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Morphological and biochemical characteristics of medlar (*Crataegus germanica*) fruits in the Forest-Steppe of Ukraine

V. M. Mezhenskyj*, L. O. Mezhenska*, B. M. Mazur*, Y. M. Marchuk*, O. V. Topchii**, A. P. Ivanytska**

National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine
Ukrainian Institute of Plant Varieties Examination, Kyiv, Ukraine

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Prof. V. L. Symyrenko Department of Horticulture, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony st., 15, Kyiv, 03041 Ukraine. Tel.: +380-50-297-27-39. E-mail: mezh1956@ukr.net

Ukrainian Institute of Plant Varieties Examination, Henerala Rodymtseva st., Kyiv, 03041 Ukraine. Tel.: +380-98-022-88-51. E-mail: otopchiy1992@gmail.com

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This study was carried out to determine the morphological traits of the fruit as well as the dry matter, sugars, and organic acids of medlar (*Crataegus germanica* (L.) Kuntze) genotypes which were grown near Kyiv, Ukraine in 2022–2024. A total of 15 genotypes were evaluated in the study, including 14 varieties originating from Western, Central, and Eastern European countries, the North Caucasus, and Iran, and one local semi-wild form. Significant differences were detected among the genotypes on the morphological and biological characters and on the chemical composition of the fruit. Fruit diameter ranged from 16.97 to 42.17 mm, fruit weight from 2.39 to 34.37 g, pyrena percentage from 0.00% to 16.82%. 'Apyrena' and 'Seedless' are characterized by the complete absence of pyrenas and seeds in the fruit. In terms of fruit diameter and fruit weight genotypes are grouped into very small fruit ('Apyrena'), small fruit (semi-wild medlar, 'Seedless' and 'Nottingham'), medium-sized fruit ('Gojtkhivska', 'Monstruose d'Evreinoff', 'Haidegger', '25-hrammovaja', 'Elburs', 'Silberberger', 'Delice des Vannes', and 'Sladkaja Drachyova'), and large fruit ('Holland', 'Dutch Giant', 'Dniprovska', and Flanders Giant®). The correlation between fruit diameter and fruit weight is very strong, r = 0.98. The weight of pyrenas in the fruit is moderately correlated with the fruit weight, r = –0.45. Medlar pyrenas varied in length from about 8.75 to 13.53 mm, in width from 6.06 to 11.01 mm and in thickness from 3.97 to 7.12 mm. The largest pyrenas were found in 'Dutch Giant', 'Holland', Flanders Giant®, 'Dniprovska', and 'Gojtkhivska', accordingly 0.33, 0.33, 0.35, 0.37, 0.48 g; the smallest pyrenas (0.11 g) were found in semi-wild medlar fruit. The fruits of the ultra-early 'Hoitkhivska' variety began to soften on the tree in late October. The early ripening varieties 'Elburs', 'Haidegger', 'Nottingham', 'Silberberger' and semi-wild medlar reached consumer ripeness when stored indoors at room temperature for two weeks. Late-ripening varieties include 'Delice des Vannes', 'Dutch Giant', Flanders Giant®, 'Holland', 'Monstruose d'Evreinoff', 'Sladkaja Drachyova', and '25-hrammovaja'. Fruits of ultra-late varieties 'Apyrena', 'Dniprovska', and 'Seedless', were harvested in the late October without bletting. In December, fruit after repeated freezing outdoors on the tree, when the flesh had reached a soft consistency, consisted of dry matter from 19.7% to 26.2%. The total sugar ranged from 8.5% to 17.1%, monosaccharides from 8.3% to 16.0%, titratable acidity from 0.28% to 1.12%, ascorbic acid from 2.94 to 4.84 mg/100 g, sugar/acidity index from 10.0 to 50.8.

Keywords: *Mespilus germanica*; cultivar; fruit weight; pyrena percentage; monosaccharides; sugar/acidity index.

Introduction

Carl Linnaeus (1753) established the genus *Mespilus*, in which he included 7 species. Several hundred species of *Mespilus* were subsequently described by many botanists. Later they were transferred to the genera *Aronia*, *Cotoneaster*, *Crataegus*, *Eriobotrya*, *Pyracantha*, *Sorbus*, etc. According to Friedrich Medikus (1789), *Mespilus* is a monotypic genus with *Mespilus germanica* L., which was agreed by most systematists a long time. Phylogenetic studies have shown sister relationships between *Mespilus* and *Crataegus* (Campbell et al., 2007; Potter et al., 2007), and due to the lack of a single character that can distinguish *Mespilus germanica* (= *Crataegus germanica* (L.) Kuntze) from any *Crataegus* species, it has been proposed to unify both genera by assigning a section rank to Mespilus (Lo et al., 2007; Mezhenska & Mezhenskyj, 2013). With such a unification, it was suggested that the name *Crataegus* be retained and conserved for nomenclatural stability (Talent et al., 2008). Instead, James Phipps (2016) provides numerous reasons to distinguish *Crataegus* and *Mespilus* as separate genera. In the latest system of the genus *Crataegus*, *Mespilus* has been elevated to the rank of a subgenus (Ufimov & Dickinson, 2020). The nomenclature employed for this species is *Crataegus germanica*, the correct name for the species. The species is cultivated under the traditional name of medlar.

The medlar tree has a history of many thousands of years cultivation and has held a high place among fruit trees. This plant was cultivated for its fruit by the Assyrians and then introduced to Europe, where it has been popular since antiquity and during the Middle Ages. But later in modern times this fruit was neglected and forgotten. Worldwide production has declined significantly and most of the fruit is now produced by home gardeners (Baird & Thieret, 1989; Webster, 2008). But now we see that the interest in this exceptional fruit tree is reawakening and that it's starting to be grown and used again (Nistor et al., 2024).

The hard and astringent fruits of the medlar become edible through a process called bletting, when the fruit is overripe and almost fermented. This process causes a rapid softening of the medlar fruit tissue, accompanied by an increase in soluble pectin and a decrease in insoluble pectin, but no galacturonic acid is formed (Roelofsen, 1954). The flesh becomes sweet and has the consistency of jam. Unfortunately, bletting the medlar is more acceptable for consumption, so the fruit becomes softer and creamier over time, but this process results in the loss of antioxidant activity (Żołnierczyk et al., 2023). Traditionally, the bletted fruit was eaten raw for dessert. The fruit is also baked whole, stewed or roasted over a fire and used for processing to make jams, jellies, marmalades, preserves, pies, syrups and liqueurs (Baird & Thieret, 1989; Webster, 2008).

The fruit, leaves, bark and wood are used for medicinal purposes (Bibalani & Mosazadeh-Sayadmahaleh, 2012; Voaides et al., 2021). In addition to a wide range of traditional uses, medlar fruit is comercially important for trade in large stores and regional open-air markets, and the fruit waste is a rich source of secondary metabolites for various applications (Nistor et al., 2024). Medlar was also used as feed for the cattle (Fedorov & Fedorov, 1937). The medlar has a better resistance to pests and climatic conditions than most of the other traditional fruit species (Voaides et al., 2021). The medlar tree, with its large white flowers and deep green leaves, possesses ornamental appeal. Trees are suitable for solitary and group settings, as well as for the arrangement of hedges and edges (Lypa et al., 1952). Medlar has been used as dwarfing rootstock for pear and quince.

