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Study of adaptive states and variability of phenological development of introduced woody plants of the genus Berberis L. in the conditions of the Altai Botanical Garden

The article considers the features of phenological development and adaptive capabilities of the genus *Berberis* L. during primary introduction in the conditions of the Altai Botanical Garden. The characteristics of the origin of the collection taxa of the genus are given; the taxonomic composition of the collection fund of the genus *Berberis* L. as of 2025 is verified. The introduced species are divided by soil-geographical origin, where the introduced species are distributed into 5 groups. An introduction assessment of the genus *Berberis* L. is given based on ecological-geographical, morpho-biological characteristics. The adaptive potential of introduced species is assessed based on long-term phenological observations, where the full development cycle is established. Based on the results of the assessment of the prospects of introduced species, two groups of species prospects were identified: promising (83%) of the collection fund and less promising (17%). Based on this assessment, introduced species are recommended for use in phytomelioration, gardening and park construction, as ornamental and fruit crops in Eastern Kazakhstan.

Keywords: introduction, collection fund, genus *Berberis* L., prospects, adaptation, phenological phases.

Introduction

Currently, urbanization of cities is a significant cause of depletion of natural resources, leading to disruption of the ecological balance of plant communities. In this regard, the problem of greening recreational areas and restoring urban ecosystems under the influence of anthropogenic and technogenic activities is acute. The range of such plants is based on their resistance to aggressive environmental conditions and a complex of protective and environment-forming functions.

Plants of the genus *Berberis* L. are universal for landscaping city streets, parks, squares. Numerous representatives of the genus combine decorative, valuable food, medicinal qualities [1]. They are often used to form hedges or borders, creating natural dividing strips and adding a visual accent in green spaces, they can also be planted individually on lawns or combined into decorative groups [2]. These plants are easy to care for, while they have high decorative qualities. The bright berries of the bush attract birds and animals.

The first botanical taxonomy of the genus was compiled at the end of the 16th century by K. Linnaeus and included 2 species—*Berberis vulgaris* L. and *Berberis cretica* L. By the end of the 19th century, the genus already had 150 species. In 1905, the Austrian botanist S.K. Schneider published a monograph with the most complete description of the genus, which included 156 species from 22 sections [3]. According to the research conducted by A. Redder (1949), the genus includes 175 species [4]. According to the latest data from the website The Plant List [5], the genus has about 580 species. Plants of the genus Berberis L. belong to the department MAGNOLIOPHYTA, class MAGNOLIOPSIDA, order BERBERIDALES, family BERBERIDACEAE Juss.

In nature, they are represented by shrubs or small trees with loose, thorny branches and beautiful flowers. Wide geographical distribution of the genus *Berberis* L. (tropical, subtropical, temperate and cold zones) indicates its ancient origin. Paleobotanists note leaf imprints in layers dating back to the Oligocene and Miocene periods of Western Europe and in the Sarmatian deposits of Krynka. Modern centers of species diversity of the genus are located in Southeast Asia (China, the provinces of Sichuan, Yunnan and Southeast Tibet), in Central Asia (the Himalayas) and on the West Coast of South America [6]. The unpretentiousness of the genus and its ability to adapt allowed it to occupy vast territories not only in latitudinal zonality, but also in vertical zonality. Some species grow at an altitude of 4,300 m above sea level (*Berberis diaphana* Maxim.), are mainly deciduous shrubs from Central Asia [2].

The genus *Berberis* L. in the wild flora of Eastern Kazakhstan is represented by two species—*Berberis sibirica* Pall. and *Berberis heteropoda* Schrenk [7, 8]. Expansion of the range of plants for landscaping the cities of the East Kazakhstan region is possible with the involvement of non-regional species.

The aim of the study is to investigate the phenological characteristics and adaptive capabilities of the genus *Berberis* L. under introduction conditions.

Research objectives:

- to verify the taxonomic composition of introduced species of the collection fund of the genus *Berberis* L. in the Altai Botanical Garden;
- to establish the ecological and geographical confinement of the natural growth of introduced species of the genus *Berberis* L.;
- to provide a morphological and biological assessment of the genus under the conditions of introduction;
- to determine the calendar dates of the onset of phenological phases of development of introduced species of the genus for practical application;
- to summarize the results of the initial testing of the genus *Berberis* L. in the Altai Botanical Garden, to assess the prospects of the species for economic use.

In general, representatives of the genus Berberis L. are an important and versatile resource that finds application in various areas of human activity: in medicine, food industry and landscape design.

Objects and methods of research

The object of the research is a collection of the genus *Berberis* L. of the Altai Botanical Garden in the amount of 30 taxa, of which 20 are foreign species, 8 varieties, and 2 local species.

The climate of the introduction area is sharply continental, with characteristic frosty long winters and cool short summers. The mountainous relief softens the sharply continental climate. The average temperature in January is -12.6^0 C, the absolute maximum is 41.6^0 C. The period of active vegetation of plants is short, 69–135 days. The Selyaninov hydrothermal coefficient is within 1.2. Sufficient precipitation with average daily temperatures above 10^0 C during the growing season allows plants to adapt to a temperate climate. The soils of the arboretum are represented by mountain chernozems with a humus content of 4–6%, with a well-defined profile. Along the left edge of the site there is an oxbow lake of the Bystrukha River, which dilutes the chernozems with sandy soils and provides additional soil drainage [9].

