https://doi.org/10.31489/2024BMG2/64-75 Received: 12 December 2023 | Accepted: 16 February 2024

UDC 58.084.2

L.A. Tuchina[1], A.N. Danilova[2], O.A. Lagus[2], A.A. Sumbembayev[1, 2]*

[1]*al-Farabi KazNU, Almaty, Kazakhstan;*
[2]*Altai Botanical Garden, Ridder, Kazakhstan*
**Corresponding author: aydars@list.ru*

Selection of *Bergenia crassifolia* specimens based on a complex of decorative characteristics in the flora of Kazakhstan Altai and their introduction in the Altai Botanical Garden

The purpose of the study is to select *Bergenia crassifolia* specimens from different eco-geographical habitats in natural populations of the Kazakhstan Altai based on a complex of decorative characteristics and their introduction testing in the Altai Botanical Garden, creating promising forms for inclusion in the landscaping assortment. The growth of *B. crassifolia* in the Kazakhstan Altai has been established on the mountain ranges of the Southern and Southwestern Altai in the mountain forest and alpine belts with a vertical distribution threshold of 1100–1800 m above sea level. For introduction, promising samples of *B. crassifolia* based on economically valuable indicators were selected on the ridges of the Southern and Southwestern Altai. Classical botanical methods were used. Based on the results of the research, a collection of 74 specimens of *B. crassifolia* was created in the Altai Botanical Garden, among them 59 decorative specimens with high winter hardiness, a full cycle of seasonal development, responding to weather conditions by changing the duration of the phenological phases of development. Based on the timing of flowering, the samples are classified as spring-early flowering and spring-mid flowering. Based on the results of a comparative assessment, 8 forms were recommended for inclusion in the landscaping assortment with a decorative score of 87–98 points.

Keywords: Bergenia crassifolia, decorativeness, Kazakhstan Altai, collection, introduction, form.

Introduction

The most universal method for studying and preserving economically valuable plant species in botanical gardens is introduction [1]. This method allows us to determine the adaptive potential of species in culture. The use of the introduction method for reconstruction (restoration) of natural populations is one of the effective ways to maintain population reproduction and a reliable tool for the conservation of biodiversity [2].

One of the possibilities for solving this problem may be the selection of species of ornamental plants by attracting and studying in culture the most interesting local wild species [3]. In this regard, long-term research on the introduction of species of local flora in botanical gardens is of great importance. Reproduction and introduction into the practice of landscaping of such species can be one of the effective steps for their protection and reproduction. *B. crassifolia* has a special place among introduced species that are potential objects for ornamental gardening [3].

Bergenia crassifolia (L.) Frisch is a winter-green, predominantly mountain-forest species, long known in folk practice as a tea substitute, dyeing, tanning, and medicinal plant. In traditional medicine it is used as an astringent, hemostatic, anti-inflammatory, wound healing, analgesic, and normalizes metabolism [4–6]. The species is actively used in pharmacology and phytochemistry [7–13]. The antioxidant properties of the species are widely known [14–16]. The species contains arbutin, which is actively used in cosmetology [17–20]. Work to establish the natural reserves of this plant is carried out both in Kazakhstan and throughout the species habitat [21–26]. Meanwhile, an information search showed a small number of publications on the introduction of *B. crassifolia* as an ornamental plant [27–33].

Long-term floristic studies have revealed the growth of *B. crassifolia* in the East Kazakhstan region on the territory of the Kazakhstan Altai in two geographical areas: Southern and Southwestern Altai [32]. Despite the wide distribution of the species in the geographical regions of the region, its potential in the Kazakhstan Altai as an ornamental plant has not been sufficiently studied both in natural conditions and during introduction.

The purpose of the work is to select *B. crassifolia* specimens from different ecological and geographical habitats in natural populations of the Kazakhstan Altai based on a complex of decorative characteristics, their

introduction testing in the Altai Botanical Garden, and the creation of promising forms for inclusion in the landscaping assortment.

Experimental

The object of the study is specimens of *B. crassifolia* from different ecological and geographical locations from the Southern and Southwestern Altai.

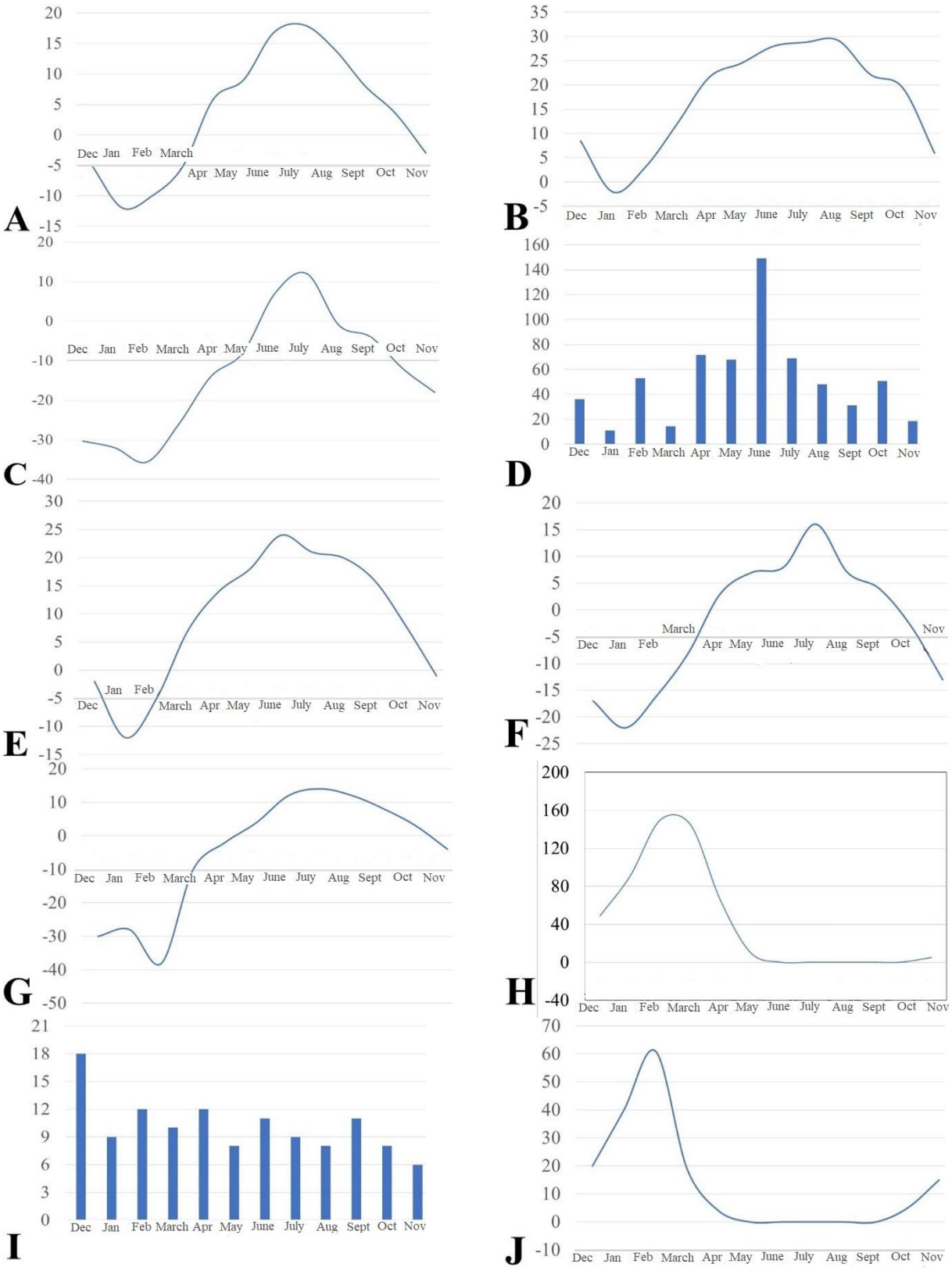
The material was attracted from nature by living plants and planted in the exhibition of natural flora of the Altai Botanical Garden. Sampling of *B. crassifolia* for introduction testing in the Altai Botanical Garden was carried out in natural habitats on the territory of the Kazakhstan Altai in the Southern and South-Western Altai. These are territorially isolated geographical areas with different habitat conditions and altitude limits.

