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Ecological conditions of growth and breeding analysis of *Viburnum opulus* populations in the Kazakhstan part of the Altai Mountains

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Abstract. *Danilova AN, Vdovina TA, Isakova EA, Kotukhov YA, Sumbembayev AA. 2024. Ecological conditions of growth and breeding analysis of* Viburnum opulus *populations in the Kazakhstan part of the Altai Mountains. Biodiversitas 25: 2845-2857.* The purpose of this paper was to study the ecological growth conditions of *Viburnum opulus* L. populations and the variability of the main morphological parameters of the vegetative and generative spheres of the species at the interpopulation level in the Kazakhstan part of the Altai Mountains as a future promising donor for breeding work. As a result of field research, using route-reconnaissance, traditional geobotanical, and morphometric methods, 24 isolated locations of *V. opulus* were discovered in the Kazakhstan Altai in the geographical areas of Kalbinsky, Western, and Southern Altai. These areas' ecological conditions of the species growth were studied for the first time, based on which the characteristics of plant communities with the participation of *V. opulus* were compiled. It was found that the species grows mainly in three types of associations: tree-shrub, shrub-meadow in the forest zone, and steppe shrub-meadow in the mountain-steppe zone. Plant communities with the participation of *V. opulus* occupy areas on the northwestern and southeastern mountain slopes associated with river valleys. The vertical range of distribution of the species varies from 395 to 913 masl. The total area of the territory occupied by plant communities with the participation of *V. opulus* was 198.85 ha. Furthermore, when studying interpopulation variability in 9 populations isolated from each other and located in different ecological and geographical growing conditions, 3 main groups of characteristics were identified depending on the degree of variability. High variability was revealed in the height of the shrubs, fruits in the cluster and their weight, the color of ripe berries, taste indicators for fruit bitterness from 1 to 4 points, and yield. Promising populations regarding productivity were identified in Kalbinsky, Western, and Southern Altai, depending on the ecological and geographical growth in the Kazakhstan Altai.

Keywords: Distribution, morphological trait, plant communities, variability, *Viburnum opulus,* yield

Abbreviations: masl: meters above sea level, pop: population

INTRODUCTION

The conservation and rational use of plant genetic resources are paramount in the face of accelerating global climate change. This environmental shift poses a significant threat to the survival of natural vegetation and the stability of ecosystems worldwide (IPCC 2021). As climatic conditions become increasingly unpredictable, the need to understand and preserve the genetic diversity of wild plants becomes ever more critical. Global climate change has a profound impact on plant ecosystems, leading to altered growth patterns, shifts in species distribution, and increased vulnerability to diseases and pests (Walther et al. 2002; Parmesan and Yohe 2003). These changes threaten the integrity of natural habitats and the biodiversity they support. Kazakhstan is also experiencing significant climate changes that are impacting its wild plant species. The country's average annual temperature has risen by 0.3°C per decade over the past century, leading to altered precipitation patterns and more frequent extreme weather events (UNDP 2022). Investigation of natural diversity within wild plant populations is crucial for the sustained development and conservation of plant species (Bellard et al. 2012). This knowledge serves as a foundational resource for the selection and establishment of high-yielding introduced populations (Segelbacher et al. 2022).

Forests in Kazakhstan, which cover about 5% of the country, are also under threat, including Kazakhstan part of the Altai Mountainous country, which is a natural habitat for 2450 plant species (Kotukhov 2005). This geographic region of Kazakhstan poses a large amount of plant genetic resources, including wild berry bushes. One of the most promising bush species there is *Viburnum opulus* L., commonly known as guelder rose or European cranberrybush. Botanically, *V. opulus* belongs to the genus *Viburnum* L., classified within the Adoxaceae family (Flora of Kazakhstan 1965). This is a shrub or small tree, that typically grows to a height of 2-4 m with 5-10 cm leaves. The leaves are opposite, simple, and palmately lobed with three lobes. The flowers are white and arranged in corymbs about 10 cm across. The inflorescence is heterostylous, consisting of larger, sterile outer flowers and smaller, fertile inner flowers. The flowering period is late spring to early summer (May to June). The fruit is a bright red drupe,

7-10 mm in diameter, containing a single seed. *Viburnum opulus* is common in natural habitats of Europe, some regions of North Africa and North Asia, central zone of Russia, norther and eastern Kazakhstan (Kajszczak et al. 2020).

According to the "Flora of Kazakhstan" (1965), the territory of Kazakhstan is divided into 36 floristic regions. *V. opulus* could be found in 14 of them: 1) Spurs of the General Syrt, 2) Tobol-Ishim (north), 3) Irtysh, 4) Semipalatinsk pinery, 5) Kokchetav, 7) Aktobe, 10a) Ulutau, 11) East upland, 11a) Karkaraly, 12) Zaysan, 22) Altai, 23) Tarbagatai, 24) Dzungarian Alatau (north), and 25) Ile Kungei Alatau (Flora of Kazakhstan 1965). Therefore, this species is found in all climatic zones of the country, except for arid and extra-arid areas. The bushes of *V. opulus* could be found in the undergrowth and along the edges of damp deciduous, coniferous, and mixed forests, in tree and shrub thickets along the banks of springs, rivers, lakes, swamps, ravines, gorges, and mountain slopes, in burnt areas and clearings.

Viburnum opulus is a valuable decorative, medicinal, and food plant. Its fruits are high in vitamins, particularly vitamin C, and contain significant amounts of antioxidants, which helps in reducing oxidative stress and preventing chronic diseases such as cardiovascular diseases and certain cancers (Kraujalytė et al. 2013). Raw berries of *V. opulus* are commonly used in preserves, jellies, and sauces (Stabnikova et al. 2024). The berries have been reported to possess anti-inflammatory and antispasmodic properties, making them useful in the treatment of conditions like arthritis and muscle spasms (Kraujalytė et al. 2013; Moldovan et al. 2017; Zarifikhosroshahi et al. 2020; Zakłos-Szyda et al. 2020; Capar et al. 2021; Dienaitė et al. 2021; Skrypnik et al. 2021). Extracts from *V. opulus* fruits have also shown antimicrobial activity against pathogenic bacteria and fungi, suggesting their potential use in preventing and treating infections (Česonienė et al. 2012). The *in vitro* studies revealed the antimicrobial potential of *V. opulus* against several pathogenic gram-positive and gram-negative bacteria and the possibility of regulating the root formation process during clonal micropropagation (Muratova et al. 2021; Goławska et al. 2023). *Viburnum opulus* demonstrates an important ecological role as well - it has an extensive root system that helps stabilize soil and prevent erosion, particularly along riverbanks and in areas prone to flooding (Dostálek et al. 2007), while fruits of *V. opulus* are an important food source for many bird species (Hernández 2009). Due to a significant role for humankind and wildlife, *V. opulus* was also comprehensively studied for genetic diversity (Ozrenk et al. 2020; Yaman 2022; Hamm et al. 2023). Studies of the biochemical parameters of genotypes of *V. opulus* growing in the natural environment have revealed the great potential of this species for breeding (Ozrenk et al. 2020). However, *V. opulus* populations in the Kazakhstan part of the Altai Mountains remains poorly studied (Vdovina and Lagus 2023).