Phenological observations of introduced species were carried out according to the Methodology of Phenological Observations in Botanical Gardens of the USSR (1979) [10, 11].

Biometric analysis of shoots was performed according to the method of G.F. Lakin (1990) [12].

Evaluation of the viability and prospects of introduced species based on visual observations using the scale of P.I. Lapin (1973) and M.N. Kosaev (1987) [13, 14].

Evaluation of the introduction value of species of the genus *Berberis* L. will allow to expand the range of products for economic use in Eastern Kazakhstan [15, 16].

Research results and their discussion

Testing of the genus *Berberis* in the Altai Botanical Garden began in 1952. The first taxa were grown from seeds of unknown origin and were represented by species specimens of *B. vulgaris* L., *B. integerrima* Bunge, *Berberis x serrata* Koehne. The species were selected based on the ecological conditions of plant growth in natural conditions. About 35 species, forms and varieties were tested during this period. The samples of taxa currently in the collection were grown from seeds of cultural origin obtained from countries of the near and far abroad. The collection includes plants obtained from seeds of their own reproduction and natural populations.

The varietal material was mainly drawn from a private nursery located in the outskirts of Almaty, using live plants. Currently, the collection of the Altai Botanical Garden contains 30 species, forms and varieties of the genus *Berberis* L., which are adapted to varying degrees to the harsh climatic conditions of the Kazakh Altai.

The characteristics of the origin of the collection plants are given in Table 1.

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Table 1

Characteristics of the origin of collection taxa of the genus Berberis L.

Species name	Origin of source material/age
B. × *ottawensis* Schneid. cv. *Superba*	Russia, NIISS named after Lisavenko, Barnaul, live plants/2007
B. amurensis Rupr.	Russia, Moscow, VILR, seeds/1979
B. chinensis Poir.	Ireland, Dublin, National Botanic Garden, seeds/2005
B. circumserrata (C.K. Schneid.) C.K. Schneid..	Russia, Moscow, GBS, seeds/1985
B. crataegina DC.	Belgium, Beveren, Municipal Arboretum, seeds/2007
B. diaphana Maxim.	Ireland, Dublin, National Botanic Garden, seeds/2004
B. dielsiana Fedde	Russia, Ussuri region, Mountain Taiga station, seeds/2008
B. heteropoda Schrenk	Kazakhstan, ABS, reproduction, seeds/2008
B. integerrima Bunge	Unknown/1955
B. koreana Palib.	Russia, NIISS named after Lisavenko, Barnaul, live plants/1970
B. lecomtei Schneid.	Sweden, Bergian Botanical Garden, Stockholm, seeds/1972
B. orientalis Schneid.	Russia, Stavropol Botanical Garden named after V.V. Skripchinsky, Stavropol, seeds/1966
B. poiretii C.K. Schneid.	Kazakhstan, GBS Almaty, seeds/1989
B. sibirica Pall.	Kazakhstan, East Kazakhstan region, Listvyaga ridge, seeds of natural origin/1991
B. sieboldii Mig.	Belarus, Centralized Botanical Garden, Minsk, seeds/1981
B. silva-taroucana Schneid.	Lithuania, Kaunas Botanical Garden, Kaunas, seeds/1977
B. thunbergii DC.	Russia, NIISS named after Lisavenko, Barnaul, live plants/2002
B. th. cv. *Carmen*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2007
B. th. cv. *Atropurpurea Nana*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2007
B. th. cv. *Colden Ring*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2009
B. th. cv. *Kornik*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2007
B. th. cv. *Maria*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2009
B. th. cv. *Pink Attraction*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2007
B. th. cv. *Red Rocket*	Kazakhstan, Almaty, nursery “Mountain gardener”, live plants/2009
B.th. f. *atropurpurea* Chenault	Germany, Botanical Garden of the University of Mainz/2002
B. turcomanica Karel.	Italy, Botanical Garden of the Technical University of Udine, seeds/2007
B. vulgaris f. *atropurpurea* Bunge	Russia, TSHA Moscow, seeds/1971
B. vernae Schneid.	Germany, Botanical Garden of Berlin, seeds/1969
B. virescens Hook.	Russia, Botanical Garden of the Ural Branch of the Russian Academy of Sciences, Sverdlovsk, seeds/1976
B. vulgaris L.	Kazakhstan, ABS, reproduction, seeds/2009

Taxonomic composition of the collection fund of the genus *Berberis* L. is represented by 8 sections, 3 subsections (Table 2):

Table 2

Taxonomic composition of the collection fund of the Altai Botanical Garden of the genus *Berberis* L.

Section	Subsection	Name of species
Vulgares		*Berberis vulgaris* L.
		Berberis vulgaris f. atropurpurea Bunge
		Berberis sieboldii Mig.
		Berberis orientalis Schneid.
		Berberis koreana Palib.
		Berberis amurensis Rupr.
Sinenses		*Berberis chinensis* Poir.
		Berberis poiretii C.K. Schneid.