Southern Altai, which is part of the Kazakhstan Altai, is located at the junction of the borders with Russia, the Mongolian Republic and China. It is formed by a system of high ridges: Southern Altai, Altai Tarbagatai, Sarymsakty, Narym, Kurchum, Azutau and others. Absolute heights within the region vary from 600 to 3400 m.

The climatic features of the region are determined, on the one hand, by altitudinal zonation, and on the other, by the influence of humid northwestern Atlantic winds that bring precipitation. Annual precipitation reaches 400 mm in the foothills to 800–1000 m in the mountain forest belt. Southern Altai is the coldest place in the Kazakhstan Altai. Average temperature in July is: +14…+18°, in January: –14…–18°. The sum of positive average daily temperatures is 1200–2200°. Summer is cool and short — 90–100 days, summer frosts are common. Altitudinal zonation is typical for the soils and vegetation of the Southern Altai Mountains, the nature of which depends on the geographical location and height of the mountain range, slope exposure [34].

Southwestern Altai is formed from high ranges: Western Listvyaga, Kholzun, Koksu, Tigiretsky, Lineysky, Ivanovsky, Ubinsky and Ulbinsky. Absolute heights within the region vary from 500 to 2500 m. Among the named ridges there are aligned intra-mountain depressions of tectonic origin: Leninogorskaya and Zyryanovskaya. The climate is sharply continental. Long-term average temperature in July is +18°…+22°, January –18°…–22°. Sum of positive average daily temperatures is 2600°–2800°. The maximum depth of soil freezing is 40–120 cm. The amount of precipitation varies from 400 to 550 mm per year in the western part to 1500 mm at the upper forest limit in the eastern and northeastern parts of the region [34].

The Altai Botanical Garden is located on the southeastern outskirts of the city of Ridder in the mountainous zone of the southwestern periphery of Southwestern Altai in the foothills of the ridge Ivanovsky. The absolute heights of the garden are 770–860 m. The climate is sharply continental, characterized by cold long winters, hot summers, sharp fluctuations in air temperature and humidity throughout the day, season, and year. According to the Ridder weather station, the average annual air temperature is 1.8 °C with an absolute maximum of +41.5 °C and a minimum of –46.7 °C. Frost-free period is 51–139 days. Average annual precipitation ranges from 432 to 937 mm with a summer maximum. The snow cover is stable and disappears in the second half of April. The average long-term duration of the period with stable snow cover is 156 days. Over the past decade, it has fluctuated from 132 to 173 days. As a rule, the coldest time is the second half of winter — January-February, where the annual minimum air temperatures are also shifted. The real beginning of spring and plant growing season is April. According to the Ridder weather station, April is characterized by sharp changes in air temperatures from –13° to 22.0 °C. The period is dangerous for plants in late April – May due to spring frosts [35]. The limiting factor for the introduction of plants in the Altai Botanical Garden is sudden changes in temperature and humidity throughout the year, season and day, and a short growing season. According to average long-term data, the last spring frosts occur at the beginning of the third ten days of May, and the first autumn frosts — in the first ten days of September [36]. Meteorological conditions during the years of research differed significantly, which made it possible to objectively evaluate the material being studied. For example, the years 2004, 2010, 2019, 2023 were hot and dry, the years 2006, 2008 were warm but with a cold spring and warm and moderately rainy, the years 2007, 2020, 2021 were warmer and more humid. etc. (Fig. 1.)



A — Average daily temperature, °C; *B* — Maximum temperature, °C; *C* — Minimum temperature, °C;
D — Precipitation level, mm; *E* — Average daily temperature, °C; *F* — Average night temperature, ^{0}C;
G — air temperature on the soil surface, °C; *H* — Soil freezing depth, cm;
I — Average wind speed, m/s; *J* — Snow depth, cm

Figure 1. Meteorological conditions of the introduction area

To carry out the primary selection based on visual indicators of *B. crassifolia* that are promising for decorative traits in natural populations, the route-reconnaissance method was used [37]. In nature, plants were selected with high decorative properties, such as the size and shape of the leaf blade, the height and strength of the peduncle, the size and color of the flower from pale pink to intense crimson. Introduction studies were carried out according to the method of K.A. Sobolevskaya [38] and based on existing methods of cultivating plants in botanical gardens [39-40]. The assessment of decorativeness and adaptability to external environmental conditions was carried out on a 100-point scale by V.N. Bylov [41].

The level of variability of biometric indicators is calculated by the value of the coefficient of variation Cv: less than 12 % — the level of variability is low, 13–20 % — medium, 21–40 % — high, more than 40 % — very high [42]. Latin names of plants are given according to the international POWO platform [43].

Results and discussion

Introduction trials of *B. crassifolia* in the Altai Botanical Garden began in 1970 and are currently ongoing (Fig. 2). During this period, more than 400 samples passed the initial test, as a result of which a modern collection of 74 forms for various economic purposes was created. Among them are 59 decorative specimens, of which 25 are involved in the second introduction stage to select from this diversity the most valuable forms suitable for mass reproduction and introduction into production.

