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ORIGINAL PAPER

Evaluation of the possibility and prospects of introducing plants for growth in the Akmola region (Kazakhstan)

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ABSTRACT

The article considers issues for increasing the stability and durability of spaces, as well as optimizing and expanding the range of industrial plantings by improving the esthetic properties of industrial plantations with the introduction of shrubs into the culture to enrich the visual environment. Shrubby vegetation in the industrial zones of the Akmola region is not rich in species composition. A review of the literature indicates that the number of ornamental breeds for practical use can be expanded at the expense of non-native shrub plants. To solve this problem work is underway to adapt new plant species, but the improvement of industrial zones with the necessary shrub vegetation creates many difficulties associated with unfavorable soil and climatic conditions of this region. The soils of the Akmola region are categorized as ordinary black soil as well as being characterized by a heavy mechanical composition, increased salinity, and low water. The content of humus in the soils of the Akmola region fluctuates from low to medium (2.0-4.5%). The second problem in the nutrition of plants since there is a low content of mobile phosphorus in the soil which is the main element that affects the drought resistance and yield of plants. Deficits of mobile phosphorus is connected with the low content of organic matter and mineral parts of the soil. Therefore, plant species adapted to the soil and climatic conditions of the Akmola region were selected with monitoring of the state of physical development of adaptable introduced shrub plants. As a result, introduced frost- and heat-resistant decorative forms resistant to soil and climatic conditions of the Akmola region have been introduced to landscaping projects. During the research, measures were analyzed and carried out aimed at improving their sustainability and care based on the introduction of new species. A comprehensive assessment of the degree of adaptation of growing shrubs introduced to the Akmola region was conducted based on the following three criteria: the nature of growth, generative development, and short-term resistance to winter hardiness in the conditions of natural growth. The types of introduced shrubs included the following: *Spiraea media*, *Euonymus europaeus*, *Tamarix ramosissima*, *Caragana frutex* and *Berberis vulgaris*. In order to determine the prospects for the use of introduced shrubs in industrial landscaping, a comprehensive assessment of their

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success in accordance with growing plants in industrial plantations was done. During the statistical processing of the collected data, the level of profitability and growth of the were obtained depending on the degree of adaptation of the species to the climatic conditions of the Akmola region in North Kazakhstan. As a result of this study, promising species of shrubs were identified to expand the range of plants for a wide and comprehensive introduction to the landscaping of industrial areas. In the case of the Akmola region, *T. ramosissima*, *B. vulgaris* and *C. frutex* are the 3 types of shrubs for growing in the garden that is recommended to use based on their high value for adaptability and success.

KEY WORDS

adaptation, introduction, shrubs, winter hardiness

Introduction

The issue of the introduction of new sustainable ornamental species of shrubs for industrial landscaping that are ecologically and sanitarily important has recently become very relevant for gardening in the natural and climatic conditions of the Akmola region. Intensive landscaping is not possible without the use of non-native species of shrubs alongside a composition of local arboriflora. The transfer of shrubs to new conditions is accompanied by stages of adaptation and acclimatization during which they show all the flexibility of species adaptation. Localization of shrubs in regions with harsh climatic conditions, such as the Akmola region, should be considered one of the possible ways to improve the quality of life in adverse climates (Nysanbaev, 2009; Zhumagulov, 2010). The range of shrub species used in green construction should be determined regionally based on specific climatic conditions.

One of the main indicators of the success of localization is the degree of adaptation of the plant to the new growing conditions. Adaptation is the process of adapting the structure and function of an organism to environmental conditions. Adaptation allows species to survive in the new environment, increases the rate of reproduction, and reduces mortality (Babich *et al.*, 2008). The adaptability of shrubs ultimately determines their prospects for green building. Many local species used in the landscaping of industrial areas are characterized by high decorative, ecological and sanitary properties, as well as being more resistant and durable in industrial plantings.