The aim of this paper was to study the ecological conditions of *V. opulus* populations and the variability of the main morphological parameters of the vegetative and generative organs of the species at the interpopulation levels in the Kazakhstan part of the Altai Mountains, as well as the possibility to use *V. opulus* for breeding programs. The study of the morphological variability of *V. opulus* in various habitats was aimed at the identification of ecological and morphological responses to growing conditions and to determine the species' potential as a donor for breeding and genetic selection of promising forms.

MATERIALS AND METHODS

Study area

The object of the study was species *Viburnum opulus* commonly found in natural plant populations of the Kazakhstan part of the Altai Mountains (Kazakhstan Altai). The names of accepted genera and species of vascular plants found in plant communities with the participation of *V. opulus* were verified according to the Plants of the World Online website (POWO 2023).

The main territory of material collection on the territory of the Kazakhstan were the Southern, Western, and Kalbinsky Altai geographical areas (Table 1, Figure 1). The identified locations of populations of the study object in the Kazakhstan Altai were mapped in the ArcGIS program, formatted in an electronic meta-database, and posted on the GBIF (2024). The following methods were used during fieldwork: route reconnaissance, traditional geobotanical, and morphometric methods (Vdovina and Lagus 2023). At the stage of field surveys, the growing areas of *V. opulus* were identified, the coordinates of the main points of the areas were determined, and the area was measured.

Methods and statistics

The experiments were conducted during 2012-2015 and in 2023. Fresh material collected during the phase of full fruit ripening (late September-first ten days of October) was used for the study. To assess interpopulation variability in each population, 50 fruits were collected from at least 10 individual plants. The yield was calculated as the total number of fruits per plant. The taste qualities of the fruits were assessed organoleptically on a 6-point scale of taste variations based on the presence of bitterness in the fruits: 0 points - fruits are sweet, sweet and sour, bland without bitterness; 1 point - sour-sweet with a slight bitterness; 2 points - slightly bitter; 3 points - sour and bitter; 4 points - bitter; 5 points - very bitter (Vdovina and Lagus 2023). The color variability of *V. opulus* fruits was identified according to MacAdam (1974) scale. The eye measured crown density from 0 to 1, where 0 is the minimum density, and 1 is the maximum. Statistical analysis including mean values, minimum and maximum valurs, Coefficients of Variation (CV) was carried out using the Statistica 6.1 software. To assess the level of variability of the studied indicators for breeding and genetic analysis, the following scale of levels of variability was used: Cv<12% - low, Cv≥13-20% - medium, Cv≥21-40% - high, Cv> 40% - very high (Yaman 2022).

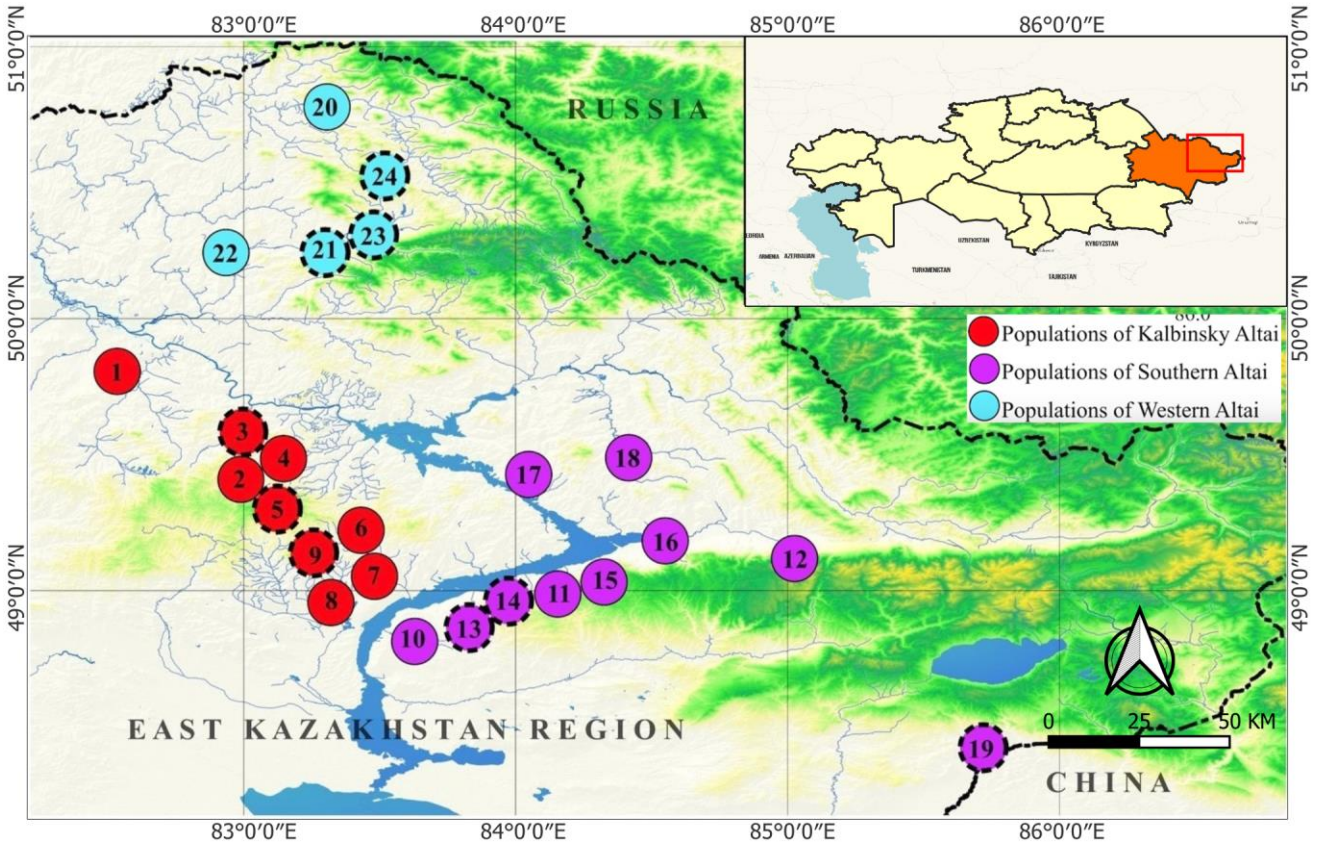

Figure 1. Geographical points of *Viburnum opulus* populations found in the Kazakhstan Altai. Note: The dotted line indicates populations selected for selection and genetic analysis

Natural populations of *V. opulus* were studied in various ecological and geographical habitats, where the climate was formed under the influence of the proximity of the deserts of Mongolia and Central Asia, its location in the center of the Eurasian continent, remote from the oceans, as well as under the influence of continental-oceanic transport of air masses (Khapilina et al. 2021b). Following the classification adopted in the "Flora of Kazakhstan"(Flora of Kazakhstan 1956), Kazakhstan Altai belongs to the floristic region 22 Altai. The geographical location of the region, its geological structure, the complexity and diversity of the relief, as well as soil-climatic and hydrological conditions, determine its division into 3 physical-geographical regions: Southern Altai, Western Altai, Kalbinsky Altai (Kotukhov et al. 2020).

