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MORPHOMETRIC ANALYSIS OF *ASIMINA TRILOBA* (L.) DUNAL FRUITS AND SEEDS FROM THE KHOROL BOTANICAL GARDEN COLLECTION

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Background. Pawpaw – *Asimina triloba* (L.) Dunal is a promising fruit crop for introduction in Ukraine, yet the expansion of the industry remains constrained by the limited availability of superior clonal material. Successful commercialization in new cultivation areas requires comprehensive studies of the species' biological performance under local environmental conditions. This study aimed to evaluate the morphometric characteristics of fruits and seeds from the collection of the Khorol Botanical Garden and to characterize the phenotypic variability of the studied germplasm under the environmental conditions of the Left-Bank Forest-Steppe of Ukraine. The results provide a basis for the identification of promising genetic resources for further breeding and cultivation.

Materials and Methods. In 2025, 13 genotypes, including the Italian cultivar 'Prima 1216' and hybrid seedlings originating from the 'Michurinka' cultivar, were analysed. Morphometric parameters (weight, length, width, thickness) and shape indices were calculated for fruits (n = 10 per genotype) and seeds (n = 20 per genotype). Seed-to-fruit ratio was also calculated. Statistical analysis included one-way ANOVA, Fisher's LSD test, and Pearson correlation coefficients ($P \leq 0.05$).

Results. The linear dimensions of pawpaw fruits ranged from 6.2 cm to 8.0 cm in length and from 3.8 cm to 5.3 cm in width. Fruit weight exhibited significant variability (CV = 37.5%), ranging from 46.0 g to 136.3 g. 'Prima 1216' produced significantly larger fruits than all other evaluated genotypes, reaching a maximum fruit weight of 195.7 g. The mean seed count per genotype varied from 6.7 to 11.1. 'Prima 1216' fruits exhibited an excellent seed-to-fruit ratio of 3.7 %. In the hybrid genotypes 'Tsukerkova' and 'Furshetna', which performed best in this regard, the seed-to-fruit ratios were 7.3 and 7.9 %, respectively. Seed weight, length, and width varied between 0.7 g and 1.0 g, 18.4 to 26.7 mm, and 10.0 to 13.6 mm, respectively. Correlation analysis showed that fruit weight was most strongly associated with fruit width (r = 0.97). Fruit size was negatively correlated with seed-to-fruit ratio (r = -0.78 to -0.87), indicating an inverse association between fruit size and the relative proportion of seeds.

Conclusions. The studied genotypes exhibited high phenotypic diversity in the conditions of the Left-Bank Forest-Steppe of Ukraine. 'Prima 1216' exhibited the lowest seed-to-fruit ratio (3.7 %), followed by the hybrid selections 'Tsukerkova' (7.3 %) and 'Furshetna' (7.9 %). These genotypes represent promising genetic resources that deserve further evaluation for breeding programmes and subsequent commercial cultivation.

Keywords: pawpaw, fruit weight, seed-to-fruit ratio, morphometric traits, forest-steppe

INTRODUCTION

Pawpaw (*Asimina triloba* (L.) Dunal) belongs to the family *Annonaceae* Juss. The native range of this species is from Southeastern Canada to the Central and Eastern USA (Peterson, 1991; Plants of the World Online, 2025). The species grows primarily in the temperate biome and is the most cold-hardy fruit tree in the family *Annonaceae*. The pawpaw produces the largest edible fruits native to the USA, which are characterised by a unique aroma and high nutritional value (Darrow, 1975; Peterson, 1991; Pomper *et al.*, 2010). Fruit weight may reach 500 g, whereas the average fruit weight ranges from 150 to 200 g (Hormaza, 2014). The tissues of fruit contain a diverse array of significant bioactive compounds, making it a subject of increasing interest in pharmacognosy and nutritional science. Recent pharmacological evaluations of fruit extracts have demonstrated potent biological activities, most notably anti-cancer and anti-obesity effects. Given this unique biochemical composition, the pawpaw holds substantial potential for development as a functional food and for application within the pharmaceutical industry (Aluko, 2012; Adainoo, 2024; Griffin *et al.*, 2024).