Continuation of Table 2

Section	Subsection	Name of species
Angulosae	Diaphanous	*Berberis diaphana* Maxim.
		Berberis circumserrata Schneid.
		Berberis virescens Hook.
	Eufranchetime	*Berberis. lecomtei* Schneid.
	Siberian	*Berberis sibirica* Pall.
Dasystach		*Berberis dielsiana* Fedde
Integerrimae		*Berberis integerrima* Bunge
		Berberis turcomannica Karel.
		Berberis vernae Schneid.
Tschonoskyanae		*Berberis* × *ottawensis Schneid.* cv. *Superba*
		Berberis thunbergii DC.
		Berberis thunbergii f. atropurpurea Chenault
		Berberis thunbergii cv. *Atropurpurea Nana*
		Berberis thunbergii cv. *Carmen*
		Berberis thunbergii cv. *Colden Ring*
		Berberis thunbergii cv. *Maria*
		Berberis thunbergii cv. *Kornik*
		Berberis thunbergii cv. *Red Rocket*
		Berberis thunbergii cv. *Pink Attraction*
		Berberis silva- taroucana Schneid.
Heteropodae		*Berberis heteropoda* Schrenk
Crataeginae		*Berberis crataegina* DC.

Territorially, according to soil-geographical origin, introduced species are classified into 5 regions: North American, East Asian, Central Asian, Central Asian—Kazakhstan and European-Caucasian [2] (Table 3).

Table 3

Territorial division by soil-geographical origin of the collection fund of ABS *Berberis* L.

Types/areas	European-Caucasian	Central Asian - Kazakhstan	Central Asian	East Asian	North American
1	2	3	4	5	6
Berberis amurensis Rupr.				+	
B. chinensis Poir.	+				
B. circum — serrata Schneid.				+	
B. crataegina DC.	+				
B. diaphan Maxim.			+		
B. dielsiana Fedde			+		
B. integerrima Bunge		+			
B. koreana Palib.				+	
B. lecomtei Schneid.			+		
B. orientalis Schneid.	+				
B. × ottawensis Schneid. cv. *Superba*					+
B. poiretii C.K. Schneid.				+	
B. sieboldii Mig.				+	
B. sibirica Pall.		+			
B. silva — taroucana Schneid.			+		
B. heteropoda Schrenk		+			
B. thunbergii DC.				+	
B. thunbergii. f. atropurpurea Chenault				+	
B. turcomanica Karel.		+			
B. vernae Schneid.			+		

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Continuation of Table 3

1	2	3	4	5	6
B. virescens Hook.					+
B. vulgaris L.	+				
B. vulgaris f. atropurpurea Bunge	+				
B. thunbergii cv. *atropurpurea nana*					
B. thunbergii cv. *Carmen*					
B. thunbergii cv. *Colden Ring*					
B. thunbergii cv. *Maria*					
B. thunbergii cv. *Kornik*					
B. thunbergii cv. *Red Rocket*					
B. thunbergii cv. *Pink Attraction*					

As of 2025, the collection of the genus *Berberis* L. is dominated by introduced species from the East Asian and Central Asian regions, which account for 29% of the Altai Botanical Garden's collection. Species from the European-Caucasian region account for 12.5%, while those from the Central Asian-Kazakhstan region make up 16%. The North American region is represented by a single species—*B.* × *ottawensis* Schneid. cv. *Superba*.

The introduction assessment of the genus *Berberis* includes an analysis of potential risks and benefits associated with the introduction of its species into new regions. The assessment consists of the following characteristics of the introduced species: eco-geographical, morpho-biological, adaptive. The history of the development of species in certain soil-geographical conditions determines their ecology.

In relation to soil fertility, the introduced species of the genus *Berberis* L. are oligotrophs—17 (57%), mainly natives of the Central Asian and East Asian regions. Mesotrophs are represented by 6 (20%) species—natives of the East Asian region—*B. amurensis*, *B. koreana*, *B. poirretii*, *B. sieboldii*, Central Asian—*B. dilsiana*, Central Asian-Kazakhstan—*B. integerrima* and make up a smaller part of the collection. Eutrophs are represented by the European—Caucasian and North American races 7 (23%) (Fig. 1).

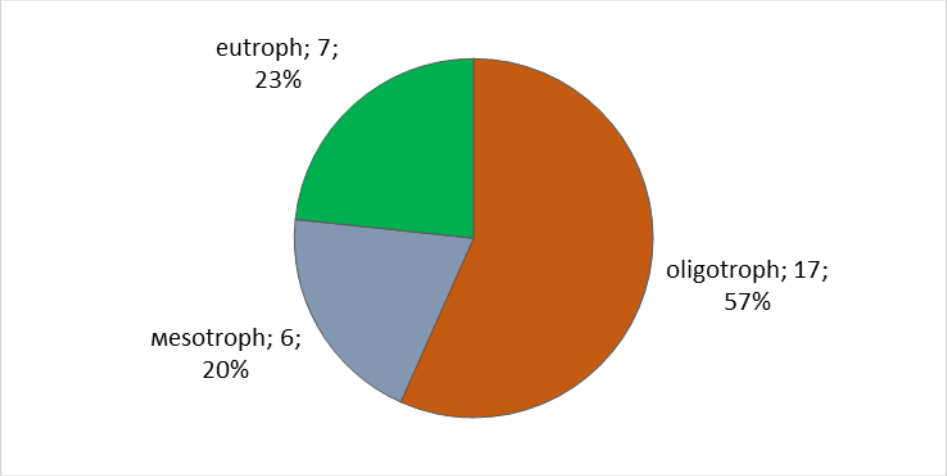

Figure 1. Classification of the collection of the genus *Berberis* L. in relation to soil fertility

The largest percentage of collection species of barberries are xerophytes from East and Central Asia—9 (30%) and mesoxerophytic species—natives of mountainous regions, which make up 13 (43%). The European-Caucasian race in the collection fund of barberries is represented by mesophytes—8 (27%). Plants of this genus tolerate waterlogging, while thickening of shoots and an increase in the rate of shoot growth are noted, which is not always a positive condition for introduction (Fig. 2) [16].

