

Article ID: 7418  
DOI: 10.5586/aa.7418

#### Publication History

Received: 2021-02-07  
Accepted: 2021-07-18  
Published: 2021-11-25

#### Handling Editor

Barbara Łotocka; Warsaw  
University of Life Sciences –  
SGGW, Poland;  
<https://orcid.org/0000-0001-5913-8424>

#### Authors' Contributions

TD: coordinating the research, analysis and interpretation of data, writing and reviewing of the manuscript; OF: designing ideas and methods, conceptualization, data analysis; VM: field coordinator, writing, reviewing, and editing of the manuscript; IT: data collection and writing the manuscript

#### Funding

Budget topic: No. III-91-19.464  
“Morphologo-anatomical and resource characteristics of related species of medicinal plants of Ukraine.”

#### Competing Interests

No competing interests have been declared.

#### Copyright Notice

© The Author(s) 2021. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits redistribution, commercial and noncommercial, provided that the article is properly cited.

ORIGINAL RESEARCH PAPER in MORPHO-ANATOMY OF USABLE PLANTS – FUNCTION AND ADAPTATION

# Morphological Features of Fruits and Seeds of Some Species of the Genus *Crataegus* L. of the Flora of Ukraine

Tetiana Dvirna <sup>1\*</sup>, Oksana Futorna <sup>2</sup>,  
Valentyna Minarchenko <sup>3</sup>, Iryna Tymchenko <sup>1</sup>

<sup>1</sup>Department of Systematics and Floristics of Vascular Plants, M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, Ukraine

<sup>2</sup>NSC Institute of Biology and Medicine, Kyiv National Taras Shevchenko University, Ukraine

<sup>3</sup>Pharmacognosy and Botany Department, Bogomolets National Medical University, Ukraine

\* To whom correspondence should be addressed. Email: [dvirna\\_t@ukr.net](mailto:dvirna_t@ukr.net)

## Abstract

The genus *Crataegus* L. is one of the largest species in the family Rosaceae Juss. The fruits are used as medicinal raw materials (*Crataegus fructus*), as they contain a set of biologically active compounds. The genus is voluminous and taxonomically problematic due to significant variability, hybridization, apomixis, and polyploidy. As a result, it is difficult to determine the species of the genus. Species of the genus have a number of diagnostic features, one of which is a distinct fruit with seeds. The aim of our study was to identify and compare the diagnostic features of the fruits of seven species of the genus *Crataegus* flora of Ukraine, which are most often used as medicinal raw materials and are the most common in Ukraine – *Crataegus laevigata*, *C. monogyna*, *C. pentagyna*, *C. pseudokyrstostyla*, *C. sanguinea*, *C. fallacina*, and *C. rhipidophylla*. The study was performed using scanning and digital microscopy, and descriptions were made by standard methods. As a result, we identified features that clearly distinguished the studied species from each other. We identified mature fruits that contain only one pyrene (*C. monogyna*, *C. pseudokyrstostyla*, *C. fallacina*, and *C. rhipidophylla*), and several pyrenes (*C. laevigata*, *C. pentagyna*, and *C. sanguinea*) among the studied species of the genus. The studied species are characterized by spherical and ellipsoidal fruits. The predominant color is fulvous/brown with different shades, but almost-black fruits of the species *C. pentagyna* are well distinguished. Fruits of all studied species of the genus are fleshy, except *C. sanguinea*, which is floury. The species is characterized mainly by yellow flesh fruits, except *C. pentagyna*, which has ribbed fruits. The fruits of *C. monogyna* plants differ from those of other studied species by the spinous-tuberous surface relief. Pyrenes of triangular shape are observed only in *C. pentagyna*. We suggest that these features can be used as additional diagnostic tools to determine the species of the genus *Crataegus* flora in Ukraine.

## Keywords

diagnostic features; pyrenes; sculpture; flesh; medicinal raw materials; *crataegi fructus*

## 1. Introduction

There are more than a thousand species of the genus *Crataegus* L. worldwide. According to the Catalogue of Life (Roskov et al., 2019), there are 1,447 Latin names of hawthorn, which is the common name of the species in the genus. In the *Flora of Eastern Europe*, Tselëv (2001) has listed over 1,500 species for the genus *Crataegus*. According to various sources, in Ukraine, there are 33 native species and several

cultivated species that are becoming wild (Cherepanov, 1995; Fedoronchuk, 2003, 2017; Mosyakin & Fedoronchuk, 1999).

The genus *Crataegus* is voluminous and taxonomically problematic because of significant variability, hybridization, apomixis, and polyploidy (Fedoronchuk, 2017; Iukhymenko, 2019; Mezhens'ka & Mezhens'kiï, 2013). As a result, it is difficult to accurately determine the species of the genus. Generally, they differ in the occurrence and morphological features of modified shortened shoots (thorns), such as size, shape, degree of dissection, and pubescence of the leaf blade, and in the shape, size, surface type and other features of fruit and number of seeds.

Comprehensive studies of species of the genus *Crataegus* for the purposes of taxonomy in Ukraine have been carried out over almost a century, but even currently there are a number of controversial issues due to the inherent hybridization of hawthorns and variability of features depending on environmental growth conditions. This complicates the task of identifying clear diagnostic features of hawthorn raw materials for their standardized use in the pharmaceutical industry and medicine. Therefore, a comparative analysis of the main diagnostic morphological and anatomical features of the fruits of model species of the genus *Crataegus* was undertaken in this study, and the results are provided below.

One of the controversial issues regarding the morphological characteristics of the generative organs of the genus *Crataegus* is in the determination of the type of fruit. For example, according to Krylov (1903) it is a "spherical drupe," while according to Bobrov et al. (2009) it is a "pyrenarium-like apple." Fedoronchuk (2017) classified the fruit as an "apple," in which fully or partially grown leaves (many-locular carpels) grow with the inner wall of the hollow axis of the flower (hypanthium), which subsequently becomes fleshy, whereas Iukhymenko (2019) and Korovkin (2007) classified it as "stone-like apple," and according to Vanin (1967) and Gubanov et al. (2013), the fruit is an apple. In other literature sources, the name "berry-like fruit" has been incorporated (Alaghawani & Naser 2013; Christensen, 1992). According to one of the main anatomical and morphological features, the type of hawthorn fruit is a "pyrenarium." It is characterized by the presence of a hard sheath formed from the inner tissues of the pericarp, which surrounds the seeds and arises from the coenocarpic gynoecium (Artiushenko & Fedorov, 1986) with dry sepals that remain on it (Iukhymenko, 2019; Ufimov, 2013). Following Bojňanský and Fargašová (2007), we consider pyrene as a seed covered with a stony layer, and fruits that contain pyrene as stone fruits. A review of the fragmentary literature available on the morphological features of hawthorn suggested that in the studies of fruits, attention was mostly paid to their size, weight, color, number of pyrenes (seeds surrounded by fruit endocarpium), color of flesh, and morphometric characteristics of seeds.