The first documented introduction of the medlar in Ukraine can be traced back to 1811 at the Kremenets Botanical Garden (Lypa et al., 1952). However, it has been cultivated in the Crimea and adjacent areas of Southwestern Ukraine and Transcarpathia for a considerably longer period (Dobrochaieva, 1954). The species accessions are represented in the dendrological collections across a range of natural zones, reflecting the species' adaptability to diverse environmental conditions (Kokhno & Kurdyuk, 1994; Oleshko & Doroshenko, 2013). Seed progeny of different forms of medlar grown in botanical institutions show significant variability in fruit characteristics, which allows the selection of the best genotypes (Grygorieva et al., 2018). Currently, varieties of foreign breeding are being cultivated by amateur gardeners and are held in collections at scientific institutions in Ukraine (Mezhenskyj, 2008; Mezhenskyj & Mezhenska, 2015, 2023).

Materials and methods

The experimental work was conducted in collection orchard of the Educational, Research and Productive Laboratory of Genetic Resources, Introduction and Breeding of Rare Fruits and Ornamental Plants of the Prof. V. L. Symyrenko Department of Horticulture of the National University of Life and Environmental Sciences of Ukraine (NULESU), located at the Agronomic Research Station of NULESU in Pshenychne village, Bila Tserkva district, Kyiv region. The region is characterized by a typical warm-summer humid continental climate according to the Köppen climate classification scheme (Peel et al., 2007). Medlar cultivars were grafted onto *Crataegus chlorocarpa* seed rootstock. Trees were grown at a planting distance of 5 × 4 m. Traditional crop management practices were used, including inter-row cultivation and mechanical weed control, except irrigation.

Fruits of 15 medlar genotypes were examined, including a commercial selection and a small-fruited semiwild seedling of one of the collection accessions (Table 1).

Table 1
Medlar genotypes and their source used in the study

Name of accession	Collection number	National accession number	Ancestry	Donor
'Apyrena'	03823	UN9500032	Old European variety	Vladimiro Rocco, Stanghella, Italy
'Delice des Vannes'	04520	UN9500035	Old Dutch variety	Julian Geyer, Graz, Austria
'Dniprovska'	04605	UN9500041	Seedling of a European large-fruited variety	Victor Chyrka, Dnipropetrovsk Region, Ukraine
'Dutch Giant'	04522	UN9500038	Old Dutch variety	Julian Geyer, Graz, Austria
'Elburs'	04524	UN9500042	Iranian variety	Julian Geyer, Graz, Austria
Flanders Giant®	04523	UN9500036	Selection of Boomkwekerij Hortus Conclusus, Uitbergen, Belgium	Julian Geyer, Graz, Austria
'Gojtkhivska'	02655	UN9500029	Genotype collected by Nikolaj Drachyov near Gojtkh, Krasnodar Kray, Russia	Vladimir Svechnikov, Donetsk, Rostov Region, Russia
'Haidegger'	03950	UN9500033	Local Austrian variety from Styria	Julian Geyer, Graz, Austria
'Holland'	03124	UN9500030	Old Dutch variety	Mendel University in Brno, Lednice, Czech Republic
'Monstruose d'Evreinoff'	03822	UN9500031	Genotype collected by Vladimir Evreinoff near Mirabel, Tarn-et-Garonne, France	Vladimiro Rocco, Stanghella, Italy
'Nottingham'	03968	UN9500040	Old English variety	Julian Geyer, Graz, Austria
'Seedless'	04744	UN9500037	Old European variety	Ömer Selim, Trabzon, Turkey
'Silberberger'	03952	UN9500034	Local Austrian variety	Julian Geyer, Graz, Austria
'Sladkaja Drachyova'	02654	UN9500028	Genotype collected by Nikolaj Drachyov in Krasnodar Kray, Russia	Vladimir Svechnikov, Donetsk, Rostov Region, Russia
'25-hrammovaja'	02653	UN9500027	Genotype collected by Nikolaj Drachyov in Krasnodar Kray, Russia	Vladimir Svechnikov, Donetsk, Rostov Region, Russia
Semiwild	02248F_1	–	Seedling of plants from the collection of the Volyn Botanical Garden	Volodymyr Batochenko, Radyvyliv, Rivne region, Ukraine

Fruits were harvested for measurements at the end of October in 2022–2024. After two weeks of storage at room temperature, the fruits were evaluated to determine the extent of softening. In early December 2024, fruits were collected from the trees for biochemical analysis.

20 pomes of each genotype were used for measurement of fruit diameter (mm) and fruit weight (g), and seed height, width and thickness (all in mm) were measured on 20 seeds. Fruit diameter and stone linear parameters were measured using a mechanical caliper with a sensitivity of 0.1 mm. Both fruit and seed mass were measured using an Adventurer™ electronic laboratory balance (Ohaus, China, 2010) with a sensitivity of 0.01 g. The percentage of seeds was calculated using the following ratio: seed weight / fruit weight. The number of seeds was determined by cutting all the pyrenas removed.

For determining the content of dry matter from the average sample of fruit pulp, two 25 g weights were taken to the nearest 0.01 g and placed in pre-weighed porcelain cups. After weighing, the cups with the samples were placed in a drying cabinet SP 150 K (RIVASTAL, Ukraine, 2023) heated to 120 °C for 20 minutes and then dried in an oven at 60–70 °C until air dry. After air drying, the material was dried at 100 °C for 4 hours. The dried samples were cooled in a desiccator and weighed. After weighing, the cups were dried again at 100 °C for one hour. They were then cooled in a desiccator and weighed. The cups with the dry matter were dried and weighed until the difference between the two weights (parallel) did not exceed 0.01–0.02 g. All weighing was performed on an electronic balance AXIS AD 100 (Axis, Poland, 2011). Data are expressed as a percentage by raw mass.

The sugar content was determined by the Bertrand method, which is based on the ability of reducing sugars with a free aldehyde or ketone group to reduce copper sulfate to copper oxide in an alkaline environment. Two 20 g samples were taken, from which an aqueous extract was obtained in a water bath and then clarified with 30% acetic acid lead solution. Two parallel 50 mL filtrate samples were transferred to 100 mL conical flasks and inversion was performed by adding 5.5 mL of 20% hydrogen chloride solution. The solution obtained after inversion was used for the determination of total sugar. For the determination of monosaccharides, no inversion was performed. The mixture was boiled for exactly 3 minutes, then the copper oxychloride was allowed to settle for 1–2 minutes and the liquid was filtered. 15–20 mL of an iron-ammonium alum solution was added to the copper oxide to oxidize it to copper sulfate. The resulting light green liquid containing the ferrous oxide salt in a Bunsen flask was immediately titrated with a solution of 0.1 N potassium permanganate until a pink color appeared. The monosaccharide content of the test solution was determined by the amount of potassium permanganate solution used for titration and the titer of copper permanganate according to the corresponding table (Tkachyk, 2017). Data are expressed as a percentage by raw mass. After thorough mixing, two parallel 20 g samples were taken from the crushed middle sample. The samples were washed with distilled water into 200 mL volumetric flasks. The volume of the liquid in the flask was brought to 2/3. The flask was placed in a water bath and held at 80 °C for 15 minutes. The contents of the flask were shaken periodically. After cooling (to 20 °C), the liquid in the flask was made up to the mark with distilled water, shaken and filtered. Two parallel 50 mL samples of the filtrate were transferred to 250 mL conical flasks, a few drops of phenolphthalein solution were added and titrated with 0.1 N alkaline solution until a pink color developed. The resulting value is converted to malic acid by multiplying by a factor of 0.0067 (Tkachyk, 2017). Data are expressed as a percentage by raw mass.