Modern biological science focuses on identifying novel plant species as potent sources of biologically active compounds. The strategic development of this field involves plant introduction, selection, and the refinement of cultivation and extraction techniques to create advanced nutritional supplements (Mezhenskyj *et al.*, 2023; Krasovskyi *et al.*, 2025). Changes in lifestyle and demographics, coupled with a deeper understanding of the link between diet and health, have shifted consumer demand toward food that prevents nutrition-related diseases. Consequently, there is an increasing interest in agrobiodiversity and underutilized fruits that enhance physical and mental well-being. This has led to exponential growth in the market for functional foods and botanicals (Colombo *et al.*, 2020; Donno & Turrini, 2020).

Pawpaw has been introduced into many European countries as a promising fruit crop (Bellini *et al.*, 2003; Brindza *et al.*, 2019; Brannan and Coyle, 2021; Lehner *et al.*, 2022a, 2022b), including Ukraine (Grabovetzkaya *et al.*, 2006; Derevianko *et al.*, 2009). Despite this growing interest, the expansion of the industry remains constrained by the limited availability of superior clonal material and a lack of standardized rootstocks. Furthermore, successful commercialization in new cultivation areas requires comprehensive studies of the species' biological performance and fruit morphological quality traits under local environmental conditions. In this context, the morphometric analysis of fruits and seeds and the subsequent selection of promising new forms are essential steps for identifying genotypes with high yield potential and desirable fruit characteristics. Such evaluations provide valuable information for breeding programmes and for the future development of *Asimina triloba* orchards in the region. Despite the increasing number of studies on pawpaw cultivation in Europe, comparative morphometric analyses of germplasm collections maintained under the environmental conditions of central Ukraine remain scarce. Therefore, the present study aimed to evaluate the fruit and seed morphometric characteristics of pawpaw genotypes maintained in the Khorol Botanical Garden collection in order to characterize their phenotypic variability and identify promising germplasm for future breeding and conservation programmes.

MATERIALS AND METHODS

Plant material. The *A. triloba* seeds were obtained from the Novokakhovske Research Farm (courtesy of Olha Hravovetska). Mature seedlings, originating from the 'Michurinka' cultivar developed at the Novokakhovske Research Farm, have been maintained in the Khorol Botanical Garden nursery alongside a grafted 'Prima 1216' tree of Italian breeding. All genotypes were cultivated under identical environmental and horticultural conditions within the collection orchard, thereby minimizing the influence of cultivation practices on the evaluated morphometric traits.

Analysis. In 2025, ten fruits and twenty seeds were randomly sampled from each genotype for morphometric analysis. Although the sample size was sufficient for comparative morphometric evaluation, it should be considered when interpreting genotype-specific differences and correlation patterns. The linear dimensions of the fruits (length and width) and seeds (length, width, and thickness) were measured in centimetres and millimetres, respectively, using a digital calliper 300-I-0.01 (Shahe, China, 2021). For each genotype, the fruit and seed weights (in grams) were measured using an electronic laboratory balance FEH-300 (TM Dniproves, Ukraine, 2022). Fruit shape and seed shape indices were calculated as the ratio of length to width. Seed-to-fruit ratio was calculated for each fruit and genotype using the following equation:

Statistical analysis. 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 Fisher's least significant difference (LSD) test. Pearson correlation coefficients were calculated using genotype mean values ($n = 13$), and their statistical significance was assessed using Student's t-test ($P \leq 0.05$). Correlation coefficients were interpreted as measures of statistical association among genotype mean values rather than evidence

of causal relationships between traits. Because the correlation analysis was performed using genotype mean values (n = 13), the obtained coefficients describe patterns of trait co-variation among genotypes and should be interpreted accordingly.

RESULTS AND DISCUSSION

According to C. Ferrer-Blanco *et al.* (2022), the 3–10 carpels of the pawpaw gynoecium develop to become a fruit cluster. The fruits are simple berries, spreading from swollen receptacles, unevenly oblong-cylindrical, and pulpy. Seeds are 3-many per pistil, bean-shaped, slightly compressed laterally, with a tough seed coat (Kral, 1997). Under the conditions of the Khorol Botanical Garden, pawpaw fruits begin to ripen in the first decade of October. The fruits are of a cylindrical-oval shape and slightly curved. As the fruits ripen, their colour changes from green or light green with a yellowish tint to lemon-yellow (**Fig. 1**).