We analyzed the available data on morphological and anatomical features of the *Crataegus* spp. fruits of the following species: *Crataegus orientalis* Palas ex. M. Bieb. var. *orientalis*, *C. aronia* (L.) Bosc. ex DC. var. *aronia*, *C. meyeri* Pojark., *C. tanacetifolia* (Lam.) Pers., *C. pontiaca* Koch, *C. ambigua* C. A. Mey., *C. pojarkovae* Kossykh, and *C. orientalis* Pall. ex M. Bieb. (Fikret et al., 2006) and *C. sanguinea*, *C. douglasii*, and *C. submollis* (Iukhymenko, 2019). We found that complex studies were either absent or fragmentary data were available. In particular, Turkish botanists studied the genotype features of 42 samples of fruits and seeds of the genus; the length, width, weight, and the ratio of length to width of the fruit were taken into account (Fikret et al., 2006). In addition, a comprehensive study of *C. ambigua* C. A. Mey was conducted, including studies of the anatomical structure of the fruit (Tuyakova et al., 2016), and taxonomic analysis of Crimean species (*C. pojarkovae* Kossykh and *C. orientalis* Pall. ex M. Bieb). Based on these results, it was noted that the main diagnostic features were fruits: their variation in color and size (Letukhova et al., 2014).

Fruits of hawthorns (*Crataegus fructus*) are mostly used as medicinal raw materials. Because of the presence of a set of biologically active compounds, preparations with hawthorn fruits have multiple therapeutic effects, among which the most significant are lipid-lowering, antiatherosclerotic, hypotensive, and cardioprotective effects (Antsyshkina et al., 1990; Evdokimova, 1999; Pengzhan, 2012; Samylina et al., 2010). The *State Pharmacopoeia of Ukraine* (2014) (SPU) lists 12 species of the genus

*Crataegus*, the raw materials of which are permitted for use in medicine. Five of these species exist naturally in the flora of Ukraine – *Crataegus laevigata* (Poir.) DC., *C. monogyna* Jacq., *C. pentagyna* Waldst. & Kit., *C. pseudokyrstostyla* Klok. (*C. curvisepala* Lindm.), and *C. sanguinea* Pall. (Mezhens'ka & Mezhens'kiï, 2013; Mosyakin & Fedoronchuk, 1999; SPU, 2014). This publication is the first in a series focused on the study of macro- and micromorphological features of raw organs of the genus *Crataegus* in Ukraine. The aim of this study was to identify and compare the diagnostic features of the fruits of seven species of the genus *Crataegus* (*C. laevigata*, *C. monogyna*, *C. pentagyna*, *C. pseudokyrstostyla*, *C. sanguinea*, *C. fallacina* Klokov, and *C. rhipidophylla* Gand.) that are most common in Ukraine and are most often used as raw materials.

## 2. Material and Methods

The fruits of seven species of the genus *Crataegus* of the flora of Ukraine, collected and identified by the authors, and samples from the National Herbarium of Ukraine (KW; <http://sweetgum.nybg.org/science/ih/herbarium-details/?irn=125430>) were selected for this study (Table 1).

For each species, 30 fruits were used for analysis. All quantitative indicators were processed using the methods of variation statistics using the program Statistica StatSoft ver. 10 (USA). We did not perform a statistical comparison of species, because the aim of this work was to identify diagnostic features of the fruits of species of the genus *Crataegus*, which are most often used in medicinal raw materials, rather than resolving problems of species taxonomy.

The sculpture of the fruit surface was studied using a scanning electron microscope (SEM) (JSM-6060 LA; JEOL, Japan). Samples for SEM research were processed according to the standard method: dehydrated objects were fixed on brass tables and sprayed with a thin layer of a mixture of gold and platinum in a vacuum chamber. A Superior 10-220x digital microscope (Sigeta, Ukraine) was used for macromorphological studies. The size of the fruits and seeds was determined using a measuring ruler on a millimeter scale. The terminology following Artiushenko and Fedorov (1986), Bojňanský and Fargašová (2007), and Korovkin (2007) were used for morphological and anatomical feature descriptions.

## 3. Results

Detailed descriptions of the studied species of the genus *Crataegus* obtained from the analysis of literature data (Cherepanov, 1995; Grossgeim, 1952; Gubanov et al., 2013; Komarov, 1939; SPU, 2014; Zerov, 1954, 1965) and our own research results are provided below (Table 2).

***Crataegus laevigata*.** The fruits are elliptical to short-ellipsoidal in shape (Figure 1A). The color is brownish-red, brown, or black, flesh yellow and juicy in consistency. The length of the fruit varies from 5 to 9 mm [mean =  $7.6 \pm 0.9$  mm, CV (coefficient of variation) = 5%], and width varies from 4 to 9 mm (mean =  $6.6 \pm 0.75$  mm, CV = 8%). The relief of the surface of fruits is collicular (Figure 2A), and there are epicuticular waxes, which are represented by wax plates. The number of pyrenes is two (three), and they have two or three sutures on the dorsal and ventral sides (Figure 1H). They are irregularly shaped, convex, ribbed on the dorsal side, flat, or grooved on the ventral side. The sculpture of the surface of pyrenes is reticular-collicular (Figure 1H, Figure 3A).

***Crataegus monogyna*.** The shapes of the fruits vary from widely-short-ellipsoidal or ovoid to rounded (Figure 1E). The color is dark red, brownish-red, and flesh is yellow and juicy. Fruit length varies from 5 to 10 mm (mean =  $7.6 \pm 0.95$  mm, CV = 9%) and width varies from 4 to 6 mm (mean =  $5.7 \pm 0.7$  mm, CV = 10%). Epicuticular wax is well developed and is represented by wax crusts and crystals (Figure 2B). There is one pyrene (Figure 1I), the seam is visible on the lateral side, and there are two or three vague grooves on the dorsal side. Pyrene is characterized by a reticular relief (Figure 2I, Figure 3C).

