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Bio-ecological characteristics of *Malus* genus species in the context of prospective directions in horticulture and landscape forestry

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Abstract. The study aimed to conduct a comparative assessment of representatives of the genus *Malus* based on morphological traits, biological characteristics, physiological mechanisms of resistance to fungal pathogens, ornamental value, and significance within the frameworks of horticulture, landscape forestry, and shelterbelt afforestation. Employing an integrative approach, the research examined the morphological traits and biological characteristics of domestic apple, European

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wild apple, Siberian crab apple, hybrid crab apple, and plum-leaved apple. Comparative analysis was carried out to evaluate the susceptibility and resistance of these species to scab pathogens and other diseases. The findings indicated that the domestic apple is characterised by large fruit size, with an average fruit mass of no less than 150 g. In contrast, the average fruit mass for Siberian crab apple, cherry crab apple, and hybrid crab apple does not exceed 0.7 g, 1.8 g, and 3.2 g, respectively. The authors have developed an integrated scale for the comparative evaluation of *Malus* species (or crab apple varieties) based on overall ornamental value. This scale included five criteria: crown appearance, leaf aesthetics, floral attractiveness, fruit visual appeal, and resistance to apple scab. For the first time, fruits of different *Malus* species have been analysed for seed productivity. Among these, crab apple varieties, particularly the European wild apple and the plumleaved apple, were identified as having the highest average number of seeds per fruit – 10 and 8 seeds, respectively. It was also shown that the seeds of the wild apple are relatively large, with the 100-seed weight exceeding 3.9 g. The study highlighted findings that confirm the ornamental value of certain *Malus* species, notably the Siberian crab apple and the hybrid crab apple, which received the highest overall ornamental scores of 4.5 and 5. This contrasts with the European wild apple, cherry apple, and domestic apple, which scored lower for ornamental attributes (3.2-3.9). It was noted that crab crab apple species such as *Malus sylvestris* (L.) Mill. and *Malus baccata* (L.) Borkh. are well-suited for use in the creation of forest-park landscapes. Under the conditions of the Northern Forest-Steppe of Ukraine, *Malus* species were differentiated by their resistance to the scab pathogen (*Venturia inaequalis* Cooke). The results established that domestic apple (cultivar Dozhnytsia), hybrid crab apple, and plum-leaved apple exhibited high resistance to this pathogen, which affects both foliage and fruit. The practical application of these findings lies in enriching the informational database on *Malus* species with updated data, enabling their utilisation in various thematic studies

Keywords: *Malus*; morphology; plant physiology; resistance to phytopathogens; comparative evaluation

INTRODUCTION

The rational utilisation, introduction, and preservation of fruit and ornamental plant species, particularly those belonging to the genus *Malus* L., is a pressing issue in modern fruit and ornamental horticulture. Apple orchards have traditionally held not only practical but also aesthetic value. Apple trees possess a wide range of adaptive traits, including high winter hardiness, frost resistance, and drought tolerance, and are also prised for their ornamental qualities. These qualities contribute significantly to human psychological and emotional well-being and create visually pleasing, harmonious, and aesthetically appealing environments. However, like all plant species, apple trees are susceptible to a variety of fungal, bacterial, and viral diseases that can negatively impact yield, aesthetic quality, and the lifespan of orchards. As reported by P. Abbasi *et al.* (2019) and S. Nabi *et al.* (2023), one of the most dangerous diseases affecting apple trees is scab (caused by the fungus *Venturia inaequalis* (Cooke) Winter), as well as powdery mildew (caused by the sac fungus *Podosphaera leucotricha* Salm) and fruit rot or moniliosis (caused by *Monilinia fructicola* (G.Winter) Honey). Diseases such as crown gall, caused by the gram-negative bacterium *Agrobacterium tumefaciens* Stevens, and powdery mildew can significantly reduce apple yields by up to 50% or more. Powdery mildew infections are particularly problematic due to their chronic nature, which can reduce not only the current but also future yields of an orchard. Despite the wide range of apple diseases, scab and fruit rot remain the most commercially significant diseases worldwide.

As noted by R. Spengler (2019) and E. Greaves and B. Husband (2022), many species and hybrids of the genus *Malus*, such as *Mallus baccata* (L.) Borkh., *Malus prunifolia* (Willd.) Borkh., *Malus sieversi* (Ledeb.), *Malus baccata* (L.) Borkh., *Malus prunifolia* (Willd.) Borkh., *Malus sieversii* (Ledeb.), *Malus sylvestris* (L.) Mill., *Malus praecox* (Pall.) Borkh., *Malus domestica* (Borkh.) Borkh., *Malus* × *domestica* × *Malus sieversii*, are capable of hybridisation. This capability allows for the creation of a diverse range of hybrid materials with promising applications in horticulture and landscape forestry. While the primary purpose of apple trees is fruit production, as highlighted by J. Ji *et al.* (2021), certain species are cultivated for their ornamental value. These are often referred to as flowering or ornamental apples. However, species and cultivars that combine both fruit production and ornamental qualities, such as high disease resistance and attractive growth habits, flowers, leaves, and fruits, are particularly valuable.

In the context of global climate change, the domestic apple remains a primary fruit crop worldwide, including Ukraine. As of 1 January 2023, apple orchards in Ukraine covered an area of 95,100 hectares, with a total fruit production of 1.17 million tonnes (FAO, 2023). According to C. Bragard *et al.* (2021) and Y. Khajuria *et al.* (2022), there is a continuous need for new theoretical knowledge regarding the domestic apple, particularly concerning its biometric and morphometric characteristics, such as fruit quality, yield, and resistance to fungal pathogens.

The genus *Malus* Mill. comprises approximately 36 species and 4 hybrids (although some sources suggest

closer to 70), which are classified as small, deciduous trees or shrubs within the rose family (*Rosaceae* Juss.). Apple trees of summer and autumn cultivars exhibit a wide range of adaptive traits, tolerating significant temperature drops in air temperature to as low as -30 to -40°C. Notably, as A. Cebulj *et al*. (2022) have observed, apple cultivars grafted onto seedling rootstocks exhibit higher frost resistance compared to those grafted onto clonal rootstocks. Additionally, D. Gómez-Candón *et al*. (2022) have highlighted the high drought toleran ce of apple trees, enabling their cultivation in arid southern regions. A. Arabzada and A. Sadigov (2023), and M. Hardie *et al*. (2024) have noted that most apple species can thrive in various soil types, although soils with shallow groundwater tables, deep sands, or stony compositions are less suitable. Breeding programs focused on the genetic diversity of the genus *Malus* Mill. (1768), agricultural traits such as yield, fruit quality (both quantitative and qualitative), and resistance to fungal diseases are prioritised. Despite their high vitality, apple trees are vulnerable to adverse abiotic and biotic environmental factors (Woodall *et al.,* 2023). The authors propose a method for evaluating the ornamental value of plants on a seasonal basis. Each ornamental feature is assessed visually using a 4-12-point scale, and various coefficients are suggested to determine the significance of each specific feature, taking into account its degree of expression. Common criteria for evaluating ornamentality include: the architecture of the trunk and crown, crown shape, bark colour, leaf (or needle) size and colour, leaf vitality, flower and inflorescence size and colour, duration of flowering, attractiveness of fruits and inflorescences, fruit and inflorescence retention, fragrance, and three indicators of plant vitality (damage) and natural growing conditions (winter hardiness, frost resistance).

Despite existing approaches to assessing the ornamentality of certain woody plants, there remains a gap in knowledge regarding a comprehensive approach to evaluating the aesthetic qualities and resistance of various apple species and cultivars to adverse abiotic and biotic environmental factors. This gap defined the aim and objectives of the current research. Therefore, the aim of this study was to evaluate representatives of the genus *Malus* based on a complex of morphological features and bioecological characteristics, which are important for the future development of horticulture and landscape forestry.