The Southern Altai Mountain system is located at the junction of the borders with Russia, Mongolia, and China. Altitude within the region varies from 600 to 700 masl. (low small hills) in the foothill belt in the west and southwest, in the south - ridges 1,500 to 3,400 masl, and in the northeast from 2,000 to 2,500 masl. The climate is sharply continental. The climatic features of Southern Altai 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 and 800-1,000 mm in the mountain forest belt. Southern Altai is the coldest place in the Kazakhstan Altai (Khapilina et al. 2021a, Kotukhov et al. 2018).

Western Altai is formed by a high (1,500-2,800 masl) ridges system. Low-mountain and submountain areas are within 500-700 masl. The climate is sharply continental, characterized by cold, long winters, hot summers, and sharp fluctuations in air temperature throughout the day, season, and year. The amount of precipitation varies from 400 to 550 mm per year in the western part and up to 1500 mm at the upper forest limit in the eastern and northeastern parts of the region (Sumbembayev et al. 2022; Kubentayev et al. 2023).

Kalbinsky Altai is formed by the Kalbinsky ridge and at absolute heights are 400-1600 masl. Low-mountain is the most widely developed type of relief, with a small hilly character along the periphery. The climate of Kalbinsky Altai is sharply continental. The average temperature of the warmest month (July) is +19+22°C, and the coldest month (January) is from 14 to 19°C. The low-mountain Kalbinsky Altai is characterized by relatively less moisture compared to the Southern and Western Altai. Average annual precipitation varies from 280 to 400 mm, with a summer maximum shifted to spring (Danilova and Sumbembayev 2021; Orazov et al. 2024).

The soils in the research areas are light chestnut, forming the main background against which the vertical spectrum of soils characteristic of the Kazakhstan Altai appears: dark chestnut, steppe chernozems and forest-steppe, gray forest soils, mountain taiga acid soils, and mountain meadow chernozems (Kotukhov 2021).

Table 1. Habitats of *Viburnum opulus* populations on the territory of the Kazakhstan Altai in the Altai Mountainous country

Population	Location	Coordinates of the main points of the sections				Community type
		Latitude	Longitude	Altitude (m a.s.l.)	Area (ha)	
Kalbinsky Altai						
1	Eastern part of Kalbinsky Ridge, the northwestern slope of the Baichi River Valley	49.8269	82.5269	620.0	2.75	Forb-grass moderately moist meadow
2	Eastern part of Kalbinsky Ridge, northwestern slope, Targyn River valley	49.5142	83.0375	644.0	3.20	Shrubbed moderately moist meadow
3	Eastern part of Kalbinsky Ridge, southeastern slope, Tainty River Valley	49.5247	83.0261	597.0	1.0	Bushy poplar-birch forest
4	Eastern part of Kalbinsky Ridge, southeastern slope, Tainty River Valley	49.5247	83.0608	587.0	0.700	Poplar-willow bush forest
5	Eastern part of Kalbinsky Ridge, southeastern slope, Laila River Valley	49.3514	83.1042	650.0	1.30	Tree-shrub-tall grass forest
6	Eastern part of Kalbinsky Ridge, southeastern slope, Laila River Valley	49.1236	83.3450	720.0	0.50	Poplar-birch-reed forest
7	Eastern part of Kalbinsky Ridge, southeastern slope, Laila River Valley	49.0842	83.4214	623.0	0.50	Birch-shrub-forb forest
8	Eastern part of Kalbinsky Ridge, southeastern slope, Laila River Valley	49.0850	83.3533	617.0	1.5	Shrubby mixed-grass, moderately moist meadow
9	Eastern part of Kalbinsky Ridge, intermountain gorge, along the bank of the Laila River	49.1058	83.3419	670.0	1.8	Tree-shrub-forb forest
Southern Altai						
10	Narym Ridge, northwestern slope, the Valley of the Kaiyndysu River	48.9244	83.7203	501	1.5	Steppe shrubby meadow
11	Narym ridge, northwestern slope, Kanai River Valley, Kanaisay tract	49.04583	84.0442	408	7.4	Tree-shrub coastal moist forest
12	Narym ridge, northwestern foothills, Valley of the Naryn River	49.17028	85.0056	728	1.0	Excessively wet meadow, swamp
13	Narym Ridge, northwestern slope, the Valley of the Shortan River	48.9133	83.7336	544	3.5	Tree-shrub-tallgrass forests
14	Narym Ridge, northwestern slope of the Kanasai Gorge, Kanai River Valley	49.0489	84.0419	544	2.7	Shrubbery, moderately moist coastal meadow
15	Narym ridge, northwestern slope of the gorge, Valley of the Karaseir River	49.0503	84.0936	461	7.5	Poplar-viburnum-birch forest
16	Narym intermountain depression, the Valley of the Naryn River	49.2061	84.5211	395	5.5	Shrub thickets
17	Northwestern spurs of the Bukhtarma Mountains, Borodino River Valley	49.4269	84.0061	410	4.0	Tree-shrub tall-grass forest area
18	Bukhtarma Mountains, northwestern foothills, Berezovka River Valley	49.5186	84.3931	553	8.0	Birch-poplar tall grass forest area
19	Azutau ridge, northwestern foothills, Bas-Terekty River Valley	48.4544	85.6936	657	5.5	Steppe shrubby meadow
Western Altai						
20	Southeastern spurs of the Ubinsky ridge, Valley of the Butachikha River	50.8329	83.2894	695	15.0	Shrubby forb-grass meadow
21	Southeastern foothills of the Ubinsky ridge, Valley of the Ulba River	50.2758	83.2881	507	4.0	Moderately moist edge of dark coniferous forest
22	Foothills of the Ubinsky ridge, southeastern spurs, Valley of the Ulba River	50.2741	82.8967	910	12.0	Mixed moderately moist shrubby forest
23	Foothills of the Ulbinsky ridge, southeastern slope, Valley of the Ulba River	50.3559	83.4494	815	11.0	Mixed moderately moist shrubby forest
24	Foothills of the Ubinsky ridge, southeastern spurs, Valley of the Zhuravlikha River	50.4217	83.4978	913	97.0	Mixed moderately moist shrubby forest

RESULTS AND DISCUSSION

Field research identified 24 points of *V. opulus* populations in various plant communities in the Kazakhstan Altai, covering Kalbinsky, Southern, and Western Altai (Figure 1). Geobotanical studies have elucidated the spatial distribution patterns, ecological characteristics, and phytocenotic features of *V. opulus* in the Kazakhstan Altai region. It was found that populations of *V. opulus* are primarily located on the northwestern and southeastern slopes of the mountain ridges. Individual populations of *V. opulus* were also found in intermountain gorges with watercourses. The vertical distribution range of the species within the surveyed region extends from 395 to 913 masl. Moreover, *V. opulus* plants was observed growing in both open areas of slopes and gorges as well as under the sparse canopy of tree species.

A discernible pattern in the distribution of *V. opulus* across the geographical regions of the Kazakhstan Altai has been identified. In the Kalbinsky Altai, this species is primarily confined to the valleys of mountain rivers on the northwestern and southeastern slopes of the Eastern Kalbinsky Ridge. *V. opulus* contributes to the formation of heterogeneous tree-shrub communities and moderately moist forb-shrub meadows within an altitudinal range of 587 to 720 masl. In Southern Altai, plant communities with the participation of *V. opulus* were found along river valleys in the northwestern foothills and slopes of ridges and mountains, intermountain depressions in the altitudinal range from 395 to 728 masl. In Western Altai, habitats of *V. opulus* were found on the southeastern foothills of the ridges along river valleys in shrubby-forb meadows and mixed forests at an altitude of 507 to 913 masl.