The method is based on the reducing properties of ascorbic acid, which reduces the blue dye (2,6-dichlorophenolindophenol) to a colorless compound. 25 mL of a mixture of hydrochloric acid and metaphosphoric acid were poured into a porcelain mortar, 10 g of crushed fruit pulp added and the mixture rubbed with glass powder until a homogeneous mass was obtained. The ground mass was transferred to a 100 mL graduated flask. After settling, part of the extract was filtered through a dry double filter into a dry flask. From the resulting filtrate, 10 mL of the solution was pipette and titrated with 0.001 N 2,6-dichlorophenolindophenol (Tilman's dye) until it turned pink (Tkachyk, 2017). Data are expressed as 1 mg/100 g raw mass.

Statistical analysis of the study data was performed using an analysis of variance (ANOVA). Results are expressed as means ± standard deviation. Tukey's (HSD) test analyzed the differences between the means ($P < 0.05$). Coefficients of variation (CV) were determined as indicators of variability.

Results and discussion

The genotypes under study had differences in fruit size and shape (Fig. 1).

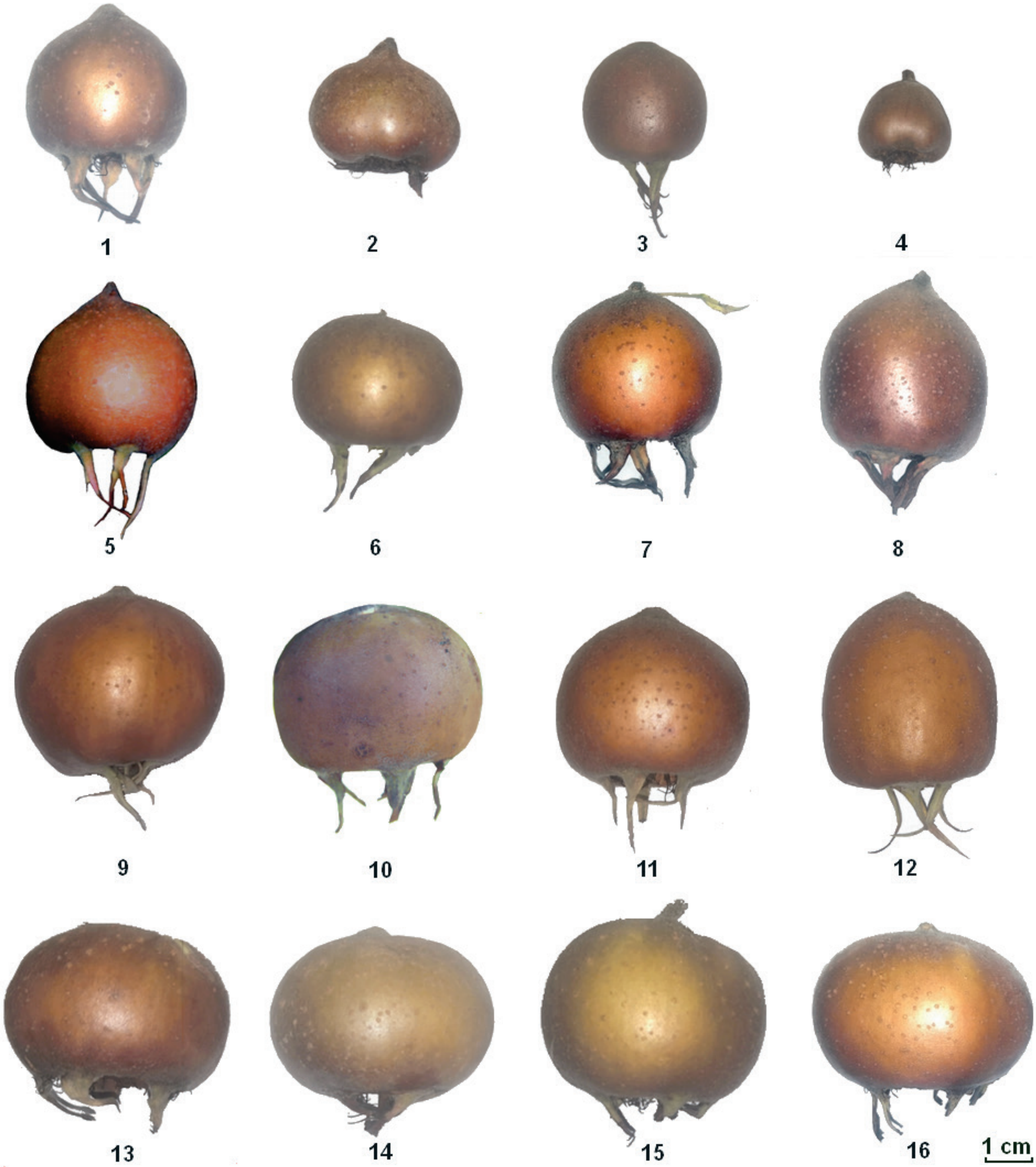

Fig. 1. Fruit shape and size of medlar cultivars: *1* – 'Nottingham'; *2* – 'Seedless'; *3* – Semiwild; *4* – 'Apyrena'; *5* – '25-hrammovaja'; *6* – 'Silberberger'; *7* – 'Delice des Vannes'; *8* – 'Sladkaja Drachyova'; *9* – 'Gojtkhivska'; *10* – 'Monstruose d'Evreinoff'; *11* – 'Haidegger'; *12* – 'Elburs'; *13* – 'Holland'; *14* – 'Dniprovska'; *15* – 'Dutch Giant'; *16* – Flanders Giant®

Medlar pomes are flattened, spherical, ovoid and conical. They have a very wide open hypanthium surrounded by calyx lobes. Sepals are curved, straight and bent. The fruits can be divided into very small, small, medium and large. The 'Apyrena' had very small fruits, averaging only 1.7 cm in diameter. Semi-wild medlar and the 'Seedless', and 'Nottingham' varieties had small fruits with a diameter of 2–3 cm. 'Gojtkhivska', 'Monstruose d'Evreinoff', 'Haidegger', '25-hrammovaja', 'Elburs', 'Silberberger', 'Delice des Vannes', and 'Sladkaja Drachyova' varieties had medium-sized fruits with a diameter of 3–4 cm. Under our conditions, the fruits of 'Holland', 'Dutch Giant', 'Dniprovska'and Flanders Giant® had the largest fruit diameter, exceeding 4 cm (Table 2).