The district is characterized by low amount of species, which are mainly represented by spruce and to a lesser extent the following: *Pinus sibirica* Du Tour, *Betula pendula* Roth, *Populus tremula* L., *Salix alba* L., *Sorbus aucuparia* L., *Alnus glutinosa* (L.) Gaertn., *Rosa canina* L., *Prunus fruticosa* Pall., *Juniperus communis* L. Geobotanists have noted that there are about 700 species of higher plants belonging to more than 70 families in the region. However, there is information that the entire local flora includes over 1000 species. More than 100 species of compound flowers and from 30-60 species of *Poaceae*, *Lamiaceae*, *Rosaceae*, *Caryophyllaceae*, *Brassicaceae*, *Cruciferae*, *Apiaceae* and *Fabaceae* plants grow in the region. The remaining families include from 10 to 20 species each (Nysanbaev, 2009; Zhumagulov, 2010).

According to a study conducted by the LEGO Group in the northeastern part of Hungary in the area of acid dunes near the plant in Nyíregyháza (November 2015), more than 10,000 seedlings of 1-2 years old of 16 species of trees and shrubs were planted and covered 20% of the recovery area. Specific plans and surveys have been developed for each of the rehabilitated forest areas. In the first year, the survival rate of woody plants varied from 4 to 66% for different species. Climate can reduce height of the plants and the the survival rate of the tree. Seven species showed some (often contradictory) the extreme variability in growth related to the studied environment (Halassy *et al.*, 2020).

An assessment was conducted about the relationship between the characteristics along with the climatic and socio-economic conditions of 486 species of ornamental trees in 46 urban parks in Spain. Special emphasis was placed on the relationship of plant properties and climatic and socio-economic factors of non-native species relative to the non-native species found in Spain. A clear link was found between species characteristics and climatic influences such as more brightly colored plant species in warm winter parks and those more resistant to cold and shade in parks with cold winters and continental climates. According to the study, most of the registered species are non-native (82%), *i.e.*, mostly introduced trees and shrubs (Bayon *et al.*, 2021).

Abnormally severe winters, which are the main selection factor, strongly affect the condition and longevity of plants. While the effects of warm winters primarily affect the flowering and fruiting of plants, very cold winters result in deaths and severe damage to many plant species. Changes in the reproductive capabilities of plants are also closely related to the freezing of plants (buds, shoots and sometimes the entire plant). Excessive flowering and, consequently, fruit yield and seed quality can be sharply reduced (Bayon *et al.*, 2021; Tkachenko *et al.*, 2022).

Monitoring the winter hardiness of plants of different ages allows us to observe changes in the resistance of theplant structure. In introduced species, an increase in winter hardiness is observed during the transition from juvenile to mature which is reflected in the value of the winter hardiness coefficient (Demchenko, 2021). Local air volume and winter hardiness have been found to have a significant direct effect on adaptation. Winter-hardy and tall breeds are planted more often than others. Residence time is indirectly connected with significant positive relationship between number of planted tree species in botanical gardens and increases the success of adaptation. Most of the biological characteristics of tree species indirectly affect adaptation. Therefore, the failure to recognize such deviations when introducing the plants indicates that our ability to determine the success of the localization of other plant species may be occured (Maurel *et al.*, 2016).

In the case of the Akmola region, the possibility of using a shrub for planting purposes is mainly determined by the minimum temperature which the seed can withstand without significantly losing the plant's decorative properties. We can notice their short-term tolerance to the meso-relief of the land, wind direction and speed, air humidity, soil moisture, the height of the snow cover, etc. One of the main biological features like growt that determine the possibility of introduction, can often move in one direction or another under the influence of such microclimatic differences (Bulygin, 1979; Zalivskaya *et al.*, 2009). The ability to withstand adverse temperatures for a long time and the success of overwintering is determined not only by the winter conditions, but also by the plant general condition, the degree of completion of growth processes, timely deforestation, and reduced physiological activity (Kohno, 1980).

Thus, the best indicators of success of localization in the harsh natural and climatic conditions of the Akmola region are frost resistance, short-term tolerance, growth activity, habitation, The results of such studies help to expand the range of ornamental plants in industrial areas, as well as help identify new plants to introduce with a high adaptability to the adverse conditions of the industrial environment.

The purpose of the study is to assess the survival rate and introduction resistance of local species of shrubs growing in the natural and climatic conditions of the Akmola region for further use in green building. The study was conducted in the city of Astana in northern Kazakhstan on the property of the Botanical Garden.

Materials and methods

The objects of study were bushes to be introduced which are growing in the Akmola region. For the study we obtained species that have been successfully growing in industrial green areas for many years which are Mediterranean, European, multi-branched, bushy, simple barberry shrubs. These species are fully adapted to local climatic conditions and today form the basis of plantations in the Akmola region.

