




UDC: 634.45: 581.47:581.48 (477.53)

MORPHOMETRIC ANALYSIS OF *DIOSPYROS* SPP. FRUITS FROM THE KHOROL BOTANICAL GARDEN COLLECTION

Volodymyr Krasovskiy ¹, Volodymyr Mezhenyskyj ²,
Liudmyla Mezhenyska ², Taisiia Cherniak ¹,
Maryna Diachenko-Bohun ³, Tetyana Shkura ³, Svitlana Pototska ⁴

¹ Khorol Botanical Garden
1/79, office 46, Kremenchutska St., Khorol, Poltava region 37800, Ukraine

² National University of Life and Environmental Sciences of Ukraine 
15 Heroiv Oborony St., Kyiv 03041, Ukraine

³ V. H. Korolenko Poltava National Pedagogical University 
2 Ostrohradskiy St., Poltava 36003, Ukraine

⁴ T. H. Shevchenko National University "Chernihiv Colehium" 
53, Hetmana Polubotka St., Chernihiv 14013, Ukraine

Krasovskiy, V., Mezhenyskyj, V., Mezhenyska, L., Cherniak, T., Diachenko-Bohun, M., Shkura, T., & Pototska, S. (2026). Morphometric analysis of *Diospyros* spp. fruits from the Khorol Botanical Garden collection. *Studia Biologica*, 20(2), 189–202. doi:[10.30970/sbi.2002.875](https://doi.org/10.30970/sbi.2002.875)

Background. The genus *Diospyros* L. (Ebenaceae) comprises approximately 787 taxonomically recognised species, primarily distributed in tropical and subtropical regions. Among the species introduced to Ukraine, *D. kaki* is the most widely cultivated, owing to its nutritionally valuable fruits, rich in sugars, antioxidants, and minerals. While *D. kaki* can tolerate winter temperatures down to -18 °C (and occasionally to -22 °C) in southern Ukraine, *D. virginiana* is the most frost-resistant species, tolerating temperatures as low as -37 °C, which enables its cultivation throughout the country. Hybrids of these species, developed in Ukraine, combine the large fruit size characteristic of *D. kaki* with the high winter hardiness of *D. virginiana*, thereby facilitating the northward expansion of high-quality persimmon cultivars.

Materials and Methods. The study was conducted at the Khorol Botanical Garden (Forest-Steppe zone of Ukraine) and included 18 persimmon genotypes. Plant material comprised *D. virginiana* seedlings and American cultivars ('Early Golden', 'Meader', 'Prok'), alongside the Ukrainian interspecific hybrid 'Sosnivska'. In 2025, morphometric analysis was performed on a randomly selected sample of 20 fruits per genotype. Measurements



included fruit weight and linear parameters (height, diameter, and shape index), as well as seed dimensions (length, width, and thickness) and weight. Data were processed using descriptive statistics, correlation analysis, and analysis of variance (ANOVA). Fisher's least significant difference (LSD) test was used to determine significant differences ($p \leq 0.05$).

Results. Significant morphological variability in fruit and seed characteristics was observed among the 18 studied genotypes. The 'Sosnivska' hybrid produced the largest and heaviest fruits, with a mean weight of 75.2 g, significantly exceeding all *D. virginiana* genotypes. Among the latter, 'Prok' exhibited the highest fruit weight (38.4 g), followed by 'Krasotka' and 'Meader', while certain seedlings produced the smallest fruits (under 10 g). Fruit weight and number of seeds showed high variability, with seed counts ranging from zero to eight. Strong positive correlations were identified between fruit weight and linear dimensions ($r > 0.9$), and between seed width and weight ($r = 0.767$). However, fruit weight exhibited no significant correlation with seed number ($r = 0.129$).

Conclusions. The substantial morphological variability observed within the *Diospyros* collection provides a solid basis for selective breeding. The hybrid cultivar 'Sosnivska' demonstrates the effectiveness of interspecific hybridisation, combining superior fruit weight with high environmental adaptability. Moreover, the absence of a significant relationship between fruit weight and seed number ($r = 0.129$) indicates that breeding for larger fruits with reduced seed content is feasible, which is particularly important for both fresh consumption and industrial processing.

Keywords: *Diospyros virginiana*, persimmon, fruit and seed traits, introduction, hybridisation, cultivars, Forest-Steppe zone

INTRODUCTION

Genus *Diospyros* L. (Ebenaceae) comprises 787 accepted species distributed mainly in tropical and subtropical regions, with only a few species extending into the temperate zones (Royal Botanic Gardens, 2025). In Ukraine, *D. kaki* Thunb., *D. lotus* L., and *D. virginiana* L. have been introduced (Kokhno, 2002) and are currently regarded as promising fruit crops for both amateur and commercial orchards across the southern, western, and central regions of the country (Hrabovetska, 2020, 2023).

Among them, *D. kaki*, the Oriental persimmon, is the most widely cultivated fruit species of the genus *Diospyros*, which includes both ebony and persimmon trees. According to Food and Agriculture Organization of the United Nations (2025), its global harvested area exceeds 1.1–1.2 million ha, and the world production reached 4.4–5.1 million tonnes between 2020 and 2023. Persimmon cultivation is a promising venture due to its high market value, adaptability to diverse climatic conditions, and overall resilience (Jain *et al.*, 2023). Fresh and dried persimmons are nutritionally valuable products that have a high sugar content, including glucose and fructose, providing energy. The fruit is also a good source of ascorbic acid (vitamin C), carotene (provitamin A), flavonoids (vitamin P), crude fibre, and minerals, especially potassium (Butt *et al.*, 2015). As noted by M. Sharma *et al.* (2024), persimmon fruits possess a wide range of pharmacological properties. Different varieties of oriental persimmon exhibit varying levels of frost resistance. In southern Ukraine, mature trees of *D. kaki* can tolerate temperatures as low as $-18\text{ }^{\circ}\text{C}$ and, in some cases, down to $-22\text{ }^{\circ}\text{C}$ (Hrabovetska, 2020).