Table 2
The characteristics of fruits, 2022–2024 (x ± SD, n = 20)

Cultivar	Year	Diameter, mm	Weight, g	Pyrena percentage, %
'Apyrena'	2022	17.90 ± 1.88h	2.54 ± 0.13j	0
	2023	15.40 ± 0.89k	2.48 ± 1.71j	0
	2024	17.60 ±3.05i	2.15 ± 0.48h	0
	2022–2024	16.97 ± 2.29l	2.39 ± 0.77j	0
'Delice des Vannes'	2022	31.40 ± 0.42de	18.2 ± 0.84e	13.93 ± 2.01ab
	2023	30.60 ± 1.34ghi	16.17 ± 0.88g	10.92 ± 1.60cd
	2024	30.80 ± 1.48def	14.20 ± 1.24e	13.84 ± 1.81c
	2022–2024	30.93 ± 1.15gh	16.19 ± 1.93g	12.90 ± 2.22b
'Dniprovska'	2022	41.20 ± 0.84a	27.6 ± 1.34c	12.54 ± 2.28bcd
	2023	42.00 ± 1.58ab	35.48 ± 3.43ab	9.05 ± 1.37def
	2024	41.80 ± 1.30a	37.48 ± 3.53c	12.8 ± 1.61cd
	2022–2024	41.67 ± 1.23ab	30.19 ± 4.28c	11.45 ± 2.42cd
'Dutch Giant'	2022	41.80 ± 1.15a	35.80 ± 1.92a	9.90 ± 1.01efghi
	2023	40.40 ± 3.29b	33.29 ± 7.87b	8.44 ± 1.63ef
	2024	42.40 ± 0.54a	34.00 ± 2.72a	9.84 ± 1.68e
	2022–2024	41.53 ± 2.07ab	34.37 ± 2.57a	9.40 ± 1.53e
'Elburs'	2022	32.10 ± 1.88d	17.8 ± 2.59e	8.84 ± 1.23ghi
	2023	34.60 ± 1.14de	21.60 ± 1.84e	8.90 ± 0.60def
	2024	32.20 ±2.28d	19.56 ± 2.47d	10.68 ± 1.54e
	2022–2024	32,97 ± 2.07e	19.65 ± 2.68e	9.50 ± 1.40e
Flanders Giant®	2022	40.30 ± 0.45a	34.8 ± 0.84a	10.48 ±1.59cdefgn
	2023	40.40 ± 0.89b	32.38 ± 2.70bc	12.80 ± 1.94bc
	2024	41.40 ± 2.07a	30.64 ± 4.50b	10.83 ± 1.30e
	2022–2024	40.70 ± 1.33b	32.61 ± 3.34b	11.37 ± 1.84cd
'Gojtkhivska'	2022	37.60 ± 0.42b	20.8 ± 3.27d	14.33 ±2.55ab
	2023	38.00 ± 2.12c	30.90 ± 1.69bc	17.14 ± 3.05a
	2024	38.00 ± 1.58b	27.48 ± 2.49c	16.39 ± 1.10b
	2022–2024	37.87 ± 1.44c	26.39 ± 4.95d	15.96 ± 2.52a
'Haidegger'	2022	33.80 ± 1.48c	17.2 ± 1.10e	10.29 ± 0.72defgh
	2023	35.80 ± 1.10cd	23.74 ± 1.69de	9.70 ± 0.70de
	2024	34.60 ± 1.34c	20.91 ± 1.22c	11.41 ± 0.72de
	2022–2024	34.73 ± 1.49d	20.62 ± 3.05e	10.47 ± 0.99de
'Holland'	2022	41.50 ± 1.58a	28.2 ± 1.48c	7.97 ± 1.24i
	2023	43.60 ± 1.34a	37.92 ± 3.14a	9.03 ± 2.75def
	2024	41.40 ± 0.89a	29.58 ± 3.46bc	9.28 ± 1.61cd
	2022–2024	42.17 ± 1.60a	31.90 ± 5.16bc	9.84 ± 3.06e
'Monstruose d'Evreinoff'	2022	38.50 ± 2.24b	30.40 ± 0.55b	12.24 ± 0.79bcd
	2023	40.20 ± 1.10bc	30.68 ± 3.05c	13.05 ± 1.38bc
	2024	34.80 ± 1.64c	14.14 ± 1.56e	12.6 ± 2.48cd
	2022–2024	37.83 ± 2.83c	25.07 ± 8.21d	12.63 ± 1.61bc
'Nottingham'	2022	29.40 ± 0.42f	12.2 ± 0.84g	13.50 ± 3.96ab
	2023	28.60 ± 1.67i	11.49 ± 0.72h	14.74 ± 2.94ab
	2024	29.00 ± 1.58efg	10.16 ± 0.99f	19.11 ± 1.08a
	2022–2024	29.00 ± 1.30ij	11.28 ± 1.21h	15.78 ± 3.67
'Seedless'	2022	29.10 ± 0.74f	10.00 ± 1.87h	0
	2023	29.00 ± 1.41hi	12.12 ± 2.17h	0
	2024	28.40 ± 1.67g	10.49 ± 1.40f	0
	2022–2024	28.83 ± 1.28j	10.87 ± 1.75h	0
'Silberberger'	2022	31.2 ± 1.15de	18.6 ± 1.34e	14.49 ± 1.69ab
	2023	33.40 ± 1.14ef	17.75 ± 1.97fg	13.55 ± 2.66b
	2024	30.60 ± 0.55def	13.23 ± 0.63e	12.34 ± 2.25cd
	2022–2024	31.73 ± 1.55fg	16.53 ± 2.67fg	13.46 ± 2.26b
'Sladkaja Drachyova'	2022	30.00 ± 1.15de	17.6 ± 0.55e	9.78 ± 0.49fghi
	2023	31.00 ± 1.22gh	19.54 ± 1.44ef	9.26 ± 1.80def
	2024	28.80 ± 1.64g	15.60 ± 1.51e	10.50 ± 1.68e
	2022–2024	29.93 ± 1.50hij	17.58 ± 2.03f	9.85 ± 1.44e
'25-hrammovaja'	2022	32.00 ± 0,00d	15.00 ± 0.71f	8.25 ± 1.41hi
	2023	32.20 ± 4.21fg	24.64 ± 2.85d	7.08 ± 1.25f
	2024	32.40 ± 1.51d	18.59 ± 1.53d	10.39 ± 1.43e
	2022–2024	32.20 ± 2.40ef	19.41 ± 2.68e	8.57 ± 1.90e
Semi-wild medlar	2022	23.20 ± 1.25g	6.40 ± 0.55i	15.82 ±1.70a
	2023	22.20 ± 0.84j	7.00 ± 0.34i	16.42 ± 1.64a
	2024	22.40 ± 1.52h	5.66 ± 0.85g	18.21 ± 8.64 ab
	2022–2024	22.60 ± 1.23k	6.36 ± 0.84i	16.82 ± 2.27a
CV , %	2022–2024	16.9	47.5	45.7

It is known that the largest medlar fruits can reach 7–8 cm in diameter (Fedorov & Fedorov, 1937). However, the varieties with such giant fruits, e. g. 'Monstruose d'Evreinoff' do not realize their potential in our conditions.

In terms of fruit weight, the genotypes studied are grouped in the same way as for diameter. 'Apyrena' had very small fruits with an average weight of only more than 2 g, and semi-wild medlar, 'Seedless' and 'Nottingham' had small fruits of 6–11 g. 'Gojtkhivska', 'Monstruose d'Evreinoff', 'Haidegger', 'Elburs', '25-hrammovaja', 'Silberberger', 'Delice des Vannes', and 'Sladkaja Drachyova' had medium-sized fruits weighing 16–26 g on average, and fruits of the largest varieties 'Dutch Giant', Flanders Giant®, 'Holland', and 'Dniprovska' weighed 30–34 g on average.