Field expeditions were conducted on the natural flora the Akmola region to identify the most promising species for primary introduction to the various regions of Kazakhstan. According to the results of the research, 5 types of ornamental plants recommended for introduction tests were selected which included the following: *Spiraea media* Schm., *Euonymus europaeus* L., *Tamarix ramosissima* Ledeb., *Caragana frutex* L. and *Berberis vulgaris* L.

Plant growth

Field expedition work for the collection of plant materials for scientific research was carried out in the period from 2020 to 2021. The study of the seasonal dynamics of growth and development of plants in crop conditions was carried out according to the generally accepted method of phenological observations in the Akmola region.

We identified indicators of short-term tolerance to frost of the following: *Spiraea media*, *Euonymus europaeus*, *Tamarix ramosissima*, *Caragana frutex and Berberis vulgaris* shrubs to be potentially introduced which were in the collection of the Astana Botanical Garden. To assess winter hardiness, a seven-point scale of winter hardiness assessment was used based on the degree of freezing of plants based on Lapin and Sidneva (1973) and according to the method of Sidneva.

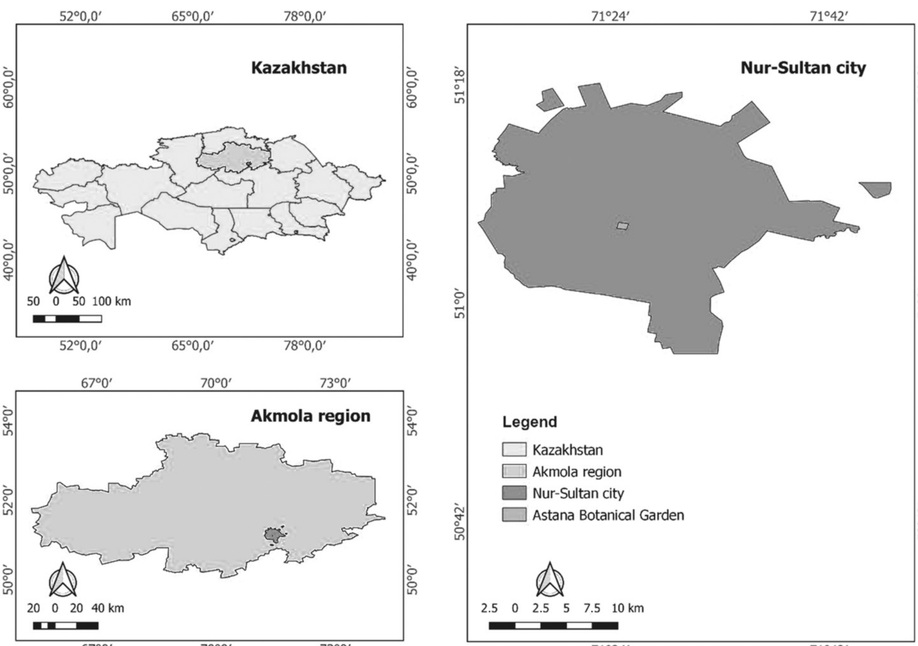


Fig. 1.
Geographical location of the research area

Based on this seven-point scale trees with scores of 1-2 are considered winter-hardy, 3 – medium--hardy, a score of 5 – weakly hardy and 6-7 – not winter-hardy, where the minimum score 1 – damaged (the plant does not grow), and the maximum score 7 – the plant grows completely.

The Astana Botanical Garden assessed the adaptive potential of these species of shrubs based on the study of phenological and morphological features according to generally accepted methods (Bulygin, 1979). Phenological observations were carried out every 3 days. The time of passage of such phenophases as swelling and opening of vegetative and generative buds, the beginning and end of shoot growth, isolation, blooming, completion of growth, flower and leaf fall, lignification of shoots, budding, flowering, laying, maturation, and fall of mature fruits were recorded. The phenophase was considered to have occurred if it was observed in at least 30% of shoots of all individuals of the studied species.

The measurement of seed sizes (length, width and thickness) was carried out using a caliper with an accuracy of 0.1 mm with 100 seeds of each species having been measured.