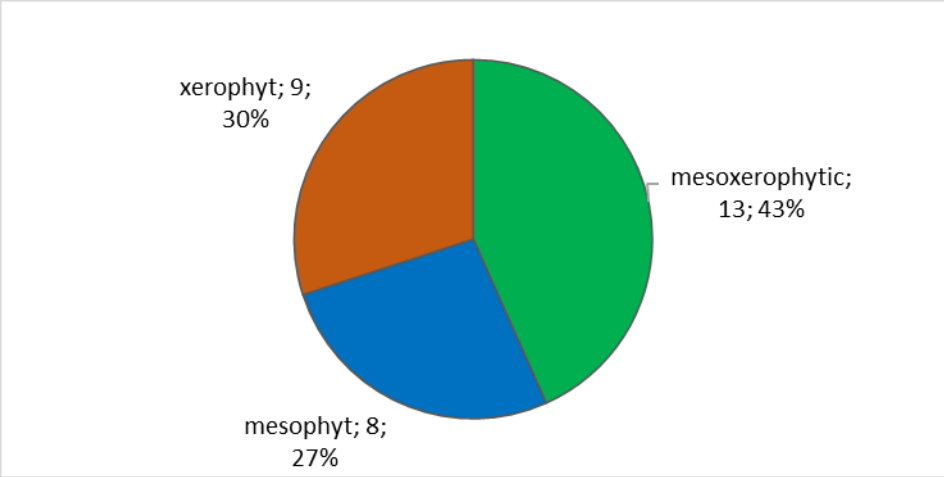

Figure 2. Classification of the collection of the genus *Berberis* L. by moisture conditions

The genus *Berberis* L. is characterized by high photophilousness, although many species are also capable of growing in partial shade. Representatives of the European-Caucasian and East Asian regions tolerate shading satisfactorily in conditions of a sharply continental climate.

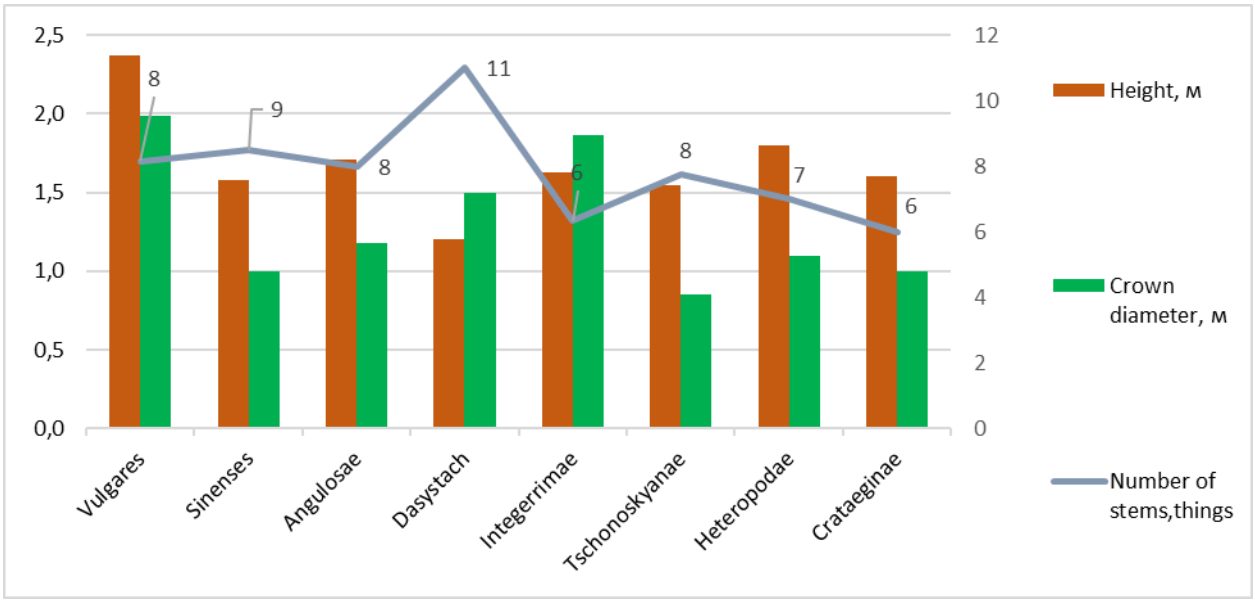

Figure 3. Changes in biological characteristics of introduced species of the genus *Berberis* L. in the arboretum

Changes in the biological characteristics of introduced species clearly reflect their adaptive capacity to the sharply continental conditions of the introduction site and are evident to varying degrees in traits such as height, crown structure, shoot formation, and reproductive ability (Fig. 3).