**Table 1** The KW Herbarium specimens analyzed in the study.

Species	Origin of the specimens	Date and authors	Herbarium number
<i>Crataegus laevigata</i>	Transcarpathian region, Berehiv district, Borzhava forestry, oak-hornbeam forest	2007-07-19; Minarchenko V. M., Solomakha T. D.	146032
	Transcarpathian region, Berehiv district, Borzhava forestry, oak-hornbeam forest	2007-07-19; Minarchenko V. M., Solomakha T. D.	146027
	Ivano-Frankivsk region, Kosiv district, Hutsulshchyna National Nature Park, Yabluniv village, roadside	2006-07-19; Iakushenko D., Fitsailo T.	068216
<i>C. monogyna</i>	Poltava region, Poltava district, outside the village of Machuxy, ravine forest in the direction of the village of Kalashnyky	2007-05-21; Davydov D. A.	00112518
	Ivano-Frankivsk region, Kolomyia district, near the village of Kolomyia	2006-07-11; Minarchenko V. M.	146031
	Lviv region, Starosambirskyi district, near the town of Dobromyl, on the slopes of Lysa mountain	2007-08-24; Tymchenko I. A.	146030
	Transcarpathian region, Vynohradiv district, Onok village, slope	2006-08-16; Minarchenko V. M., Tymchenko I. A.	146029
	Mykolaiv region, Pervomaiskyi district, Protech tract, village Migia, slopes, Southern Bug River	2001-07-26; Minarchenko V. M.	146028
<i>C. pentagyna</i>	Khmelnitsky region, Horodytskyi district, village Ivankovtsi	1968-05-27; Moroz I., Fedoronchuk M.	145062
	Crimea, village Skalyste	1983-08-13; Fedoronchuk M.	145065
	Crimea, when descending from the Red Stone, below through the Shikhtinsky pass, in the forest	1988-06-18; Fedoronchuk M.	097688
	Crimean region, when climbing to the Ayu-Dag	1982-09-08; Fedoronchuk M.	–
<i>C. pseudokyrstostyla</i>	Zhytomyr region, Novograd-Volynskyi district, village Kurchycya, on the edge of an oak forest	2007-05-20; Orlov O. O., Fitsailo T. V.	091915
	Kyiv region, Makariv district, village Kozynici	2019; Minarchenko V. M.	146033
	Zhytomyr region, Zhytomyr district, 1 km west of Zhytomyr, slopes to the river Lisova, old sparse pine forest	2005-08-23; Orlov O. O., Fitsailo T. V.	075127
	Lviv region., Zolochivsk district, village Bilyj Kamin, meadow near the Western Bug River	1986-06-27; Shumilova A. V.	096432
	Vinnitsia region, Kopikov district, near the village of Majdan Bobryk, edge of oak forest	2003-07-04; Fitsailo T. V.	091934
<i>C. sanguinea</i>	Zhytomyr region, Korosten district, the outskirts of Korosten, on a pasture	2005-09-24; Orlov O. O.	073892
	In the afforestation of Derkul forest research station, Luhansk region, Bilovodsk district, Horodyshche village	2007-08-08; Filimonova M. V.	074872
	USSR; Kirovohrad region, Dolyna district, Veseli Bukovenky village	1949-06-20; Hryn F.	146175
	Vinnitsia; cultivated	1928-11-10; Yankovskyi K. O.	146175
	Goloseevo	1939-10-01; Lypa O. L.	146177

(Continued on next page)

**Table 1** (Continued)

Species	Origin of the specimens	Date and authors	Herbarium number
<i>C. fallacina</i>	Zhytomyr region, Zhytomyr district, 1 km southeast of the village Dovzhik, the eastern edge of the oak-pine forest	2005-08-30; Orlov O. O., Fitsailo T. V.	075118
	Rivne region, Dubno district, Molodizhne, 116, on the side of the road, VH 3392	2013-08-11; Goncharenko V. I.	115028
	Zhytomyr region, Ovruch district, village Potapovochi near the road	2008-05-21; Orlov O. O.	095361
	Transcarpathian region, Svalyava district, Svalyava forestry, near the village of Pasika	2007-07-20; Minarchenko V. M., Solomakha T. D.	146036
	Ivano-Frankivsk region, Kolomyia district, near the village of Spas	2005-07-20; Tymchenko I. A., Minarchenko V. M.	146035
	Kyiv region, Makariv district, village Kozynchi	2019; Minarchenko V. M.	146034
<i>C. rhipidophylla</i>	Transcarpathian region, Berehiv district, Borzhava forestry, hornbeam-oak forest	2007-07-19; Minarchenko V. M., Solomakha T. D.	146037
	Kyiv region, Makariv district, Mykolayivka village	2012-06-20; Solomakha T. D., Tymchenko I. A., Minarchenko V. M.	14603

**Table 2** Morphological features of fruits of species of the genus *Crataegus* L.

Species name	Shape	Color	Flesh	Pyrene		
			Color	Consistence	Number	Shape
<i>C. laevigata</i>	Spherical (short-ellipsoidal)	Brownish-red, brown, black	Yellow	Juicy	2(3)	Dorsal – convex, ventral – flat
<i>C. monogyna</i>	Widely-short-ellipsoid, ovoid, rounded	Dark red, brownish red	Yellow	Juicy	1	Rounded
<i>C. pentagyna</i>	Almost spherical, short-ellipsoidal	Black, purple-black	Reddish-brown	Juicy	2–5	Triangular
<i>C. pseudokyrstostyla</i>	Elongated-ellipsoidal, cylindrical	Dark red, with green spots, reddish-brown	Yellow-orange	Juicy	1	Ellipsoidal
<i>C. sanguinea</i>	Spherical (short-ellipsoidal)	Blood red (brownish red)	Yellow	Floury	2(3)–4(5)	Triangular
<i>C. fallacina</i>	Ellipsoidal or ovoid-ellipsoidal	Yellowish-brown or red	Yellow	Juicy	1	Flattened stone
<i>C. rhipidophylla</i>	Elongated-ellipsoidal, ellipsoidal, cylindrical	Dark red, yellow, burgundy, black	Yellow	Juicy	1	Flattened stone