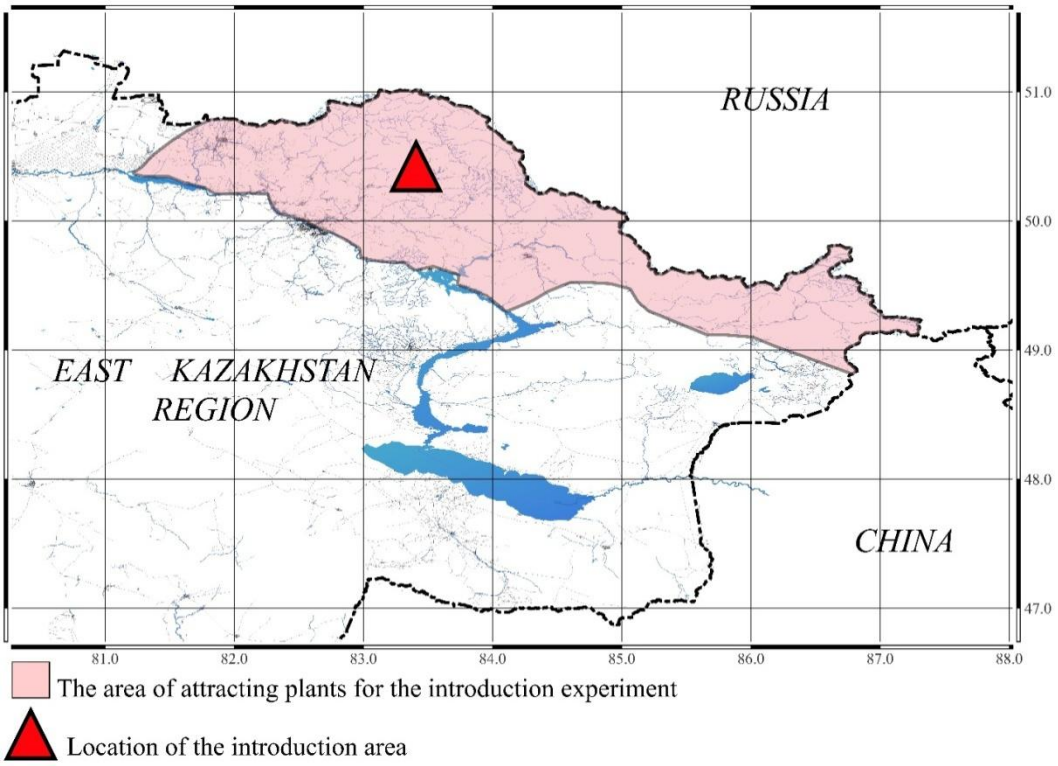


Figure 2. Territory for attracting *Bergenia* forms

As shown by long-term floristic studies conducted by employees of the Altai Botanical Garden (Ridder, East Kazakhstan region), *B. crassifolia* is found everywhere within the studied geographical areas.

In Southwestern Altai, populations of the species were identified on the Listvyaga, Ivanovsky, Kholzun, Ulbinsky, Lineisky, Ubinsky ridges. In Southern Altai, the locations of *B. crassifolia* populations are localized in the eastern periphery on the Sarymsakty, South Altai Tarbagatai, Southern Altai, and Kurchum ridges. In both regions, the species grows in mountain forest and alpine zones. Typical habitats of the species in the mountain forest belt are fir-cedar forests, 1400–1800 m a.s.l., sparse cedar-larch forests, 1700–1800 m a.s.l. and larch forests, 1100–1300 m a.s.l.

In the alpine belt, the habitats of the species are the northwestern and northeastern rocky slopes of carts, overgrown kurums, moss-lichen tundra, highland rocks with a vertical distribution threshold of 2000–2400 m a.s.l. in the South-Western Altai and 2400–2600 m a.s.l. — in the south.

Pure *B. crassifolia* thickets in the mountain forest belt in the Southwestern and Southern Altai formed in fir-cedar forests on the northwestern slopes with a vertical distribution threshold of 1400–1800 m a.s.l. and sparse cedar-larch forests at an altitude of 1700 m a.s.l. In the alpine belt, pure thickets of *B. crassifolia* form along rock cracks and near boulders on the northwestern and northern slopes, 1900–2000 m a.s.l. In larch forests at an altitude of 1100–1300 m a.s.l. In the vegetation cover, together with *B. crassifolia*, the growth of herbaceous species of taiga tall grass was noted: *Aconitum anthoroideum* DC., *Aquilegia glandulosa* Fisch. et Link., *Calamagrostis epigejos* (L.) Roth., *Chamaenerion angustifolium* (L.) Scop., *Stemmacantha carthamoides* (Willd.) Dittrich., *Hedysarum alpinum* L., *Paeonia anomala* L. *Solidago dahurica* (Kitag.) Kitag. ex Juz., *Saussurea latifolia* Ledeb., *Thalictrum foetidum* L. etc.

As surveys of natural populations have shown, the most variable in the size of the leaf blade, the height of the peduncle, the size and shape of the inflorescence, the size and color of the flowers are individuals of *B. crassifolia* in the mountain forest belt of Southwestern Altai (Fig. 3). Accordingly, for the introduction test, decorative samples were attracted mainly from the territory of South-Western Altai from the Ivanovsky, Listvyaga, Ulbinsky, Lineevsky ridges and slightly from the Southern Altai from the Sarymsakty, Southern Altai and South Altai Tarbagatai ridges. A total of 74 samples were tested during 2010–2023, including 59 decorative ones.

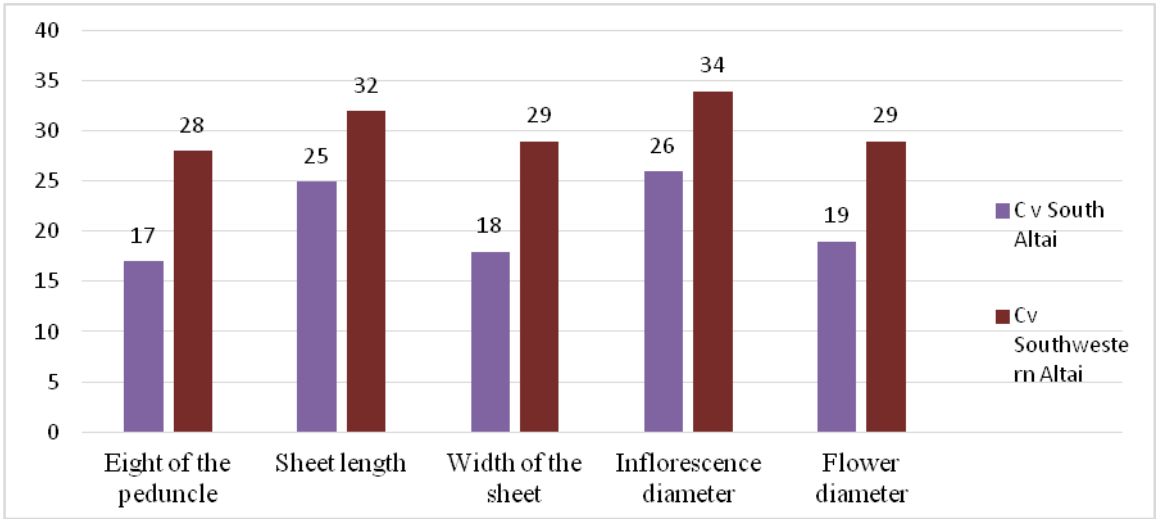


Figure 3. Coefficients of variation of morphometric features of *B. crassifolia* in natural populations of the Southern and Southwestern

The results of the initial introduction test showed that in the experiment, all 59 decorative specimens of *B. crassifolia* are characterized by the full implementation of the annual development cycle, which indicates their wide ecological plasticity and allows us to conclude that their introduction was successful. In ecological terms, *B. crassifolia* is a winter-green species, so the plants do not complete the growing season; in a green state, they go under the snow and emerge green after the area is cleared of snow cover.