D. virginiana, the American persimmon, is a tree indigenous to the eastern United States with two ploidy forms: tetraploid and hexaploid. The hexaploid form is particularly

winter-hardy and may be grown as far north as Canada (Frost, 2015). As this species grows in areas where the lowest temperature recorded has been $-39\text{ }^{\circ}\text{C}$, it is extremely winter-hardy and can therefore be cultivated throughout Ukraine (Grigorieva & Klymenko, 2005; Derevianko *et al.*, 2016). Promising seedlings have been selected at the Khorol Botanical Garden (Krasovskiy *et al.*, 2022). Among other species, the American persimmon is the most frost-resistant under Ukrainian conditions. It has the longest and deepest dormancy period. The rootstock *D. virginiana* can withstand frosts down to $-37\text{ }^{\circ}\text{C}$, while grafted trees can withstand frosts down to $-30\text{ }^{\circ}\text{C}$ or lower (Hrabovetska, 2023). However, the fruits of *D. virginiana* are considerably smaller than those of the Oriental persimmon.

This limitation is addressed by the *D. kaki* \times *D. virginiana* hybrids developed in Ukraine. They combine the large fruit size (50–250 g) of the Oriental persimmon with the high frost resistance (-20 to $-27\text{ }^{\circ}\text{C}$) of the American persimmon, thereby expanding the potential cultivation area of high-quality hybrid persimmon varieties further north (Derevjanko, 2013; Hrabovetska, 2020).

D. lotus, the Caucasian persimmon, is native to southeastern Europe and southwestern Asia. Its fruit is very small (1–2 cm in diameter), but sweet and locally popular (Mehdiyeva *et al.*, 2017). Unfortunately, this species is not sufficiently winter-hardy, even in southern Ukraine (Derevjanko, 2013). According to the recent data reported by O. A. Hrabovetska (2020), adult trees in the Kherson region bear fruit, although not annually. However, under the climatic conditions of the Poltava region, *D. lotus* trees fail to flower or produce fruit.

MATERIALS AND METHODS

Plant material. *D. virginiana* seeds were collected in 2007 from two sources: a private collection maintained by Yurii Bohdanovskiy in Feodosia (Autonomous Republic of Crimea, Ukraine) and the Nova Kakhovka Experimental Station. Both collections are of particular importance as they served as the basis for the developing cultivars later included in the State Register of Plant Varieties of Ukraine. Consequently, seedlings derived from this material are expected to carry valuable breeding traits.

Seedlings grown from the collected seeds were planted in 2014 in the orchard of the Khorol Botanical Garden, located in the Forest-Steppe zone of Ukraine. Several trees were subsequently grafted with *D. virginiana* cultivars 'Early Golden', 'Meader', and 'Prok', developed in the USA, as well as 'Sosnivska', a Ukrainian cultivar selected from the progeny of a *D. kaki* \times *D. virginiana* cross. All cultivars were obtained from private growers and grafted onto *D. virginiana* rootstocks. The experimental site is located at approximately 49.7772° N, 33.2596° E. The study included 48 ten-year-old trees planted at a spacing of 4×2 m. Standard horticultural practices were applied, with the exception of irrigation. The region has a humid continental climate with warm summers (Dfb) according to the Köppen climate classification (Beck *et al.*, 2018), and the soil is classified as ordinary chernozem.

Morphometric analyses. Twenty fruits per genotype, collected in 2025, were randomly selected for the assessment of fruit and seed traits. Fruit height and diameter were measured using a digital calliper (model 300-I-0.01; Shahe, China, 2021). Seeds were measured for length, width, and thickness. For each genotype, fruit and seed weight were measured using an electronic laboratory balance (FEH-300; TM Dniproves, Ukraine, 2022). Fruit shape and seed indices were calculated as the ratios of height to diameter and length to width, respectively.

Statistical analysis. Descriptive statistics were used to summarize the data, including mean values (Mean), standard deviation (SD), and coefficient of variation (CV%). Statistical analyses were performed using Microsoft Excel Office 2019. Analysis of variance (ANOVA) was applied to test differences among means, and Pearson correlation coefficients were calculated for normally distributed data. Fisher's least significant difference (LSD) test was used to identify significant differences between means at a 95% confidence level ($p \leq 0.05$).

RESULTS AND DISCUSSION

The fruits of the studied persimmon genotypes exhibited considerable morphological diversity in size, shape, and colour (see **Fig. 1**), reflecting both interspecific differences and substantial intraspecific variability within *D. virginiana*. This diversity represents a valuable phenotypic resource for breeding programmes aimed at improving fruit quality while preserving adaptability to temperate climatic conditions.