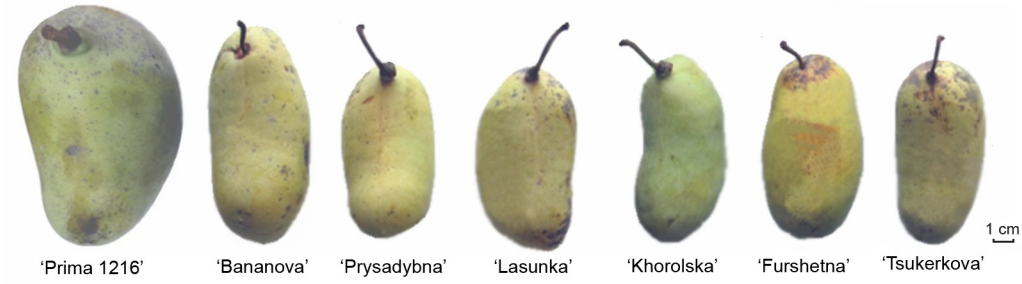

Fig. 1. Fruits of pawpaw genotypes

The linear dimensions of pawpaw fruits range from 6.2 cm to 8.0 cm in length and from 3.8 cm to 5.3 cm in width. The fruits of 'Prima 1216' significantly exceed other genotypes in width, while in terms of length, they do not significantly differ from the genotypes that have received cultivar names (**Table 1**).

These hybrid seedlings received cultivar names because they exceed other seedlings in the population in terms of fruit length and weight. The fruit weight indicator is the most variable, with a coefficient of variation of 37.5 %. The fruits of 'Prima 1216', with an average weight of 136.3 g, were significantly larger than those of all other genotypes in the collection, being approximately twice as heavy as the named hybrid genotypes and nearly three times as heavy as the remaining seedlings. The maximum fruit weight recorded for 'Prima 1216' was 195.7 g. Although higher fruit weights have been reported for this cultivar under other growing conditions, 'Prima 1216' consistently produced the largest fruits among the evaluated genotypes in the present study. According to Bellini *et al*. (2003), 'Prima 1216', developed in Italy, has an average weight of 195.0–209.5 g, belonging to the group of the heaviest cultivars among the 15 studied under the conditions of Northern Italy. The lower fruit weight observed under the conditions of the Left-Bank Forest-Steppe compared with values reported for Northern Italy may reflect differences in environmental conditions and growing practices. According to O. A. Hrabovetska (2023), during summer droughts, pawpaw leaves often suffer from dry winds, leading to foliar damage and significantly reduced photosynthetic efficiency. As R. B. Frost (2023) points out, the weight of pawpaw cultivar fruits varies depending on the growing site.

Table 1. **Morphometric indicators of pawpaw fruits ($\bar{x}$ ± SD, n = 10), 2025**