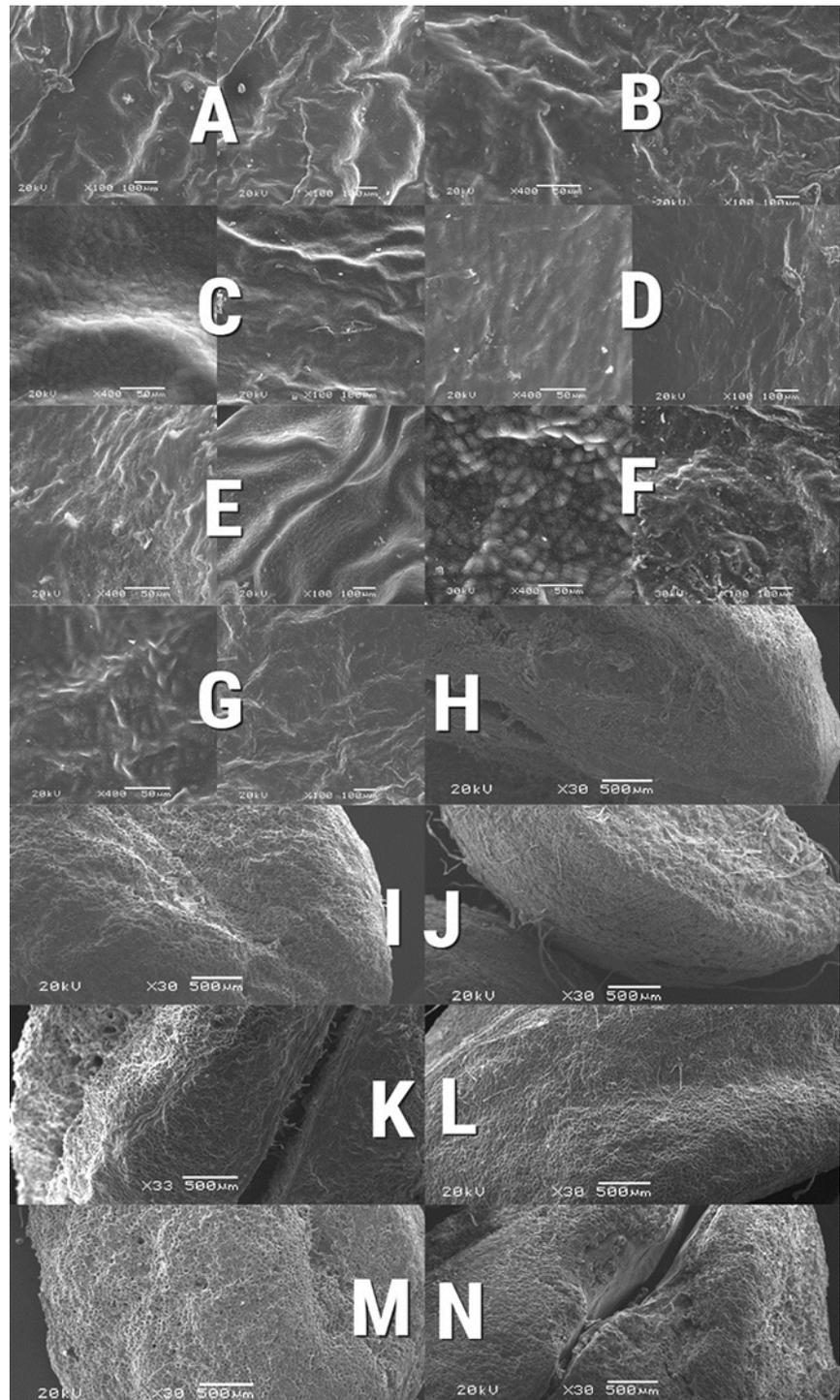
***Crataegus pentagyna*.** The fruits are almost spherical, round, or short-ellipsoidal (Figure 1F). The color is almost black or purple-black with a glaucinus coating at the base. The flesh is underdeveloped and reddish-brown. Fruit length varies from 6 to 9(12) mm (mean =  $8.9 \pm 1.5$  mm, CV = 17%), and width varies from 6 to 8 mm (mean =  $7.2 \pm 0.5$  mm, CV = 6%). The relief of the surface of the fruits is indistinctly collicular (Figure 2C). Epicuticular wax is well developed and is represented by wax



**Figure 1** General view of the fruits and pyrenes surface of the studied species of the genus *Crataegus* L.: *C. laevigata* (A); *C. sanguinea* (A); *C. fallacina* (C); *C. pseudokyrstostyla* (D); *C. monogyna* (E); *C. pentagyna* (F); *C. rhipidophylla* (G); *C. laevigata* (H); *C. monogyna* (I); *C. pentagyna* (J); *C. pseudokyrstostyla* (K); *C. sanguinea* (L); *C. fallacina* (M); *C. rhipidophylla* (N).

crusts. The number of pyrenes varies from two to several (three–four) (Figure 1J). The ventral side of the pyrene is a dilated pterygoid with a longitudinal crest, and the apex is narrow, rounded on the dorsal side, with a longitudinal groove. Pyrenes are characterized by a reticular relief (Figure 2J, Figure 3J).