All species show a decrease in bush height by 20 to 35%, the crown diameter is preserved due to the good shoot-forming ability of the species. Under the conditions of introduction, obvious changes in biological parameters are observed in the Integerrimae section, where under the conditions of introduction, the height of the bushes decreases by 40% while maintaining the crown diameter. Skeletal branches are strong, thick at the base, from 5 to 8 pcs. The Sinenses section is represented by 2 species, one of which (*B. poiretii*) has good adaptation to the harsh conditions of Eastern Kazakhstan, adapts with difficulty *B. chinensis* to changes in environmental conditions, which is expressed in a decrease in the height of the bush by 35% compared to the genetically determined height, a weakening of the shoot-forming ability and a decrease in the number of stems to 5–7 pieces, while in natural growing conditions their number is 12–20 pieces. In the species from the Angulosae section, under the conditions of introduction, a slight increase in biometric indi-

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cators is noted—in height by 5–10%, all bushes with well-developed stems from 5 to 12 pieces. The Vulgares section is distinguished by high plasticity of species to environmental conditions of a sharply continental climate, preserving the habit of the bush. Introduced species from other sections showed minor changes in biometric indicators [17].

The annual average growth rates in height and trunk diameter of introduced species indicate the degree of their adaptability to unfavourable environmental conditions (Fig. 4).

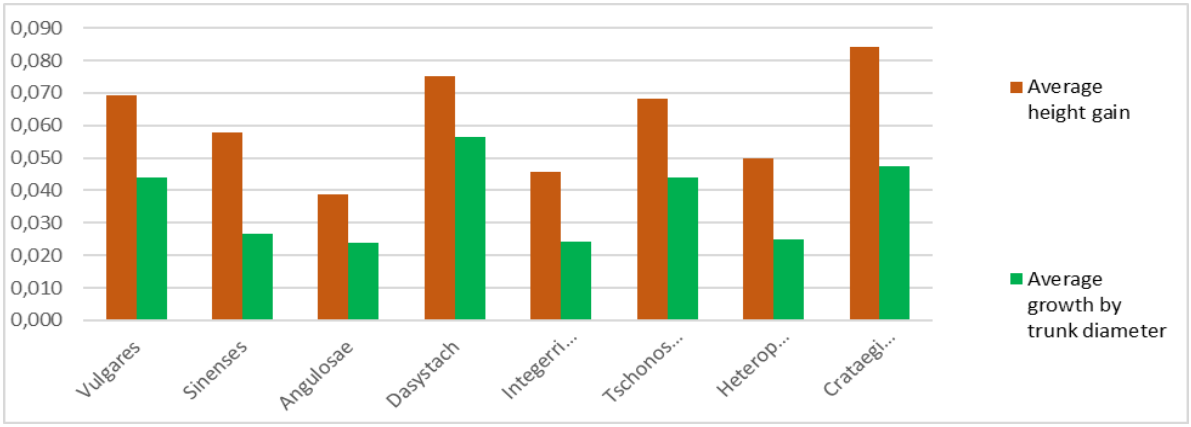

Figure 4. Indicators of annual average growth in height and trunk diameter of introduced species of the genus Berberis L., m

The most pronounced adaptive abilities for recovery after the winter period were demonstrated by species belonging to the sections Vulgares, Dasystach, Tschonoskyanae, Crataeginae. According to long-term indicators, the annual growth of species of this group fluctuates from 0.068 to 0.084 m in height and from 0.044 to 0.056 m in trunk diameter. Species of the sections Angulosae and Integerrimae are restored annually, but with lower indicators from 0.039-0.046 m and 0.024 m, respectively.

The most significant indicator influencing the adaptive processes of plants under introduction conditions is the ability to withstand prolonged, stable frosts in the winter period, early autumn frosts and the return of late spring frosts [18].

An analysis of the nature of overwintering of species based on long-term observations has established that the majority of species have winter hardiness of grade II, with partial damage to the annual growth (shoot) (Fig. 5). Average winter hardiness of grade III with complete damage to the annual growth is noted in the Sinenses and Angulosae sections.