Based on the study of the seasonal rhythm of development according to the timing of flowering, the tested decorative samples are conditionally distributed into two groups: spring-early flowering and spring-mid-flowering. Phenological observations have shown that only the timing and duration of flowering change from year to year depending on weather conditions and the origin of the samples, while their sequence remains unchanged.

Seven samples isolated from alpine formations in the altitudinal range from 1700 to 2500 m a.s.l. were classified as spring-early flowering. They begin to bloom in the first ten days of May at average daily air temperatures of +8–11 °C. Depending on the weather conditions in spring, the period from the beginning of flowering to its completion ranges from 11 to 13 days. Almost every year, flowers are damaged by spring frosts from mild to severe, which negatively affects the formation of seeds. The specimens are characterized by small, low-growing plants with a thin rhizome immersed in the substrate and small rounded leaves (5×7 cm or 8×11 cm), often brightly colored with antoncians in spring and autumn. The peduncles are thin, the inflorescences are dense, hemispherical or almost spherical. The flowers are small, from bright crimson to pale pink.

The group of spring-mid-flowering samples includes 52 selections from mountain forest formations (1100–1500 m above sea level). They begin to bloom in the late second to early third decade of May at average daily air temperatures of +14–16 °C. The flowering period lasts 16–22 days. Every year, with rare exceptions, flowering ends with seed production. Specimens of this group are distinguished by powerful growth, large round-heart-shaped long-petioled leaves (27×33, 29×37 cm), thick superficial rhizome, strong peduncles up to 2 cm in diameter, simple or branched from the base or in the upper part. The inflorescences are dense, capitate or spreading, almost paniculate. The flowers are large, up to 2.2 cm in diameter, with colors ranging from pale pink or pale purple to intense crimson.

During observations, the absence of self-seeding was established in both groups. In culture, plants grow annually and fill the free space between individuals due to the growth of rhizomes.

According to the results of a comparative assessment, out of 25 specimens that passed the second stage of introduction, with a decorative score of 87–98 points, 8 forms were included in the landscaping assortment of ornamental plants.

Below are their brief descriptions.

Form 59-10. The original sample was taken from the Ivanovsky Ridge. The leaves are large, the blades are rounded-heart-shaped, 25×24 cm. The peduncle is strong, 58–63 cm tall, 2 cm thick, branched in the upper part. The inflorescence is spreading, loose up to 20 cm, with up to 200 flowers. The flowers are large, 2.2 cm in diameter, bright pink, up to 5 % of the flowers in the inflorescence are fasciated. The decorativeness score is 98 (Fig. 4).

Form 59-14. The original sample was taken from the Ivanovsky Ridge. The leaves are large, the blades are round, 19 cm long, 20 cm wide. The peduncle is strong, up to 43 cm high, 1.8 cm in diameter. The inflorescence is dense, compact, large: 17 cm wide, 13 cm high, numbering from 170 up to 200 flowers. The flowers are large, 18 mm in diameter, pale pink. Decorativeness score is 95 points (Fig. 5).

Form 25-83. The original sample was taken from the Lineisky Ridge. The leaves are large, leaf blades measuring 22×24 cm; in spring and autumn they are intensely colored with antoncians. The peduncle is strong, durable, branched, up to 2 cm in diameter, 52–57 cm high. The inflorescence is dense, hemispherical, 16 cm long and 14 cm wide, with 150–180 flowers. The flowers are large, with a diameter of 21 mm, a height of 19 mm, bright pink, up to 5 % fasciated in the inflorescence, and have 6–8 petals. The decorativeness score is 94 points (Fig. 6).

Form 26-83. The original sample was taken from the Lineisky Ridge. The leaves are large, the blades are round, 18 cm wide, 19 cm long. The peduncle is strong, branched in the upper part, 45–50 cm in height. The inflorescence is loose, spreading, 10 cm wide, 10 cm long, contains up to 140 flowers. The flowers are of medium size, diameter 14 mm, length 13 mm, pale pink. The decorativeness score is 90 (Fig. 7).

Form 1120. The original sample was taken from the Ubinsky ridge. The leaves are medium-sized, rounded blades, 15×15 cm. The peduncle is thin, durable, up to 1 cm thick, 35–40 cm tall, branched in the upper part. The inflorescence is loose, spreading, 12 cm long, 9 cm wide. The flowers are medium-sized, 12–15 mm in diameter, bright crimson. Decorativeness score is 87 (Fig. 8).

Form 59-13. The original sample was taken from the Ubinsky ridge. The leaves are large, the plate is rounded-heart-shaped, 23 cm long, 20 cm wide. The peduncle is strong, durable, 35–40 cm high. The inflorescence is compact, 9 cm long and 8 cm wide, with up to 100 flowers. The flowers are large, 16 mm in diameter and 17 mm in height, dark pink. The decorativeness score is 90 (Fig. 9).

Form 916. The original sample was taken from the Kholzun Ridge. The leaves are medium-sized, long-petiolate, the leaf blade is elongated, 19 cm long, 15 cm wide. The peduncle is thin, strong, branched from the base, 40 cm high. The inflorescence is loose, drooping at the bottom, 12 cm wide, has up to 120 flowers. The flowers are medium-sized, pink, 12 mm in diameter, 13 mm in height. The decorativeness score is 91 (Fig. 10).

Form 1125. The original sample was taken from the Kholzun Ridge. The leaves are large, long-petiolate, the plate is rounded-heart-shaped, 23 cm long, 20 cm wide. The peduncle is strong, stable, branched in the upper part, 42–47 cm high. The inflorescence is compact, almost spherical, 14 cm wide, contains 140–180 flowers. The flowers are large, up to 23 mm in diameter, 17 mm high, dark pink. The decorativeness score is 97 (Fig. 11).