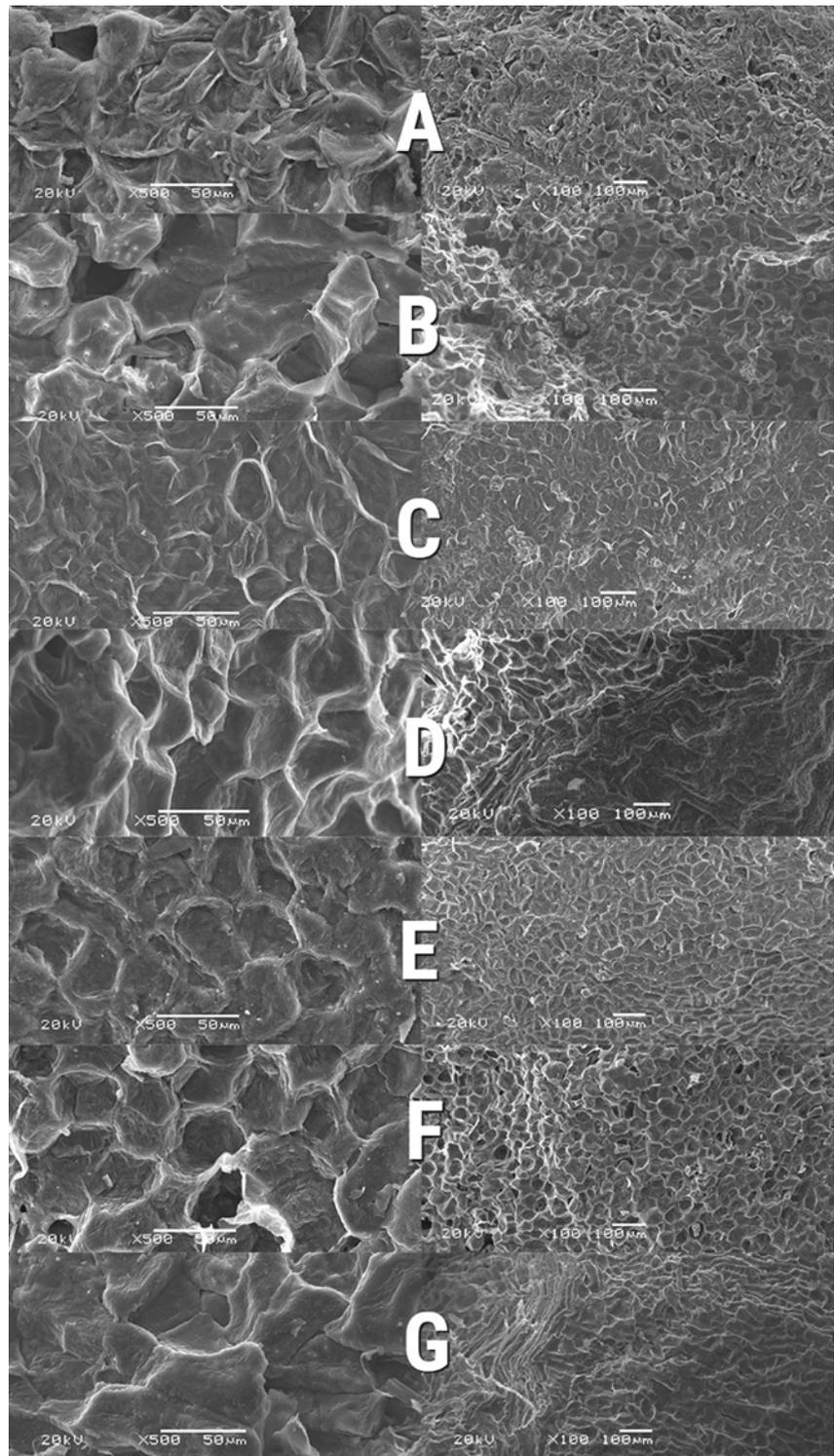
***Crataegus pseudokyrstostyla*.** The fruits are spherical, oblong-ellipsoidal, or cylindrical in shape (Figure 1D). The color is dark red, often with green spots,



**Figure 2** The sculpture of the surface of fruits and pyrenes of the studied species of the genus *Crataegus* L.: *C. laevigata* (A); *C. monogyna* (B); *C. pentagyna* (C); *C. pseudokyrstostyla* (D); *C. sanguinea* (E); *C. fallacina* (F); *C. rhipidophylla* (G); *C. laevigata* (H); *C. monogyna* (I); *C. pentagyna* (J); *C. pseudokyrstostyla* (K); *C. sanguinea* (L); *C. fallacina* (M); *C. rhipidophylla* (N).

reddish-brown, and the flesh color is yellow-orange. The relief of the surface of fruits is collicular, and epicuticular wax is represented by well-developed waxy irregular platelets (Figure 2D). Fruit length varies from 9 to 11 mm (mean =  $10.1 \pm 0.45$  mm, CV = 7%), and width varies from 5 to 6 mm (mean =  $5.45 \pm 0.35$  mm, CV = 8%). There is one pyrene (Figure 1K), characterized by pitted relief (Figure 2K, Figure 3D).

***Crataegus sanguinea*.** The fruits are almost spherical or short-ellipsoidal in shape (Figure 1B). Their color is blood-red (brownish-red) and rarely orange-yellow.



**Figure 3** The sculpture of the pyrene surface of the studied species of the genus *Crataegus* L.: *C. laevigata* (A); *C. monogyna* (B); *C. pentagyna* (C); *C. pseudokyrstostyla* (D); *C. sanguinea* (E); *C. fallacina* (F); *C. rhipidophylla* (G).

The flesh is yellow with floury consistency. Fruit length varies from 7 to 10 mm (mean =  $8.6 \pm 0.9$  mm, CV = 10%), and width varies from 7 to 9 mm (mean =  $8.1 \pm 0.7$  mm, CV = 11%). The relief is collicular-pitted, and epicuticular wax is well developed, represented by wax crusts (Figure 2E). There are 2(3)–4(5) pyrenes (Figure 1L). Pyrenes are elliptic to obovoid, with sutures on the ventral side and one or three keels on the dorsal side. Their relief is collicular-pitted (Figure 2L, Figure 3E).

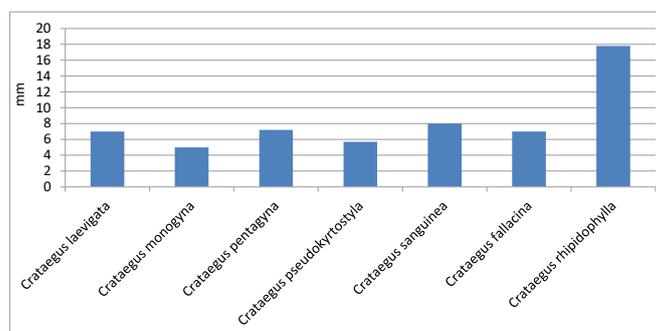
***Crataegus fallacina*.** Fruits are spherical, short-elliptical, ellipsoidal, or ovoid ellipsoidal (Figure 1C). The color of the fruit is yellowish-brown or red. The flesh is yellow and juicy. Fruit length varies from 9 to 12 mm (mean =  $8.6 \pm 0.9$  mm, CV = 10%), and width varies from 5 to 9 mm (mean =  $8.1 \pm 0.7$  mm, CV = 11%). The relief of the fruit surface is collicular, with well-developed epicuticular wax (Figure 2F), which is represented by wax crusts and granules. Papillae are present on the fruit surface. Their area is approximately 0.39–0.41 mm<sup>2</sup>. There is one pyrene (Figure 1M). Its dorsal side is convex with four grooves, and the ventral side is flat with one furrow and a prominent nose. The relief is reticulated-pitted (Figure 2M, Figure 3F).