Genotype	Weight, g	Length, cm	Width, cm	Shape index	Number of seeds, pcs.	Seed-to-fruit ratio, %
'Prima 1216'	136.3 ± 38.04^{a}	8.0 ± 1.81^{a}	5.3 ± 1.01^{a}	1.5 ± 0.05^{d}	5.4 ± 0.97^{g}	3.7 ± 0.37^{g}
'Bananova'	70.7 ± 28.96^{b}	7.6 ± 1.56^{a}	4.1 ± 0.55^{bcd}	1.9 ± 0.24^{abc}	8.9 ± 2.60^{bcde}	10.7 ± 3.02^{ef}
'Prysadybna'	63.5 ± 14.89^{bc}	7.4 ± 1.01^{ab}	3.9 ± 0.75^{bcd}	1.9 ± 0.20^{ab}	9.4 ± 2.59^{abcde}	11.3 ± 3.09^{d}e
'Lasunka'	68.6 ± 18.00^{bc}	7.5 ± 0.96^{ab}	4.2 ± 0.91^{bc}	1.8 ± 0.26^{bc}	11.1 ± 3.51^{a}	12.2 ± 5.62^{cde}
'Khorolska'	62.5 ± 16.48^{bcd}	7.9 ± 1.43^{a}	3.9 ± 0.66^{bcd}	2.0 ± 0.26^{a}	10.1 ± 2.85^{bc}	12.6 ± 7.13^{cde}
'Furshetna'	62.1 ± 18.13^{bcd}	7.2 ± 1.26^{abc}	4.1 ± 0.49^{bcd}	1.8 ± 0.20^{bc}	6.7 ± 0.95^{fg}	7.5 ± 2.62^{f}
'Tsukerkova'	64.8 ± 14.81^{bc}	7.5 ± 0.89^{ab}	4.2 ± 0.91^{b}	1.8 ± 0.20^{bc}	8.5 ± 2.01^{bcde}	11.0 ± 3.12e
#7	48.2 ± 11.39^{de}	6.3 ± 0.65^{cd}	3.7 ± 0.27^{bcd}	1.7 ±0.14^{c}	8.6 ± 1.07^{bcde}	14.8 ± 2.94^{bc}
#8	46.0 ± 6.90^{e}	6.3 ± 0.67^{cd}	3.7 ± 0.48^{bcd}	1.7 ±0.23^{c}	8.0 ± 1.41^{ef}	14.6 ± 3.23^{bcd}
#9	46.4 ± 8.06^{e}	6.3 ± 0.48^{cd}	3.6 ± 0.44^{d}	1.8 ± 0.24^{bc}	8.2 ± 1.03^{def}	16.3 ± 3.22^{ab}
#10	49.6 ± 6.74^{de}	6.3 ± 0.61^{cd}	3.6 ± 0.23^{cd}	1.7 ± 0.24^{bc}	9.1 ± 0.99^{bcde}	19.0 ± 2.61^{a}
#11	55.2 ± 11.59^{cd}	6.6 ± 0.57b^{cd}	3.7 ± 0.38^{bcd}	1.8 ±0.21^{bc}	9.8 ± 1.81^{abcd}	15.5 ± 3.56^{bc}
#12	47.3 ± 11.53^{e}	6.2 ± 0.56^{d}	3.7 ± 0.44^{bcd}	1.7 ± 0.24^{c}	8.3 ± 0.82^{cdef}	18.7 ± 5.01^{a}
lim	46.0–136.6	6.2–8.0	3.8–5.3	1.5–2.0	6.7–11.1	3.7–19.0
CV, %	37.5	9.7	11.7	7.0	16.8	35.0

Note: $\bar{x}$ – mean; SD – standard deviation; n – number of replications; lim – range of variation (min–max); CV – coefficient of variation; different letters within a column indicate statistically significant differences according to the LSD test (P ≤ 0.05)

The hybrid pawpaw population at the Khorol Botanical Garden originated from seeds of the 'Michurinka' cultivar obtained through open pollination. This cultivar is characterised by an average fruit weight ranging from 130 to 160 g, reaching up to 320 g in southern Ukraine (Hrabovetska, 2015). As expected for open-pollinated progeny, most hybrid seedlings produced substantially smaller fruits than the maternal cultivar, reflecting segregation of quantitative fruit-size traits. Among the hybrid selections, only the 'Bananova' selection produced the largest fruits, which approached the average weight of the maternal cultivar.

In the United States, R. G. Brannan *et al*. (2015) studied 10 cultivars, where fruit weight ranged from 84 to 204 g, fruit length from 7.9 to 11.5 cm, and fruit width from 4.6 to 6.4 cm. Over a three-year study, K. W. Pomper *et al*. (2008) found that the fruit weight of 8 cultivars varied between 65 and 189 g. An analysis of nine popular cultivars in the USA, conducted by B. Adainoo *et al*. (2022), showed that fruit weight ranged from 137 to 334 g and fruit length ranged from 7.6 to 9.9 cm. According to Brindza *et al*. (2019), under the conditions of Slovakia, the average fruit weight of hybrids ranged from 92.2 to 154.6 g. In Romania, the fruit weight of 23 genotypes, analysed by A. F. Tabacu *et al*. (2020) over three years, ranged from 35.0 to 189.5 g; notably, this broad range was observed within a single genotype, indicating significant annual variability. The linear

parameters of the fruits in this study also exhibited annual variation. On average, the fruit length of the investigated genotypes ranged from 5.9 to 9.8 cm (max. 10.0 cm), while the width fluctuated between 3.9 and 6.7 cm (max. 7.9 cm). Similar annual fluctuations were reported by B. A. Szilagyi *et al*. (2016), who observed that over a six-year experiment, fruit length and width varied between 7.4 and 12.2 cm (averaging 9.1 cm) and 3.8 and 5.8 cm (averaging 4.6 cm), respectively.

The investigated genotypes produced predominantly ellipsoidal fruits, with a shape index ranging from 1.5 to 2.0. The highest values were observed in 'Khorolska', 'Prysadybna', and 'Bananova', while the lowest value was recorded in 'Prima 1216' due to its significantly larger fruit width. These differences demonstrate substantial diversity in fruit morphology among the evaluated genotypes despite their common growing conditions.