Both 'Haidegger' and 'Gojtkhivska' grown in the Khorol Botanical Garden have a similar fruit diameter to these cultivars under our conditions, but with a lower fruit weight (Krasovskyi et al., 2022). The same pattern was observed for the varieties 'Gojtkhivska', 'Sladkaja Drachyova', and '25-hrammovaja', which we observed in the steppe zone of the south-eastern part of Ukraine (Mezhenskyj, 2008). Comparison of morphometric parameters of fruits of varieties of world selection in our collection with genotypes of seed origin, selected in the National Botanical Garden of the National Academy of Sciences of Ukraine, growing in the same natural zone, indicates the possibility of increasing the size and weight of fruits as a result of selection. Thus, fruit diameter of these genotypes varies from 2 cm to 5.1 cm and fruit weight from 5.7 to 54.2 g (Grygorieva et al., 2018). However, large-fruited genotypes are less hardy. For example, during the harshest winter of 2005/2006, all genotypes with fruit diameters greater than 3 cm froze under the conditions of southeastern Ukraine. (Mezhenskyj, 2008).

Fruit width and fruit weight of wild accessions from the South Caspian region varied from 1.4 to 2.3 cm and 1.5 to 5.6 g, respectively (Khadivi et al., 2019). The medlars cultivated in Turkey have fruit diameter that range from about 2 to 3 cm and fruit weight varied from about 5 to 20 g (Sususoglu Durul & Unver, 2016). The genotypes from another region of Turkey characterized by fruit diameters ranged from 2.3 to 4.3 cm and fruit weight from 6 to 36 g (Aygün & Tasçi, 2013). In Romania, the study of medlar fruits in spontaneous flora and in cultivated state revealed a significant variation in terms of average fruit diameter between 1.6 and 4.8 cm and average fruit weight between 2.4 and 47.8 g. Correlation between these traits is very strong, r = 0.928 (Cosmulescu et al., 2019). In our study, the correlation between fruit diameter and fruit weight is also very strong, r = 0.976.

The review of studies by authors from different countries on the variability of both fruit diameter and fruit weight shows that these indicators vary from 1.8 to 4.4 cm and 5.2 to 37.5 g, respectively (Voaides et al., 2023). Medlar fruits cultivated worldwide range from very small (about 10 g) to large (over 80 g).

As far as medlar varieties are concerned, 'Royal' has the largest fruit in Montenegro, with a diameter of 3.6 cm and a weight of 25.5 g (Šebek et al., 2019).

The weight of pyrenas in the fruit is moderately correlated with the fruit weight, r = –0.45. In the fruits of the semi-wild medlar, pyrenas make up the largest part (16.8%). In the varieties with the largest fruits, 'Dniprovska', Flanders Giant®, 'Holland', and 'Dutch Giant', the percentage of pyrenas is 11.5%, 11.4%, 9.8% and 9.4%, respectively. '25-hrammovaja' has the best index with a seed content of only 8.6%, which is about half that of the semi-wild medlar. Both genotypes 'Apyrena' and 'Seedless' are characterized by the complete absence of pyrenas and seeds in the fruit. This could make them more valuable to consumers, but their fruits, especially 'Apyrena', are significantly smaller than those of the other varieties. With respect to fruit weight and percentage of pyrenas, the studied genotypes exhibit significant variation, with a coefficient of variation of 47.5% and 45.7%, respectively.

The two-factor analysis shows that genotype has a significant effect on fruit diameter and fruit weight, with effects of 94.3% and 87.4%, respectively. In contrast, the effect of year conditions is only 0.2% and 2.8%, respectively. The percentage of pyrenas depends on the genotype by 59.9% and on the year conditions by 4.2%.

There are typically 5 pyrenas in each medlar fruit. Medlar pyrenas are quite large and irregularly shaped (Fig. 2). They vary in length from about 8.8 to 13.5 mm, in width from 6.1 to 11.0 mm and in thickness from 4.0 to 7.1 mm (Table 3). Wild Iranian small medlar pomes have pyrena lengths ranging from 5.6 to 10.9 mm, while pyrenas widths range from 3.9 to 8.2 mm (Khadivi et al., 2019).

The largest pyrenas are found in the large-fruited varieties such as Flanders Giant®, 'Holland', 'Dniprovska' and 'Dutch Giant', and middle-fruited 'Gojtkhivska'. The last variety has the heaviest pyrenas, weighing as much as 0.48 g. Similar data are provided by Sususoglu Durul & Unver (2016), who reported that the pyrena weight of different medlar types grown in Turkey varied from 0.12 to 0.45 g. Semi-wild medlar is characterized by the smallest and therefore lightest seeds, the weight is only 0.11 g. In nature, the smaller wild medlar pyrenas range in weight from 0.06 to 0.31 g, with an average of 0.16 g (Khadivi et al., 2019).

There was a significant variation in presence/absence of seeds in pyrenas with coefficient of variation 53.7%. The majority of varieties produced pyrenas with seeds, often more than 70%, including 'Silberberger', semi-wild medlar, 'Haidegger' and 'Elburs'. In contrast, only 4% of 'Dutch Giant' pyrenas contained seeds, and 'Nottingham' pyrenas had no seeds inside. The data on the high percentage of seedless pyrenas in these last two varieties requires additional observations, since this is only one year of data from 2024. Natural conditions can affect the development of fruits and seeds. For example, the fruits of both 'Haidegger' and 'Gojtkhivska' grown in the Khorol Botanical Garden do not form seeds (Krasovskyi et al., 2022).

Fig. 2. 'Goitkhivska' pyrenas and seeds:
1 – pyrena; *2* – transverse section of pyrena with seed; *3* – transverse section of pyrena without seeds; *4* – seeds

Table 3
The characteristics of pyrenas, 2024 (x ± SD, n = 20)

Genotype	Height, mm	Width, mm	Thickness, mm	Pyrenas with seeds, %	Weight, g
'Delice des Vannes'	10.65 ± 0.38de	7.48 ± 0.40e	5.04 ± 0.87dfgh	66.7	0.20
'Dniprovska'	12.40 ± 0.50b	10.62 ± 0.56a	7.12 ± 0.62a	64.0	0.37
'Dutch Giant'	12.42 ± 1.06b	10.89 ± 0.70a	5.21 ± 0.43dfg	4.0	0.33
'Elburs'	11.68 ± 0.68c	8.14 ± 0.84cd	5.62 ± 0.81cd	71.4	0.23
Flanders Giant®	13.15 ± 0.60a	11.01 ± 0.70a	6.12 ± 0.47bc	48.0	0.35
'Gojtkhivska'	13.53 ± 1.30a	10.62 ± 1.09a	7.03 ± 0.63a	53.0	0.48
'Haidegger'	11.08 ± 0.49cd	7.40 ± 0.91e	5.26 ± 0.71df	72.0	0.25
'Holland'	13.14 ± 0.67a	10.03 ± 0.45b	6.39 ± 0.85b	34.6	0.33
'Monstruose d'Evreinoff'	11.07 ± 0.50d	8.33 ± 0.70c	4.67 ± 0.65gh	46.7	0.20
'Nottingham'	11.15 ± 0.59cd	8.65 ± 0.48c	4.60 ± 0.43h	0.0	0.22
'Silberberger'	10.15 ± 0.78e	7.69 ± 0.68de	4.79 ± 0.97fgh	77.3	0.18
'Sladkaja Drachyova'	10.97 ± 0.24d	7.56 ± 0.40de	4.71 ± 0.68fgh	33.3	0.19
'25-hrammovaja'	11.22 ± 0.53cd	8.69 ± 0.79c	5.01 ± 0.27fgh	24.0	0.20
Semi-wild medlar	8.75 ± 0.39f	6.06 ±0.33f	3.97 ± 0.41i	76.0	0.11
CV, %	11.3	17.8	17.5	53.7	37.8

Note: different letters indicate values that are significantly different within one column according to results of the Tukey test ($P < 0.05$).