Statistical indicators were calculated using the program Statistica. The following statistical indicators were calculated: the average value with the main error X ±mx; the mean square deviation ∑; the coefficient of variability C, %; the accuracy of the experiment p [%]; the reliability of the conclusion I; the correlation coefficient g; correlation analysis (Mitropol'skij, 1965; Gusev, 2002); one-factor analysis of variance (Svalov, 1985; Lakin, 1990;). To determine the average height and diameter we construct the corresponding curves. The research data was processed at a 5% statistical significance level.

Results

The climate of the Akmola region is characterized by frequent changes in air masses. Invasion of cold Arctic air during the summer months often causes frost during the growing season but no summer month guarantees frost.

After the end of late spring frosts, which may damage the growing shoots, the winter hardiness of shrubs, the subject of the study, was assessed. In the landscaping of industrial areas with a harsh climate, both local and introduced species are actively used. In the winter of 2020 no climatic anomalies were recorded. Thus, the growing season of 2020 was characterized by less precipitation and low relative humidity. The average monthly air temperature above normal were obtained in July is 18.5°C and in August which is 21.7°C (Fig. 2).

Plants of flora from Kazakhstan, North America and Siberia that turned out to be the least resistant were: *Berberis vulgaris*, *Caragana frutex* and *Tamarix ramosissima* (Table 1).

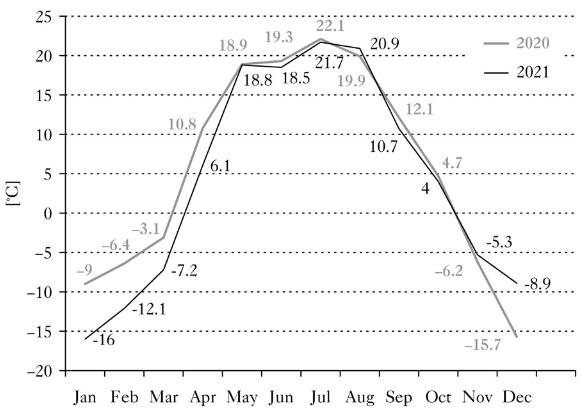


Fig. 2.

Average monthly and annual air temperatures in the Akmola region in 2020 and 2021

Observation of the seasonal development of the introduced plants showed that the beginning of their growth phase in the spring does not occur simultaneously, In many shrubs, the buds germinate in the first half of May before the air temperature reaches +5°C with thermophilic seeds germinating later (Table 2).

The growth and development of plants is influenced by the sum of air temperatures during the growing season. When comparing the sum of temperature above 5°C to start and end the growing season of plants, we found that the this demand of local species is much lower. If in local species the onset of vegetation takes 10-15 days with temperatures above +5°C, then in introduced species it takes 20-30 days from the beginning of the season. The end of the growing season in local species is 25-30 days before the onset of autumn frosts and in winter species 31-36 days. The initial phenophases (bud burst and flowering) are determined by air and soil temperature (Table 2).

Early vegetation was observed starting on: 20.04.2022 for *Spiraea media* and *Berberis vulgaris*, 28/04/2022 for *Caragana frutex* and 25/05/2022 with fruits of *Euonymus europaeus* beginning to ripen in late August 2022 year (Table 2).

The analysis of phenoregulation, which was carried out in the botanical garden over several years, showed that in the process of restructuring the cycle of plant development introduced in connection with the climatic rhythm of the Akmola region, both the timing and duration of the onset of phenological phases changed. In introduced species with early stages of onset and end of vegetation, the seasonal development cycle usually corresponds to the climatic cycle of the study area which ends at temperatures above +5°C. The vegetation period of plants requiring high temperatures exceeds the end of the growing season which negatively affects growth and height.

The short growing season forces many species to develop rapidly in the first half of summer to produce fully grown offspring. Based on the flowering period the introduced species are divided into the following groups: early flowering May 2-15 (*Spiraea media*, *Caragana frutex* and *Berberis vulgaris)* and late flowering June 2-10 (*Euonymus europaeus*) (Table 2).

Table 1.

Indicators of winter hardiness of shrubs in 2020-2021

The name of the plant	Winter hardiness	
	2020	2021
Spiraea media Schm.	2	1
Euonymus europaeus L.	2	1
Tamarix ramosissima Ledeb.	2	1
Caragana frutex L.	1	1
Berberis vulgaris L.	1	1

Table 2.