MATERIALS AND METHODS

The research was conducted at the experimental field of the Laboratory of Breeding and Technology of Growing Berry Crops at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Northern Forest-Steppe of Ukraine, Kyiv) during 2017-2021. The experimental plot is characterised by a moderately warm and insufficiently moist climate. The hydrothermal coefficient (HTC) ranges from 1.8 to 2.1. Notably, approximately 70% of precipitation occurs during the warm period of the year, while 30% falls during the cold period. Based on personal observations and data from the Hydrometeorological Service, the key climatic parameters for the research area at the Institute of Horticulture of NAAS are presented in Table 1.

Table 1. *Long-term average climatic parameters for the village of Novosilky, Fastiv District, Kyiv Region*

Indicator	Value
Sum of active temperatures, t°C	2,671-2,695
Sum of effective temperatures > 5°C	1,949-2,059
Average annual air temperature, t°C	6.7-7.0
Minimum air temperature, t°C	-34.5
Maximum air temperature, t°C	+38.0
Frost-free period duration, days	141-146
Date of autumn frosts	8-11 October
Date of last spring frosts	23-25 April
Average soil freezing depth, cm	56
Annual precipitation, mm	581-634
Precipitation during the growing period, mm	368-425
Duration of snow cover, days	87-90
Average maximum snow cover depth, cm	14-15
Vegetation period duration, days	199-205
Predominant wind direction	North-western

Source: *developed by the authors*

The terrain of the research area is a gently undulating plain. The soil is classified as dark grey, podzolized, medium loamy on carbonate loess, typical of the northern part of Ukraine's Forest-Steppe zone. The agrochemical properties of the soil are as follows: humus content in the arable layer (0-40 cm) is 2.3%, easily hydrolysable nitrogen is 78.4-98.0 mg/kg, mobile phosphorus forms are 93.2-180.9 mg/kg and exchangeable potassium ranges from 106.1 to 202.8 mg/kg. The soil's pH is heterogeneous, ranging from 5.3 to 6.0. The

physical and hydrological characteristics indicate a ratio of physical sand to physical clay of 69:31, with groundwater located at a depth of 56 metres. The analysis of weather conditions began with an assessment of apple tree conditions in the experiments. In October 2020, the air temperature averaged 9.4°C, exceeding the long-term average by 1.4°C. Precipitation during the first and third decades of October amounted to 58 mm, 26 mm more than the long-term average. November was also warmer, with an average temperature of 1.5°C above the long-term norm. Total precipitation for these autumn months reached 104.8 mm, exceeding the long-term average by 28.4 mm. Spring 2021 commenced in the third decade of March, marked by rising temperatures in April and May, reaching 18.9°C, which was 7.9°C higher than the long-term average. Total precipitation during this period amounted to 105.2 mm, 62.2 mm above the climatic norm. The coldest month of 2021 was January, with minimum temperatures as low as -13.2°C. May and June experienced substantial rainfall. Over the course of the year, total precipitation reached 521 mm, constituting 80% of the climatic norm.

The resumption of vegetation in 2021 and the timing of the onset of the fruits' technical ripeness were observed to occur 14-16 days later compared to 2019 and 2020. The flowering phase of apple trees was recorded during the second decade of May when the threat of spring frosts had passed, and sunny weather prevailed. Consequently, the fruit set percentage was high. The weather conditions in 2019 and 2020 were more conducive to the development of apple scab compared to 2021. Therefore, it was reasonable to compare years with more contrasting weather conditions (Table 2).

***Table 2**. Temperature regime during the growing season of apple trees in years with the most contrasting weather conditions*

Year	Indicator	Month of the year					
		April	May	June	July	August	September
2020	t,°C	9.7	12.5	22.4	22.1	21.8	14.8
	∑o, mm	28.4	106.4	46.5	47.6	19.0	48.2
	HTP	1.76	1.40	1.61	2.67	3.51	1.11
2021	t,°C	8.7	14.1	21.8	21.7	22.3	21.8
	∑o, mm	46.3	53.9	76.0	35.4	20.3	16.4
	HTP	0.83	0.85	1.92	2.78	2.95	1.09
Long-term average	t,°C	7,8	14.9	18.3	19.3	18.6	22.2
	∑o, mm	49.1	53,3	70,9	88.9	24.3	39.8
	HTP	1.05	0.90	2.07	2.99	3.27	1.78

***Note:** t,°C – average monthly air temperature, ∑o – monthly precipitation, HTP – hydrothermal potential*
***Source:** developed by the authors*

The study included various species of the genus *Malus* (European wild apple, Siberian crab apple, plum-leaved apple, hybrid crab apple, cherry crab apple, and three cultivars of *Malus domestica* Borkh. of Ukrainian and American selection: Reinette Symyrenko, Dozhnytsia, and Jonagold) located in different sites, including an experimental field and the territory of the village of Novosilky. These plants were studied for their morphological characteristics and physiological properties during 2020-2021 (Fig. 1).

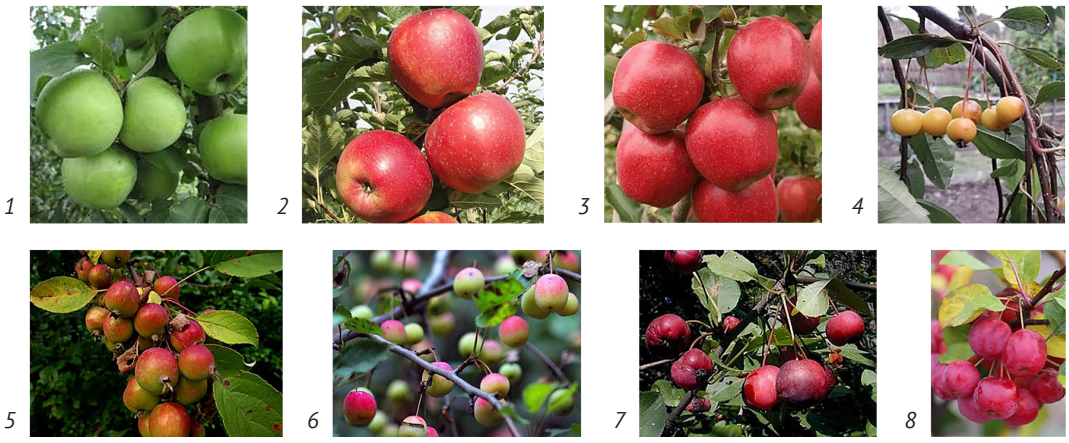

***Figure 1**. Species diversity of Malus representatives involved in the study*
***Note:** 1 – Reinette Symyrenko, 2 – Dozhnytsia, 3 – Jonagold (Malus domestica Borkh.); 4 – Siberian crab apple (Malus baccata (L.) Borkh.); 5 – European wild apple (Malus silvestris (L.) Mill.); 6 – cherry crab apple (Malus cerasifera Spach.); 7 – plum-leaved apple (Malus prunifolia (Willd.) Borkh.); 8 – hybrid crab apple (Malus hibridus (Red Sentinel))*
***Source:** compiled by the authors*

It should be noted that the studied apple species (cultivars) have North American, European, and Asian origins (Table 3).

Phenological observations were conducted according to the methodology of S. Tkachuk (2016). Biometric parameters of apple trees (trunk height, crown diameter, number of skeletal branches, leaf, fruit, and seed parameters, fruit yield) were determined according to B. Hulko (2020). The assessment of apple tree resistance to adverse biotic environmental factors was conducted according to (Methodology of phytopathological studies, 2017). Specifically, the incidence of apple scab on blossoms and ovaries was recorded in May and June, on leaves throughout July and August, and on fruits during harvest (depending on the maturity group of the studied plant). For each apple species (cultivar), 100 fruits were collected from four opposite sides of several trees and evaluated according to the scale (Table 4).