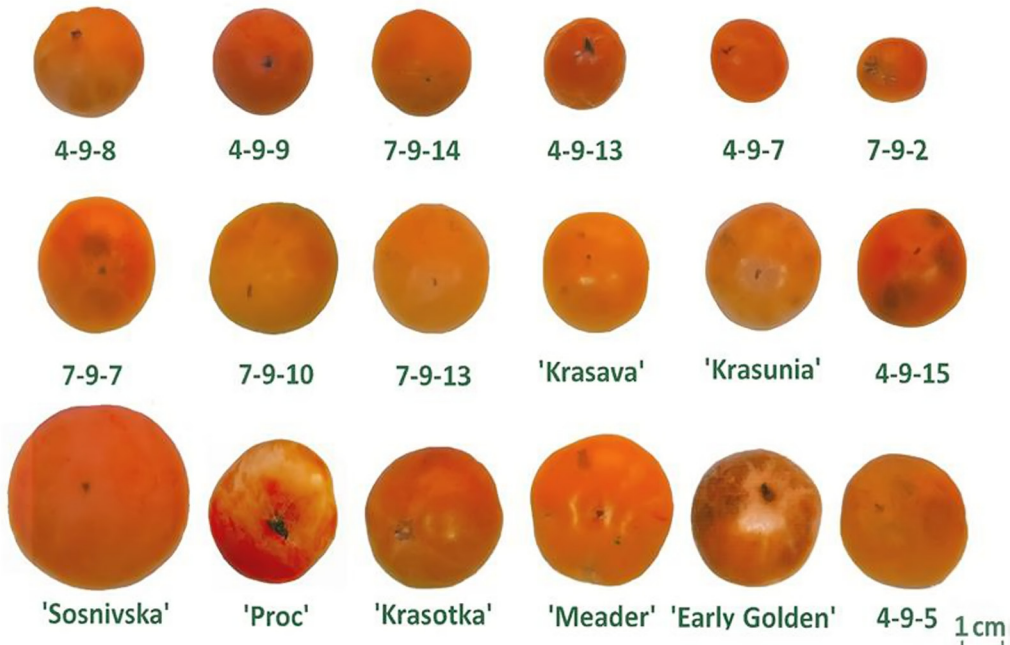


Fig. 1. Fruits of persimmon (*Diospyros* spp.) genotypes illustrating variability in fruit size, shape, and colour

In particular, the fruits of the interspecific hybrid *D. kaki* × *D. virginiana* 'Sosnivska' were visually larger than the fruits of all *D. virginiana* genotypes included in the study. This confirms that interspecific hybridization remains the most effective strategy for breaking the "size ceiling" of temperate persimmons, as the inclusion of *D. kaki* genetics consistently leads to the development of larger, more commercially viable fruits. According to Eckenwalder (2009), *D. virginiana* shows extensive morphological variability, which is associated with the presence of different chromosomal races ($2n = 60$ or 90). The fruits of *D. virginiana* are berries that are yellow, orange, or dark red (rarely purple) and are often glaucous. They are depressed-globose, globose, oblong, ovoid,

or conical in shape and measure (2-)3-5(-7.5) cm in diameter. The seeds are reddish brown and ellipsoid, measuring around 1.5 cm.

In the studied collection, fruit colour ranged from orange to red-orange, and became more intense during ripening. Globose fruit is characteristic of genotypes: 4-9-13 (shape index = 1.0), as well as 'Prok' and 7-9-2 (shape index between 0.95 and 1.0). Slightly oblate-globose fruit is found in 'Sosnivska', 4-9-7, 7-9-7, and 4-9-15 (shape index between 0.8 and 0.95). Oblate fruit is found in 'Krasava', 4-9-5, 'Krasotka', 7-9-9, 'Early Golden', 7-9-13, 'Krasunia', 4-9-8, 7-9-14, 'Mider', and 7-9-10 (shape index \leq 0.8). Overall, fruit shape variation did not follow a clear taxonomic pattern but rather reflected individual genotype characteristics, indicating that fruit shape alone is of limited diagnostic value for species differentiation but remains relevant for cultivar identification.

The genotypes presented in **Table 1** are ordered from largest to smallest according to fruit weight.

'Sosnivska' produced the largest and heaviest fruits, reflecting the contribution of *D. kaki*. These differences were statistically significant compared with all *D. virginiana* cultivars and seedlings, confirming that interspecific hybridization is the most effective strategy for increasing fruit weight in temperate climates, while retaining the cold hardiness inherited from *D. virginiana*. From a breeding perspective, such hybrids represent bridge genotypes that combine commercial fruit traits with climatic resilience.

Within *D. virginiana*, fruit size and weight varied more than sixfold among genotypes. This exceptionally wide range indicates a broad genetic base within the studied collection and is consistent with the high morphological plasticity reported for the species. This pronounced phenotypic diversity is highly important for breeding, as it indicates a broad genetic base that allows for the simultaneous selection of genotypes with improved fruit size and those maintaining high cold-hardiness and adaptability to local conditions. Among American persimmon cultivars, 'Prok' significantly exceeds others in fruit size and weight, making it a primary candidate for commercial cultivation in regions with shorter growing seasons.

The third-highest fruit weights were recorded in 'Krasotka' and 'Meader', with values exceeding 30 g. Notably, 'Krasotka' fruit is non-astringent (Krasovskiy *et al.*, 2022), which further increases its horticultural value, as it provides a rare combination of cold tolerance and immediate palatability.

In contrast, genotypes 4-9-13, 4-9-7, and especially 7-9-2 have very small fruits. While these small-fruited genotypes may lack commercial appeal for the fresh market, their morphological stability suggests a potential for specific breeding or industrial applications. Specifically, they could serve as valuable genetic resources for rootstock selection or be considered for industrial processing, provided further biochemical studies confirm a high concentration of bioactive compounds.

According to Grygorieva (2011), under similar climatic conditions of the M. M. Gryshko National Botanical Garden (Kyiv), 'Meader' fruits were reported to be 27 mm high, 36 mm in diameter, and to weigh 24 g, which is slightly smaller than the values obtained in the Khorol Botanical Garden collection. At the same site, 'Meader' fruits contained an average of 1.8 seeds (Grygorieva, 2011). This difference highlights the influence of local environmental conditions on fruit development and underscores the importance of multi-site evaluations when assessing cultivar performance and breeding value.