The total area of the territory occupied by plant communities with the participation of *V. opulus* was 198.85 hectares, of which 13.25 hectares were in Kalbinsky Altai, 46.6.0 hectares were in Southern Altai, and 139.0 hectares were in Western Altai.

The floristic composition of communities with the participation of *V. opulus* is represented by 103 species of vascular plants belonging to 84 genera Table 2). At the same time, the similarity of the floristic composition of the *V. opulus* population in the Southern and Western Altai was established at the level of 66.0-69.90% in relation to the entire flora of the communities, and in the Kalbinsky Altai this figure was 56.0%. In the composition of phytocenoses with the participation of *V. opulus*, there are species with high abundance: Kalbinsky Altai - *Bromopsis inermis* (Leyss.) Holub, *Calamagrostis epigeios* (L.) Roth, *Filipendula ulmaria* (L.) Maxim., *Lathyrus pisiformis* L., *Malva thuringiaca* (L.) Vis., *Phragmites australis* (Cav.) Trin ex Steud; Southern Altai - *Acer negundo* L., *Populus laurifolia* Ledeb., *Populus tremula* Ledeb., *Bromopsis inermis* (Leyss.) Holub, *Calamagrostis epigeios* (L.) Roth, *Veronica annagalis-aquatica* L.; Western Altai - *Acer negundo* L., *Lonicera tatarica, Populus laurifolia* Ledeb., *Bromopsis inermis* (Leyss.) Holub.

Kalbinsky Altai

Spatially isolated populations of *V. opulus* are concentrated in the valleys of mountain rivers and springs as part of tree-shrub-forb and meadow communities. The soils are mountain meadow chernozems, and the vegetation cover is well-formed. *Populus laurifolia* Ledeb is common in the tree stand. Crown density varies in a wide range from 0.3 to 0.7. The bush belt is dense, formed by *V. opulus* L., *Crataegus chlorocarpa* Maxim., *Salix viminalis* L., *Prunus padus* L.

The grass stand needs to be more evenly developed, and there are areas where it formed diffusely, in groups with a projective coverage of 50 to 65%. *Phragmites australis* (Cav.) Trin ex Steud dominates in such areas. Most localities with *V. opulus* are characterized by well-developed grass stands, formed mainly by tall forest grass species with a projective cover of 95%, and tiering is not expressed. *Viburnum* shrubs are located diffusely in spatially isolated groups of 3 to 12 individuals of different ages or as single individuals. The density of individuals in all associations is low, ranging from 3.0 to 5 shrubs per 100 m^2. Additionally, *V. opulus* in the shrub layer acts as a subordinate species, occasionally as a subdominant.

Southern Altai

Viburnum opulus grows as undergrowth in meadows, swamps, and forests. The species' identified habitats are represented by three main associations: tree-shrub and shrub-meadow associations with varying degrees of moisture were identified in the forest zone, and steppe shrub-meadow associations were established in mountain-steppe areas. The main type of soil is mountain meadow chernozem.

The vegetation cover in the surveyed associations is formed heterogeneously. The tree and shrub communities in the forest stand are dominated by *Populus laurifolia*, *P. tremula* Ledeb., and *Betula pendula* Ledeb. In the humid group of forests, *Populus nigra* L. and *Salix alba* L. are mixed into the plantings. Crown density varies in a wide range from 0.1 to 0.9. The undergrowth is well defined with a projective cover of 0.5 to 1.0. *Viburnum opulus*, *Lonicera tatarica*, *Grataegus chlorocarpa* Lenne et K. Koch, *Rosa acicularis*, *Spiraea hypericifolia* L. and *Rubus caesius* L. participate in its formation within the shrub layer in the riverbed part. The dominant species is *Salix viminalis* L.; *Salix cinerea* L. and *Caragana arborescens* Lam are also found sporadically.

In shrub-forb-meadow communities located along the valley areas of the foothills, the aspect is formed by plantings of shrubs with a density of 0.6-0.8 with a projective cover of 60 to 80%. Single individuals of *Salix alba*, *Populus laurifolia*, and *Betula pendula* represent the tree stand. In the shrub layer, the dominants are *Acer negundo* L., *Salix cinerea* L., *Prunus padus* L.; associated species: *Rosa acicularis*, *Lonicera tatarica*, *Rubus caesius*. The grass stand is sparse, with a cover percentage of no more than 35.0%, whereas *Brachypodium pinnatum* (L.) Beauv., and *Agrimonia pilosa* Ledeb. The layering of the grass stand is not clearly expressed.

Table 2. Summary floristic composition of phytocenoses with the participation of *Viburnum opulus* indicating the species abundance in the territory of Kalbinsky, Southern and Western Altai of Kazakhstan