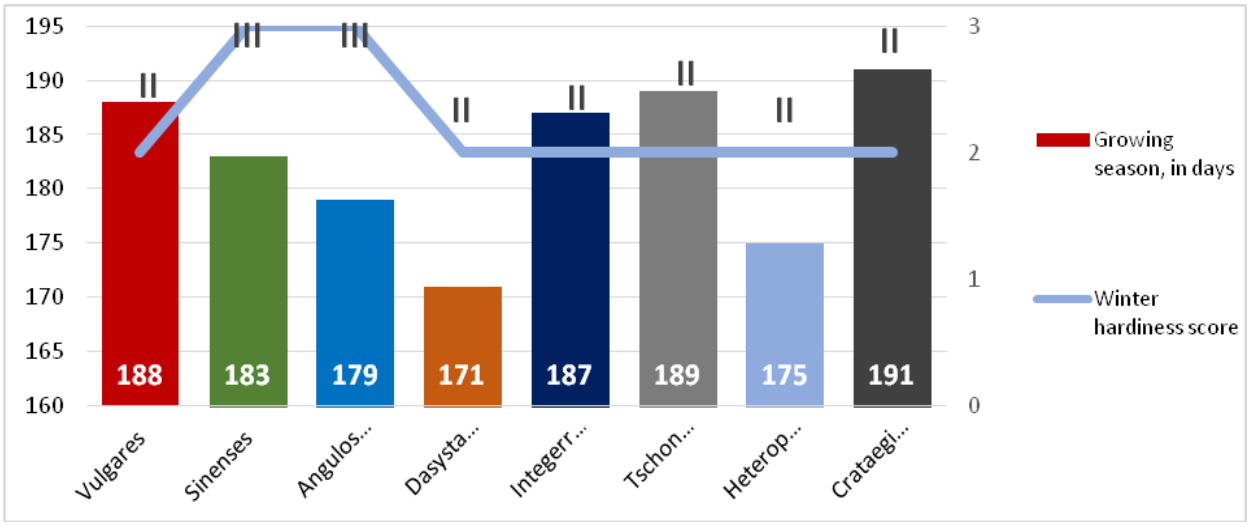

Figure 5. Indicators of winter hardiness and growing season of introduced species of the genus *Berberis* L.

High winter hardiness—I point is noted in introduced species from the Central Asian-Kazakhstan and East Asian regions. Damage to perennial lignified shoots (IV point of winter hardiness) is noted in barberries from the Angulosae (*B. lecomtei*) and Sinenses (*B. chinensis*) sections.

Comparison of the average degree of potential winter hardiness and the duration of the growing season by sections showed that all sections are characterized by an extended growing season, and an increase in the duration of which does not have a decisive effect on the degree of winter hardiness (Fig. 5). The maximum growing season is in the Crataeginae section and is 191 days, the minimum growing season is typical for the Dasystach section—171 days. Reduced winter hardiness (III points) is noted in the Sinenses and Angulosae sections. Weak winter hardiness is determined by the genotype of the introduced species, which come from the temperate zone of the Northern Hemisphere.

In new ecological conditions, introduced species adapt by changing the timing of phenological development phases, which also affects the preparation of plants for overwintering (Fig. 6) [19, 20].

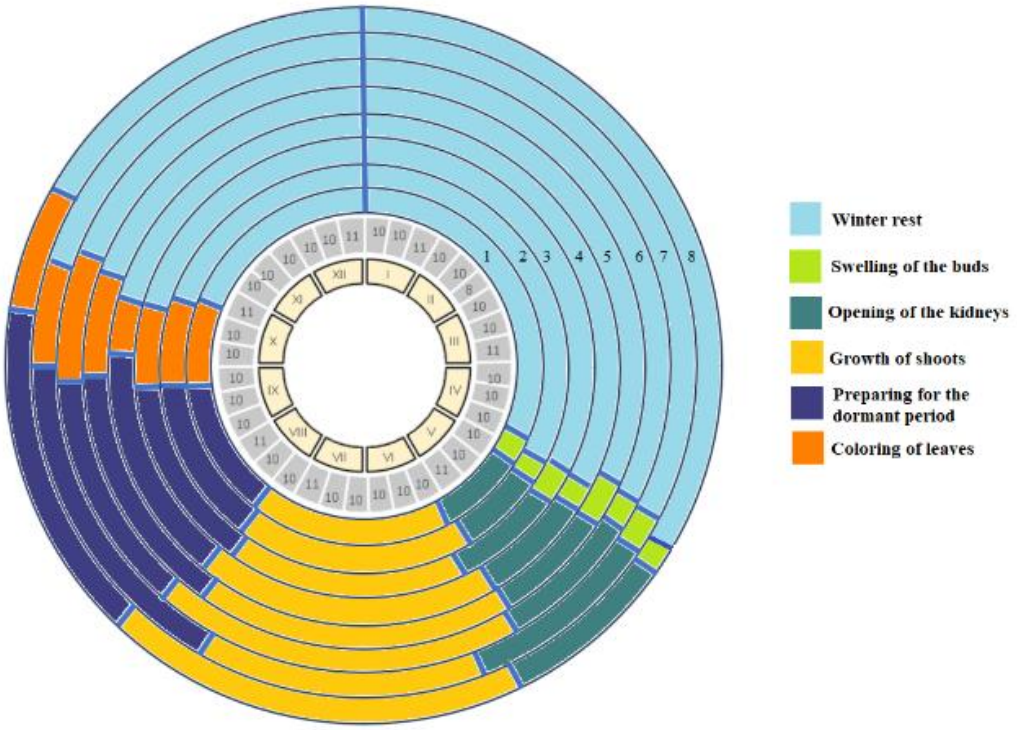

Figure 6. Diagram of the timing of the onset of phenological phases of introduced species of the genus Berberis L.: 1—Vulgares; 2—Sinenses; 3—Angulosae; 4—Dasystach; 5—Integerrimae; 6—Tschonoskyanae; 7—Heteropodae; 8—Crataeginae.

The beginning of active bud swelling is observed in the third ten-day period of April in all sections. Leaf blossoming occurs in the first ten-day period of May, 7–10 days after the bud swelling phase.