The medlar blossoms in late May and early June, and the growing season usually ends in late October. The fruits of the ultra-early 'Hoitkhivska' variety begin to soften on the tree by this time, while those of other varieties remain hard. When the fruit is harvested and stored indoors at room temperature for two weeks, the early varieties ripen: 'Elburs', 'Haidegger', 'Nottingham', 'Silberberger' and semi-wild medlar. Late-ripening varieties include 'Delice des Vannes', 'Dutch Giant', Flanders Giant®, 'Holland', 'Monstruose d'Evreinoff', 'Sladkaja Drachyova', and '25-hrammovaja'. Fruits of ultra-late varieties 'Apyrena', 'Dniprovska', and 'Seedless', harvested in late October, do not have time to receive enough heat for ripening. After two to three weeks of ripening, most of these fruits do not soften. Therefore, the fruits for biochemical analysis were harvested from the trees in December, after repeated freezing in nature, when the flesh had reached a soft consistency. The highest dry matter content (more than 26.0%) was found in the flesh of 'Delice des Vannes' and Flanders Giant®, and the lowest in 'Seedless', which had less than 20.0% dry matter (Table 4). The dry matter content of the Turkish fruit varies from 24.2% to 31.8% (Cevahir & Bostan, 2021). The fruit of the cultivars from Montenegro contains from 26.2% to 28.8% dry matter (Šebek et al., 2019).

Table 4
The biochemical content of pulp, 2024 (x ± SD, n = 2)

Cultivar	Dry matter, %	Total sugar, %	Monosaccharides, %	Sugar/acidity index	Titratable acidity, %	Ascorbic acid, mg/100g
'Apyrena'	no data	8.51 ± 0.00i	8.32 ± 0.06j	no data	no data	no data
'Delice des Vannes'	26.20 ± 0.06a	17.12 ± 0.12a	16.92 ± 0.05a	41.8 ± 1.73b	0.41 ±0.01h	3.36 ± 0.00cde
'Dniprovska'	22.00 ± 0.00i	12.38 ± 0.06g	12.06 ± 0.06h	27.2 ± 0.55de	0.46 ± 0.01g	4.00 ± 0.30bc
'Dutch Giant'	24.10 ± 0.03d	13.82 ± 0.11e	13.30 ± 0.00d	36.5 ± 2.99c	0.38 ± 0.03hi	3.36 ± 0.00cde
'Elburs'	23.94 ± 0.03e	13.92 ± 0.05e	13.58 ± 0.01c	50.8 ± 4.10a	0.28 ± 0.02k	3.16 ± 0.08de
Flanders Giant®	26.15 ± 0.07a	14.21 ± 0.00d	13.62 ± 0.06c	23.7 ± 0.47bc	0.60 ± 0.01f	3.79 ± 0.00cd
'Gojtkhivska'	25.63 ± 0.07b	13.82 ± 0.00e	13.54 ± 0.05c	13.1 ± 0.26g	1.06 ± 0.02b	2.94 ± 0.59e
'Haidegger'	22.64 ± 0.00h	14.34 ± 0.06c	12.84 ± 0.05e	19.1 ± 0.45f	0.75 ± 0.01d	3.37 ± 0.59cde
'Holland'	21.34 ± 0.03j	14.64 ± 0.00b	14.36 ± 0.06b	39.6 ± 1.51bc	0.37 ± 0.01ij	4.63 ± 0.60ab
'Seedless'	19.84 ± 0.06k	12.46 ± 0.05g	12.10 ± 0.11g	30.8 ± 0.66d	0.40 ± 0.01hi	3.79 ± 0.00cd
'Silberberger'	22.72 ± 0.06l	13.04 ± 0.11f	12.74 ± 0.00e	11.6 ± 0.25g	1.12 ± 0.01a	3.16 ± 0.08de
'Sladkaja Drachyova'	20.84 ± 0.06k	9.20 ± 0.05h	8.64 ± 0.00i	10.0 ± 0.10g	0.92 ± 0.01c	4.84 ± 0.30a
'25-hrammovaja'	23.42 ± 0.03f	13.92 ± 0.05e	12.77 ± 0.06e	41.1 ± 3.56b	0.34 ± 0.03i	3.16 ± 0.08de
Semiwild	24.52 ± 0.06d	13.12 ±0.00f	12.54 ±0.11f	18.6 ± 0.56f	0.70 ± 0.02e	3.58 ± 0.30cde
CV, %	8.7	16.4	16.9	47.2	47.8	16.0

Note: different letters indicate values that are significantly different within one column according to results of the Tukey test ($P < 0.05$).

The content of total sugars among the genotypes evaluated varies from 8.5% to 17.1%. 'Delice des Vannes' had the sweetest fruit, with the highest total sugar and monosaccharide content, 17.1% and 16.9%, respectively. This variety also had one of the highest sugar-acid indexes, 41.8. The value of medlar for dietary nutrition is determined by the fact that monosaccharides make up 92.4–98.8% of total sugars. This is confirmed by other researchers (Cevahir & Bostan, 2021; Mikulic-Petkovsek et al., 2023; Voaides et al., 2023).

Slovenian medlar fruit consists of 12.7% of total sugars (Mikulic-Petkovsek et al., 2023). According to these authors, the two main sugars in medlar are fructose and glucose in approximately equal amounts. However, other researchers point out that the content of fructose is higher than the content of glucose (Cevahir & Bostan, 2021). Glew et al. (2003a, 2003b) point out that one week after harvest, the fructose content is much higher than glucose. Gradually, as the fruit ripens, the amount of these hexoses decreases and levels off, but fructose remains higher than glucose.

These monosaccharides are the most important in fruits (Yahia et al., 2019). The natural fructose found in fruit is a useful sweetener in the diet of people with diabetes, and glucose may be a suitable substitute for sugar (Bantle, 2009). Foods with a low glycemic index (GI) may lower blood glucose levels and improve the management of blood glucose in people with type 2 diabetes. Glucose and fructose have GI 100 and 20, respectively. Despite the high GI of glucose, the GI of fruit is low; for example, apples and oranges have GIs of 39 and 40, respectively (Jenkins et al., 1981). Despite their sweet taste, medlar fruits may have applications in the development of additional strategies for the treatment of type 2 diabetes (Żołnierczyk et al., 2021; Katanić Stanković et al., 2022).