Figure 4. Form 59–10

Figure 5. Form 59–14

Figure 6. Form 25–83

Figure 7. Form 26–83

Figure 8. Form 1120

Figure 9. Form 59–13

Figure 10. Form 916

Figure 11. Form 1125

Conclusion

B. crassifolia in Kazakhstan Altai is recorded along all ridges of the mountain system of Southern and Southwestern Altai in the mountain-forest and alpine belts within the range of 1100–1800 and 2000–2600 m above sea level. The distribution of the species over a relatively wide range of altitudes in the mountains and habitats of varied conditions indicates a wide range of its ecological amplitude. This was the reason for intraspecific variability in morpho-structural organization and made it possible to select promising specimens of *B. crassifolia* in natural populations based on decorative characteristics that persist in the new soil and climatic conditions of growth in the area of introduction. A two-level cultural study of the decorative qualities of *B. crassifolia* made it possible to include 8 of the most promising forms in the landscaping assortment. At the same time, we can assume the possibility of using them as an initial basis for further breeding work to create new varieties, since when tested in culture, these forms retain their inherent hereditary characteristics and properties.

Acknowledgements

The article was prepared under the scientific and technical program BR18574125 “Study of the current state of the species diversity of vascular plants in Kazakhstan using modern methods of botany, molecular genetics and bioinformatics” (2023-2024)

References

1 Семенова Г.П. Редкие и исчезающие виды флоры Сибири: биология и охрана / Г.П. Семенова. — Новосибирск: Акад. изд-во «Гео», 2007. — 406 с.

2 Akeroyd J. Handbook for botanical gardens on the reintroduction of plants to the wild. Botanic Gardens Conservation International (BGCI) / J. Akeroyd, P.A. Wyse Jackson. — Richmond, 1995. — 200 p.

3 Шильников М.А. Эколого-биологическая оценка дикорастущих видов спиреи, перспективных для озеленения Предбайкалья / М. Шильников // Вестн. Краснояр. гос. аграр. ун-та. — 2016. — № 8. — С. 65–71.

4 Грудзинская Л.М. Аннотированный список лекарственных растений Казахстана / Л.М. Грудзинская, Н.Г. Гемеджиева, Н.В. Нелина, Ж.Ж. Каржаубекова. — Алматы, 2014. — 198 с.

5 Цырендоржиева С.В. Использование черных листьев бадана в производстве пищевых продуктов / С.В. Цырендоржиева, И.В. Хаматова // Техника и технология пищевых производств. — 2017. — Т. 45, № 2. — С. 81–86.

6 Сатыбалдиева Д.Н. Исследование состава и содержания биологически активных веществ бадана толстолистного (*Bergenia crassifolia* (L.) Fitsch.) и кровохлебки лекарственной (*Sanguisorba officinalis* L.) / Д.Н. Сатыбалдиева // Вестн. Казах. нац. ун-та. Сер. биологич. — 2013. — Т. 57, № 1. — С. 82–87.

7 Shikov A.N. *Bergenia crassifolia* (L.) Fritsch–Pharmacology and phytochemistry / A.N. Shikov et al. // Phytomedicine. — 2014. — Vol. 21, No 12. — P. 1534–1542.

8 Golovchenko V.V. et al. Structural study of bergenan, a pectin from *Bergenia crassifolia* / V.V. Golovchenko et al. // Russian Journal of Bioorganic Chemistry. — 2007. — Vol. 33. — P. 47–56.

9 Ärok R. Phytochemical comparison and analysis of *Bergenia crassifolia* L. (Fritsch.) and *Bergenia cordifolia* Sternb / R. Arok, et al. // Eur. Chem. Bull. — 2012. — Vol. 1, No 1-2. — P. 31–34.

10 Va E. Phenolic Compounds and Biological Activity of Badan (*Bergenia crassifolia* (L.) Fritsch) Leaves Growing in Russia / E. Va, et al. // Systematic Reviews in Pharmacy. — 2020. — Vol. 11, No 5. — P. 112–116.

11 Banzragchgarav O. Chemical constituents of *Bergenia crassifolia* roots and their growth inhibitory activity against *Babesia bovis* and *B. bigemina* / O. Banzragchgarav et al. // Phytochemistry Letters. — 2019. — Vol. 29. — P. 79–83.

12 Pozharitskaya O.N. Separation and evaluation of free radical-scavenging activity of phenol components of green, brown, and black leaves of *Bergenia crassifolia* by using HPTLC-DPPH method / O.N. Pozharitskaya et al. // Journal of separation science. — 2007. — Vol. 30, No 15. — P. 2447–2451.

13 Koul B. *Bergenia* genus: Traditional uses, phytochemistry and pharmacology / B. Koul et al. // Molecules. — 2020. — Vol. 25, No 23. — P. 5555.

14 Shilova I.V. Antioxidant properties of *Bergenia crassifolia* extract / I.V. Shilova et al. // Pharmaceutical Chemistry Journal. — 2006. — Vol. 40. — P. 620–623.

15 Hendrychová H. Antioxidant activity and phenolic content of *Bergenia crassifolia, B. x ornata and B. ciliata* / H. Hendrychová et al. // Natural product communications. — 2014. — Vol. 9, No 4. — P. 1934578–1400900424.

16 Kraujalienė V. Biorefining of *Bergenia crassifolia* L. roots and leaves by high pressure extraction methods and evaluation of antioxidant properties and main phytochemicals in extracts and plant material / V. Kraujalienė et al // Industrial Crops and products. — 2016. — Vol. 89. — P. 390–398.

17 Carmen P.O.P. Natural resources containing arbutin. Determination of arbutin in the leaves of *Bergenia crassifolia* (L.) Fritsch. acclimated in Romania / P.O.P. Carmen, L. Vlase, M. Tamas // Notulae Botanicae Horti Agrobotanici Cluj-Napoca. — 2009. — Vol. 37, No 1. — P. 129–132.

18 Lubsandorzhieva P.B. Chromatospectrophotometric determination of arbutin in the leaves of *Bergenia crassifolia* (L.) Fritsch / P.B. Lubsandorzhieva et al. // Pharmaceutical Chemistry Journal. — 2000. — Vol. 34. — P. 261–264.

19 Furmanowa M. *Bergenia crassifolia* (L.) Fritsch (Bergenia): Micropropagation and arbutin contents / M. Furmanowa, L. Rapczewska // Medicinal and Aromatic Plants IV. — Berlin, Heidelberg: Springer Berlin Heidelberg, 1993. — P. 18–33.

20 Akzhigitova Z. Phytochemical study of *Bergenia crassifolia* / Z. Akzhigitova et al. // Chemistry of Natural Compounds. — 2020. — Vol. 56. — P. 912–914.

21 Nekratova N.A. Resources of medicinal plants in the Kuznetsky Alatau / N.A. Nekratova, M.N. Shurupova // International journal of environmental studies. — 2014. — Vol. 71, No 5. — P. 656–666.

22 Khudonogova E.G. et al. Stocks of raw materials of wild medicinal plants in the Western Baikal Region / E.G. Khudonogova et al. // IOP Conference Series: Earth and Environmental Science. — 2019. — Vol. 315, No 7. — P. 072002.