Plant names	Kalbinsky Altai	Southern Altai	Western Altai
Trees, shrubs, subshrubs			
Acer negundo L.	sol	cop$_2$	cop$_2$
Amygdalus nana L.	-	sol	-
Betula pendula Roth	sol	sp	sp
Caragana arborescens Lam.	-	sp	sp
Cotoneaster melanocarpus Fisch. ex Blytt	-	sol	-
Crataegus chlorocarpa Lenne et K. Koch	-	sol-sp	-
Lonicera altaica Pall.	sol-s	-	-
Lonicera tatarica	sol-sp	sol-sp	cop
Populus laurifolia Ledeb.	sp	cop$_2$	cop$_2$,
Populus tremula Ledeb.	sol	cop$_1$	sp
Prunus padus L.	sp-sol	-	sp
Rhamnus cathartica L.	s	s	s
Rosa acicularis Lind	sol	sol-sp	sol
Rosa laxa Retz.	-	sp	-
Rubus caesius L.	-	sp	-
Rubus idaeus L.	-	sp	sp
Rubus saxsatilis L.	sp-sol	-	sp-sol
Salix alba L.	s	sol	-
Salix caprea L.	sp	sp	sp
Salix cinerea L.	-	sp-cop$_2$	-
Salix viminalis L.	sol	cop$_2$-sp	-
Solanum dulcamara L.	sol-s	-	-
Sorbus aucuparia subsp. *glabrata* (Wimm. & Grab.) Hedl.	s	-	s
Spiraea hypericifolia L.	sol-s	sp	s
Spiraea media	sol	sol	sol
Viburnum opulus L.	sp	sol-sp	sol
Herbaceous plants			
Achillea millefolium L.	sp	sol	sol
Aconitum volubile Pall. ex Koelle	s	s	sol
Agrimonia pilosa L.	sp	sp	s
Alfredia cernua (L.) Cass.	-	-	sol
Alopecurus pratensis L.	-	sol	sol
Angelica decurrens (Ledeb.) B. Fedtsch	-	sol	-
Angelica sylvestris L.	-	sol	-
Artemisia absinthium L.	sol	-	sol
Artemisia austriaca Jacqui.	sp	sp	sol
Artemisia sericea (Besser) Weber	-	-	sol
Artemisia vulgaris L.	-	sol	sol
Asparagus neglectus Kar. et Kir.	sp	sol	-
Brachypodium pinnatum (L.) Beauv.	cop$_2$	sp	-
Bromopsis inermis (Leyss.) Holub	sol	cop$_2$	sp-cop$_2$
Bunias orientalis L.	-	-	sol
Bupleurum aureum subsp. *aureum*	-	-	sol
Calamagrostis epigeios (L.) Roth	cop	cop	sp
Calystegia sepium (L.) R. Br.	sp	-	sp-sol
Carex macroura Meinsh.	-	-	sol
Chelidonium majus L.	-	sol	-
Cirsium arvense var. *vestitum* Wimm. & Grab.	sol	sol	-
Clematis integrifolia L.	sol	sol	sol
Conium maculatum L.	-	-	sol-sp
Cuscuta europaea L.	-	-	sp
Dactylis glomerata L.	sp	sp	sol-sp
Delphinium elatum L.	-	s	-
Dracocephalum nutans L.	-	sol	-
Echium vulgare L.	-	-	sol
Elymus mutabilis (Drob.) Tzvel.	sol	sol	sol
Elymus repens (L.) Gould	sol	s	sol-sp
Epilobium palustre L.	sp	-	-
Equisetum hyemale L.	sp-sol	sp	-
Equisetum pratense Ehrh.	sp-sol	-	sp
Equisetum sylvaticum L.	sp-sol	sp	sp
Fallopia convolvulus (L.) A. Löve	-	-	sol
Festuca altissima All.	sol	sol	s
Festuca ovina L.	-	sol	sol
Filipendula ulmaria (L.) Maxim.	cop$_2$-sp	sol	sol
Fragaria viridis Duch.	-	sol	sp-cop
Galium verum L.	sol	sol	sp
Geranium collinum Steph.ex Willd.	sol	sol	-
Hieracium umbellatum L.	-	sol	sol
Humulus lupulus L.	-	-	sp-cop$_2$
Inula helenium L.	sol	-	sol
Koenigia alpina (All.) T.M.Schust. & Reveal	-	sol	-
Lathyrus pisiformis L.	cop$_1$	sp	sol
Lathyrus tuberosus L.	sol	-	sol
Leymus angustus (Trin.) Trin.	-	sol	-
Lilium martagon var. *pilosiusculum* Freyn.	sol	-	sol
Lolium pratense (Huds.) Darbysh.	-	-	sol
Malva thuringiaca (L.) Vis.	cop$_2$	-	s
Medicago falcata L.	s	sol	s
Mentha longifolia var. *asiatica* (Boriss.) Rech.f.	-	cop$_2$,-sp.	-
Myosotis krylovii Serg.	-	sol	-
Origanum vulgare L.	sp	sol	sol
Parasenecio hastatus (L.) H. Koyama	s	-	s
Phleum pratense L.	-	sol	sol
Phragmites australis (Cav.) Trin ex Steud	cop$_1$	-	-
Poa palustris L.	sol	sol	sol
Polygonum aviculare L.	-	sol	sp
Potentilla chrysantha Trevir	-	-	sp
Rumex confertus Willd.	sp	sp	s
Salvia dumetorum Andrz. ex Besser	-	sp	-
Sanguisorba officinalis L.	-	s	s
Scirpus sylvaticus L.	-	sp	-
Setaria viridis (L.) P.Beauv.	-	-	sp
Sibbaldianthe bifurca (L.) Kurtto & T. Erikss	-	sp	-
Silene latifolia subsp. *alba* (Mill.) Greuter & Burdet	-	sol	sol
Sonchus arvensis L.	-	s	-
Stellaria bungeana Fenzl	sol	-	-
Tanacetum vulgare L.	s	sol	sol
Thalictrum simplex L.	sp	sol	sol
Tragopogon pratensis L.	sp	-	sol
Urtica dioica L.	sp	-	-
Veronica annagalis-aquatica L.	-	cop$_2$	-
Veronica beccabunga L.	-	cop$_2$	-
Vicia cracca L.	sp	sol	sp

Mountain-steppe associations with the participation of *V. opulus* were identified in steppe shrubby forb meadows, where *Crataegus chlorocarpa* Maxim formed the base of the shrub layer. Layer density - 05-07, coverage - 70%. The density of the grass stand is from 03 to 07; its share and coverage account for 60-80%. The layering is weakly expressed.

In all associations, *V. opulus* bushes are located diffusely in the area, in spatially isolated groups of 2 to 7 individuals of different ages, or as single bushes. The density of bushes in all associations is low, ranging from 2 to 7 bushes per 100 m^2. *Viburnum opulus* in the shrub layer acts as a subordinate species, occasionally as a subdominant.

Western Altai

Viburnum opulus occupies significant areas, less often found in small spots in the foothills on the southeastern slopes not exceeding above 910 masl, as part of a forest belt with a well-developed shrub layer. The identified habitats of the species represent two types of associations: tree-shrub and shrub-meadow associated with river valleys. The soils are mountain-meadow chernozems, loose, well-drained, and characterized by a constant moisture regime. Ground cover up to 23 cm is represented by litter in varying degrees of decomposition.

In the vegetation cover of tree-shrub associations, *Populus laurifolia*, *P. tremula* and *Betula pendula* form the tree layer. The density of the tree stand does not exceed 03. The shrub layer is well formed, dominated by *Lonicera tatarica* L. Among the subordinate species, the most common are *Prunus padus*, *Salix caprea*, *Rubus idaeus*, *Viburnum opulus*, *Rhamnus cathartica* L. The shrub layer density is relatively high - 0.5-0.8. *V. opulus* accounts for 3.2% of the cover.

The grass stand is well-developed and clearly three-tiered, and the total projective cover is 95%. However, there are sparse areas within dense thickets of bushes. The first tier, 120-150 cm high, comprises tall grass species. Their share in the cover is no more than 8-10% at a density of 01. The second tier, 70-90 cm high, is composed of *Clematis integrifolia* L., *Calamagrostis epigeios*, *Artemisia sericea* (Besser) Weber, and etc. The share of the second tier in the grass cover is 55-65%, with a density of 05-07. The third tier, 20-25 cm, is formed mainly by vegetative shoots of cereals and *Fragaria virides* Duch. Coverage can be up to 60%, density 07-08.

Shrub-meadow associations with the participation of *V. opulus* occupy the gentle southeastern slopes of the foothills and trails of hills along the moderately moist edges of the dark coniferous forest and shrubby forb-grass meadows at an altitude of 507-695 masl. The soil horizon is developed, reaching 112-140 cm, and the top layer up to 30 cm is loose mountain meadow chernozem. The underlying layer is represented by clays with significant inclusions of crushed stone. The ground cover is formed by litter in varying degrees of decomposition, in some places reaching 35 cm. The total projective cover is 100%. The tree layer is not expressed; singly growing *Betula pendula*, *Populus tremula* L., *Prunus padus* (tree form 10-15 m), and *Picea obovata* Ledeb are noted. In the shrub layer, the dominant species are *Prunus padus* and *Rosa xanthina*. The share of shrubs in the cover is up to 70%; the density is 04-09.

The grass stand is well-developed, three-tiered, and heterogeneous, with a total projective coverage of 85%. The first grass tier stands 150-170 cm high, above or at the level of the bush. Participation in the cover is 17-25%; density is not higher than 01. The second tier, 90-70 cm high. Coverage not more than 30%, density - 07. The third tier, 25-45 cm high. Layer density 03-07, cover - 27-35%, in open areas up to 70%.