***Table 3**. Origin of Malus species and cultivars*

No.	Species (Cultivar)	Geographic origin	Genetic origin	Chromosome count
1	*Malus baccata* (L.) Borkh.	Asia (China)	Not determined	2n = 34
2	M*alus prunifolia* (Willd.) Borkh.	Asia (Northern China)	Not determined	2n = 34
3	*Malus cerasifera* Spach.	Asia (Japan)	Not determined	2n = 34
4	*Malus hibridus* (Red Sentinel)	Central Asia	Not determined	2n = 34
5	*Malus silvestris* (L.) Mill.	Europe	Not determined	2n = 34
6	*Malus domestica* Borkh. (Reinette Symyrenko)	Europe (Ukraine)	Seedling of the Wood's Greening variety	2n = 34
7	*Malus domestica* Borkh. (Jonagold)	North America	♀Jonathan × ♂Golden Delicious	2n = 47
8	*Malus domestica* Borkh. (Dozhnytsia)	Europe (Ukraine)	♀Rubin Duky × ♂Florina	2n = 34

***Source:** compiled by the authors*

***Table 4**. Scale for assessment of apple plant infection by scab*

Degree of scab infection on leaves and fruits	Scab spot coverage on leaves and fruits, %	Resistance score
Absent	0	0
Very weak	Up to 5	1
Weak	Up to 15	2
Moderate	Up to 30	3
Severe	Up to 50	4
Very severe	Over 50	5

***Source:** Methodology of phytopathological studies... (2017)*

The conducted assessments allowed for the calculation of the number of infected plant parts (leaves, fruits, etc.) in a specific experimental variant and the calculation of the average infection score for a species (cultivar). This was done by multiplying, for example, the number of fruits by the corresponding infection score. The obtained results were summed and divided by the total number of infected fruits. The assessment of plant ornamentality was performed according to S. Tkachuk (2016). The evaluation employed a scale based on a scoring system for ornamental value, where 0 points indicate negative ornamental value (lack of attractiveness), and scores range progressively as follows: 1 point – very low (minimal ornamental appeal); 2 points – low (ornamental qualities are noticeable but not pronounced); 3 points – moderate (distinct ornamental features that stand out against the background of other plantings); 4 points – high (above-average attractiveness); 5 points – very high (exceptional appeal, evoking strong emotional reactions and admiration from observers). The assessment was conducted using five criteria (Table 5).

***Table 5**. Assessment of ornamental value on a 5-point scale*

Scale	Criterion	Scale
I	Ornamental value of the crown	0-5
II	Ornamental value of flowers	0-5
III	Ornamental value of leaves	0-5
IV	Ornamental value of fruits	0-5
V	Resistance to disease agents	0-5

***Source:** S. Tkachuk (2016)*

The reliability of the research results and the degree of variation of the traits were evaluated using MS Excel 2007. The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS

It is worth noting that, according to phenological observations for the conditions of the Northern Forest-Steppe of Ukraine, the average onset of sap flow for the studied representatives of the genus *Malus* falls on the third decade of March – the first decade of April, while the beginning of flowering, depending on the species (cultivar), is on 8-14 May, the end of flowering – on 20-24 May; the onset of technical ripeness of fruits – on the third decade of August - the first and second decades of September; the beginning of leaf fall – on the second half of August (Table 6).

***Table 6**. Features of the passage of phenophases of apple trees*

Species (Cultivar)	Sap flow resumption		Flowering onset		Fruit ripening onset	
	2020	2021	2020	2021	2020	2021
Malus baccata (L.) Borkh.	27 March	04 April	11 May	22 May	08 September	12 September
Malus prunifolia (Willd.) Borkh.	25 March	30 March	07 May	18 May	20 August	25 August
Malus cerasifera Spach.	22 March	28 March	09 May	16 May	25 August	27 August
Malus hibridus (Red Sentinel)	21 March	27 March	12 May	20 May	15 September	20 September
Malus silvestris (L.) Mill.	20 March	25 March	09 May	19 May	10 September	15 September
Malus domestica Borkh. (Reinette Symyrenko)	25 March	27 March	07 May	16 May	28 September	30 September
Malus domestica Borkh. (Jonagold)	22 March	29 March	11 May	18 May	25 September	28 September
Malus domestica Borkh. (Dozhnytsia)	22 March	28 March	12 May	18 May	20 September	22 September

***Source:** developed by the authors*

Experimental trees of the winter variety Dozhnytsia have a spreading habit. The annual shoot has an average number of lenticels, short internodes, moderate pubescence on the peripheral part, is thick, and the bark colour is red-brown (on the sunny side). The leaf blade is deep green, medium in length and width, with a frequently serrated edge. The petiole is medium in length and green with a slight anthocyanin colouration. The flowering phase falls at the end of the first decade - the beginning of the second decade of May. The flower at the bud stage is dark red. The flower diameter is medium, i.e., the petals are spread out, and their arrangement is intermediate. Fruits are formed on short shoots. Young fruits are characterised by a strong anthocyanin colouration (Fig. 2).

***Figure 2**. Young fruits of the domestic apple cultivar Dozhnytsia*
***Source:** photographed by the authors*

The fruits are medium in size, height, and diameter. The calyx lobe is long. The calyx is of medium size. The skin colour is whitish-yellow with a dominant red hue and a continuous blush with weakly distinguished stripes. The bloom on the skin is absent or weak. The area of russeting around the peduncle, cheeks, and calyx is absent or small. The peduncle is medium in length and thickness. The flesh is firm in texture and cream in colour. Notably, the Dozhnytsia cultivar demonstrates drought resistance (9 points), winter hardiness (8 points), and resistance to powdery mildew and apple scab (8-9 points).

The Reinette Symyrenko cultivar is characterised as a tree with a height of 4.3 m (on rootstock mm 106). The skeletal branches of the lower tier are strong and diverge from the trunk at an angle of about 60°, while the branches of the upper tier are almost at a right angle. The bark of the skeletal branches and the trunk is dark grey. Biometric analysis of shoots, leaves, and fruits revealed that the shoots are straight, of medium thickness, with green-brown bark covered with small, few lenticels. The annual shoot growth is 40-60 cm. The leaves are glossy, finely serrated at the edges, light green in colour, elongated-ovoid in shape, and bent in the shape of a boat at a sharp angle (Fig. 3).

For the plants of this cultivar, the flowering phase occurs during the end of the second and the beginning of the third decade of May. Notably, the flowers are large or above average in size, with white petals. Fruits form on spurs and fruit spurs, depending on the tree's load, and are large or medium in size, regularly round or flat-rounded or rounded-conical in shape with a smooth surface, deep green or light green (at technical maturity), with a slight blush on the sunny side. The average fruit weight is 142 g. Over the years 2018-2021, the fruit weight was 93 g, 195 g, 156 g, and 126 g, respectively. The fruit skin is thin, and light green in colour with warty formations and numerous white dots, which is characteristic of this cultivar. The apple flesh is tender, firm, juicy, white with a greenish tint, wine-sweet, with a pleasant spicy aftertaste. Under the conditions of the Northern Forest-Steppe of Ukraine, the technical maturity of Reinette Symyrenko fruits occurs

in the second and third decades of September. Reinette Symyrenko apple trees are also characterised by high drought resistance and wind resistance, early fruiting, and high yield.