Seed development also showed intriguing patterns. The hybrid cultivar 'Sosnivska' is known from unpublished reports to be capable of forming parthenocarpic, seedless

fruits in the absence of a pollinator. We also personally observed this phenomenon at another site. However, under the specific conditions of the current experiment with abundant pollinators, 'Sosnivska' consistently produced seeded fruits. Overall, all studied genotypes, with the sole exception of 7-9-2, produced seeds in this collection.

Table 1. Morphometric parameters of persimmon fruits (*Diospyros* spp.)

Genotype	Height, mm		Diameter, mm		Weight, g		Number of seeds, pcs.	
	Mean ± SD	min-max	Mean ± SD	min-max	Mean ± SD	min-max	x ± SD	min-max
Sosnivska	46.6±1.57 ^a	44–48	49.8±1.24 ^a	48–51	75.2±0.33 ^a	73–77	1.8±1.24 ^j	0–4
Prok	37.7±1.81 ^b	35–40	39.7±1.14 ^b	38–41	38.4±1.01 ^b	37–40	5.3±0.64 ^{cd}	5–7
Krasotka	31.0±1.4 ^d	29–33	37.8±1.40 ^c	36–40	33.3±0.64 ^c	32–34	5.2±0.77 ^{cd}	4–7
Meader	29.2±0.77 ^d	28–30	40.2±0.83 ^b	39–41	33.2±1.10 ^c	31–34	5.5±0.83 ^c	5–7
Early Golden	30.4±2.01 ^{de}	28–34	38.0 ±1.45 ^c	36–40	28.9±2.33 ^d	26–33	3.5 ±0.83 ^{fg}	3–5
7-9-7	34.3±0.80 ^c	34–35	37.4±0.81 ^c	36–38	27.9±0.53 ^d	27–28	2.2±1.15 ^{hi}	1–5
4-9-5	29.8±1.21 ^{ef}	28–31	36.1±0.79 ^c	35–37	27.3±0.78 ^d	26–28	4.4±1.58 ^{ef}	3–8
7-9-10	24.7±1.13 ⁱ	23–26	34.8±1.16 ^e	33–36	22.7±0.45 ^e	22–23	6.7±0.93 ^a	6–8
7-9-13	26.6±1.10 ^j	25–28	33.8±0.83 ^f	33–35	21.8±0.47 ^{ef}	21–22	4.7±2.56 ^{de}	2–8
Krasava	27.0±1.19 ^h	25–28	31.9±1.29 ^g	30–34	20.0±0.56 ^f	19–20	3.2±1.39 ^g	1–5
Krasunia	27.1±0.8 ^h	26–28	34.9±1.07 ^e	33–36	19.7±0.77 ^{fg}	19–21	6.6±2.09 ^{ab}	3–8
4-9-15	27.9±1.17 ^g	26–29	32.1±1.54 ^g	30–34	17.6±0.73 ^g	17–20	3.5±2.28 ^{fg}	1–7
4-9-8	25.0±0.73 ^j	24–26	33.6±1.14 ^f	32–35	17.5±0.45 ^g	17–18	5.9±0.59 ^{bc}	5–7
7-9-9	23.6±1.15 ^j	22–25	29.1±0.79 ^h	28–30	14.5±0.49 ^h	14–15	5.4±0.93 ^{cd}	5–8
7-9-14	21.3±1.08 ^k	20–23	28.7±0.75 ^h	28–30	12.4±0.33 ^h	12–13	1.7±0.88 ⁱ	1–3
4-9-13	23.8±1.21 ^j	22–25	23.7±1.17 ⁱ	22–25	9.6±0.43 ⁱ	9–10	1.7±0.47 ⁱ	1–2
4-9-7	20.1±0.72 ^j	19–21	21.8±0.44 ^j	21–22	6.2±0.18 ^j	6–6	1.8±0.44 ⁱ	1–2
7-9-2	17.9±1.21 ^m	16–19	18.9±1.21 ^k	17–20	3.9±0.13 ^j	4–4	0±0 ^j	0
LSD ₀₀₅	0.76	–	0.68	–	2.28	–	0.79	–
CV, %	23.8	–	21.5	–	65.1	–	59.7	–

Note: Values are means±SD (n = 20). Different letters within a column indicate significant differences according to the LSD test ($p \leq 0.05$)

On average, each 7-9-10, 'Krasunia', 4-9-8, 'Mider', 7-9-9, and 'Prok' fruit contains more than five seeds, with a maximum of eight, which corresponds to the upper limit reported for *D. virginiana* (Briand, 2005). The very high coefficient of variation for seed number per fruit suggests strong phenotypic plasticity of this trait, which may facilitate selection for reduced seed number.

Although variation in fruit linear dimensions was within the normal range for plants (Mezhenskyj, 2017), the coefficient of variation for fruit weight (65.1%) and number of seeds per fruit (59.7%) were very high. Such pronounced variability facilitates the selection of genotypes for breeding purposes, particularly for economically important traits such as large fruit size and reduced seed number.

The seeds of the studied genotypes varied considerably in size, shape, and weight. They ranged in colour from light to dark brown with a reddish tint and were predominantly ellipsoidal (see Fig. 2).



Fig. 2. Seed of persimmon (*Diospyros* spp.) genotypes illustrating variability in fruit size, shape, and colour

The genotypes listed in **Table 2** are arranged from largest to smallest by seed weight.

