablokov' × 'Moskovskij Rubin' cross to produce cultivars tailored to specific industrial and retail needs. Furthermore, all purple-leaved hazelnuts in the studied population are distinguished by the exceptional ornamental value. The intense anthocyanin pigmentation of both leaves and husks makes these genotypes highly attractive for landscape architecture and ornamental

gardening. Combining high-quality nut production with aesthetic appeal significantly enhances the economic attractiveness of the selected hybrids, as these hybrids can be utilised both in commercial orchards and as decorative elements in urban environments or private gardens.

CONCLUSIONS

The studied hybrid population of purple-leaved hazelnut exhibits substantial phenotypic variability in nut morphological traits, providing a robust and scientifically sound basis for targeted breeding. Average nut weight ranged from 1.4 to 3.4 g, while kernel percentage varied widely from 25.3 to 55.3%, indicating a broad segregation of economically valuable traits within the population. Among the evaluated genotypes, 'Profesorskiy' was identified as the most promising overall, while 'Aspirantskiy' was distinguished by the production of "very large" nuts, exceeding the corresponding parameters of the maternal cultivar 'Akademik Yablokov' and confirming the high genetic potential of the applied hybrid combination. The results demonstrate that selection for high productivity should prioritise genotypes combining large nut volume with reduced shell thickness, as shell thickness was identified as the primary factor limiting kernel yield. This conclusion is supported by the strong negative correlation between kernel percentage and shell thickness ($r = -0.670$). Transgressive segregation for nut shape was observed within the hybrid population, most notably in genotype #66, which produced oblate nuts despite the elongated nut shape of both parental cultivars. This finding indicates a complex inheritance of nut morphology in purple-leaved hazelnut hybrids and highlights the breeding value of segregating populations for generating novel phenotypes. The identification of genotypes characterised by large nuts, high kernel quality, and low fibre content, particularly 'Profesorskiy' and genotype #60, demonstrates the suitability for direct consumption and industrial processing. At the same time, all evaluated genotypes possess pronounced ornamental value due to stable anthocyanin pigmentation of leaves and husks, which significantly enhances the attractiveness for landscape use. Overall, the best-performing

genotypes identified in this study represent a valuable genetic resource for hazelnut breeding. The future multi-year evaluation, official registration, and regionalisation will provide a reliable foundation for the development of sustainable nut production systems and multifunctional ornamental plantings in Ukraine and comparable temperate regions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Морфометричний аналіз горіхів гібридної популяції пурпуроволисткового фундука (*Corylus avellana* L.)

Анотація. Фундук (*Corylus avellana* L.) є стратегічно важливою горіховою культурою з високою харчовою цінністю та значним економічним потенціалом. Хоча промислове вирощування переважно базується на зеленолиستкових генотипах, інтерес до пурпуроволисткових форм неухильно зростає завдяки їхній декоративній привабливості та підвищеному антиоксидантному потенціалу, пов'язаному з антоціановою пігментацією. Однак інформація про морфометричні ознаки горіхів та їхню мінливість у гібридних популяціях пурпуроволисткового фундука залишається обмеженою. Метою цього дослідження було проаналізувати морфометричні характеристики горіхів у гібридній популяції пурпуроволисткового фундука, створеної в Національному університеті біоресурсів і природокористування України. Експериментальний матеріал включав горіхи з 23 дорослих кореневласних гібридних кущів, отриманих у результаті схрещування сортів 'Академик Яблоков' та 'Московский Рубин'. Масу горіха та ядра, лінійні розміри,

товщину шкаралупи, відсоток ядер та індекс форми горіха оцінювали за допомогою стандартних морфометричних і статистичних методів. Результати виявили значну фенотипову мінливість морфологічних ознак горіхів, із середньою масою горіха від 1,4 г до 3,4 г. За сукупністю господарських ознак генотип 'Професорський' було визначено найперспективнішим, який дав найважчі горіхи (3,4 г) та ядра (1,6 г). Кореляційний аналіз виявив сильний негативний зв'язок між відсотком ядра та товщиною шкаралупи ($r = -0,670$), ідентифікуючи останню як основний лімітуючий фактор для врожайності ядра. Досліджувана гібридна популяція являє собою цінний генетичний ресурс для селекції фундука, що дозволяє добирати генотипи, придатні як для комерційного виробництва горіхів, так і для декоративного використання. Поєднання високої якості горіхів з вираженими декоративними ознаками, пов'язаними зі стабільною антоціановою пігментацією, підкреслює потенціал пурпуроволисткового фундука для диверсифікованого сільськогосподарського виробництва та ландшафтного застосування

Ключові слова: антоціанова пігментація; фенотипова мінливість; маса горіха; вихід ядра; товщина шкаралупи; селекція