At the level of individual fruits across the entire sample, the seed count ranged from 4 to 19, which is consistent with the data (4–14) reported by O. A. Hrabovetska (2015, 2023). The mean seed count per genotype varied from 6.7 to 11.1 in our study. Usually, in pawpaw fruit, there are two rows of seeds (12 to 20 seeds) (Pomper & Layne, 2005). Among the evaluated genotypes, 'Prima 1216' exhibited the lowest mean seed number, averaging 5.4 (ranging from 4 to 7) under our conditions.

A high proportion of seeds relative to edible flesh is considered one of the major limitations affecting consumer acceptance of fresh pawpaw fruit. According to R. N. Peterson (1991), the seed-to-fruit ratio varies considerably, from a low of 11 per cent to a high of 45 per cent, with a mean of 28 per cent. In our study, 'Prima 1216' fruits exhibited an excellent seed-to-fruit ratio of 3.7 per cent. Among the hybrid genotypes, 'Tsukerkova' and 'Furshetna' exhibited the lowest seed-to-fruit ratios, averaging 7.3 % and 7.9 %, respectively. Therefore, genotypes characterised by a lower seed-to-fruit ratio may be considered promising candidates for further evaluation with respect to fresh-market production.

The seeds are large, bean-shaped, laterally compressed, and glossy, with a colouration ranging from light to dark brown (**Fig. 2**).

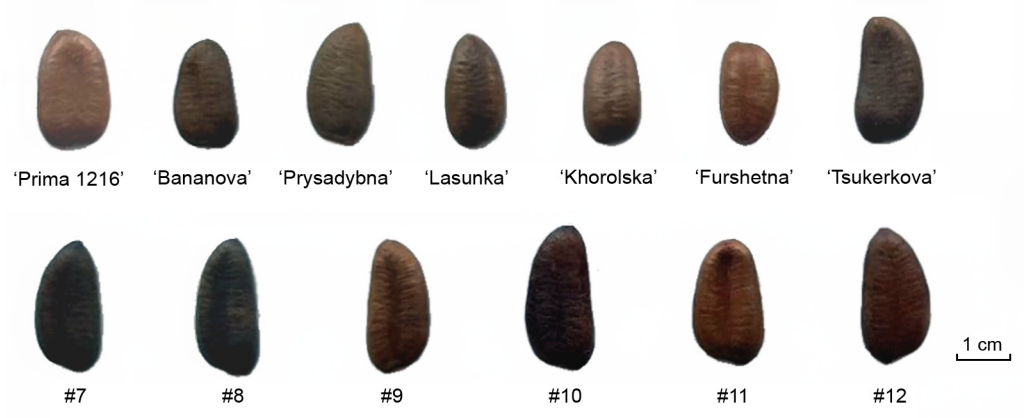

Fig. 2. Seeds of pawpaw genotypes

In the investigated genotypes, the seed weight ranges from 0.7 to 1.0 g (**Table 2**). Observations of a larger sample indicate a wider variability range of 0.5–2.0 g

(Hrabovetska, 2015, 2023). According to Brindza *et al*. (2019), under the conditions of Slovakia, the average seed weight of hybrids fluctuated between 0.8 and 1.4 g. Similar data for various genotypes in Romania, ranging from 0.9 to 1.8 g, were reported by A. F. Tabacu *et al*. (2020). In addition to genotypic influence, seed weight depends on environmental factors. Specifically, over a six-year observation period, the average annual seed weight was found to vary from 1.3 to 1.7 g (Szilagyi *et al*., 2016).