23 Aidarbayeva D.K. Natural resources of some medicinal plants of Kazakhstan / D.K. Aidarbayeva et al. // International Multidisciplinary Scientific GeoConference: SGEM. — 2018. — Vol. 18, No 6.2. — P. 385–391.

24 Konovalova M.E. Biodiversity and structure of undisturbed mountain Siberian Pine taiga of the Idarsky Belogorye Ridge (East Sayan) / M.E. Konovalova et al. // Contemporary problems of ecology. — 2020. — Vol. 13. — P. 48–59.

25 Aidarbayeva D.K. Resources Of Food And Medicinal Plants Ridge Altai Tarbogatai / D.K. Aidarbayeva, A.D. Mursal // Ecological education and ecological culture of the population. — 2018. — P. 34–39.

26 Martusova E. Geobotanic Characteristics Of Vegetation In The Baikal State Biosphere Reserve / E. Martusova, A. Sizykh, A. Shekhovtsov // International Journal of Ecosystems & Ecology Sciences. — 2019. — Vol. 9, No 1. — P. 1–10.

27 Radeloff H. Megasea (*Bergenia crassifolia*) and its cultivation in Germany as a source of tannin / H. Radeloff et al. // Forrchungsdienst. — 1940. — Vol. 9. — P. 443–454.

28 Yeo P.F. Further observations on Bergenia in cultivation / P.F. Yeo // Kew Bulletin. — 1971. — Vol. 26, No 1. — P. 47–56.

29 Yang M. Habitat change effects on the flowering behavior of *Bergebnia crassifolia* (L.) Fritsch / M. Yang et al. // Vegetos. — 2013. — Vol. 26, No 1. — P. 218–222.

30 Turbina I.N. Results of Introduction of *Bergenia craccifolia* (L.) Fritsch in Taiga Zone of Western Siberia / I.N. Turbina, I.V. Kravchenko // The bulletin of Irkutsk State University. Geoarchaeology, Ethnology, and Anthropology Series. — 2018. — No 23. — P. 43–53.

31 Habtemariam S. The hidden treasure in Europe's garden plants: Case examples; Berberis darwinni and Bergenia cordifolia / S. Habtemariam // Medicinal & Aromatic Plants. — 2013. — Vol. 2, No 4. — P. 1–8.

32 Ануфриева О.А. Итоги интродукции *B. crassifolia* на Западном Алтае / О.А. Ануфриева // Ботаническая наука на службе устойчивого развития стран Центральной Азии. — Алматы, 2003. — С. 90–95.

33 Данилова А.Н. Ассортимент растений для озеленения городов и сел Восточного Казахстана / А.Н. Данилова, Ю.А. Котухов, О.А. Ануфриева, А.А. Винокуров, Е.Я. Сатеков. — Риддер, 2011. — 82 с.

34 Егорина А.В. Физическая география Восточного Казахстана / А.В. Егорина, Ю.К. Зинченко, Е.С. Зинченко. — Усть-Каменогорск: Альфа-Пресс, 2003. — 187 с.

35 Данилова А.Н. Адаптационная оценка *Cypripedium macranthon Sw*. в Алтайском ботаническом саду / А.Н. Данилова, А.А. Сумбембаев, Ю.А. Котухов // Проблемы ботаники Южной Сибири и Монголии. — 2021. — Т. 20, № 1. — С. 151–155.

36 Алтайскому ботаническому саду — 80 лет. — Усть-Каменогорск: Медиа-Альянс, 2015. — 59 с.

37 Щербаков А.В. Полевое изучение флоры и гербаризация растений / А.В. Щербаков, А.В. Майоров. — М.: Изд-во Моск. гос. ун-та, 2006. — 84 с.

38 Соболевская К.А. Исчезающие растения Сибири в интродукции / К.А. Соболевская. — Новосибирск: Наука, 1984. — 222 с.

39 Денисова Л.В. Программа и методика наблюдений за ценопопуляциями видов растений Красной книги СССР / Л.В. Денисова, С.В. Никитина, Л.Б. Заугольная. — М.: Госагропром СССР; ВНИИ охраны природы и заповедного дела, 1986. — 125 с.

40 Методика фенологических наблюдений в ботанических садах // Бюлл. ГБС АН СССР. — 1979. — Вып. 113. — С. 3–8.

41 Былов В.Н. Основы сортоизучения и сортооценки декоративных растений при интродукции / В.Н. Былов // Бюлл. ГБС. — 1971. — Вып. 81. — С. 69–77.

42 Зайцев Г.Н. Методика биометрических расчётов / Г.Н. Зайцев. — М.: Наука, 1973. — 150 с.

43 Plants of the World Online. (POWO, 2022). — [Electronic resource]. — Access mode: https://powo.science.kew.org/cite-us

Л.А. Тучина, А.Н. Данилова, О.А. Лагус, А.А. Сумбембаев

Қазақстан Алтайының флорасындағы сәндік сипаттамалар кешеніне негізделген *Bergenia crassifolia* (L.) Frisch үлгілерін таңдау және оларды Алтай ботаникалық бағында интродукциялау

Зерттеудің мақсаты — Қазақстан Алтайының табиғи популяцияларының әртүрлі экологиялық-географиялық өсу орындарынан *Bergenia crassifolia* үлгілерін сәндік сипаттамалары кешені негізінде іріктеу және оларды Алтай ботаникалық бағында интродукциялық сынақтан өткізу, көгалдандыру ассортиментіне қосу үшін перспективалы нысандарды құру. Қазақстан Алтайындағы *B.crassifolia* өсімі Оңтүстік және Оңтүстік-Батыс Алтайдың тау жоталарында теңіз деңгейінен 1100–1800 м биіктікте шоңғал тастары бар тік таулы орман және альпілік белдеулерінде анықталған. Жерсіндіру үшін Оңтүстік және Оңтүстік-Батыс Алтай жоталарында экономикалық құнды көрсеткіштер бойынша *B. crassifolia* перспективалы үлгілері таңдалды. Бұл жағдайда классикалық ботаникалық әдістер қолданылды. Зерттеу нәтижелері бойынша Алтай ботаникалық бағындағы 74 *B. crassifolia* үлгілерінің коллекциясы жасалды, оның ішінде қысқа төзімділігі жоғары, маусымдық дамудың толық циклі бар, фенологиялық фазалар дамуының ұзақтығын өзгерту арқылы ауа-райы жағдайларына жауап беретін 59 сәндік үлгілері бар. Гүлдену мерзімдері бойынша үлгілер көктемгі-ерте гүлдену және көктемгі-орта гүлдену болып бөлінеді. Салыстырмалы бағалау нәтижелері бойынша сәндік бағалауы 87–98 балл болатын 8 нысан абаттандыру ассортиментіне енгізуге ұсынылды.

Кілт сөздер: Bergenia crassifolia, сәндік, Қазақстан Алтайы, коллекция, жерсіндіру, түр.