***Figure 3**. Reinette Symyrenko plants during the phenophase of fruit ripening*
***Source:** photographed by the authors*

The studied plants of the Jonagold cultivar are characterised as fast-growing trees grafted onto the 54-118 rootstock. As a result, they grow and develop without support, reaching a height of 2.5 metres due to formative crown pruning. In commercial orchards, trees of this cultivar can grow up to 4.5 metres tall. The bark of the trunk and skeletal branches is grey-brown. The crown is spreading, medium-dense, broadly oval in young trees, and rounded in 10-year-old trees. The skeletal branches extend from the trunk at an angle of 30°. One-year-old shoots have high growth vigour and are of medium thickness. The leaves are light green with a yellow tint and oval in shape. A notable feature of the leaves is their tendency to remain on the branches for an extended period in autumn. The flowering phase occurs in the second decade of May. The flowers are fragrant, large, with white or pale pink petals, and form on spurs, fruit spurs, and one-year-old growths. Apples mature in late September to early October. The fruits are round or slightly elongated with slight ribbing in the calyx area. The apple skin is shiny with a characteristic waxy bloom, smooth, elastic, of medium thickness, greenish-yellow with a blurred, striped blush of orange or red colour, covering more than 50% of the fruit surface (Fig. 4). The flesh of the fruit is yellowish, juicy, firm, granular, crisp, sweet with a slight acidity, and exhibits excellent taste qualities (rated 4.6 on a 5-point scale). The average fruit weight in the experiment was 159.5 g (Table 7).

***Figure 4**. Jonagold plants during the phenophase of fruit ripening*
***Source:** photographed by the authors*

***Table 7**. Morphological characteristics of various Malus species (cultivars), average for 2019-2021*

Species (Cultivar)	Fruit weight, g	Peduncle length, mm	Number of seeds per 1 fruit, pcs.	100-seed weight, g
Malus baccata (L.) Borkh.	25.5	17	10	3.9
Malus prunifolia (Willd.) Borkh.	0.7	31	6	0.8
Malus cerasifera Spach.	4.9	26	8	2.2
Malus hibridus (Red Sentinel)	1.8	20	6	1.8
Malus silvestris (L.) Mill.	3.2	26	7	2.8

Table 7. Continued

Species (Cultivar)	Fruit weight, g	Peduncle length, mm	Number of seeds per 1 fruit, pcs.	100-seed weight, g
Malus domestica Borkh. (Reinette Symyrenko)	159.5	23	9	3.5
Malus domestica Borkh. (Jonagold)	142.5	12	12	3.6
Malus domestica Borkh. (Dozhnytsia)	165.5	19	11	3.8

Source: *developed by the authors*

Plants of the Siberian crab apple, *Malus baccata* (L.) Borkh. var. *baccata*, are typically tall trees (around 6.6 m) and are estimated to be around 15 years old. However, they often form a wide, semi-spherical shrub with branched limbs. The crown is almost oval in shape. The bark of the trunk and main branches is grey or grey-black, while that of two-year-old branches is red-brown, purplish-brown, or brown. The buds are reddish-brown, ovoid, around 3 mm in size, and covered in scales. The annual growth of shoots is above average. The leaves are simple and entire, oval or ovate with a wedge-shaped base and serrated to crenate margins, and are green and glossy (turning yellow, yellowish-brown, or light orange in autumn). They are approximately 6.5 cm long and 3.5 cm wide (with a range of 1.8-10.5 cm by 0.7-6.2 cm). The average petiole length is 2.4 cm. The inflorescence is umbellate, consisting of 3-5, rarely 4-8 flowers. The pedicel is about 2.5 cm long and is initially downy but later becomes glabrous. The petals are 1.3 × 0.7 cm, white or light pink, and obovate. There are approximately 15-17 stamens per flower, and the gynoecium consists of five carpels with a lower ovary.

Flowers are self-pollinating. It is worth noting that flowers are often visited by flying insects, primarily bees. The flowering phase falls at the end of the first – beginning of the second decade of May. The fruit is a somewhat spherical-elongated pome, about 1 cm long with a stalk up to 2.5 cm long. The fruit skin is initially green, and at technical maturity – yellow or dark yellow. The flesh is edible but sour. The seeds are yellow-brown, semi-spherical, measuring 0.7 × 0.6 cm, and are located in a papery core. The phase of technical ripeness is extended in time – from the end of August to the beginning of September, and the fruits remain on the branches throughout the winter period. It has been found that Siberian crab apple plants are photophilous (although they can tolerate partial shade), moderately hygrophilous, winter-hardy and drought-resistant (8-9 points), and are little susceptible to pathogens, but are damaged by leaf-eating pests (mainly leaves suffer). Having evaluated the ornamental value of Siberian crab apple plants, they are recommended for extensive use in landscaping. These plants are suitable as specimen trees (solitaires), in group plantings on lawns, in mixed compositions with coniferous species, or for creating hedges and alley plantings.

In the "Teremky" tract of the Fastiv District of Kyiv Region (2 km from the Institute of Horticulture of the NAAS of Ukraine), European wild apple trees were studied. It was found that these plants, in terms of their biomorph, are deciduous trees with numerous shoots, reaching a height of about 11 meters. Their crown is irregular, rounded, and broad. The trunk diameter is about 40 cm. The bark of the trunk and skeletal branches is greyish-brown with spots, while that of twoyear-old branches is light brown. Some specimens were distinguished by a branched crown, very knotty and twisted branches, on which numerous thorns were recorded. Others, in terms of biomorph, represented a semi-shrub with a dense crown up to 3 meters in diameter. Vegetative buds are brown and pointed. Leaves are simple, oval or rounded-oval with a pointed apex, green and glossy, up to 5.7 cm long with rounded teeth along the edges, formed on short petioles, with characteristic pubescence at the base. The flowering phase falls in the second decade of May. The flowers are fragrant, medium-sized, with pink-white perianth, and the stigmas mature 2-4 days earlier than the anthers. The sepals are relatively narrow, elongated, and close together. The flowers are often visited by pollinating insects.

The fruits are small apples, less than 4 cm in diameter, often with a wrinkled, yellowish-green rough skin, sometimes covered with white or red spots. The core of the fruit is small, and the calyx and base are shallow. The apples ripen in early September. The flesh is greenish, and very sour with a bitter aftertaste (due to the high tannin content). It is noteworthy that European wild apple trees are highly winter-hardy, drought-resistant, and shade-tolerant. The plum-leaved apple is a deciduous tree, reaching a height of 4.3 meters. The bark of the trunk and main branches is greybrown, while that of two-year-old branches is greyish-brown with a purple hue and downy, a characteristic also found on one-year-old shoots. The buds are bright brown and slightly downy. The leaves are ovate or elliptic, measuring 6.8 × 4.3 cm, with a pointed apex and sharply serrated margin, resembling plum leaves. Young leaves have downy hairs along the veins, while older leaves are almost hairless. The leaf stalk is, on average, 3 cm long (occasionally up to 5 cm). A characteristic feature is the presence of lanceolate, small stipules up to 5 mm long, pointed at the apex, which eventually fall off. The flowers are arranged in umbellate inflorescences of 4-10 flowers. The flowers are up to 5 cm in diameter and located on downy pedicels no longer than 3.5 cm. The petals of the perianth are white or light pink, obovate or elliptic with a rounded apex, and 2.5 cm long. The stipules are linear-lanceolate, membranous, and slightly

downy, unlike the lanceolate or triangular-lanceolate sepals (about 8 mm long), which eventually fall off. There are 20 stamens per flower. The flowering phase begins in the first decade of May.