Seasonal development of plants

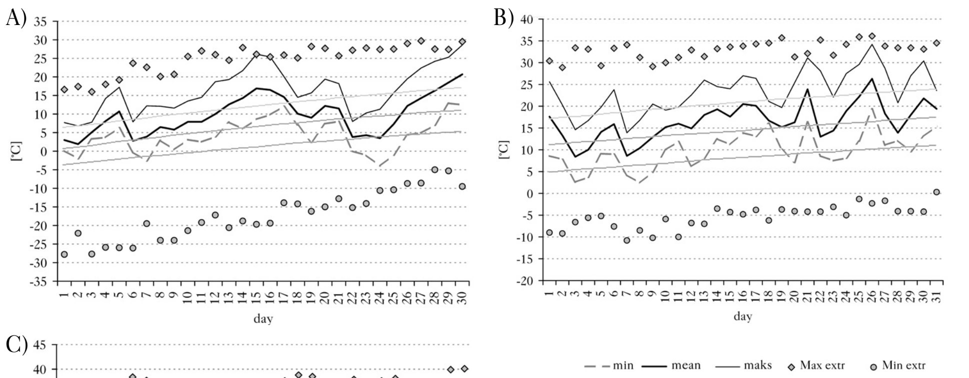
Name of plant	Winter hardiness	Swelling of buds	Budding	Growth		Flowering		Fruiting	
				start	end	start	end	start	end
Berberis vulgaris	1	20.04	24.04	02.05	–	24.05	02.06	10.06	–
Caragana frutex	1	24.04	28.04	02.05	–	06.05	26.05	02.06	–
Euonymus europaeus	2	20.04	28.04	02.05	–	28.05	12.06	–	–
Spiraea media	1	20.04	24.04	24.04		10.05	28.05	10.06	
Tamarix ramosissima	1	02.05	12.05	24.05		–	–	–	–

The annual growth of one-year seedlings of shrubs is a necessary period of the overall growth and development of the individual organism. The study of seasonal growth is important for the analysis of bioecological features of shrubs introduced for use in landscaping. The onset of seedling growth is determined by the combination of their biological characteristics and the effective spring temperature (Fig 3).

The diagrams show the main characteristics of the weather in Nursultan including air temperature and precipitation measured for every day from May to June 2022 (Fig. 3). Winter in the north of the country is cold and long (up to 6 months) and summer is moderately warm. The average temperature of the coldest month (January) is about –22°C and the hottest (July) +21°C. The average amount of precipitation is from 300 mm in the southern region and up to 650-700 mm in the northern. The growing season ranges from 135 days in the northern to 170 days in the southern region. The climate of the city of Nursultan is distinctly continental and arid. Summers are hot and dry, and winters cold and long with an average annual temperature of 3.1°C and 300 mm per year of precipitation. With an average summer temperature of about 20°C and an average winter temperature of about –15°C, it is not uncommon for the heat to exceed 40°C in summer and freezes down to –50°C possible in winter (www.pogodaiklimat.ru/monitor.php?id=35188&month=6&year=2022).

The duration of the growth period of the studied plants depends not only on their species characteristics, but also on meteorological conditions. Active growth of seedlings begins when the air temperature rises to 20°C and the soil (at a depth of 15 cm) rises to 10°C. At the beginning of the growing season, the amount of autumn-winter precipitation is very important for the warm spring conditions and in the hot summer period the amount of precipitation becomes very important (Table 3).

Phenological observations have established that in comparison with flowering, the fruiting intensity of non-native plants is lower and more variable over the years. To assess the reproductive properties of arboriflora the following were measured: fruiting score, biometric indicators



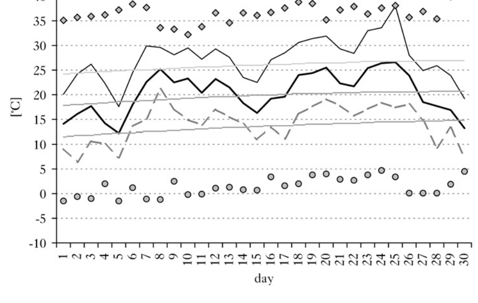


Fig. 3.