Л.А. Тучина, А.Н. Данилова, О.А. Лагус, А.А. Сумбембаев

Отбор по комплексу декоративных признаков формообразцов *Bergenia crassifolia* (L.) Frisch во флоре Казахстанского Алтая и их интродукция в Алтайском ботаническом саду

Цель исследования — отбор в естественных популяциях Казахстанского Алтая по комплексу декоративных признаков формообразцов *Bergenia crassifolia* из разных эколого-географических мест произрастания и их интродукционное испытание в Алтайском ботаническом саду, создание перспективных форм для включения в озеленительный ассортимент. Установлено произрастание *B.crassifolia* в Казахстанском Алтае на горных хребтах Южного и Юго-Западного Алтая в горно-лесном и альпийском поясах с порогом вертикального распространения 1100–1800 м над ур. м. В интродукцию перспективные образцы *B. crassifolia* по хозяйственно-ценным показателям отбирались на хребтах Южного и Юго-Западного Алтая. При этом использовались классические ботанические методы. По результатам исследований создана в Алтайском ботаническом саду коллекция из 74 образцов *B.crassifolia,* среди них 59 декоративных формообразцов с высокой зимостойкостью, полным циклом сезонного развития, реагирующие на погодные условия изменением продолжительности фенологических фаз развития. По срокам цветения образцы отнесены к весенне-раннецветущим и весенне-среднецветущим. По результатам сравнительной оценки 8 форм рекомендованы для включения в озеленительный ассортимент с оценкой декоративности 87–98 баллов.

Ключевые слова: *Bergenia crassifolia*, декоративность, Казахстанский Алтай, коллекция, интродукция, форма.

References

1 Semenova, G.P. (2007). *Redkie i ischezaiushchie vidy flory Sibiri: biologiia i okhrana [Rare and endangered species of Siberian flora: biology and conservation]*. Novosibirsk: Akademicheskoe izdatelstvo «Geo» [in Russian].

2 Akeroyd, J., & Jackson, P.W. (1995). *Handbook for botanic gardens on the reintroduction of plants to the wild*. *Botanic Gardens Conservation International.* Richmond, 200 p.

3 Shilnikov, M.A., Chernigova, E.N., Shemetova, I.S., & Shemetov, I.I. (2016). Ekologo-biologicheskaia otsenka dikorastushchikh vidov spirei, perspektivnykh dlia ozeleneniia Predbaikalia [Ecological and biological assessment of wild spirea species that are promising for landscaping the Cis-Baikal region]. *Vestnik Krasnoiarskogo gosudarstvennogo agrarnogo universiteta — Bulletin of the Krasnoyarsk State Agrarian University*, 8; 65–71 [in Russian].

4 Grudzinskaya, L.M., Gemedzhieva, N.G., Nelina, N.V., & Karzhaubekova, Zh.Zh. (2014). *Annotirovannyi spisok lekarstvennykh rastenii Kazakhstana [Annotated list of medicinal plants of Kazakhstan]*. Almaty [in Russian].

5 Tsyrendorzhieva, S.V., & Khamaganova, I.V. (2017). Ispolzovanie chernykh listev badana v proizvodstve pishchevykh produktov [Use of black bergenia leaves in food production]. *Tekhnika i tekhnologiia pishchevykh proizvodstv — Equipment and technology of food production*, 45(2); 81–86 [in Russian].

6 Satybaldiyeva, D.N., Mursaliyeva, V.K., Gemejiyeva, N.G., Sultanova, N.A., Yelibayeva, N.S., & Turasheva, S.K. (2013). Issledovanie sostava i soderzhaniia biologicheski aktivnykh veshchestv badana tolstolistnogo (*Bergenia crassifolia* (L.) Fitsch.) i krovokhlebki lekarstvennoi (*Sanguisorba officinalis* L.) [Study of the composition and content of biologically active substances in bergenia (*Bergenia crassifolia* (L.) Fitsch.) and burnet (*Sanguisorba officinalis* L.).]. *Vestnik Kazakhskogo natsionalnogo universiteta. Seriia biologicheskaia —Bulletin of the Kazakh National University. Biological series, 57*(1); 82–87 [in Russian].

7 Shikov, A.N., Pozharitskaya, O.N., Makarova, M.N., Makarov, V.G., & Wagner, H. (2014). *Bergenia crassifolia* (L.) Fritsch – Pharmacology and phytochemistry. *Phytomedicine, 21*(12); 1534–1542.

8 Golovchenko, V.V. et al. (2007). Structural study of bergenan, a pectin from *Bergenia crassifolia*. *Russian Journal of Bioorganic Chemistry, 33*; 47–56.

9 Ärok, R. et al. (2012). Phytochemical comparison and analysis of *Bergenia crassifolia* L. (Fritsch.) and *Bergenia cordifolia* Sternb., *Eur. Chem. Bull, 1*(1-2); 31–34.

10 Va, E. et al. (2020). Phenolic Compounds and Biological Activity of Badan (*Bergenia crassifolia* (L.) Fritsch) Leaves Growing in Russia. *Systematic Reviews in Pharmacy, 11*(5); 112–116.

11 Banzragchgarav, O. et al. (2019). Chemical constituents of Bergenia crassifolia roots and their growth inhibitory activity against Babesia bovis and B. bigemina. *Phytochemistry Letters, 29*; 79–83.

12 Pozharitskaya, O.N. et al. (2007). Separation and evaluation of free radical-scavenging activity of phenol components of Emblica officinalis extract by using an HPTLC–DPPH method. *Journal of separation science, 30*(15); 2447–2451.

13 Koul, B. et al. (2020). Bergenia genus: Traditional uses, phytochemistry and pharmacology. *Molecules, 25*(23); 5555.

14 Shilova, I.V. et al. (2006). Antioxidant properties of *Bergenia crassifolia* extract. *Pharmaceutical Chemistry Journal, 40*; 620–623.

15 Hendrychová, H. et al. (2014). Antioxidant activity and phenolic content of *Bergenia crassifolia*, *B.* x *ornata* and B. *ciliata*. *Natural product communications, 9*(4); 1934578-1400900424.

16 Kraujalienė, V. et al. (2016). Biorefining of Bergenia crassifolia L. roots and leaves by high pressure extraction methods and evaluation of antioxidant properties and main phytochemicals in extracts and plant material. *Industrial Crops and products, 89*; 390–398.

17 Carmen, P.O.P., Vlase, L., Tamas, M. (2009). Natural resources containing arbutin. Determination of arbutin in the leaves of *Bergenia crassifolia* (L.) Fritsch. acclimated in Romania. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37*(1); 129–132.

18 Lubsandorzhieva, P.B. et al. (2000). Chromatospectrophotometric determination of arbutin in the leaves of *Bergenia crassifolia* (L.) Fritsch. *Pharmaceutical Chemistry Journal, 34*; 261–264.