The coefficient of variation for seed length, width, thickness, and weight ranged from 16.8% to 27.5%, indicating a biologically typical level of variability. The longest seeds were observed in 'Sosnivska', the widest in 'Meader', and the thickest genotypes in 7-9-14, 4-9-7, and 'Early Golden'. According to Gryhorieva (2011), the American persimmon seedlings grown in Kyiv have seeds measuring 15–18 mm in length, 9–11 mm in width, and 4–5 mm in thickness. Seeds of 'Meader' from the Khorol collection differed significantly from those grown in Kyiv, highlighting the influence of growing conditions on seed morphology. Seed weight ranged from 0.60 g (7-9-7 genotype) to 0.15 g (4-9-7 genotype), with most genotypes producing seeds weighing around 0.4 g. 'Early Golden' seeds were the shortest and narrow but thick, which explains their high weight, similar

to that of 4-9-7. Generally, heavy seeds are considered to be better filled and tend to have higher germination potential, which is crucial for successful propagation. According to Frost (2025), 'Early Golden' is the progenitor of most American persimmon cultivars.

Table 2. Morphometric parameters of persimmon seeds (*Diospyros* spp.)

Genotype	Length, mm		Width, mm		Thickness, mm		Weight, g	
	Mean ± SD	min-max	Mean ± SD	min-max	Mean ± SD	min-max	Mean ± SD	min-max
7-9-7	14.5±1.10 ^f	13–16	13.0±0.76 ^b	12–14	4.4±0.49 ^{bc}	4–5	0.60±0.07 ^a	0.5–0.7
Meader	11.4±0.49 ^k	11–12	13.8±0.77 ^a	13–15	4.0 ±0.69 ^{def}	3–5	0.54±0.05 ^b	0.5–0.6
Early Golden	10.8 ±0.77 ^l	10–12	10.5±0.69 ^{ef}	10–11	4.7±0.80 ^{ab}	4–6	0.54±0.05 ^b	0.5–0.6
Krasotka	17.8±0.91 ^b	17–19	11.2±1.20 ^{cd}	10–13	4.3±0.47 ^{cd}	4–5	0.49±0.07 ^c	0.4–0.6
7-9-14	14.7±1.49 ^f	13–16	8.7±0.73 ^{jk}	8–10	4.9±0.72 ^a	4–6	0.48±0.08 ^c	0.4–0.6
7-9-10	16.5±0.51 ^{cd}	16–17	10.3±1.08 ^{efg}	9–11	4.3±0.44 ^{cde}	4–5	0.45±0.05 ^{cd}	0.4–0.5
4-9-8	15.7±0.80 ^e	15–17	9.4±0.50 ^{hi}	9–10	4.3±0.44 ^{cde}	4–5	0.45±0.05 ^{cde}	0.4–0.5
7-9-9	17.0±0.69 ^c	16–18	8.4±1.10 ^{kl}	7–10	3.9±0.72 ^{ef}	3–5	0.44±0.05 ^{def}	0.4–0.5
7-9-13	16.4±0.49 ^d	16–17	10.1±0.79 ^g	9–11	4.3±0.47 ^{cd}	4–5	0.44±0.05 ^{de}	0.4–0.5
4-9-5	13.7±0.67 ^{hi}	13–15	11.4±0.50 ^c	11–12	3.3±0.47 ⁱ	3–4	0.44±0.05 ^{def}	0.4–0.5
Prok	13.4±1.14 ⁱ	12–15	10.8±0.79 ^{de}	10–12	3.2±0.41 ^l	3–4	0.44±0.05 ^{def}	0.4–0.5
Krasava	12.4±0.50 ^j	12–13	9.0±0.76 ^{jl}	8–10	3.8±0.70 ^{fh}	3–5	0.41±0.09 ^{ef}	0.3–0.5
Krasunia	16.7±0.99 ^{cd}	16–18	10.8±0.72 ^{de}	10–12	4.3±0.47 ^{cd}	4–5	0.40±0.08 ^{fg}	0.3–0.4
4-9-15	14.0±0.69 ^{gh}	13–15	8.2±1.09 ^{lm}	7–10	4.0±0.65 ^{cdef}	3–5	0.37±0.06 ^{gh}	0.3–0.4
Sosnivska	19.4±0.50 ^a	19–20	9.9±0.81 ^{gh}	9–11	4.4±0.49 ^{bc}	4–5	0.35±0.05 ^h	0.3–0.4
4-9-13	14.3±1.13 ^{fg}	13–16	7.7±0.49 ^m	7–8	3.5±0.51 ^{hi}	3–4	0.30±0.09 ⁱ	0.2–0.4
4-9-7	11.5±0.51 ^j	11–12	7.0±0.76 ⁿ	6–8	4.8±0.70 ^a	4–6	0.15±0.05 ^l	0.1–0.2
LSD ₀₀₅	0.52	–	0.51	–	0.36	–	0.04	–
CV, %	16.8	–	19.3	–	17.9	–	27.5	–

Note: Values are means ± SD (n = 20). Different letters within a column indicate significant differences according to the LSD test (p ≤ 0.05)

While Eckenwalder (2009) indicates that *D. virginiana* seeds within its natural range measure approximately 15 mm, under the conditions of the Khorol Botanical Garden, the seeds of American persimmon cultivars are smaller, ranging from 11 to 13 mm. This can be attributed both to different environmental conditions and to cultivar selection, which focuses on improving fruit quality, specifically favouring genotypes with smaller seed sizes. Seed shape is a species-specific trait. For instance, while the length and width of *D. virginiana* seeds do not differ significantly (Eckenwalder, 2009), *D. kaki* seed length is approximately twice the width (Li *et al.*, 1996; Yilmaz *et al.*, 2024). *D. virginiana* seeds typically exhibit a more or less triangular shape, whereas *D. kaki* seeds are elongated-ellipsoidal.