Temperature change during the study period from April to June 2022 in the vicinity of Nur-Sultan
A – April, B – May and C – June

and seed quality ss well as length, width, thickness and volume of seeds To assess the possibilities of introducing plantin a new region, a pressing need are studies on the quality of seeds of plants. The seeds of the plants selected to be introduced species are characterized by high germination, good quality and viability (Table 4).

Seeds characteristic of these species is presented in Table 4. The introduced species *Caragana frutex*, *Berberis vulgaris* and *Spiraea media* have good quality indicators (79-60%). *Tamarix ramosissima* and *Euonymus europaeus* have quality indicators that are average (59-40%).

The quantitative and qualitative characteristic of all the considered species is influenced by the weather conditions of the growing season. Seeds of the second generation of introduced species have improved sowing qualities compared to seeds of maternal origin. The size and absolute mass of the seeds of the introduced species are increasing based on the local conditions (Abramova, 1972).

Discussion

Based on research by Turmuhametovŕ (2005), the reproductive capacity of plants increases in conditions of technogenic environmental pollution. Low seed quality indicators are compensated by their increased reproductive capasity in the conditions of industrial and transport emissions.

Ahe Astana Botanical Garden assessed the adaptive potential of introductive species of shrubs based on the study of phenological and morphological features according to generally accepted methods (Bulygin, 1979). The results of the observations showed that the stages of growth of non-native and native seeds differ significantly. For example, the budding of *Euonymus europaeus* in 2021 began on 20/04/2021, passed into the budding stage on 28/05/2021, and bloomed on 12/06/2021. Growth was observed in late April and early May. The study of the seasonal cycles and patterns of growth of introduced trees is of great importance in understanding the essence of the processes of their adaptation to new environmental conditions. All native species and hardy-tolerant introduced species start and end the growing season early. In the process of growth and development they have adapted to climatic emergencies due to the short and rapid growth period with the ability to complete the lignification process in time and timely emergence from the rest period (Nysanbaev, 2009).

Table 3.
Average monthly and annual air temperatures [°C] in the Akmola region

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Average
2020	9.0	–6.4	–3.1	10.8	18.9	19.2	22.1	19.9	12.1	4.7	–6.2	–15.7	5.6
2021	–16.0	–12.1	–7.2	6.1	18.8	18.5	21.7	20.9	10.7	4.0	–5.3	–8.9	4.3
2022	1.2	–9.2	–7.2	9.7	16.5	–	–	–	–	–	–	–	–

Table 4.
Biometric indicators of seeds of the studied species

Species	Statistical indicator					
	min-max [mm]	X+mx [mm]	δ	C [%]	p [%]	t
Berberis vulgaris	3.3-4.0	3.5 ±0.1	0.2	6.2	1.6	62.6
Caragana frutex	4.0-4.3	4.2 ±0.03	0.1	3.2	0.8	121.1
Euonymus europaeus	4.8-5.2	5.0 ±0.1	0.5	8.2	2.4	158.0
Spiraea media	1.7-2.0	1.9 ±0.03	0.1	6.2	1.6	62.4
Tamarix ramosissima	3.0-4.0	3.6 ±0.1	0.5	14.1	3.6	27.5

In the Akmola region, the fruiting of the studied species in most cases is not inferior to the fruiting of similar species in a more southerly geographic point. The quantitative and qualitative side of all the considered breeds is influenced by the weather conditions of the growing season. Seeds of the secound generation of introduced species have improved sowing qualities compared to the seeds of maternal origin.

Low seed quality indicators are compensated by their increased formation in the conditions of industrial and transport emissions.

Short-term tolerance is the result of historical and ontogenetic development of plants under certain environmental conditions. This is not a permanent condition that depends on a number of circumstances, and attempts to explain it by some factor or property of the plant are usually unsuccessful. The short-term hardiness of plants of the same species depends on the geographical origin of the seed, and varies between different one-year plantings species and. In the first years of life, one- and two-year shoots grow many introduced woody plants can be destroyed by frost, but in the future their short-term hardiness will increase. This property is also enhanced in later generations of introduced species. The results of the short-term resistance assessment of plants provides a basis for assessing the prospects of introducing of plants in industrial green spaces. Short term tolerance of introduced species is one of the main biological features that determine the possibility of their growth in the Akmola region (Nysanbaev, 2009; Zhumagulov, 2010).