The fruits are round or slightly egg-shaped, small, up to 2.2 cm in diameter, with a greenish-yellow skin (with a blush on the sunny side). In the Northern Forest-Steppe of Ukraine, the fruits reach technical maturity in the first decade of September. Notably, the apples, clustered in groups of 3-7, remain on the tree until late autumn or even the end of winter, serving as a food source for resident and migratory birds. It is worth noting that plum-leaved apple trees exhibit high frost and winter hardiness. The cherry crab apple tree, a complex hybrid (*Malus prunifolia* × *Malus baccata*) commonly found in cultivation, is a tall tree (over 4.5 m) with a loose and broad crown, reaching a diameter of 3.5 m. The leaves are simple, about 7.5 cm long, oval, ovate or elliptical in shape, with a rounded or slightly pointed apex and a serrated margin. Notably, the veins of the leaf are downy. The petioles are 3-3.5 cm long. In autumn, the leaves turn yellow or yellowish-grey. Leaf fall occurs in the second decade of October.

Incidentally, the generative buds open before the vegetative buds. Therefore, the fragrant flowers with pale pink or white petals are the first to adorn the branches abundantly. It should be noted that the sepals fall off. The fruits are small apples, 1.5-2 cm in diameter, with yellow or dark yellow skin with a blush at technical maturity. The average fruit weight was 1.8 g, although fruits weighing 2.3 and 2.5 g were found. It was noted that in some years (2019), one-year-old shoots suffered significantly from the green apple aphid (*Aphis pomi* Deg.) and the apple sucker (*Psylla mali* Schmdb.), but they showed high winter hardiness and resistance to apple scab. The hybrid apple cultivar Red Sentinel grows to a height of 2.5 m and is characterised as an upright tree, though it can occasionally take the form of a shrub. The tree's crown is spreading and branched, about 2 meters in diameter, and oval or egg-shaped, although pruning can change it to an asymmetrical shape. The annual growth of shoots is vigorous. Incomplete shoots are susceptible to frost damage but can regenerate intensively in spring.

The leaves are simple, oval or ovate, green, often with red hues, turning yellow-red and red in autumn. The buds are light pink, and the petals are pale pink or pink. The flowers reach a diameter of 3 cm. The flowering phase falls at the end of the second or third decade of April. The variety is self-fertile and is a good pollinator for self-infertile cultivars of the domestic apple (such as Ligol, Early Geneva, Champion, Jeromini, Polka, Piros, and others). The fruits are round, small, up to 4 cm in diameter, with dark yellow or orange skin with a blush (on the sunny side). The fruit stalks are 2-2.7 m long with a characteristic anthocyanin colouration. The apples are edible (can be consumed fresh or processed), ripen in the second decade of September, and remain on the branches for a long period. It is worth noting that during flowering, the hybrid apple resembles a Japanese cherry, emphasising its high ornamental value.

It should be noted that plants of this species prefer moist conditions but suffer from waterlogging, especially on clay soils. They respond well to mineral and organic fertilisers and sunlight, although they can also grow well in shade. Overall, the Red Sentinel variety prefers welldrained, moderately moist, fertile soils. Based on an evaluation of the ornamental qualities of the Siberian crab apple, it is recommended to plant these trees in parks, gardens, and squares either as solitary specimens or in group plantings as part of larger landscape compositions with trees and shrubs of other species. Additionally, the studied species and cultivars of the genus *Malus* were assessed for seed morphological characteristics (Fig. 5).

Figure 5. *Morphological characteristics of seeds from the studied Malus species and cultivars*
Note: *1 – European wild apple; 2 – domestic apple (cultivar Dozhnytsia); 3 – plum-leaved apple; 4 – Siberian crab apple; 5 – hybrid crab apple; 6 – cherry crab apple*
Source: *photographed by the authors*

As shown in Figure 5, the seed colour of various *Malus* species ranges from light brown to dark brown. Notably, the darkest seeds are found in the hybrid apple, followed by the plum-leaved apple. The seeds of the Siberian crab apple and cherry crab apple are lighter in colour. In terms of seed production, the European wild apple and plum-leaved apple stand out, with 10 and 8 seeds, respectively. Interestingly, the seeds of the wild apple are larger and have a more natural appearance (100-seed weigh 3.9 g), compared to other species.

It is noteworthy that among the studied apple species, some exhibit a "mechanical immunity" to scab, particularly those with a downy underside of the leaf, in

contrast to the smooth surface of cultivated varieties like Reinette Symyrenko and Jonagold. Another characteristic of the plumleaved apple, Siberian crab apple, and cherry crab apple is the thickened and tough leaf blade and petiole, which acts as a buffer against apple scab. The causal agent of apple scab is the ascomycete fungus *Venturia inaequalis* (Cooke) Wint. (in the conidial stage – *Fusicladium dendriticum* (Walr.) Fuck.), which infects several plant genera, including *Pyrus*, *Sorbus*, and *Cotoneaster*, but is primarily associated with *Malus* species. Initial signs of scab on apple trees were observed on leaves and fruits, and in rainy weather, the disease also affected flowers and young fruits. Although apple scab rarely kills the plant, it can cause up to 70% yield losses, posing a significant risk to apple producers. To reduce yield losses associated with this disease, chemical and biological fungicides are applied, and immune cultivars (such as Goldrush, Prima, and Jonafree) are being developed, most of which were created through controlled crosses between cultivated varieties and wild *Malus* species, especially those from East Asia.

It was found that apple scab manifests on leaves as round spots that eventually turn dark grey with a characteristic olive-velvety fungal spore coating. Notably, in the absence of precipitation, these spots have a diameter of 0.5-15 mm, but under high humidity (rainy conditions), they merge into a continuous dark grey coating. For example, the Reinette Symyrenko cultivar was observed to be more susceptible to scab during bud break, flowering, and fruit set. The first signs of scab on leaves usually appear at the end of apple blossom, while on fruits, the disease becomes evident in late June-July, particularly in dense, poorly ventilated plantings, and with high crown density. In 2019, the first signs of apple scab on leaves were noted at the end of April, and on fruits at the beginning of the third decade of May. In contrast, during 2018 and 2021, the initial symptoms on leaves were observed in late May to early June (Fig. 6).

***Figure 6**. Example of scab-affected leaves of the Reinette Symyrenko apple cultivar during the second and third decades of May*
***Note:** 1 – 12 May; 2 – 19 May; 3 – 25 May; 4 – 31 May*
***Source:** photographed by the authors*

The harm caused by apple scab lies in premature leaf fall (infected leaves begin to fall during July-August). The scab fungus overwinters in the ascospore stage on infected leaves and as mycelium in the bark tissues of infected branches. Notably, leaf loss reached about 40%, which is inextricably linked to the suppression of one-year-old shoot development, specifically by reducing their resistance to adverse abiotic environmental factors (current year's growth does not mature before the cessation of sap flow and suffers from low and high temperatures). On fruits of certain cultivars (Reinette Symyrenko) of the genus *Malus*, scab manifests as dark grey round spots of varying sizes – from small, a few millimetres in diameter, to large, diffuse spots up to 0.3-2 cm in diameter (Fig. 7).

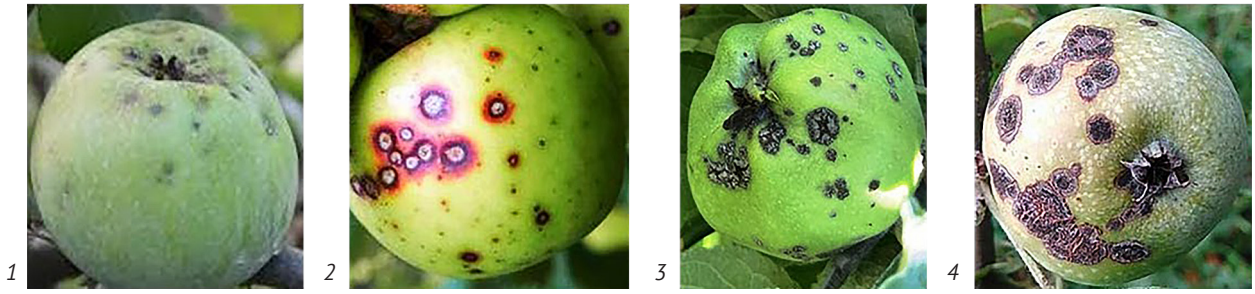

***Figure 7**. Fruits of the Reinette Symyrenko cultivar exhibiting varying degrees of scab-affected surface areas*
***Note:** the maximum permissible level of apple scab development on fruits is no more than 5%*
***Source:** photographed by the authors*

At the sites of scab infection, the outer layer of the fruit, represented by the skin, is destroyed, and the surface tissue of the middle layer becomes corky, which subsequently limits the penetration of the pathogen into the middle and inner layers of the fruit. However, this does not prevent the uneven growth of the fruits, resulting in their deformation and cracking (which reduces the marketability of the fruits), followed by rotting and dropping (Fig. 8). It should be noted that in 2020, the infection of developed fruits by the apple scab pathogen resulted in up to 35% fruit damage, while in 2019 and 2021, it was up to 18% (Table 8).