The studied genotypes were divided into three groups: the first includes American persimmon cultivars, the second consists of accessions designated as *D. virginiana*, and the third is represented by an interspecific hybrid, *D. kaki* × *D. virginiana*. These groups differ significantly in both seed size and shape. The American persimmon cultivars unquestionably belong to *D. virginiana*, which is confirmed by their documented pedigree (Frost, 2025). However, the studied accessions of *D. virginiana* do not originate from the species' natural range but from breeding collections. In these collections, the original maternal plants, growing in proximity to individuals of *D. kaki* and *D. kaki* × *D. virginiana*, could have been cross-pollinated by pollen from these taxa. This possibility is supported by seed shape characteristics.

According to the shape index, all three American persimmon cultivars and one interspecific cultivar occupy opposite ends of the ranked series, whereas the "*D. virginiana*" genotypes are positioned intermediate. 'Meader', 'Early Golden', 'Prok', and two genotypes (7-9-7, 4-9-5) have a shape index within the range of 0.9–1.2; other "*D. virginiana*" genotypes range from 1.4 to 1.9, while 'Sosnivska' and genotype 7-9-9 reach values of 2.0. The difference between these three groups is statistically significant. This suggests that the divergence of the "*D. virginiana*" accessions from typical *D. virginiana*, together with their similarity in seed shape to *D. kaki*, provides evidence of the genetic influence from the latter species. Thus, the genotypes developed at the Khorol Botanical Garden represent a valuable resource for further breeding of winter-hardy persimmons aimed at improving fruit quality. New gene combinations in hybrids of interspecific origin form the basis for the emergence of novel traits, necessitating the future creation of an F₂ hybrid population through both targeted crosses and open pollination.

This is the first evidence that seed shape indices can reveal cryptic interspecific introgression between *D. virginiana* and *D. kaki*, thereby extending the biological and breeding interpretation of seed morphology in the genus *Diospyros*. This finding provides a simple morphological tool for identifying introgressed genotypes in breeding collections where molecular data are unavailable or limited.

From a breeding perspective, the correlation analysis (**Table 3**) offers a strategic roadmap. Strong positive correlations were observed among fruit length, diameter, and weight ($r = 0.901\text{--}0.950$). A strong correlation was also found between seed width and weight ($r = 0.767$), indicating that seed width is the primary contributor to seed weight. Therefore, seed width is the most important factor affecting seed weight. The relationships between other seed parameters were weak or very weak.

Moderate correlations were detected between seed width and fruit diameter, length, and weight, suggesting a partial relationship between fruit and seed development.

In contrast, fruit weight showed almost no correlation with the number of seeds per fruit ($r = 0.129$). This result is of particular breeding importance, as it indicates that selecting for larger fruits does not necessarily lead to an increase in seed number. Consequently, it is feasible to develop genotypes combining large fruit size with low seed content, which is highly desirable for both fresh consumption and processing.

Table 3. Pearson correlation coefficients between fruit and seed parameters (r)

Indicator	Fruit length	Fruit diameter	Fruit weight	Seed length	Seed width	Seed thickness	Seed weight	Number of seeds per fruit
Fruit length	1	–	–	–	–	–	–	–
Fruit diameter	0.901	1	–	–	–	–	–	–
Fruit weight	0.950	0.918	1	–	–	–	–	–
Seed length	0.298	0.318	0.383	1	–	–	–	–
Seed width	0.464	0.680	0.449	-0.034	1	–	–	–
Seed thickness	-0.210	-0.079	-0.081	0.076	-0.130	1	–	–
Seed weight	0.238	0.492	0.207	0.001	0.767	0.015	1	–
Number of seeds per fruit	0.114	0.415	0.129	0.216	0.391	-0.234	0.332	1

Note: Significant coefficients ($p \leq 0.05$) are shown in bold ($n = 17$)

Overall, the results demonstrate the high breeding potential of the persimmon collection maintained at the Khorol Botanical Garden and highlight its value as a source of genetic diversity for the development of new cultivars adapted to temperate climates and modern market requirements.

CONCLUSIONS

The morphometric evaluation of 18 *Diospyros* genotypes cultivated in the Khorol Botanical Garden revealed substantial variability in fruit- and seed-related traits within the collection. This high level of variation represents an important resource for breeding, as it enables the selection of genotypes tailored to specific horticultural and economic objectives.

The interspecific hybrid 'Sosnivska' (*D. kaki* × *D. virginiana*) demonstrated clear and statistically confirmed superiority in fruit size and weight compared with all tested *D. virginiana* cultivars and seedlings. This confirms the effectiveness of interspecific hybridization in combining large-fruitedness with the adaptive traits of American persimmon, and highlights 'Sosnivska' as a particularly valuable genotype for further breeding and cultivation.

Of particular breeding importance is the absence of a significant relationship between fruit weight and seed number. This finding indicates that selection for increased fruit size

does not necessarily lead to a higher seed content, making it feasible to develop large-fruited, low-seeded genotypes. Such combinations are especially desirable for both fresh consumption and industrial processing.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Human Rights: this article does not contain any studies with human subjects performed by any of the authors.

Animal Studies: this article does not include animal studies.

AUTHOR CONTRIBUTIONS

Conceptualization, [V.K.]; methodology [V.M.; M.D]; formal analysis [V.M; M.D; T.S.]; investigation [V.K.; T.C.]; resources [V.K.; T.C.]; data curation [V.K.; T.C.; V.M] writing – original draft preparation [V.M.; L.M.]; writing review and editing [V.M.; L.M.]; visualization [V.K.; T.C.; V.M.; L.M.]; supervision [M.K.]; project administration [V.K; M.D.; V.M.; T.S; S.P].

All authors have read and agreed to the published version of the manuscript.