In all associations, *Viburnum* bushes are located diffusely in the area, in spatially isolated groups of 2 to 7 individuals of different ages, or as a single bush. The density of bushes in all associations is low, ranging from 2 to 5 bushes per 100 m^2. *Viburnum opulus* in the shrub layer acts as a subordinate species, occasionally as a subdominant.

The expeditionary research revealed nine isolated populations of *V. opulus* were selected for comparative selection and genetic analysis on the territory of the Kazakhstan Altai in the geographical areas of Western, Kalbinsky, and Southern Altai. In each region, three populations were selected: Pop 21, Pop 23, Pop 24 (Western Altai); Pop 3, Pop 5; Pop 9 (Kalbinsky Altai); Pop 13, Pop 14, Pop 19 (Southern Altai).

As fieldwork has shown, *V. opulus* is a shrub with gray-brown bark and smooth young shoots on the territory of the Kazakhstan Altai. The bushes on the territory of the Kalbinsky Altai and Western Altai are always multi-trunked; in the Southern Altai, both multi-trunked and small-trunked bushes are noted. In all populations, the bushes are loose and straggling (Figure 2).

A comparison of the height of fruiting *V. opulus* showed that the highest mean values were found for individuals growing in Western, Kalbinsky, and Southern Altai in tree and shrub communities (Pop 23, Pop 3, Pop 13), where this indicator varied from 3.4 m to 3.5 m. The lowest mean value was found for individuals growing in the Southern Altai in mountain-steppe conditions on shrubby meadows, where the average plant height was 1.6 m. Different growing conditions can explain the range between the studied plant height levels (Figure 3).

In the Kalbinsky Altai, Pop 9 and Pop 3 demonstrated an average level of variability of the trait: 15.1% and 18.7%, respectively. For the Pop 5, this indicator was lower; the level of variability was also low—10.8%. In the Southern and Western Altai, the mean level of variability in plant height was found in all populations in the range of 16.3-19.2%. Along with the study of plant height of fruiting plants, a comparative assessment of the size of drupe cluster, the number of fruits per cluster, the total weight of the drupe cluster were carried out as the main criteria for selecting promising forms.

Information on interpopulation variability of morphometric characters of *V. opulus* fruits is presented in Table 3.

Table 3. Interpopulation variability of morphometric characters of *Viburnum opulus* fruits in Kazakhstan Altai

Population	Statistical indicators	Average drupe cluster size, cm		Mean values		
		Length	Width	The number of fruits per drupe cluster, count	Drupe cluster's weight, g	Weight of one fruit, g
Kalbinsky Altai						
3	(M±m)	6.8±0.20	6. 4±0.49	45.6±10.7	16.1±2.45	0.7±0.02
	C%	19.8	16.64	40.8	23.4	6.5
	P%	2.5	1.16	6.0	4.5	1.2
5	(M±m)	7.2±0.6	6.8±0.4	39.16±8.14	12.4±4.33	0.4±0.01
	C%	14.0	24.93	27.48	17.5	7.5
	P%	3.3	3.44	6.5	1.27	2.1
9	(M±m)	7.6±0.2	7.2±0.3	29.3±5.7	12.5±4.2	0.5±0.01
	C%	15.6	13.4	26.4	16.7	13.0
	P%	2.6	2.1	4.9	1.27	2.3
Southern Altai						
13	(M±m)	7.23±0.61	6.84±0.44	41.8±2.9	12.1±0.8	0.3±0.01
	C%	11.2	13.76	32.8	9.38	5.61
	P%	4.23	1.05	3.41	3.54	2.12
14	(M±m)	6.88±0.51	6.24±0.44	40.5±5.88	16.12.6	0.43±0.03
	C%	15.9	17.9	22.54	27.4	8.1
	P%	2.22	2.1	5.1	5.3	3.0
19	(M±m)	5.57±0.70	4.25±0.34	24.0±4.0	8.00±1.81	0.41±0.01
	C%	18.8	12.24	24.8	30.80	2.88
	P%	5.93	3.87	4.85	6.0	1.10
Western Altai						
21	(M±m)	6.57±0.47	5.62±0.45	27±3.67	9.72±1.18	0.37±0.02
	C%	12.83	14.21	23.73	28.7	5.27
	P%	3.43	3.80	6.34	5.90	2.14
23	(M±m)	5.47±0.57	4.62±0.62	25±5.04	8.42±2.17	0.4±0.03
	C%	19.42	24.93	33.97	37.66	11.57
	P%	5.01	6.44	6.2	5.84	4.37
24	(M±m)	6.88±0.51	6.24±0.49	41.0±5.89	16.06±2.65	0.5±0.03
	C%	15.9	16.64	22.14	27.4	8.06
	P%	1.22	1.16	6.09	5.5	3.04

Note: M: the mean value, m: standard error, min-max: minimum and maximum values, C%: coefficient of variation, P%: the relative error of the mean

Figure 2. Multi-stemmed shrubs of *Viburnum opulus* in the Kazakhstan Altai

The study of the traits of *V. opulus* fruits showed that in each experimental population, depending on the degree of variability, three main groups of traits are distinguished: low, medium, and high levels of variability. The most stable morphological characteristic in all populations was the weight of one fruit: in Western Altai - 5.27-11.57%, Kalbinsky Altai - 6.5-13.0%, Southern Altai - 2.88-8.1%. Characteristics such as the length and width of the drupe cluster vary at an average level of variability in almost all populations. The exceptions were the populations Pop 23 in Western Altai and Pop 5 in Kalbinsky Altai, where high level of variability in the width of the drupe cluster (24.93%) was established.

A trait that had a high level of variability in the populations was the number of fruits in the cluster, the range of which was from 22.14 to 33.97% in Western Altai, from 26.4 to 40.8% in Kalbinsky Altai, and from 22.5 to 32.9% in Southern Altai. Significant variations at the interpopulation level were detected in weight of drupe cluster. For example, in populations from Western Altai (Pop 21, Pop 23, Pop 24), the trait variability varied at a high level, in the range of 25.5-41.05%, from Kalbinsky Altai (Pop 3, Pop 5, Pop 9), at the average level of 16.7-23.4%. In the Southern Altai, for the Pop 13, this trait has a low variation rate ot 9.38%, indicating the stability of this trait.

To comprehensively assess the variability of morphological parameters in the studied populations of *V. opulus*, qualitative morphological characteristics, such as the color of ripe fruits, were examined alongside morphometric and quantitative indicators. Visual observations revealed a variation in the berry color palette. Within each geographic area, three primary color variations of ripe fruit were identified: orange, red, and maroon (Figure 4).

Figure 5 shows the percentage of *V. opulus* fruits by the three main color variations in the Kalbinsky, Southern and Western Altai of the Kazakhstan Altai.