According to the start and end dates of shoot growth, introduced species are divided into three groups:

- with a late start, in the second ten days of June, and early completion of shoot growth, in the third ten days of July—*B. heteropoda* (PR);
- with a long period of shoot growth—with an early start of shoot growth, in the first ten days of June and a late end of shoot growth, in the second ten days of August—*B. crataegina* (RP);
- for other species, the period of shoot growth is observed from the first ten days of June to the first ten days of August (RS).

A late start of lignification of shoots (end of the third decade of June, first decade of July) is observed in plants from the East Asian, Central Asian and Central Asian-Kazakhstan regions.

The end dates of lignification reflect the readiness of introduced species for the winter period and affect the winter hardiness grades. Incomplete maturation of shoots (75%) is typical for the Crataeginae section. In

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other sections, the degree of lignification of annual shoots is 100%. The phase occurs in the third ten-day period of August and lasts 25–30 days.

One of the most important indicators of the degree of adaptation of introduced species to new conditions is fruiting [21, 22]. All introduced species enter the generative phase. Mass flowering occurs in the second half of June. Single flowering and fruiting is observed in *B. crataegina*, which indicates a reduced indicator of the degree of adaptation. In general, intraspecific differences in the passage of introduced species through the generative phase are preserved.

In the sharply continental climate of the introduction area, autumn leaf colouring and leaf fall indicate the transition of the introduced species to a dormant state and depends on the onset of the first autumn frosts [23]. Natural leaf fall is observed only in *B. sibirica* Pall. in the third ten-day period of September. For other species, leaf coloring is typical in the third ten-day period of September and forced leaf fall in the second half of October.

The fact that barberries go through a full development cycle indicates the success of their introduction.

The adaptation level was assessed based on eight main biological indicators: shoot lignification, winter hardiness, growth form retention, shoot formation, height gain, generative development, possible reproduction methods, and drought resistance. These criteria characterize the success of introduction and reflect the adaptive capabilities of introduced species to new environmental factors. Results of the prospects of introduced species of the genus *Berberis* L. are shown in Figure 7.

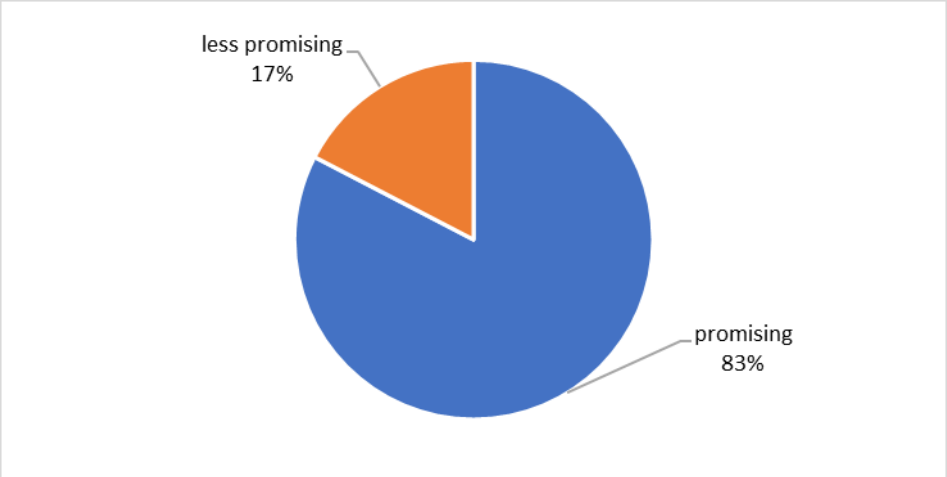

Figure 7. Evaluation of the potential of introduced species of the genus *Berberis* L.

Based on the results of the assessment of the prospects of introduced species, two groups of prospects of the genus *Berberis* L. were identified: promising and less promising. The less promising group includes *B. chinensis* Poir., *B. diaphana* Maxim., *B. vernae* Schneid., which grow in the European-Caucasian and Central Asian regions. These introduced species are characterized by reduced winter hardiness and drought resistance. The promising group includes the remaining species of the genus *Berberis* L., with high winter hardiness, preserving the genetically determined life form, with the annual passage of all phenophases, possessing high drought resistance and producing viable seeds.

Thus, the primary test of the genus *Berberis* L. in the conditions of the Altai Botanical Garden can be considered successful. The species involved showed high adaptive abilities in uncharacteristic growing conditions.

Based on this assessment, introduced species are recommended for use in phytomelioration, gardening and park construction, as ornamental and fruit crops in Eastern Kazakhstan.

Conclusions

Based on the results of verification of the collection fund of the genus *Berberis* L. of the Altai Botanical Garden, according to taxonomic ranks, 30 species, including varietal ones, belong to 8 sections, 3 subsections.

According to their affiliation with the floristic regions of their natural habitats, introduced species of the genus *Berberis* L. are classified into 6 regions: Central-South American, North American, East Asian, Central Asian, Central Asian-Kazakhstan and European-Caucasian.

According to their soil fertility requirements, the introduced species are divided into three groups: oligotrophs 17 (57%), eutrophs 7 (23%) and mesotrophs 6 (20%).

Based on moisture conditions, three groups were identified: xerophytes 9 (30%), mesophytes 8 (27%) and one intermediate group—mesoxerophytes 13 (43%).