The taste of the fruit depends on the ratio between the content of sugars and acids. In our experiment, fruits frozen under natural conditions had a very high sugar/acidity index 10.0–41.0. In Slovenia, fruit at technological maturity has an average sugar/acidity index 7.0 (Mikulic-Petkovsek et al., 2023). The sugar/acidity index of fruit that is ready to eat is as high as 12.6 in the southeast of Ukraine (Mezhenskyj & Mezhenska, 2015).

Titratable acidity of medlar fruit varies from 0.28% in 'Dutch Giant' to 1.12% in 'Silberberger'. In Turkey, the content of organic acid in fruits of local varieties was between 0.6% and 1.4% (Cevahir & Bostan, 2021). In Slovenia fruit at technological maturity consists of 1.8% organic acids (Mikulic-Petkovsek et al., 2023). The most sour fruits are found in Montenegro, with titrable acid content ranging from 1.9% to 2.3% (Šebek et al., 2019). The level of organic acids decreases with the growth, ripening and softening of the fruit (Glew et al., 2003a, 2003b).

An important biologically active ingredient such as ascorbic acid within the studied genotypes after natural freezing ranged from 3.16 to 4.84 mg/100 g. Instead, the medlar genotypes collected from the trees at the tree maturity stage, when the flesh is white and hard, and later stored under laboratory conditions until consumed, contained an order of magnitude more ascorbic acid, ranging from 21.5 to 44.2 mg/100 g (Cevahir & Bostan, 2021). The results obtained other authors demonstrate a low level of ascorbic acid, only 0.49 to 0.88 mg/100 g (Cosmulescu et al., 2020). In the process of fruit softening, the ascorbic acid is reduced (Glew et al., 2003a, 2003b; Rop et al., 2011).

Comparison of medlar fruit bletting at temperature 8 °C and at –1 to –4 °C showed that the most suitable method of fruit bletting is processing fruit with hoarfrost, which minimally alters the composition of sugars and acids (Mikulic-Petkovsek et al., 2023).

Conclusions

There are significant differences among the genotypes on the morphological characteristics and chemical composition of the fruit. Under the conditions of the Forest-Steppe of Ukraine, 'Gojtkhivska' fruit begins to reach consumer ripeness on the tree at the end of the growing season. In other varieties, bletting of fruit can occur after harvesting and storage, but this does not occur with late-ripening varieties harvested in late October. The fruit of all genotypes, if left on the tree, becomes edible after undergoing natural freezing. The flavor profile of bletted fruits is characterized by a sweet taste, which is attributed to the presence of sugars, with monosaccharides being the predominant constituents. Additionally, these fruits exhibit a high sugar-acid index.

This research will also contribute to the knowledge of different varieties that are promising for use as fruit crops.

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References

Aygün, A., & Tasçi, A. R. (2013). Some fruit characteristics of medlar (*Mespilus germanica* L.) genotypes grown in Ordu, Turkey. Scientific Papers, Series B, Horticulturae, 57, 149–151.

Baird, J. R., & Thieret, J. W. (1989). The medlar (*Mespilus germanica*, Rosaceae) from antiquity to obscurity. Economic Botany, 43(3), 328–372.

Bantle, J. P. (2009). Dietary fructose and metabolic syndrome and diabetes. The Journal of Nutrition, 139(6), 12635–12685.

Bibalani, G. H., & Mosazadeh-Sayadmahaleh, F. (2012). Medicinal benefits and usage of medlar (*Mespilus germanica*) in Gilan Province (Roudsar District), Iran. Journal of Medicinal Plants Research, 6(7), 1155–1159.

Campbell, C. S., Evans, R. C., Morgan, D. R., Dickinson, T. A., & Arsenaut, M. P. (2007). Phylogeny of subtribe Pyrinae (formerly the Maloideae, Rosaceae): Limited resolution of a complex evolutionary history. Plant Sysematics and Evolution, 266, 119–145.

Cevahir G., & Bostan S. Z. (2021). Organic acids, sugars and bioactive compounds of promising medlar (*Mespilus germanica* L.) genotypes selected from Turkey. International Journal of Fruit Science, 21, 312–322.

Cosmulescu, S. N., Trandafir, I., Scrieciu, F., & Stonescu, A. M. (2020). Content in organic acids of *Mespilus* spp. and *Crataegus* spp. genotypes. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 48(1), 171–176.

Cosmulescu, S., Scrieciu, F., Iordanescu, O., & Manda M. (2019). Some pomological characteristics of medlar (*Mespilus germanica* L.) genotypes. Acta Horiculturae, 1259, 43–46.

Cristofori, V., Silvestri, C., Pica, A. L., Bertazza, G., & Bignami, C. (2019). Evaluation of four medlar cultivars: agronomical, pomological and qualitative traits. European Journal of Horticultural Science, 84(6), 350–358.

Dobrochaieva, D. M. (1954). Mushmula – *Mespilus* L. [Medlar – *Mespilus* L.]. In: Zerov, D. K. (Ed.). Flora URSR [Flora of the Ukrainian SSR]. Vydavnytstvo AN Ukrainian SSR, Kyiv. Vol. 6. Pp. 48–49 (in Ukrainian).

Fedorov, A., & Fedorov, A. (1937). Mushmula Kavkaza [Medlar of the Caucasus]. Transactions of the Armenian Branch of the Academy of Sciences of the USSR. Biological Series, 2, 21–60 (in Russian).

Glew, R. H., Ayaz, F. A., Sanz, C., Vander Jagt, D. J., Huang, H. S., Chuang, L. T., & Strnad, M. (2003a). Changes in sugars, organic acids andamino acids in medlar (*Mespilus germanica* L.) during fruit development and maturation. Food Chemistry, 83(3), 363–369.

Glew, R. H., Ayaz, F. A., Sanz, C., Vander Jagt, D. J., Huang, H. S., Chuang, L. T., & Strnad, M. (2003b). Effect of postharvest period on sugars, organic acids and fatty acids composition in commercially sold medlar (*Mespilus germanica* 'Dutch') fruit. European Food Research and Technology, 216(5), 390–394.

Grygorieva, O., Klymenko, S., Vinogradova, Y., Vergun, O., & Brindza, J. (2018). Variation in morphometric traits of fruits of *Mespilus germanica* L. Potravinarstvo, 12(1), 782–788.

Jenkins, D. J., Wolever, T. M., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., Bowling, A. C., Newman, H. C., Jenkins, A. L., & Goff, D. V. (1981). Glycemic index of foods: a physiological basis for carbohydrate exchange. The American Journal of Clinical Nutrition, 34(3), 362–366.

Katanić Stanković, J. S., Mićanović, N., Grozdanić, N., Kostić, A. Ž., Gašić, U., Stanojković, T., & Popović-Djordjević, J. B. (2022). Polyphenolic profile, antioxidant and antidiabetic potential of medlar (*Mespilus germanica* L.), blackthorn (*Prunus spinosa* L.) and common hawthorn (*Crataegus monogyna* Jacq.) fruit extracts from Serbia. Horticulturae, 8(11), 1053.