Table 2. **Morphometric indicators of pawpaw seeds ($\bar{x}$ ± SD, *n* = 20), 2025**

Genotype	Weight, g	Length, mm	Width, mm	Thickness, mm	Shape index
'Prima 1216'	0.9 ± 0.18^{bc}	20.9 ± 2.15^{f}	13.6 ± 1.76^{a}	6.2 ± 0.75^{a}	1.5 ±0.05^{f}
'Bananova'	0.8 ± 0.15^{fgh}	21.1 ± 2.09^{ef}	11.7 ± 1.26^{ef}	4.6 ± 0.75^{b}	1.8 ± 0.24^{ee}
'Prysadybna'	0.7 ± 0.15^{gh}	20.4 ± 1.93^{fg}	11.6 ± 0.94^{def}	4.1 ± 0.83^{c}	1.8 ± 0.19^{e}
'Lasunka'	0.7 ± 0.12^{hi}	20.4 ± 1.98^{fg}	10.0 ± 0.69^{i}	4.2 ± 0.77^{b}	2.1 ± 0.26^{bc}
'Khorolska'	0.9 ± 0.15^{cde}	19.1 ± 3.03^{gh}	10.2 ± 0.89^{hi}	6.6 ± 0.69^{a}	1.9 ± 0.28^{de}
'Furshetna'	0.6 ± 0.14^{i}	18.4 ± 2.43^{h}	10.4 ± 0.56^{ghi}	4.8 ± 1.16^{b}	1.8 ± 0.26^{e}
'Tsukerkova'	0.8 ± 0.15^{efg}	22.5 ± 2.05^{de}	11.1 ± 0.76^{fg}	5.1 ± 0.39^{b}	2.0 ± 0.17^{bc}
#7	0.8 ± 0.12^{fgh}	24.1 ± 2.00^{bc}	11.2 ± 1.15^{ef}	3.3 ± 0.47^{de}	2.2 ± 0.25^{ab}
#8	0.8 ± 0.16^{defg}	25.1 ± 2.80^{bc}	11.2 ± 0.89^{ef}	4.2 ± 1.64^{c}	2.2 ± 0.23^{a}
#9	0.9 ± 0.14^{cde}	23.9 ± 2.54^{cd}	12.1 ± 1.37^{cd}	3.9 ± 1.35^{cd}	2.0 ± 0.25^{cd}
#10	1.0 ± 0.10^{a}	26.7 ± 1.81^{a}	12.7 ± 0.88^{bc}	3.1 ± 0.39^{e}	2.1 ± 0.25^{abc}
#11	0.8 ± 0.19^{cdef}	24.5 ± 2.76^{bc}	11.7 ± 1.27^{def}	4.2 ± 1.44^{c}	2.1 ± 0.29^{abc}
#12	1.0 ± 0.13^{ab}	25.5 ± 2.33^{ab}	13.0 ± 1.12^{ab}	3.1 ± 0.22^{e}	2.0 ± 0.28^{cd}
lim	0.7–1.0	18.4–26.7	10.0–13.6	3.3–6.6	1.5–2.2
CV, %	13.3	11.8	9.3	24.3	10.0

Note: $\bar{x}$ – mean; SD – standard deviation; n – number of replications; lim – range of variation (min–max); CV – coefficient of variation; different letters within a column indicate statistically significant differences according to the LSD test ($P \leq 0.05$)

Among the linear dimensions of the seeds, seed thickness exhibited the highest variability (CV = 24.3 %). This result suggests that seed thickness is the most variable seed trait among the evaluated genotypes and may therefore possess greater discriminatory value for genotype characterisation. The average seed length and width of the investigated genotypes ranged from 18.4 to 26.7 mm and 10.0 to 13.6 mm, respectively. Similar data for length (17.9–28.5 mm) and width (10.1–12.5 mm) were reported by A. F. Tabacu *et al*. (2020), while O. A. Hrabovetska (2015, 2023) observed a slightly broader range, with lengths of 15–30 mm and widths of 10–19 mm. According to R. L. Geneve *et al*. (2003), pawpaw seeds are typically 28 mm long and 15 mm wide. Weather conditions have a negligible effect on seed dimensions (Szilagyi *et al*., 2016).

The seed shape index of the investigated genotypes ranges from 1.5–2.2, with the scientifically lowest value (1.5) recorded in 'Prima 1216'. These results are consistent

with the findings of A. F. Tabacu *et al*. (2020), who reported that the shape index of elongated seeds typically varies within the range of 1.8–2.5. The lower index in 'Prima 1216' is associated with its relatively greater seed width and thickness in relation to seed length, resulting in a more rounded seed shape than in the remaining genotypes.