The onset of growth often coincides with the phenophases and onset of the leaves and is highly dependent on the thermal conditions of spring. The end of growth is determined by the supply of moisture to plants as related to the amount of precipitation in the second half of summer, especially in hot weather. In late summer, growth will continue as long as there is a favorable combination of heat and moisture (Bajtulin *et al.*, 1992).

The length of daylight affects the growth cycle of plants with those introduced to the north having an increased growth period. Also, shoots completes growth faster in a growing season with dry and hot weather than in cold and rainy weather (Lapin and Sidneva, 1973).

Intolerant introduced species do not change their cycle of development resulting in not having time to complete the growth process, and therefore, being severely damaged by frost (Zhumagulov, 2010). Late flowering and its relative duration, typical of many introduced species, significantly reduces the ripening time of the fruit which is already strictly limited to a short growing season (Babich *et al.*, 2008). As a result, these species experience a severe shortage of heat for the formation and ripening of fruits which is complicated by the low general temperature of the growing season (Halassy *et al.*, 2020) in the Akmola region. The result is poor development and immature fruits and seeds. It should be noted that with the general reduction in the duration of all phenological phases, the flowering period in the Akmola region is characterized by its elongation and duration (Alvaro *et al.*, 2021).

The beginning of the growing season is commonly very variable depending on environmental conditions. In a dry environment, leaf curling and flowering begin earlier than in wet areas. In warm and pleasant springs, the difference is smoothed (Malakhovec and Tisova, 2002a). In cold and wet springs, plant development begins later, and the phenophases last longer than in hot and dry periods (Malakhovec and Tisova, 2002b). Many researchers have found that short-lived species are characterized by early flowering and bud formation, as well as early and complete leaf fall during a short growing season (Lapin and Sidneva, 1973; Bulygin, 1979; Bajtulin *et al.*, 1992).

Limiting factors in the introduction of plants to the conditions of the Astana Botanical Garden are sharp changes in temperature and humidity throughout the year, season and day as well as aridity, salinity, steppe rodents, sunburn, and dry wind. It has been noted that the duration of the active growth of flowering plants is reduced due to a late spring and early autumn frosts (Tkachenko *et al.*, 2022). *Spiraea media* and *Caragana frutex*, short-lived shrubs are resistant to sudden changes in temperature, spring frosts and drought (Demchenko, 2021).

Ongoing agrotechnical and maintenance measures (winter covering, mulching, sanitary and anti-aging pruning, the introduction of organic and mineral fertilizers, regular weeding with soil loosening, digging, timely transplanting of herbaceous perennials, and treatment of pests and diseases) contribute to maintaining good plant conditions with minimal disadvantages (Tihonova, 1982).

Conclusion

Based on the influence of the following abiotic factors: prolonged drought, lack of atmospheric and soil moisture, very high temperatures, high emissions, as well as vibrations and noise from mobile vehicles, ionizing radiation, leading to destabilization of plantings during industrial adaptation, it can be concluded that the Akmola region is not very favorable for the introduction of many species of non-native plants. For successful acclimatization and adaptation it is necessary to carefully choose plants from the local flora or from areas with similar climatic conditions.

The passage of a full cycle of ontogenetic development by plants indicates their successful introduction. Fruiting of introduced plants is the most important indicator of their adaptation to new conditions, as it allows for the possibility of adaptive properties acquired in the process of ontogenesis. The generative development is the most responsive to environmental change. Flowering and fruiting are of special importance in urban conditions as they provide an attractive decorative appearance.

In the conditions of the Akmola region, the juvenile period of ontogenesis increases in most of the introduced species. In this regard, the entry into the fruiting phase of non-native breeds in this region occurs later than in their native habitats and in more southerly points where they have been introduced. Seeds of introduced plants in the first 3-4 years after entering the generative phase are often almost completely diffferent.

The results of the study confirm that the success of the introduction of a particular plant species depends mainly on the degree of adaptation of this species to the climatic conditions of the area that it was introduced. The adaptability of *Berberis vulgaris*, *Caragana frutex*, *Tamarix ramosissima*., *Euonymus europaeus* and *Spiraea media* shrubs determines the prospects for their introduction and further use in crops, which makes them recommended for use in industrial areas of the Akmola region.