Khadivi, A., Rezaei, M., Heidari, P., Safari-Khuzani, A., & Sahebi, M. (2019). Morphological and fruit characterizations of common medlar (*Mespilus germanica* L.) germplasm. Scientia Horticulturae, 252, 38–47.

Kokhno, N. A., & Kurdyuk, A. M. (1994). Teoreticheskie osnovy i opyt introdukcii drevesnyh rasteniy v Ukraine [Theoretical foundations and experience of introduction of woody plants in Ukraine]. Naukova Dumka, Kyiv (in Russian).

Krasovskyi, V. V., Cherniak, T. V., Fedko, R. M., & Orlovskyi, O. V. (2022). Doslidzhennia kistochok mushmuly zvychainoyi (*Mespilus germanica* L.) v Khorol's'komu botanichnomu sadu [Research on seeds of the common medlar (*Mespilus germanica* L.) in the Khorolsky Botanical Garden]. Ecological Sciences, 11(2), 125–129 (in Ukrainian).

Linnaeus, C. (1753) Species Plantarum, 1. Holmiae: Imprensis Laurentii Salvii.

Lo, E. Y. Y., Stefanović, S., & Dickinson, T. A. (2007). Molecular reappraisal of relationships between *Crataegus* and *Mespilus* (Rosaceae, Pyreae) – two genera or one? Systematic Botany, 325(3), 596–616.

Lypa, A. L., Kosarevskij, I. A., & Salatich, A. K. (1952). Ozelenenie naselennykh mest [Greening of populated areas]. Izdatel'stvo Akademii Arkhitektury Ukrainskoy SSR, Kyiv (in Russian).

Medikus, F. K. (1789). Philosophische Botanik mit kritischen Bemerkungen. 1. Mannheim.

Mezhenska, L. O., & Mezhenskyj, V. M. (2013). Rid Hlid (*Crataegus* L.) v Ukrayini: Introduktsiya, selektsiya, ekoloho-biolohichni osoblyvosti [The genus of the hawthorn (*Crataegus* L.) in Ukraine: Introduction, breeding, ecological and biological features]. Komprint, Kyiv (in Ukrainian).

Mezhenskyj, V. M. (2008). Sklad i vykorystannia kollektsiyi netradytsiynykh plodovykh kul'tur. 5. Mushmula (*Mespilus* L.) [Composition and use of the collection of non-traditional fruit crops. 5. Medlar (*Mespilus* L.)]. Plant Genetic Resources, 5, 49–54 (in Ukrainian).

Mezhenskyj, V. M., & Mezhenska, L. O. (2015). Formation of the collection and improvement of plant breeding methods of rare fruit and ornamental crops. Komprynt, Kyiv (in Ukrainian).

Mikulic-Petkovsek, M., Jakljevic, K., Veberic, R., Hudina, M., & Rusjan, D. (2023). Changes in the fruit quality parameters of medlar fruit (*Mespilus germanica* L.) after heat treatment, storage, freezing or hoarfrost. Foods, 12(16), 3077.

Nistor, D. I., Marc, R. A., & Mureșan, C. C. (2024). Phytochemistry, nutritional composition, health benefits and future prospects of *Mespilus germanica* L. (Medlar): A review. Food Chemistry: X, 22, 101334.

Oleshko, V. V., & Doroshenko, O. K. (2013). Introduktsiya derevnykh roslyn Kavkazu na Volyns′komu Polissi [The introduction of woody plants of the Caucasus in the Volyn Polissya]. Plant Introduction, 57, 92–97 (in Ukrainian).

Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen–Geiger climate classification. Hydrology and Earth System Sciences, 11(5), 1633–1644.

Phipps, J. B. (2016). Studies in *Mespilus*, *Crataegus*, and ×*Crataemespilus* (Rosaceae), I. Differentiation of *Mespilus* and *Crataegus*, expansion of ×*Crataemespilus*, with supplementary observations on differences between the *Crataegus* and *Amelanchier* clades. Phytotaxa, 257(3), 201–229.

Potter, D., Eriksson, T., Evans, R. C., Oh, S.-H., Smedmark, J. E. E., Morgan, D. R., Kerr, M. S., & Campbel, C. S. (2007). Phylogeny and classification of Rosaceae. Plant Systematic and Evolution, 266(1), 5–43.

Roelofsen, P. A. (1954). On the softening of fruits of *Mespilus germanica*. Acta Botanica Neerlandica, 3(1), 154–160.

Rop, O., Sochor, J., Jurikova, T., Zitka, O., Skutkova, H., Mlcek, J., Salas, P., Krska, B., Babula, P., Adam, V., Kramarova, D., Beklova, M., Provaznik, I., & Kizek, R. (2011). Effect of five different stages of ripening on chemical compounds in medlar (*Mespilus germanica* L.). Molecules, 16(1), 74–91.

Šebek, G., Pavlova, V., & Popović, T. (2019). Biochemical and pomological characteristics of fruit of some commercial medlar cultivars (*Mespilus germanica* L) grown in Bijelo Polje. Food and Environment Safety Journal, 18 (2), 97–104.

Sususoglu Durul, M., & Unver, H. (2016). Morphological and chemical properties of medlar (*Mespilus germanica* L.) fruits and changes in quality during ripening. AGROFOR International Journal, 1(2), 133–140.

Talent, N., Eckenwalder, J. E., Lo, E. E. Y., Christensen, K. I., & Dickinson, T. A. (2008). Proposal to conserve the name *Crataegus* L. against *Mespilus* L. (Rosaceae). Taxon, 57(3), 1007–1008.

Tkachyk, S. O. (Ed.) (2017). Metodyka provedennia kvalifikatsiynoyi ekspertyzy sortiv roslyn na prydatnist' do poshyrennia v Ukrayini: Metody vyznachennia pokaznykiv yakosti produktsiyi roslynnytstva [Methodology for conducting qualification examination of plant varieties for suitability for dissemination in Ukraine: Methods for determining quality indicators of plant products]. D. Y. Korsyn, Vinnytsia (in Ukrainian).

Ufimov, R. A., & Dickinson, T. A. (2020). Infrageneric nomenclature adjustments in *Crataegus* L. (Maleae, Rosaceae). Phytologia, 102, 177–199.

Voaides, C., Radu, N., Birza, E., & Babeanu, N. (2021). Medlar – A comprehensive and integrative review. Plants, 10, 2344.

Webster, T. (2008). *Mespilus germanica*. Medlar. In: Janick, J., & Paull, R. B. (Eds.). The encyclopedia of fruits and nuts. CABI, Oxfordshire. Pp. 674–678.

Yahia, E. M., Carrillo-López, A., & Bello-Perez, L. A. (2019). Carbohydrates. In: Yahia, E. M. (Ed.). Postharvest physiology and biochemistry of fruits and vegetables. Woodhead Publishing. Pp. 175–205.

Żołnierczyk, A. K., Ciałek, S., Styczyńska, M., & Oziembłowski, M. (2021). Functional properties of fruits of common medlar (*Mespilus germanica* L.) extract. Applied Scienves, 11, 7528.

Żołnierczyk, A. K., Pachura, N., Bąbelewski, P., & Taghinezhad, E. (2023). Sensory and biological activity of medlar (*Mespilus germanica*) and quince 'Nivalis' (*Chaenomeles speciosa*): A comperative study. Agriculture, 13, 922.