REFERENCES

- Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. (2018). Present and future Köppen–Geiger climate classification maps at 1-km resolution. *Scientific Data*, 5(1), 180214. doi:10.1038/sdata.2018.214
[Crossref](#) • [PubMed](#) • [PMC](#) • [Google Scholar](#)
- Briand, C. H. (2005). The common persimmon (*Diospyros virginiana* L.): the history of an underutilized fruit tree (16th–19th centuries). *Huntia*, 12(1), 71–89.
[Google Scholar](#)
- Butt, M. S., Sultan, M. T., Aziz, M., Naz, A., Ahmed, W., Kumar, N., & Imran, M. (2015). Persimmon (*Diospyros kaki*) fruit: hidden phytochemicals and health claims. *EXCLI Journal*, 14, 542–561.
[Google Scholar](#)
- Derevjanko, V. (2013). Introduction and prospects for economic use of Caucasian persimmon (*Diospyros lotus* L.) in the south of Ukraine. *Chornomorski Botanical Journal*, 9(4), 584–594. doi:10.14255/2308-9628/13.94/12 (In Ukrainian)
[Crossref](#) • [Google Scholar](#)
- Derevyanko, N. V., Derevyanko, V. N., & Horbenko, N. Ye. (2016). The Introduction of American Persimmon (*Diospyros virginiana* L.) in Ukraine. *Scientific Bulletin of UNFU*, 26(5), 48–59. doi:10.15421/40260507 (In Ukrainian)
[Crossref](#) • [Google Scholar](#)
- Eckenwalder, J. E. (2009). Ebenaceae Gürke. In *Flora of North America* Editorial Committee (Eds.), *Flora of North America north of Mexico* (Vol. 8, pp. 254–258). Oxford University Press. Retrieved from <http://floranorthamerica.org/Ebenaceae>
[Google Scholar](#)
- Food and Agriculture Organization of the United Nations (FAO). (n.d.). FAOSTAT: Crops and livestock products (QCL). FAOSTAT. Retrieved December 01, 2025, from <https://www.fao.org/faostat/en/#data/QCL>
- Frost, R. (2025). Assimilated ancestries of American persimmon cultivars (landrace *Diospyros virginiana*). *Journal of the American Pomological Society*, 79(2), 9–20. doi:10.71318/ehdazj02
[Crossref](#) • [Google Scholar](#)

- Jain, S., Ranganna, G., Mohapatra, S., Rathod, M., Homeshvari, Kore, D. S., Saxena, S., & Anushi. (2023). A comprehensive review on Persimmon (*Diospyros kaki*): botanical, horticultural, and varietal perspectives. *International Journal of Environment and Climate Change*, 13(11), 4437–4457. doi:10.9734/ijec/2023/v13i113624
[Crossref](#) • [Google Scholar](#)
- Hrabovetska, O. A. (2020). Prospects of persimmon (*Diospyros L.*) in the south of Ukraine. *Plant Genetic Resources*, 27, 44–54. doi:10.36814/pgr.2020.27.04 (In Ukrainian)
[Crossref](#) • [Google Scholar](#)
- Hrabovetska, O. A. (2023). Pawpaw, persimmon, unabi are real – promising uncommon fruit crops in the south of Ukraine. *Climate-Smart Agriculture: Science and Practice* (pp. 59–83). Riga, Latvia: Baltija Publishing. doi:10.30525/978-9934-26-389-7-4 (In Ukrainian)
[Crossref](#) • [Google Scholar](#)
- Grygorieva, O. V. (2011). Morfolohichni ta biolohichni osoblyvosti i reproduksiiia khurny virhynskoi (*Diospyros virginiana L.*) v umovakh Lisostepu Ukrainy [Morphological and bioecological features and reproduction of oriental persimmon (*Diospyros virginiana L.*) in the Forest-Steppe of Ukraine]. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 7(2), 121–140. (In Ukrainian)
[Google Scholar](#)
- Grigorieva, O. V., & Klimenko, S. V. (2005). Rid *Diospyros L. (Ebenaceae Guerke)* v Ukraini: introduktsiia, perspektyvy kultyvuvannia [*Diospyros L. (Ebenaceae Guerke)* genus in Ukraine: introduction, perspectives of cultivation]. *Plant Introduction*, 2, 21–26. (In Ukrainian)
[Google Scholar](#)
- Kokhno, M. A. (2002). *Ebenaceae*. In M. A. Kokhno, (Ed.), *Dendroflora Ukrainy. Dukorosli i kultyvovani dereva i kyshchi. Pokrytonasinni. Chastyna I* [*Dendroflora of Ukraine. Wild and cultivated trees and shrubs. Angiosperms. Part I*]. Kyiv: Phytosotsiotsentre. (In Ukrainian)
[Google Scholar](#)
- Krasovskiy, V., Cherniak, T., Hapon, S., & Orlovsky, O. (2022). Difference between virgin pumpkin samples (*Diospyros virginiana L.*) in the Khorol Botanical Garden collection. *Ecological Sciences*, 1(40), 154–159. doi:10.32846/2306-9716/2022.eco.1-40.28 (In Ukrainian)
[Crossref](#) • [Google Scholar](#)
- Li, S., Gilbert, M. G., & White, F. (1996). *Diospyros kaki*. Linnaeus f. In Z. Y. Wu & P. H. Raven (Eds.), *Flora of China* (Vol. 15, p. 225). Missouri Botanical Garden Press & Science Press. Retrieved from http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=200017585
- Mehdiyeva, N., Alizade, V., Batsatsashvili, K., Kikvidze, Z., Khutsishvili, M., Maisaia, I., ... & Bussmann, R. W. (2017). *Diospyros lotus L. Ebenaceae*. In R. W. Bussmann (Ed.), *Ethnobotany of the Caucasus*. (pp. 265–269). Cham: Springer. doi:10.1007/978-3-319-49412-8_130
[Crossref](#) • [Google Scholar](#)
- Mezhen'skyy V. M. (2017) *Osnovy naukovykh doslidzhen u sadivnytstvi. Rozrakhunky v Microsoft Excel* [*Fundamentals of scientific research in horticulture. Calculations in Microsoft Excel*]. Kyiv: Lira-K. (In Ukrainian)
[Google Scholar](#)
- Royal Botanic Gardens, Kew. (n.d.). *Diospyros L.* In *Plants of the World Online*. Retrieved December 01, 2025, from <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:326017-2>
- Sharma, M., Goyal, P., & Mittal, P. (2024). Therapeutic potentials of persimmon (*Diospyros kaki*): an updated review. *Research Journal of Pharmacy and Technology*, 17(6), 2757–2760. doi:10.52711/0974-360x.2024.00432
[Crossref](#) • [Google Scholar](#)