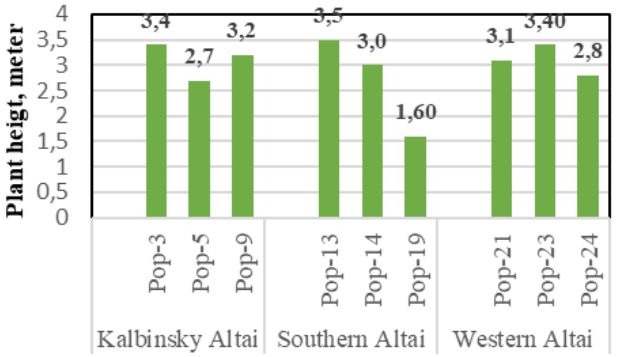

Figure 3. Height of fruiting plants of *Viburnum opulus* in the Kazakhstan Altai

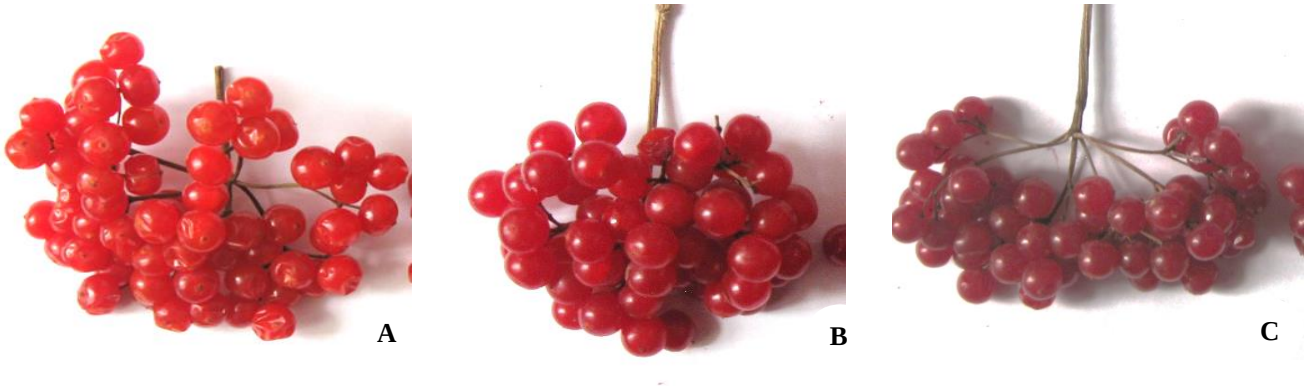

Figure 4. Color variations of *Viburnum opulus* fruits collected on the territory of the Kazakhstan Altai. Note: A. Orange; B. Red; C. Maroon

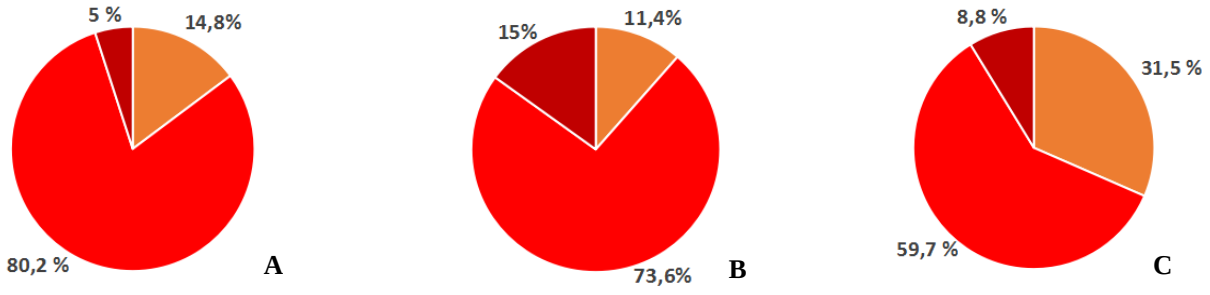

Figure 5. Color variations of mature fruits of *Viburnum opulus* in the Kazakhstan Altai. Note: A. Kalbinsky Altai; B. Southern Altai, C. Western Altai. : Red fruits (%), ; Orange fruits (%), : Maroon fruits (%)

Viburnum opulus with red fruits dominated across all experimental populations. In percentage terms, this type constituted 59.7% in Western Altai, and 80.0 and 73.6% in Kalbinsky and Southern Altai, respectively. Plants bearing orange and dark burgundy fruits were found in smaller quantities in Kalbinsky and Southern Altai, with the exception of the Western Altai, where they accounted for 35.1% of the total number of observed plants. It was noted that no discernible pattern could be established in the distribution of plants with varying fruit colors relative to the environmental conditions of the population locations.

The organoleptic analysis revealed that *V. opulus* fruits in Western Altai, irrespective of color, were predominantly sour-bitter, with a taste rating of 3 points. Additionally, individual bushes bearing bitter fruits were identified across all three color variations (orange, red, maroon), and these fruits received a taste rating of 4 points.

In the Kalbinsky Altai, various taste variations were identified within the experimental populations. In Pop 9, the fruits were medium-sized, round, slightly flattened at the ends, red or orange in color, and had a slightly bitter taste, with a taste variation rating of 2 points. In Pop 5, the fruits were red or maroon, oval-round, and short-pointed at the top; they had a sour and bitter taste, with a taste rating of 3 points. In Pop 3, fruits of all three color variations (red, orange, dark burgundy) were noted; the taste was sour and bitter, with a taste score of 3 points.

In the Southern Altai, specifically on the Narymsky Ridge in the Shortan River Valley within a tree-shrub-tall grass forest (Pop 13) and the Kanasai Gorge in the Kanai River Valley within a bushy, moderately moist coastal meadow (Pop 14), *V. opulus* bushes with red and maroon fruits were identified. The berries were characterized by a sweet and sour taste with a slight bitterness, earning a taste rating of 1 point. In Pop 19, bushes with orange and red fruits were observed, along with sporadic occurrences of forms with maroon fruits. The taste qualities of the orange and red fruits were slightly bitter, with a score of 2 points, whereas the maroon fruits had a sour-bitter taste, with a score of 3 points.

Given that yield is the primary criterion for determining the economic value of fruit and berry plants with edible fruits, this indicator was analyzed in nine experimental populations of *V. opulus*. Fruits were harvested from five bushes in each population to assess the mean yield. The results for each population are presented in Figure 6.

As a result of the studies, inter-population differences in yield were established depending on the population's location. The highest productivity of *V. opulus* fruiting plants was recorded in the Western and Southern Altai, specifically within the tree and shrub communities (Pops 21 and 13) of the mountain forest belt, where fruiting per plant varied from 2.3 to 2.9 kg. In the Southern Altai, the yield indicators exhibited an average level of variability. Populations in the Kalbinsky Altai, although part of tree and shrub communities, were characterized by lower yields ranging from 1.1 to 2.1 kg per plant. This variation was likely associated with the number of fruiting shoots, the number of fruits in each cluster, and the average weight of an individual fruit. *V. opulus* in the mountain-steppe conditions of the Southern Altai (Pop 19) also demonstrated a low yield of 1.7 kg per plant.

In the Kalbinsky Altai, two populations (Pop 5 and 9) exhibited high variability in the yield index, at 33.5 and 36.3%, respectively, while Pop 3 showed very high variability (Cv=42.5%). Based on a comparative analysis in the Southern Altai, Pops 13 and 19 had average variability in bush yield, at 17.5 and 14.8%, respectively. A higher level of variability was observed in Pop 14, where the variability was 25.7%. In the Western Altai, all three experimental populations demonstrated a high level of variability in yield indicators, ranging from 25.9 to 34.8%.

The assessment of plant density in the studied populations (Figure 7) indicated that the highest density of *V. opulus* plants (plants/100 m²) was found in Pops 4 and 9, with 5 bushes per 100 m². Conversely, the lowest density was observed in Pop 12, with 2.3 plants per 100 m², and in Pop 16, with 2.5 plants per 100 m².