Changes in biometric indicators under introduction conditions have been established. In the Angulosae section, an increase in bush height by 5–10% is observed, in the Integerrimae section, a decrease in bush height of up to 40% is noted, in the remaining sections, the height decreases from 20 to 35%. The crown diameter is maintained in all sections due to the good shoot-forming ability of the genus, with the exception of *B. chinensis.* from the section Sinenses. According to the annual average growth in height and trunk diameter of introduced species, annual recovery is noted in all sections. High adaptive abilities after overwintering are distinguished for the sections Vulgares, Dasystach, Tschonoskyanae, Crataeginae.

The level of adaptation of introduced species by the limiting factor—winter hardiness—is determined. Winter hardiness of the II point with partial damage to the annual growth is noted in most sections. Average winter hardiness of the III point with complete damage to the annual growth is noted in the Sinenses and Angulosae sections. In general, introduced species also show sufficient winter hardiness, which indicates high ecological plasticity of the genus.

Analysis of phenological observations shows that the passage of the entire vegetation cycle from the bud swelling phase to the end of leaf fall is extended in introduced species. The duration of the vegetation period in the arboretum of the Altai Botanical Garden is 171–191 days.

Determination of calendar dates of seasonal development of introduced species of the genus *Berberis* L., the beginning and end of the growing season, the duration of shoot growth, the degree of lignification, flowering and fruiting of all studied species have practical benefits in landscaping populated areas, use in household plots, as ornamental and fruit crops. The completion of the full development cycle by introduced species indicates the success of their introduction and resistance to unfavourable environmental conditions.

Based on the results of the assessment of the prospects of introduced species, two groups of prospects of species of the genus *Berberis* L. were identified: promising and less promising.

Thus, the initial testing of the genus *Berberis* L. in the Altai Botanical Garden can be considered successful.

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Author Contributions

The manuscript was written with the participation of all authors. All authors approved the final version of the manuscript. **Isakova E.A.** – Development of relevance, Data collection and processing, Research; **Vinokurov A.A.** – Data curation, Formal analysis, Methodology; **Danilova A.N.** – Supervision, Writing of the draft; **Lagus O.A.** – Generalization of conclusions, Editing.

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Е.А. Исакова, А.А. Винокуров, А.Н. Данилова, О.А. Лагус

Алтай ботаникалық бағы жағдайында *Berberis* L. туысына жататын жерсіндірілген ағаш өсімдіктердің бейімделуін және фенологиялық дамуының өзгергіштігін зерттеу

Мақалада Алтай ботаникалық бағы жағдайында алғашқы жерсіндіру кезінде *Berberis* L. туысының фенологиялық дамуы мен бейімделу мүмкіндіктерінің ерекшеліктері қарастырылған. *Berberis* L. туысы коллекциялық таксондарының шығу тегі сипатталып, 2025 жыл бойынша коллекциялық қордың таксономиялық құрамы нақты анықталған. Интродуценттер топырақтық-географиялық шығу тегіне қарай бес топқа бөлінген. *Berberis* L. туысына экологиялық-географиялық және морфобиологиялық сипаттамалар негізінде интродукциялық бағалау жүргізілген. Көпжылдық фенологиялық бақылаулар негізінде интродуценттердің даму циклін толық өткені анықталып, олардың бейімделу әлеуеті бағаланған. Бағалау нәтижесінде интродуценттердің болашағы бойынша екі топ айқындалды: перспективті түрлер (83 %) және аз перспективті түрлер (17 %). Осы бағалау негізінде интродуценттер Шығыс Қазақстанда фитомелиорация, бағбандық және саябақ құрылысында сәндік және жемісті дақылдар ретінде қолдануға ұсынылады.

Кілт сөздер: жерсіндіру, коллекциялық қор, *Berberis* L. туысы, болашағы, бейімделу, фенологиялық фазалар.

Е.А. Исакова, А.А. Винокуров, А.Н. Данилова, О.А. Лагус

Исследование адаптивных состояний и изменчивости фенологического развития интродуцированных древесных растений рода *Berberis* L. в условиях Алтайского ботанического сада

В статье рассматриваются особенности фенологического развития и адаптационные возможности рода *Berberis* L. при первичной интродукции в условиях Алтайского ботанического сада. Приводятся характеристики происхождения коллекционных таксонов рода, выверен таксономический состав коллекционного фонда рода *Berberis* L. по состоянию на 2025 год. Проведено деление интродуцентов по почвенно-географическому происхождению, где интродуценты распределены на 5 групп. Дана интродукционная оценка рода *Berberis* L. по эколого-географическим, морфобиологическим характеристикам. Оценен адаптационный потенциал интродуцентов на основе многолетних фенологических наблюдений, в ходе которых установлено прохождение полного цикла развития. По результатам оценки перспективности интродуцентов выявлено две группы перспективности видов: перспективные (83 %) коллекционного фонда и менее перспективные (17 %). На основе данной оценки интродуценты рекомендованы к применению для фитомелиорации, садоводства и садово-паркового строительства, как декоративные и плодовые культуры в Восточном Казахстане.

Ключевые слова: интродукция, коллекционный фонд, род *Berberis* L., перспективность, адаптация, фенологические фазы.

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