Authors' contributions

Conceptualization – A.Sh., D.N., S.M., S.M.; Data curation – A.Sh., D.N., S.M., S.M.; Formal analysis – A.Sh., D.N., S.M., S.M.; Methodology – A.Sh., D.N., S.M., S.M.; Project administration – A.Sh., D.N., S.M., S.M.; Software – A.Sh., Zh.B.; Supervision – D.N., S.M., S.M.; Visualization – A.Sh., Zh.B.; Writing-original draft – A.Sh., D.N., S.M., S.M.; Writing-review and editing – A.Sh., D.N., S.M., Zh.B., S.M.

Conflicts of interest

The authors declare that they have no conflict of interest.

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STRESZCZENIE

Ocena możliwości i perspektyw rozwoju roślin introdukowanych w regionie Akmola w Kazachstanie

W artykule podjęto problematykę możliwości i perspektyw rozwoju krzewów introdukowanych w celu wzbogacenia środowiska przyrodniczego w regionie przemysłowym Akmola w Kazachstanie (ryc. 1). Roślinność krzewiasta stref przemysłowych tego regionu nie jest bogata. Liczbę gatunków ozdobnych można poszerzać, wykorzystując krzewy gatunków introdukowanych. Obecnie trwają prace nad możliwościami adaptacyjnymi nowych gatunków roślin. Wzbogacenie stref przemysłowych o krzewy stwarza wiele trudności związanych z niesprzyjającymi warunkami glebowymi i klimatycznymi (ryc. 2 i 3; tab. 3). W pracy dokonano podziału gatunków roślin dostosowanych do warunków glebowych i klimatycznych regionu Akmola. Kompleksową ocenę stopnia przystosowania krzewów introdukowanych w tym regionie przeprowadzono na podstawie 3 kryteriów: charakteru wzrostu, rozwoju generatywnego oraz krótkotrwałej odporności w warunkach wzrostu. Badaniami objęto: *Spiraea media* Schm., *Euonymus europaeus* L., *Tamarix ramosissima* Ledeb., *Caragana frutex* L. i *Berberis vulgaris* L. W celu określenia perspektyw zastosowania tych krzewów w przemysłowym regionie Akmola dokonano kompleksowej oceny powodzenia introdukcji w świetle aktualnego stanu i perspektyw ich uprawy na plantacjach przemysłowych (tab. 1 i 2). Określono stopień opłacalności i możliwości wzrostu gatunków w zależności od stopnia przystosowania do warunków klimatycznych regionu Akmola w Kazachstanie. W wyniku przeprowadzonych badań zaleca się stosowanie gatunków *Tamarix ramosissima*, *Berberis vulgaris* oraz *Caragana frutex*.

Krótki okres wegetacji zmusza wiele gatunków do szybkiego rozwoju w pierwszej połowie lata, aby wydać na świat potomstwo. W zależności od okresu kwitnienia gatunki te można podzielić na grupy: wcześnie kwitnące (2-15 maja) – *Spiraea media*, *Caragana frutex* i *Berberis vulgaris* oraz późno kwitnące (2-10 czerwca) – *Euonymus europaeus* (tab. 2).

Warunki abiotyczne regionu Akmola (przedłużająca się susza, brak opadów atmosferycznych i mała wilgotność gleby, bardzo wysokie temperatury, duża emisja, wibracja i hałas przemieszczających się pojazdów, a także promieniowanie jonizujące prowadzące do destabilizacji nasadzeń podczas adaptacji przemysłowej) nie sprzyjają introdukcji gatunków. W warunkach regionu Akmola u większości gatunków introdukowanych wydłuża się młodociany okres ontogenezy. Wejście w fazę owocowania ras introdukowanych następuje w tym regionie później niż w ich ojczyźnie.

Wyniki badań potwierdzają, że powodzenie introdukcji danego gatunku roślin zależy głównie od stopnia jego przystosowania do warunków klimatycznych obszaru introdukcji. Adaptacyjność krzewów *Berberis vulgaris*, *Caragana frutex*, *Tamarix ramosissima*, *Euonymus europaeus* i *Spiraea media* określa perspektywy ich wprowadzenia oraz dalszego wykorzystania na terenach przemysłowych regionu Akmola w Kazachstanie (tab. 4).