***Figure 8**. Cracked and deformed fruits infected with apple scab*
***Source:** photographed by the authors*

***Table 8**. Scab infection of leaf and fruit surfaces concerning plant species (cultivars), % average for 2018-2021 (n = 5)*

Species (Cultivar)	Percentage of surface infection	
	Leaves	Fruits
Malus baccata (L.) Borkh.	12	18
Malus prunifolia (Willd.) Borkh.	5	2
Malus cerasifera Spach.	0	0
Malus hibridus (Red Sentinel)	4	0
Malus silvestris (L.) Mill.	0	0
Malus domestica Borkh. (Reinette Symyrenko)	0	0
Malus domestica Borkh. (Jonagold)	15	10
Malus domestica Borkh. (Dozhnytsia)	10	7

***Source:** developed by the authors*

The table shows that different species (cultivars) of the genus *Malus* have varying percentages of leaf and fruit surface affected by the disease, indicating different levels of resistance to the apple scab pathogen. It was found that *Malus prunifolia* (Willd.) Borkh., *Malus hibridus* cultivar Red Sentinel, and *Malus domestica* Borkh. cultivar Dozhnytsia were immune, as the percentage of surface affected by apple scab was zero. It is worth noting that the high resistance of the earlywinter cultivar Dozhnytsia to apple scab is associated with the presence of the scab resistance gene *Malus floribunda* 821 Vf (Fig. 9).

***Figure 9**. Fruits (apples) of the Dozhnytsia cultivar, immune to apple scab*
***Source:** photographed by the authors*

Incidentally, the Dozhnytsia cultivar is part of a group of other apple cultivars immune to scab developed by the Institute of Horticulture of the NAAS of Ukraine (Harant, Edera, Amulet, Skifske zoloto, Perlyna Kyieva, etc.), which have been included in the State Register of Plant Varieties suitable for distribution in Ukraine since 2006 (Boldyzheva, 2020). It is characterised by a very compact crown, harvest maturity in the second decade of September, high yield (fruits weighing 165 g, yield – 41.3 t/ha, with an average yield per tree of about 25 kg), but a tendency to overload.

Returning to the tabular data, it can be seen that for *Malus baccata* (L.) Borkh., a low level of fruit infection (up to 5%) was observed. Similarly, low levels of leaf scab infection (up to 15%) were observed for *Malus silvestris* (L.) Mill. and *Malus domestica* Borkh. cultivar Jonagold (a latewinter cultivar of American selection, developed in 1943 at the Geneva Experiment Station, New York). *Malus silvestris* (L.) Mill. and *Malus domestica* Borkh. cultivar Reinette Symyrenko exhibited a moderate level of fruit infection, with more than 15-18% of the fruit surface affected by scab spots. A comparison of the studied species (cultivars) of the genus *Malus* for resistance to apple scab prompted an evaluation

of their ornamental qualities. To assess the ornamental value of apple trees, the following criteria were considered: crown habit, leaves (colour, leafiness), flowers (size, petal colour), and fruits (size, colour), taking into account the level of surface infection by the scab fungus (Table 9). Based on the tabular data, nearly all studied species (cultivars) received the maximum score for crown decorativeness, except for *Malus silvestris* (L.) Mill., as its plants had grown for about 3 years in natural conditions under severe compaction. The European wild apple, Siberian crab apple, plum-leaved apple, and hybrid crab apple were characterised by high leafiness, elegance, and a pleasant range of green leaf colours, receiving the maximum score (5). The plum-leaved apple received only 3 points for leaf decorativeness, as it did not evoke a high emotional response. For the studied cultivars of domestic apple, leaf decorativeness was reduced to 4 points due to the high abundance of fruits. In terms of flower decorativeness, the maximum score (5) was obtained by the wild apple, cherry crab apple, hybrid crab apple, and the domestic apple cultivar Dozhnytsia (Fig. 10).

***Table 9**. Ornamental assessment of Malus species (cultivars)*

Species (Cultivar)	Criteria, points					Overall ornamental rating, points
	I	*II*	*III*	*IV*	*V*	
Malus baccata (L.) Borkh.	3	5	4	4	4	4.0
Malus prunifolia (Willd.) Borkh.	5	5	5	5	5	5.0
Malus cerasifera Spach.	5	5	4	3	4	4.2
Malus hibridus (Red Sentinel)	5	3	5	4	5	4.4
Malus silvestris (L.) Mill.	5	5	5	5	5	5.0
Malus domestica Borkh. (Reinette Symyrenko)	5	4	5	5	4	4.6
Malus domestica Borkh. (Jonagold)	5	4	5	4	4	4.4
Malus domestica Borkh. (Dozhnytsia)	5	4	5	5	5	4.8

***Note:** I – crown ornamentation; II – leaf ornamentation; III – flower ornamentation; IV – fruit ornamentation; V – resistance to apple scab*
***Source:** developed by the authors*

***Figure 10**. Studied Malus species (cultivars) during the flowering phase*
***Note:** 1 – Malus baccata (L.) Borkh.; 2 – Malus hibridus (Red Sentinel); 3 – Malus cerasifera Spach.; 4 – Malus silvestris (L.) Mill.; 5 – Malus prunifolia (Willd.) Borkh.; 6 – Malus domestica Borkh. (Jonagold); 7 – Malus domestica Borkh. (Dozhnytsia); 8 – Malus domestica Borkh. (Reinette Symyrenko)*
***Source:** photographed by the authors*

For the remaining studied species (cultivars) of apples, flower decorativeness was at the level of 4 points, particularly for the Reinette Symyrenko cultivar, which was associated with the manifestation of apple scab. The fruits of the Dozhnytsia cultivar were distinguished by their large size, colours, and shape against the background of leaves and crown, which contributed to increased overall decorativeness. The miniature,

beautiful in colour, shape, and numerous fruits of *Malus baccata* (L.) Borkh., *Malus cerasifera* Spach., and *Malus hibridus* (Red Sentinel) provided high decorativeness to the plants. In summary, the berry apple and hybrid apple had the highest overall decorativeness (5 points). Among the domestic apple cultivars, the Dozhnytsia cultivar also received a high decorativeness score (4.8). For other studied species (cultivars) of the genus *Malus*: *Malus silvestri*s (L.) Mill., *Malus prunifolia* (Willd.) Borkh., *Malus cerasifera* Spach., *Malus domestica* Borkh. (Reinette Symyrenko), and *Malus domestica* Borkh. (Jonagold), the decorativeness score was above average – 4.0; 4.2; 4.4; 4.4, and 4.6, respectively.