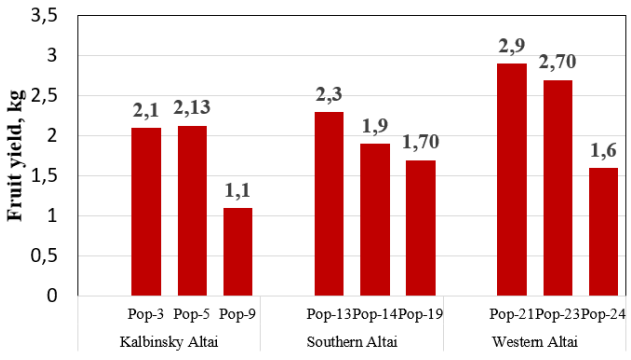

Figure 6. Yield indicators of *Viburnum opulus* in different ecological conditions of the Kazakhstan Altai

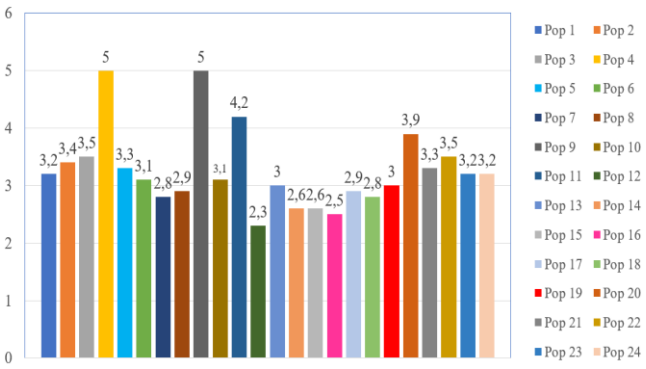

Figure 7. The density of *Viburnum opulus* plants in the studied populations

Discussion

In the introduction, it was previously stated that *V. opulus* is currently a very popular research subject on a global scale. However, information on the population-level study of this species is practically absent for the Kazakhstan part of the Altai mountainous region. Unlike other previously conducted studies on the selection of *V. opulus* forms, where cultivated collections were studied (Goławska et al. 2023), only wild forms were used in our study. This study marks the beginning of population research of the species in its natural habitats, aiming to identify promising donor forms based on biological and economic characteristics for inclusion in the breeding process. In comparison with other studies on the selection of *V. opulus*, where only physical and chemical parameters were used (Çolak et al. 2022), the selection in our study was also based on the parameters of population productivity and fruit size.

Expeditionary research conducted in the Kazakhstan part of the Altai mountainous region (Kazakhstan Altai) identified 24 sites where *V. opulus* grows. Of these, 9 sites were located in the Kalbinsky Altai, 10 in the Southern Altai, and 5 in the Western Altai. These sites were spatially isolated, and general environmental indicators and differences were established regardless of geographic location.

Based on extensive geobotanical information obtained from route and reconnaissance surveys in the Kazakhstan Altai, a characterization of communities involving *V. opulus* was compiled. The species was found to predominantly grow in three types of associations: tree-shrub, shrub-meadow in the forest zone, and steppe shrub-meadow in the mountain-steppe zone. Plant communities with *V. opulus* were located on the northwestern and southeastern mountain slopes, primarily associated with river valleys. The vertical distribution range of the species varied from 395 to 913 meters above sea level.

The total area occupied by plant communities involving *V. opulus* was found to be 198.85 hectares. Analyzing these areas revealed an uneven distribution of the species across different geographical regions. In the Kalbinsky Altai, *V. opulus* communities occupied 11.2 hectares; in the Southern Altai, they covered 46.6 hectares; and in the Western Altai, they extended over 137 hectares. Field observations indicated that *V. opulus* did not form thickets but was diffusely distributed in spatially isolated groups of no more than 2-7 individuals of varying ages or as single bushes. Additionally, the density of bushes per unit area was low across all regions: 3.5±0.6 bushes/100 m² in Kalbinsky Altai, 2.9±0.3 bushes/100 m² in Southern Altai, and 3.3±0.2 bushes/100 m² in Western Altai.

The floristic composition of plant communities involving *V. opulus* varied significantly across geographical areas. In the tree-shrub and meadow associations of the Kalbinsky Altai, the herbaceous cover's layering was not pronounced. In contrast, in the Southern and Western Altai, the tree-shrub and shrub-forb-meadow communities of the forest belt exhibited distinct layering in the herbage; however, in the mountain-steppe regions, the steppe shrubby forb meadows showed less pronounced layering. *V. opulus* participated in forming the shrub layer as a subordinate species in all surveyed plant associations and occasionally as a subdominant.

Interpopulation variability studies of *V. opulus* in different ecological and geographical conditions identified three main groups of characteristics: low, medium, and high levels of variability. High variability was observed in the height of the bushes, the number and weight of fruits in clusters, the colors of ripe berries, and taste indicators for fruit bitterness (ranging from 1 to 4 points). Dimensional characteristics exhibited a smaller amplitude of variability than counting characteristics, consistent with general variability patterns.

Comparative interpopulation analysis indicated that fruiting bushes of *V. opulus* in tree and shrub communities were more productive, suggesting that fruiting depends on climatic factors, particularly moisture supply, and the type of community in which the species is located. The coefficient of variability for yield in the nine experimental populations of Kazakhstan Altai ranged from average to very high, indirectly indicating the trait's dependence on the plant genotype.

Yield assessment materials must consider the taste qualities and sizes of fruits to identify populations in Kazakhstan Altai as donors of promising genotypes based on selection and genetic traits. This identification is essential for creating new varieties, forms, and hybrids after studying the biochemical composition of the fruits.

In conclusion, the research is very important for modern fundamental and applied science to search and identify promising donor forms of *V. opulus* growing in natural places in the Western, Kalbinsky and Southern Altai in the Kazakh part of the Altai Mountainous country. They are of great scientific interest for genetics and breeding since, at the present stage in Kazakhstan, there is an acute problem of creating highly productive regionalized domestic varieties. Therefore, the research is necessary to attract biologically productive forms into the breeding process, replenishing the cultural gene pool of *V. opulus*.

Interpopulation ecological studies, along with selection and genetic analyses, made it possible to reveal the potential capabilities of *V. opulus* from various habitats in the Kazakhstan Altai as a most valuable donor of promising forms based on biological and economic traits for selection.

Comparing the interpopulation variability of the studied morphological characters of *V. opulus* allowed us to predict the efficiency of the selection process. In particular, to improve the organoleptic properties of fruits, the main attention in the breeding process should be directed to the search for forms with a reduced bitterness content.

Based on the results of the research, it was found that the most valuable source populations for selecting promising forms for breeding work, due to the good balance of biological and economic indicators, size and taste of fruits, and yield, is the population in the Kalbinsky Altai; this location was recorded on the Eastern Kalbinsky ridge, in a tree-shrub forb forest, 670 masl. The Southern Altai populations on the Narymsky Ridge, in the Valley of the Shortan River in a tree-shrub-tall grass forest at sea

level, were identified as promising forms for selection, and on Azutau Ridge, northwestern foothills, in the Valley of the Bas-Terekty River, on a steppe shrub meadow.

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