***Crataegus rhipidophylla*.** The fruits are elongated-ellipsoidal, ellipsoidal, or cylindrical in shape (Figure 1G). The color is bright or dark red, yellow, burgundy, or black. The flesh is yellow and juicy. Fruit length varies from 8 to 15 mm (mean  $12.6 \pm 2.74$  mm, CV = 18%), and the width is 1.3–2 times greater than the length. The relief of the fruit surface is collicular with well-developed epicuticular wax (Figure 2G). Wax is represented by wax films and platelets. There is one pyrene (Figure 1N). The dorsal side is convex, and the ventral side is flat. The surface relief of the pyrene is reticulate (Figure 2N, Figure 3G).

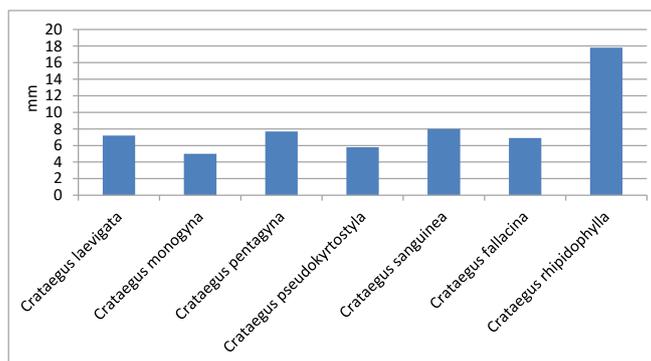
#### 4. Discussion

Morphological features of fruits are important for species identification (e.g., Alaghawani & Naser, 2013; Meheub et al., 2019). A comprehensive study of the fruits and pyrenes of selected species of the flora of Ukraine was conducted for the first time. In the present study, it was found that the species of the genus *Crataegus* native to the flora of Ukraine are characterized by spherical and ellipsoidal fruits. The species differ in fruit size, with lengths varying from 5–9 mm (*C. laevigata*) to 8–15 mm (*C. rhipidophylla*) (Figure 4) and widths varying from 4–6 mm (*C. monogyna*) to 7–9 mm (*C. sanguinea*) (Figure 5). The predominant color is fulvous/brown with different shades, but almost black fruits of the species *C. pentagyna* are well distinguished.

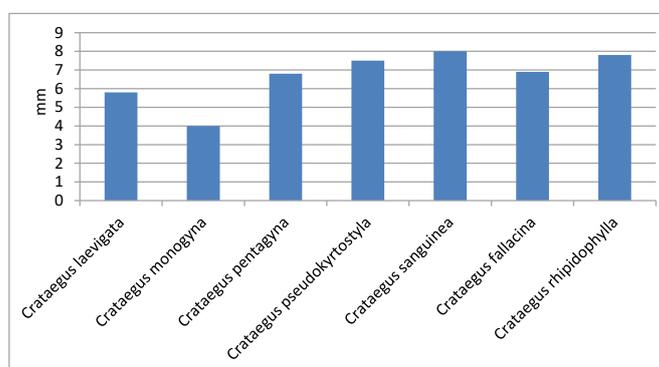
Fruits of all studied species of the genus are fleshy, except *C. sanguinea*, which is floury. The species are characterized mainly by yellow fruits. The exception is *C. pentagyna*, which is reddish-fulvous. The fruits are usually topped with nondrooping, triangular, and pointed sepals that are bent outward. The surface of nonfixed fruits (fresh) in the studied species is smooth and shiny, except for the species *C. monogyna*, which has grooved fruits and the species *C. pentagyna*, which has ribbed fruits. The fruits of the studied species had very sparse pubescence at the base. The exception is the fruits of *C. pentagyna*, which have dense glaucinus coating pubescence, present both at the base and at the apex of the fruit. In all studied species, the fruits are covered with a solid layer of wax, and the studied species differ in the type of epicuticular wax. Thus, wax platelets are characteristic of *C. pseudokyrstostyla*, *C. laevigata*, and *C. rhipidophylla*, wax spathele are



**Figure 4** Fruit lengths in the studied species of the genus *Crataegus* L. (axis y is the length in mm).



**Figure 5** Fruit widths in the studied species of the genus *Crataegus* L. (axis y is the width in mm).



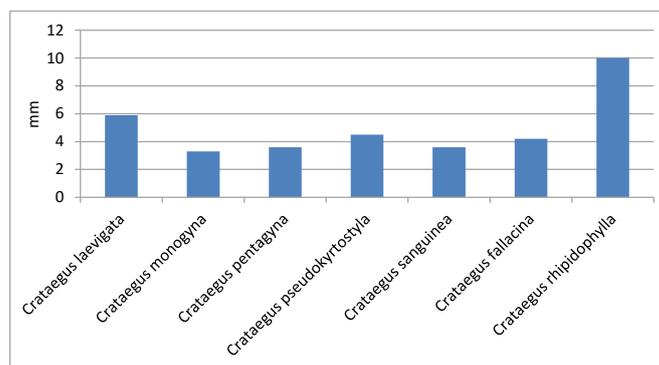
**Figure 6** Pyrene lengths in the studied species of the genus *Crataegus* L. (axis y is the length in mm).

characteristic of *C. pentagyna* and *C. pseudokyrstostyla*, and wax peels are characteristic of *C. fallacina*, *C. pentagyna*, and *C. sanguinea*. In the vast majority of the studied species, the relief of the fruit surface is collicular (*C. laevigata*, *C. pentagyna*, *C. pseudokyrstostyla*, *C. fallacina*, and *C. rhipidophylla*), collicular-pitted (*C. sanguinea*), and awned-undulating (*C. monogyna*). We identified mature fruits that contain only one pyrene (*C. monogyna*, *C. pseudokyrstostyla*, *C. fallacina*, and *C. rhipidophylla*), and several pyrenes (*C. laevigata*, *C. pentagyna*, and *C. sanguinea*) among the studied species of the genus.