DISCUSSION

Plants of the genus *Malus* exhibit varying levels of susceptibility to fungal and bacterial infections, viruses, mycoplasmas, and nematodes. Notably, over 70 pathogens of fungal diseases affecting domestic apple trees have been identified. Furthermore, it is known that pathogens, pest damage, and various abiotic factors are the primary causes of significant damage to apple trees. Overall, apple trees are considered long-lived plants, with the average lifespan of domestic apple trees being 50-60 years, and in some cases exceeding 100 (Reig *et al.*, 2019). Interestingly, the lifespan of domestic apple trees on seedling rootstocks exceeds 30 years, and on vegetative rootstocks up to 20 years or more, but this also depends on crown formation and pruning methods and timing, which influence fruit growth and quality (Kviklys *et al.*, 2022).

According to A. Chaploutskyi and R. Butsyk (2023), the most recognised *Malus* species include: *Malus angustifolia*, *Malus asiatica* (Chinese pearleaf crab apple), *Malus baccata* (Siberian crab apple), *Malus baccata* var. *baccata* (Chinese crab apple), *Malus baccata* var. *mandshurica* (Manchurian crab apple), *Malus coronaria* (Sweet crab apple), *Malus doumeri*, *Malus florentina* or *Malus floribunda* (Japanese flowering crab apple), *Malus fusca* (Oregon crab apple), *Malus halliana* or *Malus ioensis* (prairie crab apple), *Malus niedzwetzkyana* (Niedzwetzky's apple), *Malus orientalis* (eastern crab apple), *Malus prunifolia* (plum-leaved apple), *Malus pumila* (domestic apple), *Malus sargentii* (Sargent crab apple), *Malus sieboldii* (Siebold's crab apple), *Malus sieversii* (large-fruited apple), *Malus sylvestris* Mill. (European crab apple or European wild apple), *Malus sylvestris* var. *praecox* (Pall.) Borkh. (early crab apple), *Malus toringoides* (cut-leaf crab apple), and *Malus pumila* (domestic apple).

In Ukrainian forests, species such as the European wild apple (*M. sylvestris*) and early crab apple (*M. praecox*) can be found. The former is typically a tall tree (up to 10 meters) with smooth leaves, while the latter is also a tree, but smaller (up to 5 meters) with hairy undersides to its leaves. According to A. Arnal *et al.* (2022), the cultivated range of apple trees is constantly expanding. Biologically, members of the genus *Malus* are typically trees, occasionally large shrubs, characterised by alternate, petiolate, simple or lobed leaves, and early-shedding stipules. Flowers are perfect, white, pink, or red, and arranged in corymbs or umbels. There are five sepals and five petals. There are 20-50 stamens. The ovary is inferior, five-chambered, with two ovules in each chamber, from which seeds with a dark brown coat develop. There are five styles, fused at the base, less commonly nearly free, and mostly hairy. The fruit is a pseudocarp (apple), fleshy, most often globose, depressed at the ends, with flesh lacking stone cells (Kondratenko & Kuzminets, 2018; Hulko, 2020).

According to Z. Chen *et al.* (2021), most cultivated apple varieties (subspecies, cultivars), numbering over 20,000 known worldwide, are classified within the complex cultigen species *M. domestica*, which has a complex hybrid origin due to extensive breeding and nursery practices. The large-fruited apple (*Malus sieversii* (Leded.) M. Roem., 1847), predominantly found in southeastern Kazakhstan, is the sole ancestor of most domestic apple cultivars developed over the past 2,000 years, except a few cultivars resulting from hybridisation between the crab apple and the Japanese flowering crab apple (*Malus floribunda* Siebold ex Van Houtte, 1865). T. Davies *et al.* (2021) reported that only five parental cultivars – McIntosh, Jonathan, Red Delicious, Golden Delicious, and Cox's Orange Pippin – were involved in the creation of 60% of the 439 commercial cultivars examined.

According to M. Ruhsam *et al.* (2022), the European wild or crab apple (*Malus sylvestris* (L.) Mill., 1768) is a wild species native to Europe and grows as a tree. The genome of this species is largely derived from the Central Asian wild apple (*Malus sieversii*). Another species, Siebold's crab apple (*Malus toringo* Siebold), is a small tree or shrub with light pink flowers and orange fruits, 6-8 mm in diameter. This species is used in ornamental horticulture and, less commonly, as a rootstock for apple trees (Lou *et al.*, 2020). Similar arguments can be made for other species. For instance, the plum-leaved apple or Chinese apple (*Malus prunifolia* (Willd.) Borkh., 1803) has a hybrid origin, forming ovate or elliptic leaves and small red fruits (5 cm in diameter), and is native to China. It is used as an ornamental tree, rootstock, and as a parent in breeding programs. Notably, this species has been used to develop frost- and winter-hardy, large-fruited (up to 200 g), and high-quality cultivars such as Pepin Shafrannyi, Kytaika Zolota early, and Belfler-kytaika (Li *et al.*, 2022).

According to X. Chen *et al.* (2019), the Siberian crab apple (*Malus baccata* (L.) Borkh, 1803), native to North Asia (China, Mongolia, etc.), has ornamental qualities due to its numerous white fragrant flowers, grouped in clusters of 4-6, and spherical, cherry-like red-yellow fruits. It is important to note that the seeds of this species are considered toxic due to their high content of hydrocyanic acid. These plants are characterised by

their undemanding nature regarding soil types and light conditions, high frost resistance, and resistance to fungal diseases. Despite their small fruits, they are sometimes used in hybridisation programs to create promising forms of domestic apple. The Siberian crab apple is also a good pollinator for all species of the genus *Malus*, as its plants have a longer flowering period. On the other hand, the Japanese flowering crab apple (*Malus floribunda* Siedold ex Van Houtte), native to China and Japan, as noted by scientists from the L.P. Simirenko Horticulture Research Station of the IH NAAS of Ukraine, V. Voloshina and V. Gomenyuk (2021), is a natural species or a hybrid of Siebold's crab apple (*Malus toringo* Siebold or *Malus sieboldii* Rehder) and *Malus baccata*. It produces beautiful pink flowers and red apples. The aforementioned authors emphasise that *Malus floribunda* Siedold ex Van Houtte is a frost-resistant species of apple, capable of withstanding temperatures as low as -25°C, and is moisture-loving, with low susceptibility to powdery mildew, scab, and bacterial blight. Therefore, in addition to its ornamental value (including in bonsai culture), this species is widely used in hybridisation to create cultivars of commercial importance (such as the cultivars Ariane and Evereste).

Many species of the genus *Malus* are used in ornamental gardening. These include the narrow-leaf crab apple (*Malus angustifolia* (Aiton) Michx, 1803), native to the southeastern United States, which is a tree with highly fragrant flowers and fruits (Mansfeld *et al.*, 2023), and the transitional crab apple (*Malus transitoria* (Batalin) CK Schneid, 1906), found in China, growing as a 7-8-meter-tall tree with light pink flowers and dark yellow or orange fruits (Guo *et al.*, 2022). Additionally, Niedzwetzky's apple, which has been used in hybridisation with small-fruited apple species to create ornamental forms, should be considered. As noted by V. Mezhenskyj and L. Mezhenska (2021), the dominant gene controlling anthocyanin pigmentation in apples originated from *Malus niedzwetzkyana* Dieck ex Kohne, 1891, which is used in colourful compositions and as a solitary plant on lawns or as a hedge. On the other hand, the shrubby crab apple (*Malus brevipes* Render) is represented by only one cultivar in cultivation, and its origin is unknown. However, in breeding programs, more domesticated species are often used, such as the Chinese pearleaf crab apple (*Malus asiatica* Nakai, 1915), which is widely distributed in northern and northeastern China and has been cultivated for a long time. According to researchers B. Liu *et al.* (2019), this species is a tree with ovate or elliptic leaves, light pink petals, red pollen, and spherical yellow fruits with a blush or yellow-green skin and a fragrant, refreshing flesh. Another long-domesticated species is the eastern crab apple (*Malus orientalis* Uglitzk), which, according to Ł. Walas *et al.* (2024), is distributed across a significant area of Turkey, through the Caucasus to the mountain ecosystems of Iran.