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

Trait	Fruit length	Fruit width	Fruit weight	Fruit shape	Number of seeds	Seed-to-fruit ratio	Seed length	Seed width	Seed thickness	Seed weight	Seed shape
Fruit length	1.00	–	–	–	–	–	–	–	–	–	–
Fruit width	**0.75**	1.00	–	–	–	–	–	–	–	–	–
Fruit weight	**0.73**	**0.97**	1.00	–	–	–	–	–	–	–	–
Fruit shape	0.22	-0.48	-0.46	1.00	–	–	–	–	–	–	–
Number of seeds	-0.05	-0.54	-0.51	**0.76**	1.00	–	–	–	–	–	–
Seed-to-fruit ratio	**-0.79**	**-0.87**	**-0.78**	0.26	0.50	1.00	–	–	–	–	–
Seed length	**-0.84**	-0.51	-0.46	-0.36	0.04	**0.69**	1.00	–	–	–	–
Seed width	-0.25	0.22	0.34	**-0.64**	-0.53	0.08	0.52	1.00	–	–	–
Seed thickness	**0.85**	**0.67**	**0.65**	0.14	-0.21	**-0.67**	**-0.71**	-0.22	1.00	–	–
Seed weight	-0.36	-0.13	-0.01	-0.24	-0.08	0.51	**0.66**	**0.72**	-0.17	1.00	–
Seed shape	**-0.73**	**-0.72**	**-0.76**	0.10	0.48	**0.68**	**0.69**	-0.25	**-0.59**	0.13	1.00

Note: significant coefficients (P ≤ 0.05) are shown in bold (n =13)

Pearson correlation analysis (n = 13) revealed multiple statistically significant relationships among fruit and seed morphological traits. Because the correlations were calculated using genotype mean values, the observed relationships describe patterns of trait co-variation among genotypes and should be interpreted as statistical associations rather than evidence of causal relationships. Fruit weight showed an extremely strong positive correlation with fruit width (r = 0.97), indicating that fruit width was the trait most strongly associated with fruit weight among the studied morphometric characteristics. Fruit length was also positively correlated with fruit width (r = 0.75), fruit weight (r = 0.73), and seed thickness (r = 0.85), but negatively correlated with seed length (r = -0.84) and seed-to-fruit ratio (r = -0.84).

Seed-to-fruit ratio exhibited strong negative correlations with fruit length, width, and weight (r ranging from -0.78 to -0.87) and seed thickness (r = -0.67), indicating that larger fruits tended to have a lower seed-to-fruit ratio than smaller fruits. However, because these relationships were derived from correlation analysis, they should be interpreted as statistical associations rather than evidence of causal allocation mechanisms. In contrast, seed-to-fruit ratio was positively correlated with seed length (r = 0.69), and seed shape (r = 0.68).

Regarding seed morphology, seed weight was strongly and positively correlated with seed width (r = 0.72) and moderately correlated with seed length (r = 0.66). A significant negative relationship between seed length and thickness (r = -0.71) indicates contrasting patterns of seed morphology among genotypes, with seeds tending to be either relatively elongated or relatively thick.

Notably, the number of seeds did not show statistically significant correlations with fruit or seed size traits, indicating that seed quantity varies independently from fruit morphology. However, the number of seeds was strongly and positively correlated with fruit shape index (r = 0.76), indicating that more elongated fruits tended to contain a greater number of seeds.

Among the evaluated morphometric traits, fruit width showed the strongest positive association with fruit weight (r = 0.97), whereas fruit length exhibited a weaker relationship. Larger fruits generally tended to have a lower seed-to-fruit ratio, indicating an inverse association between fruit size and the relative proportion of seeds. Seed weight was most strongly associated with seed width, while seed morphology reflected an inverse relationship between seed length and thickness. The number of seeds was largely independent of fruit and seed size characteristics, except for its positive association with fruit shape index. These findings describe patterns of trait co-variation within the studied germplasm and should not be interpreted as evidence of direct causal relationships.

CONCLUSIONS

The studied *Asimina triloba* genotypes exhibited considerable phenotypic diversity under the conditions of the Left-Bank Forest-Steppe of Ukraine, demonstrating substantial variation in fruit and seed morphometric traits among the evaluated germplasm. Among the genotypes under study, ‘Prima 1216’ exhibited the largest fruits and the lowest seed-to-fruit ratio, while the hybrid selections ‘Tsukerkova’ and ‘Furshetna’ also exhibited favourable low seed-to-fruit ratios. Correlation analysis revealed that fruit width was the trait most strongly associated with fruit weight. In addition, larger fruits generally exhibited lower seed-to-fruit ratios. These relationships describe patterns of trait co-variation among the evaluated genotypes and should not be interpreted as evidence of causal relationships. The observed associations suggest that both fruit size and seed-to-fruit ratio should be considered when selecting promising genotypes for further breeding.