Pyrenes exhibit different shapes: irregular (*C. laevigata* and *C. sanguinea*), rounded (*C. monogyna* and *C. laevigata*), triangular (*C. pentagyna*), and ellipsoidal (*C. laevigata*, *C. pseudokyrstostyla*, *C. fallacina*, and *C. rhipidophylla*). They also vary in sizes: from 3–5 mm in length (*C. monogyna*) to 7–8 mm (*C. pseudokyrstostyla*) (Figure 6), and most species have a width of 3–4 mm (Figure 7). Pyrenes of all species are yellow, smooth on the lateral sides, and grooved on the dorsal and abdominal sides. The exceptions are the pyrenes of *C. sanguinea* and *C. pseudokyrstostyla*, which are pitted. They are highly compressed in *C. sanguinea* and *C. fallacina*. The relief of the surface of the pyrene is reticulated (*C. pentagyna* and *C. monogyna*), reticular-collicular (*C. laevigata*), reticulated-pitted (*C. fallacina*), collicular-pitted (*C. sanguinea*), and pitted (*C. pseudokyrstostyla*).

We found that, in general, the morphological features of pyrenes in the studied species are similar. The size of pyrenes of different species of the genus *Crataegus* varies from 5 to 15 mm in length and 4 to 15 mm in width.

Pyrenes are yellowish-brown in *C. sanguinea*, *C. fallacina*, and *C. rhipidophylla*, orange in *C. sanguinea*, red in *C. fallacina*, *C. pseudokyrstostyla*, and *C. sanguinea*,



**Figure 7** Pyrene widths in the studied species of the genus *Crataegus* L. (axis *y* is the width in mm).

red-brown in *C. laevigata*, *C. monogyna*, *C. sanguinea*, and *C. rhipidophylla*, and black in *C. pentagyna*.

Thus, we identified features that clearly distinguished the studied species from each other. The almost black color is characteristic of the fruits of *C. pentagyna*. The largest fruits are observed in *C. rhipidophylla*. The fruits of *C. monogyna* plants differ from those of other studied species in the spinous-tuberous surface relief. Pyrenes of triangular shape are observed only in *C. pentagyna*. In our opinion, these features can be used as additional diagnostic tools to determine the species of the genus *Crataegus* flora of Ukraine. Our findings can be included in the relevant chapter of the *European Pharmacopoeia*, including the *State Pharmacopoeia of Ukraine*, to the chapter on medicinal herbal raw materials and herbal medicines.

## References

- Alaghawani, W., & Naser, I. (2013). Study the hypoglycemic effect of *Crataegus laevigata* in diabetic rats. *Journal of Pharmaceutical and Clinical Research*, 5(4), 145–149.
- Анцышкіна [Antsyshkina], А. М. [A. M.], Барабанов [Barabanov], Е. И. [E. I.], Самыліна [Samulina], І. А. [I. A.], & Каверіна [Kaverina], Н. В. [N. V.]. (1990). О фармакологической активности препаратов боярышника [About the pharmacological activity of hawthorn preparations]. *Фармація [Pharmacy]*, 2, 63–65.
- Артюшенко [Artiushenko], З. Т. [Z. T.], & Федоров [Fedorov], А. А. [A. A.]. (1986). *Атлас по описательной морфологии высших растений. Плод [Atlas of descriptive morphology of higher plants. Fruit]*. Наука [Nauka].
- Бобров [Bobrov], А. В. [A. V.], Меликян [Melikyan], А. П. [A. P.], & Романов [Romanov], М. С. [M. S.]. (2009). *Морфогенез плодов Magnoliophyta [Morphogenesis of Magnoliophyta fruits]*. Либроком [Librokom].
- Bojňanský, V., & Fargašová, A. (2007). *Atlas of seeds and fruits of Central and East-European flora. The Carpathian Mountains region*. Springer Science & Business Media.
- Черепанов [Cherepanov], С. К. [S. K.]. (1995). *Сосудистые растения России и сопредельных государств (в пределах бывшего СССР) [Vascular plants of Russia and neighboring states (within the former USSR)]*. Мир и Семья-95 [Peace and Family-95].
- Christensen, K. I. (1992). *Revision of Crataegus sect. Crataegus and nothosect. Crataeguineae (Rosaceae-Maloideae) in the old world*. American Society of Plant Taxonomists. <https://doi.org/10.2307/25027810>
- Евдокимова [Evdokimova], О. В. [O. V.]. (1999). Фармакологическое действие препаратов боярышника [Pharmacological action of hawthorn preparations]. *Современные проблемы фармацевтической науки и практики: научные труды ВНИИФ [Modern Problems of Pharmaceutical Science and Practice: Scientific Works of the All-Russian Scientific Research Institute of Phytopathology]*, 38(2), 205–212.
- Федорончук [Fedoronchuk], М. М. [M. M.]. (2003). Види судинних рослин, описані з території України, їх типіфікація та критичний аналіз: родина Rosaceae Juss. (рід *Crataegus* L.) [Species of vascular plants described from the territory of Ukraine, their typification and critical analysis: Family Rosaceae Juss. (genus *Crataegus* L.)]. *Український ботанічний журнал [Ukrainian Botanical Journal]*, 60(2), 145–153.
- Федорончук [Fedoronchuk], М. М. [M. M.]. (2017). Таксони Rosaceae флори України: положення в новій системі родини, побудованій за даними