However, the most popular species is the domestic or cultivated apple (*Malus domestica* Borkh., 1803) (Brite, 2021), one of the most widespread species of the genus *Malus*. It is believed that the centre of origin of the domestic apple is Central Asia (where its ancestor, *Malus sieversii*, can still be found) due to the genetic diversity of samples found there. A. Kumar *et al.* (2022) report that over 7,500 cultivars of this species are cultivated worldwide, varying in yield and plant habit, and are propagated by clonal grafting onto rootstocks. Depending on their intended use, they are grown for fresh consumption, processing, and the production of juices, beverages, jam, jelly, dried products, and more. According to D. Maharani and T. Mursitama (2023), global apple production in 2023 amounted to 83 million tonnes, with almost half (47%) of total production coming from China. A. Olivares *et al.* (2020) report that domestic apple cultivars are diploid in terms of ploidy (although triploid cultivars such as Rhode Island Greening, Cortland, Jonathan, Crispin (Mutsu), and Spur Gold exist, producing sterile pollen and requiring pollinator cultivars), and have 17 chromosomes (allopolyploid 2n = 2x = 34), with a complete genomic complex.

It is worth noting that apple cultivars are cross-pollinated and are sometimes classified based on their peak bloom day within a 30-day blooming period. Depending on the climate, there are 4 to 7 pollination groups for the domestic apple: A – early bloom, e.g., between 1-3 May; B – early midseason, 4-7; C – mid-season, 8-11; D – late mid-season, 12-15; E – late, 16-18; F and H – very late, between 19-23 and 24-28 May, respectively. Pollinators are selected from cultivars within a 6day overlap period. Compatible pollination for a given cultivar occurs with the same or a nearby group (A with A or A with B, but not A with C or D). O. Havryliuk *et al.* (2023) consider Golden Gem and Professor Springer to be universal pollinators for columnar apple cultivars. In general, commercial apple production relies on pollinators, and their contribution to apple production is significant. Among pollinator plants, *Malus sylvestris* (L.) Mill. is an important species. Overall, apple species diversity has further decreased due to the use of a limited number of desirable specimens in breeding programs (Mbovora *et al.*, 2021).

In summary, the close attention of scientists and researchers to members of the genus *Malus*, the search for and selection based on productive, morphological, physiological, and biochemical characteristics, and the identification of economically valuable species (forms, cultivars) in the creation, distribution, and evaluation of new genetic diversity that meets the modern requirements of horticultural and landscape management systems remain relevant.

CONCLUSIONS

An integrated scale has been proposed to assess species (cultivars) of the genus *Malus* based on their overall

ornamental value, which includes five indicators: crown attractiveness, leaf attractiveness, flower attractiveness, fruit attractiveness, and resistance to apple scab. Based on the developed scale, a comparative assessment of a group of ornamental apple species (cultivars) or crabapples was conducted based on morphological, biological, and physiological characteristics, which is important for the priority directions of fruit and ornamental horticulture in the conditions of the Northern Forest-Steppe of Ukraine.

To expand the genetic diversity of tree stands in ornamental and fruit gardening systems, it is recommended to introduce crab apple cultivars (forms) characterised by a small above-ground part, decorative habitus, including the size and colour of leaves, flowers, and fruits, increased immunity to fungal pathogens, and versatile pollinator plants, which contributes to the formation of effective garden ecosystems. Morphological studies have shown that crab apple cultivars, compared to cultivars of the domestic apple, are characterised by weak (<15-20 cm/year) or moderate (>21-25 cm/year) growth and a compact crown, anthocyanin leaf colouration (*Malus hibridum*), white, light pink, and pink petals, small fruits (< 5 cm in diameter) with long stalks (>2 cm), high male fertility, a longer flowering period (>14 days), and fruit retention on branches, as well as undemanding growth conditions.

It has been found that, in terms of fruit size, in addition to cultivated cultivars, the European wild apple stands out, with an average fruit weight of 25 g, while the Siberian crab apple (0.74 g), cherry crab apple (1.8 g), and plum-leaved apple (4.9 g) have small fruits. It has been shown that the largest fruits, weighing over 100 g, belong to the cultivars Reinette Symyrenko, Jonagold, and Dozhnytsia, which are characterised by high taste qualities. It has been noted that crab apple cultivars are characterised by weak or moderate growth and a compact crown, undemanding growth conditions, and disease resistance, making them promising tree resources for the formation of ornamental gardening systems, park forestry, and shelterbelt afforestation.

Among the studied cultivars of the domestic apple, it is recommended to cultivate the immune and high-yielding cultivar Dozhnytsia, bred by the Institute of Horticulture of the NAAS of Ukraine, which will allow reducing or avoiding the chemical control of scab and contribute to obtaining environmentally friendly and inexpensive fruits (plantations of such cultivars can reduce fungicide costs by up to 70%).

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CONFLICT OF INTEREST

None.

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Біоекологічні особливості представників роду *Malus* в контексті перспективних напрямків садового і лісопаркового господарств

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Анотація.Мета дослідження полягала в порівняльному оцінюванні представників роду Malus за морфологічними ознаками, біологічними особливостями, фізіологічними механізмами стійкості до збудників грибних хвороб, декоративністю й значимістю в системі садового, лісопаркового господарства, полезахисного лісорозведення. На основі комплексного підходу охоплено морфологічні ознаки і біологічні особливості яблуні домашньої, яблуні лісової, яблуні ягідної, яблуні гібридної, яблуні сливолистої, а також проведене порівняльне вивчення специфіки ураження та стійкості рослин видів роду *Malus* до збудників парші плодів та інших хвороб. Показано, що яблуня домашня характеризуються крупноплідністю (середня маса плоду складає не менше 150 г), тоді як для яблуні ягідної, яблуні вишнеплідної і яблуні гібридної середня маса плоду не більше 0,7, 1,8 і 3,2 г відповідно. Авторами статті розроблено інтегральну шкалу для порівняльного оцінювання видів (сортів) або crabapple роду *Malus* за загальним показником декоративності рослин, який включає 5 критеріїв: декоративність крони; листків; квіток; плодів та стійкість до парші рослин яблуні. Вперше проаналізовано плоди різних видів роду *Malus* за насіннєвою продуктивністю, серед яких виокремлено креби, зокрема яблуню лісову і яблуню сливолисту середня кількість насінин у плоді яких найбільша і становить 10 і 8 насінин, відповідно. Також показано, що плоди яблуні лісової характеризуються крупністю насіння (маса 100 насінин > 3,9 г). Висвітлено результати, які підтверджують декоративну цінність окремих представників роду *Malus*, а саме яблуні ягідної і яблуні гібридної, рослини яких характеризуються найвищим загальним балом 4,5 і 5, порівняно з яблунею лісовою, яблунею вишнеплідною і яблунею домашньою, які мали нижчий бал за декоративністю 3,2-3,9. Зазначено, що рослини креби (*Malus silvestris* (L.) Mill., *Malus baccata* (L.) Borkh. та інші) доцільно використовувати формуванні лісопаркових ландшафтів. В умовах Північного Лісостепу України диференційовано види яблуні за резистентністю до збудника парші (*Venturia inaequalis* Cooke), при цьому встановлено, що рослини яблуні домашньої (сорту Дожниця), яблунь гібридної і сливолистої є високостійкими до вищезазначеного збудника, який уражує листя і плоди. Практичне використання отриманих результатів полягає в доповненні сучасними даними інформаційної бази представників роду *Malus*, що дозволить їх використовувати в різних тематичних дослідженнях

Ключові слова: *Malus*; морфологія; фізіологія рослин; стійкість до фітопатогенів; порівняльна оцінка