The identified genotypes represent promising genetic resources that warrant further evaluation under different environmental conditions before their potential use in breeding programmes and commercial cultivation in Ukraine.

The present study focused on fruit and seed morphometric traits of thirteen pawpaw genotypes cultivated under the environmental conditions of the Left-Bank Forest-Steppe of Ukraine. Although the obtained results clearly demonstrate substantial phenotypic variability among genotypes, the relatively limited number of sampled fruits and the use of genotype mean values for correlation analysis should be considered when interpreting the observed relationships. Furthermore, economically important traits, including productivity, fruit chemical composition, storability, transportability and resistance to abiotic and biotic stresses, were beyond the scope of the present study and

should be evaluated in future long-term studies before practical recommendations for commercial cultivation can be formulated.

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.; V.M]; 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 [V.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.

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МОРФОМЕТРИЧНИЙ АНАЛІЗ ПЛОДІВ *ASIMINA TRILOBA* (L.) DUNAL ІЗ КОЛЕКЦІЇ ХОРОЛЬСЬКОГО БОТАНІЧНОГО САДУ

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Обґрунтування. Азиміна трилопатева (*Asimina triloba* (L.) Dunal) – перспективна плодова культура для інтродукції в Україні, проте розширення її промислового вирощування стримує обмежена доступність елітного клонового матеріалу. Успішна комерціалізація в нових регіонах вирощування потребує комплексних досліджень біологічних особливостей виду та якості плодів у місцевих екологічних умовах. Метою дослідження є оцінка морфометричних характеристик плодів і насіння з колекції Хорольського ботанічного саду для виявлення перспективних генотипів з метою подальшої селекції й аматорського садівництва.

Матеріали та методи. У 2025 р. проаналізовано 13 генотипів, включаючи італійський сорт 'Prima 1216' та гібридні сіянці, походженням від сорту 'Мічурінка'. Визначали морфометричні параметри (маса, довжина, ширина, товщина) та індекси форми плодів (n = 10 на генотип) і насіння (n = 20 на генотип). Також розраховано співвідношення маси насіння до маси плоду. Статистичний аналіз включав однофакторний дисперсійний аналіз, критерій найменшої істотної різниці Фішера та коефіцієнти кореляції Пірсона ($P \leq 0,05$).

Результати. Лінійні розміри плодів азиміни варіюють від 6,2 см до 8,0 см у довжину та від 3,8 см до 5,3 см у ширину. Маса плодів виявила значну мінливість (CV = 37,5 %), коливаючись від 46,0 г до 136,3 г. 'Prima 1216' був найбільшим генотипом, досягаючи максимальної маси плоду 195,7 г. Середня кількість насіння на генотип варіювала від 6,7 до 11,1 шт. Плоди сорту 'Prima 1216' продемонстрували відмінне співвідношення маси насіння до маси плоду – 3,7 %. У гібридних генотипів 'Цукеркова' та 'Фуршетна', які виявилися найкращими за цим показником, співвідношення маси насіння до маси плоду становило 7,3 % та 7,9 % відповідно. Маса, довжина та ширина насіння варіювали в межах 0,7–1,0 г; 18,4–26,7 мм та 10,0–13,6 мм відповідно. За результатами кореляційного аналізу встановлено, що маса плода найбільшою мірою визначається його шириною ($r = 0,97$). Сильний негативний зв'язок між розміром плоду та вмістом насіння ($r = -0,78…-0,87$) вказує на алокаційний компроміс, за якого більші плоди спрямовують пропорційно більше біомаси в оплодень.

Висновки. Досліджені генотипи демонструють високе фенотипове різноманіття за умов Лівобережного Лісостепу України. ‘Prima 1216’ продемонстрував найкращий показник вмісту насіння (3,7 %), далі за показниками розташовуються гібридні форми ‘Цукеркова’ (7,3 %) та ‘Фуршетна’ (7,9 %). Ці генотипи рекомендовані як цінні генетичні ресурси для створення інтенсивних садів і подальших селекційних програм, спрямованих на підвищення товарності плодів.

Ключові слова: азиміна, маса плода, співвідношення маси насіння до маси плоду, інтродукція, Лісостеп

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