- молекулярно-філогенетичного аналізу [Taxa of Rosaceae of the Ukrainian flora: Position on a new system of the family according to molecular phylogenetic data]. *Український ботанічний журнал* [Ukrainian Botanical Journal], 74(1), 3–15.  
<https://doi.org/10.15407/ukrbotj74.01.003>
- Fikret, B. M., Çelik, F., Turkoglu, N., Ozrenk, K., & Ozgokçe, F. (2006). Some fruit traits of hawthorn (*Crataegus* spp.) genetic resources from Malatya, Turkey. *Research Journal of Agriculture and Biological Sciences*, 2(6), 531–536.
- Гроссгейм [Grossgeim], A. A. [A. A.]. (Ed.). (1952). *Флора Кавказа. Том 5. Rosaceae-Leguminosae* [Flora of the Caucasus Vol. 5. Rosaceae-Leguminosae]. Издательство Академии наук СССР [USSR Academy of Sciences Publishing House].
- Губанов [Gubanov], И. А. [I. A.], Киселева [Kiseleva], К. В. [K. V.], Новиков [Novikov], В. С. [V. S.], & Тихомиров [Tikhomirov], В. Н. [V. N.]. (2013). *Иллюстрированный определитель растений Средней России. Том 2. Покрытосеменные (двудольные: раздельнолепестные)* [An illustrated guide to plants of Central Russia. Volume 2: Angiosperms (Magnoliopsida: Archichamydae)]. Товарищество научных изданий КМК [KMK Scientific Publishing Association].
- Юхименко [Iukhymenko], Ю. С. [Yu. S.]. (2019). *Біоекологічні особливості видів роду Crataegus L. при інтродукції в умовах Правобережного Степового Придніпров'я* [Bioecological features of species of the genus *Crataegus* L. with the introduction in conditions of Right-bank steppe Pridneprov'ya] [Unpublished doctoral dissertation]. М. М. Gryshko National Botanical Garden, National Academy of Sciences of Ukraine.
- Комаров [Komarov], В. Л. [V. L.]. (Ed.). (1939). *Флора СССР* [Flora of the USSR] (Vol. 9). Издательство Академии наук СССР [USSR Academy of Sciences Publishing House].
- Коровкин [Korovkin], О. А. [O. A.]. (2007). *Анатомия и морфология высших растений. Словарь терминов* [Anatomy and morphology of higher plants: Glossary of terms]. Дрофа [Drofa].
- Крылов [Krylov], П. Н. [P. N.]. (1903). *Флора Алтая и Томской губернии – Corneae: практическое пособие. Т. 2. Papilionaceae* [Flora of Altai and Tomsk province – Corneae. A practical guide. Vol. 2. Papilionaceae]. Типо-Литография М. Н. Кононова [Тиро-Lithograph by M. N. Kononov].
- Летухова [Letukhova], В. Ю. [V. Yu], Потапенко [Potapenko], И. Л. [I. L.], & Федорончук [Fedoronchuk], М. М. [M. M.]. (2014). Анализ таксономии некоторых видов рода *Crataegus* (Rosaceae) флоры Крыма [Taxonomic analysis of some species of the genus *Crataegus* (Rosaceae) from the flora of Crimea]. *Український ботанічний журнал* [Ukrainian Botanical Journal], 71(2), 182–187.  
<https://doi.org/10.15407/ukrbotj71.02.182>
- Mehebut, M. S., Mahmud, N. U., Rahman, M., Surovy, M. Z., Gupta, D. R., Hasanuzzaman, M., Rahman, M., & Islam, M. T. (2019). Chitosan biopolymer improves the fruit quality of litchi (*Litchi chinensis* Sonn.). *Acta Agrobotanica*, 72(2), Article 1773.  
<https://doi.org/10.5586/aa.1773>
- Меженська [Mezhens'ka], Л. О. [L. O.], & Меженський [Mezhens'kii], В. М. [V. M.]. (2013). *Рід Глід (Crataegus L.) в Україні: інтродукція, селекція, еколого-біологічні особливості* [Genus hawthorn (*Crataegus* L.) in Ukraine: Introduction, selection, ecological and biological features]. Компринт [Komprint].
- Mosyakin, S. L., & Fedoronchuk, M. M. (1999). *Vascular plants of Ukraine. A nomenclatural checklist*. М. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine.
- Pengzhan, L. (2012). *Composition of hawthorn (Crataegus spp.) fruits and leaves and emblic leafflower (Phyllanthus emblica) fruits* [Doctoral dissertation, University of Turku]. UTUPub. <http://urn.fi/URN:ISBN:978-951-29-4982-3>
- Roskov, Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P. M., Bourgoin, T., DeWalt, R. E., Decock, W., van Nieukerken, E., Zarucchi, J., & Penev, L. (Eds.). (2019). *Species 2000 and ITIS Catalogue of Life, 2019 Annual Checklist*. <http://www.catalogueoflife.org/annual-checklist/2019/search/all/key/crataegus/fossil/1/match/1>
- Самылина [Samylina], И. А. [I. A.], Сорокина [Sorokina], А. А. [A. A.], & Пятигорская [Piatigorskaiia], Н. В. [N. V.]. (2010). Боярышник (*Crataegus*): возможности медицинского применения [Hawthorn (*Crataegus*): Possibilities of medical application]. *Фарматека* [Farmateka], 8, 83–85.
- Державна фармакопея України. Т. 3.* [State Pharmacopoeia of Ukraine. Vol. 3.]. (2014). ДП Український науковий фармакопейний центр якості лікарських засобів [Ukrainian Scientific Pharmacopoeial Center for Quality of Medicines].
- Цвелёв [Tselëv], Н. Н. [N. N.]. (2001). Род 38. Боярышник – *Crataegus* L. [Genus 38. Hawthorn – *Crataegus* L.]. In Н. Н. [N. N.] Цвелёв [Tselëv] (Ed.), *Флора Восточной Европы* [Flora of Eastern Europe] (Vol. 10, pp. 557–586). Мир и Семья [Peace and Family].

- Tuyakova, A. T., Imanbayeva, A. A., Duysenova, N. I., & Ishmuratova, M. Y. (2016). Anatomical structure study of aerial organs of *Crataegus ambigua* C. A. Mey. *Biosciences Biotechnology Research Asia*, 13(3), 1303–1309. <https://doi.org/10.13005/bbra/2270>
- Уфимов [Ufimov], P. A. [R. A.]. (2013). Род боярышник (*Crataegus* L., *Rosaceae*) во флоре Восточной Европы и Кавказа [Genus hawthorn (*Crataegus* L., *Rosaceae*) in the flora of the Eastern Europe and Caucasus] [Unpublished doctoral dissertation]. Ботанический институт им. В. Л. Комарова РАН [Komarov Botanical Institute of the Russian Academy of Sciences].
- Ванин [Vanin], A. И. [A. I.]. (1967). *Определитель деревьев и кустарников* [Determination key of trees and shrubs]. Лесная промышленность [Timber Industry].
- Зеров [Zerov], Д. К. [D. K.]. (1954). *Флора УРСР* [Flora of the Ukrainian SSR] (Vol. 6). Академія наук УРСР [Academy of Sciences URSS].
- Зеров [Zerov], Д. К. [D. K.]. (Ed.). (1965). *Визначник рослин України* [Determination key of plants of Ukraine]. Урожай [Urozhai].