19 Furmanowa, M., & Rapczewska, L. (1993). *Bergenia crassifolia* (L.) Fritsch (Bergenia): Micropropagation and arbutin contents. In *Medicinal and Aromatic Plants IV* (pp. 18–33). Berlin, Heidelberg: Springer Berlin Heidelberg.

20 Akzhigitova, Z. et al. (2020). Phytochemical study of *Bergenia crassifolia*. *Chemistry of Natural Compounds, 56*; 912–914.

21 Nekratova, N.A., & Shurupova, M.N. (2014). Resources of medicinal plants in the Kuznetsky Alatau. *International journal of environmental studies, 71*(5); 656–666.

22 Khudonogova, E.G. et al. (2019). Stocks of raw materials of wild medicinal plants in the Western Baikal Region. *IOP Conference Series: Earth and Environmental Science, 315*(7); 072002.

23 Aidarbayeva, D.K., et al. (2018). Natural resources of some medicinal plants of Kazakhstan. *International Multidisciplinary Scientific GeoConference: SGEM, 18*(6.2); 385–391.

24 Konovalova, M.E. et al. (2020). Biodiversity and structure of undisturbed mountain Siberian Pine taiga of the Idarsky Belogorye Ridge (East Sayan). *Contemporary problems of ecology, 13*; 48–59.

25 Aidarbayeva, D.K., & Mursal, A.D. (2018). Resources of Food And Medicinal Plants Ridge Altai Tarbogatai. In *Ecological education and ecological culture of the population*; 34–39.

26 Martusova, E., Sizykh, A., & Shekhovtsov, A. (2019). Geobotanic Characteristics of Vegetation In The Baikal State Biosphere Reserve. *International Journal of Ecosystems & Ecology Sciences, 9*(1); 1–10.

27 Radeloff, H. et al. (1940). Megasea (Bergenia crassifolia) and its cultivation in Germany as a source of tannin. *Forrchungsdienst., 9*; 443–454.

28 Yeo, P.F. (1971). Further observations on Bergenia in cultivation. *Kew Bulletin, 26*(1); 47–56.

29 Yang, M. et al. (2013). Habitat change effects on the flowering behavior of *Bergenia crassifolia* (L.) Fritsch. *Vegetos, 26*(1); 218–222.

30 Turbina, I.N., & Kravchenko, I.V. (2018). Results of Introduction of *Bergenia craccifolia* (L.) Fritsch in Taiga Zone of Western Siberia. *The bulletin of Irkutsk State University. Geoarchaeology, Ethnology, and Anthropology Series, 23*; 43–53.

31 Habtemariam, S. (2013). The hidden treasure in Europe's garden plants: Case examples; Berberis darwinni and Bergenia cordifolia. *Medicinal & Aromatic Plants, 2*(4); 1–8.

32 Anufrieva, O.A. (2003). Itogi introduktsii B. *crassifolia* na Zapadnom Altae [Results of the introduction of B. *crassifolia* in Western Altai]. *Botanicheskaia nauka na sluzhbe ustoichivogo razvitiia stran Tsentralnoi Azii — Botanical science in the service of sustainable development of Central Asian countries*. Almaty, 90–95 [in Russian].

33 Danilova, A.N., Kotukhov, Yu.A., Anufrieva, O.A., Vinokurov, A.A., & Satekov, E.Ya. (2011). *Assortiment rastenii dlia ozeleneniia gorodov i sel Vostochnogo Kazahstana [Assortment of plants for landscaping cities and villages of Eastern Kazakhstan]*. Ridder [in Russian].

34 Egorina, A.V., Zinchenko, Yu.K., & Zinchenko, E.S. (2003). *Fizicheskaia geografiia Vostochnogo Kazakhstana [Physical geography of Eastern Kazakhstan]*. Ust-Kamenogorsk: Alfa-Press [in Russian].

35 Danilova, A.N., Sumbembaev, A.A., & Kotukhov, Yu.A. (2021). Adaptatsionnaia otsenka *Sypripedium macranthon* Sw. v Altaiskom botanicheskom sadu [Adaptation assessment of Cypripedium macranthon Sw. in the Altai Botanical Garden]. *Problems of botany of Southern Siberia and Mongolia, 20*(1); 151–155 [in Russian].

36 (2015). *Altaiskomu botanicheskomu sadu — 80 let [Altai Botanical Garden is 80 years old]*. Ust-Kamenogorsk: Media Alians [in Russian].

37 Shcherbakov, A.V., & Mayorov, A.V. (2006). *Polevoe izuchenie flory i gerbarizatsiia rastenii [Field study of flora and herbarization of plants]*. Moscow: Izdatelstvo Moskovskogo gosudarstvennogo universiteta [in Russian].

38 Sobolevskaya, K.A., & Kharkevich, S.S. (1984). *Ischezaiushchie rasteniia Sibiri v introduktsii [Endangered plants of Siberia in introduction]*. Novosibirsk: Nauka [in Russian].

39 Denisova, L.V., Nikitina, S.V., & Zaugolnova, L.B. (1986). *Programma i metodika nabliudenii za tsenopopuliatsiiami vidov rastenii Krasnoi knigi SSSR [Program and methodology for observing cenopopulations of plant species from the Red Book of the USSR]*. Moscow: Gosagroprom; VNII okhrany prirody i zapovednogo dela [in Russian].

40 (1979). Metodika fenologicheskikh nabliudenii v botanicheskikh sadakh [Methodology for phenological observations in botanical gardens of the USSR]. *Bulleten Glavnogo botanicheskogo sada Akademii nauk SSSR — Bulletin of the Main Botanical Garden of the USSR Academy of Sciences, Issue 113*; 3–8 [in Russian].

41 Bylov, V.N. (1971). Osnovy sortoizucheniia i sortootsenki dekorativnykh rastenii pri introduktsii [Basics of variety study and variety assessment of ornamental plants during introduction]. *Bulleten Glavnogo botanicheskogo sada Akademii nauk SSSR — Bulletin of the Main Botanical Garden of the USSR Academy of Sciences, Issue 81*; 69–77 [in Russian].

42 Zaitsev, G.N. (1973). *Metodika biometricheskikh raschetov [Methodology of biometric calculations]*. Moscow: Nauka [in Russian].

43 Plants of the World Online. (POWO, 2022). Retrieved from https://powo.science.kew.org/cite-us

Information about the authors

Tuchina Lidia Alexeevna — Junior researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: altai_bs@mail.ru;

Danilova Aleftina Nikolayevna — Leading researcher, candidate of biological science, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: a-n-danilova@yandex.ru;

Lagus Olga Anatolievna — Junior researcher, master of biology, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: lelik_ridder1994@mail.ru;

Sumbembayev Aidar Aytkazyevich — PhD, general director of Altai Botanical Garden, Ridder, Kazakhstan; e-mail: aidars@list.ru.