Yilmaz, N., Gündoğdu, M. A., Başaran, T., Gür, E., & Şeker, M. (2024). Production techniques of nursery plants in *Diospyros* species. In H. Çetinkaya & H. Gözel (Eds.), *Strategies for reforestation and sustainable fruit farming* (Chapter 10, pp. 189–199). Nobel Tip Kitabevleri Ltd. doi:10.69860/nobel.9786053359395
[Crossref](#) • [Google Scholar](#)

МОРФОМЕТРИЧНИЙ АНАЛІЗ ПЛОДІВ *DIOSPYROS* SPP. ІЗ КОЛЕКЦІЇ ХОРОЛЬСЬКОГО БОТАНІЧНОГО САДУ

**Володимир Красовський¹, Володимир Меженський²,
Людмила Меженська², Таїсія Черняк¹, Марина Дяченко-Богун³,
Тетяна Шкура³, Світлана Потоцька⁴**

¹Хорольський ботанічний сад
вул. Кременчуцька, 1/79, офіс 46, Хорол, Полтавська обл. 37800, Україна

²Національний університет біоресурсів і природокористування України
вул. Героїв Оборони, 15, Київ 03041, Україна

³Полтавський національний педагогічний університет ім. В. Г. Короленка
вул. Остроградського, 2, Полтава 36000, Україна

⁴Національний університет “Чернігівський колегіум” імені Т. Г. Шевченка
вул. Гетьмана Полуботка, 53, Чернігів 14000, Україна

Обґрунтування. Рід *Diospyros* L. (*Ebenaceae*) налічує близько 787 таксономічно визнаних видів, які переважно поширені у тропічних і субтропічних регіонах. Серед видів, інтродукованих в Україні, *D. kaki* є найширше культивованим завдяки поживній цінності плодів, багатих на цукри, антиоксиданти та мінеральні речовини. Хоча *D. kaki* здатна витримувати зимові температури до $-18\text{ }^{\circ}\text{C}$ (а інколи до $-22\text{ }^{\circ}\text{C}$) у південних регіонах України, *D. virginiana* є найбільш морозостійким видом, витримуючи зниження температури до $-37\text{ }^{\circ}\text{C}$, що дає змогу вирощувати її на всій території країни. Гібриди цих видів, створені в Україні, поєднують великий розмір плодів, характерний для *D. kaki*, з високою зимостійкістю *D. virginiana*, що сприяє просуванню високоякісних сортів хурми на північ.

Матеріали і методи. Дослідження проводили на базі Хорольського ботанічного саду (Лісостепова зона України) та охоплювали 18 генотипів хурми. Рослинний матеріал включав сіянці *D. virginiana* й американські сорти ('Early Golden', 'Meader', 'Prok'), а також український міжвидовий гібрид 'Соснівська'. У 2025 р. було проведено морфометричний аналіз випадкової вибірки з 20 плодів кожного генотипу. Визначали масу плодів і їхні лінійні параметри (висоту, діаметр, індекс форми), а також розміри насіння (довжину, ширину, товщину) та його масу. Обробку даних здійснювали методами описової статистики, кореляційного аналізу та дисперсійного аналізу (ANOVA). Для визначення достовірних відмінностей застосовували критерій найменшої істотної різниці Фішера (LSD) за $p \leq 0,05$.

Результати. Серед 18 досліджуваних генотипів виявлено значну морфологічну мінливість ознак плодів і насіння. Гібрид 'Соснівська' формував найбільші та найважчі плоди зі середньою масою 75,2 г, що достовірно перевищувало показники всіх генотипів *D. virginiana*. Серед них сорт 'Prok' характеризувався найбільшою масою плодів (38,4 г), далі йшли 'Krasotka' та 'Meader', тоді як окремі сіянці

формували найдрібніші плоди (менше 10 г). Маса плодів і кількість насінин відзначалися високою мінливістю, при цьому кількість насінин коливалася від нуля до восьми. Виявлено сильні позитивні кореляції між масою плодів і їхніми лінійними розмірами ($r > 0,9$), а також між шириною та масою насіння ($r = 0,767$). Водночас маса плодів не мала достовірного зв'язку з кількістю насінин ($r = 0,129$).

Висновки. Значна морфологічна мінливість, виявлена в колекції *Diospyros*, створює надійну основу для селекційної роботи. Гібридний сорт 'Соснівська' демонструє ефективність міжвидової гібридизації, поєднуючи високу масу плодів зі значною екологічною адаптивністю. Крім того, відсутність істотного зв'язку між масою плодів і кількістю насінин ($r = 0,129$) свідчить про можливість селекції крупноплідних форм зі зменшеним вмістом насіння, що є особливо важливим як для споживання у свіжому вигляді, так і для промислової переробки.

Ключові слова: *Diospyros virginiana*, хурма, ознаки плодів і насіння, інтродукція, гібридизація, сорти, Лісостеп