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Original article

DENDROLOGICAL COLLECTIONS OF THE KULUNDA CLUSTER FEDERAL RESEARCH CENTER OF AGROECOLOGY

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Background. *In 2016, the Kulunda Arboretum was given the status of a specially protected natural area of federal significance. A long-term array of data on the introduction potential of woody plants in collections forms the basis for regulating introduction work and increasing the efficiency of mobilization of economically important plants.*

Purpose *– assess the current state of bioresource collections of the Kulunda Arboretum.*

Materials and methods. *The objects of the study are the gene pool of the Kulunda Arboretum - 137 species, forms and hybrids. Clarification of the taxonomic composition of the gene pool of the collections and generalization of experimental inventory data (age, preservation, taxation parameters, viability, renewal) was carried out with the involvement of departmental materials and databases.*

Results*. The taxonomic composition of the collections, the age, safety, taxation and reproductive indicators of the introduced species has been specified. An analysis of the natural ranges of introduced woody plants revealed the predominance of representatives of the European (28%) and North American (19%) dendroflora. The ratio of the collection fund in terms of vitality indicators is given. It was revealed that 31,9% of plants are in good condition and promising for involvement in programs for the conservation and rational use of biological diversity. On the basis of a long-term study of plants and the experience of their introduction (since 1977), a group of tree species capable of invasive dispersal outside the collection areas of the Kulunda arboretum was identified.*

Conclusion. *Based on the inventory of collection areas of the Kulunda Arboretum, the composition of trees and shrubs was clarified (137 taxa, 52 genera, 24 families) and ranked according to preservation (from 50 to 100%) and viability (good – 31,9%, satisfactory – 47,2%, unsatisfactory – 22,2% of species). Based on the results of the inventory of arboretum collections, species that may pose an invasive threat were identified. A natural decline of species from collections is predicted, which determines the relevance of the task of preserving the gene pool of adapted introduced species by introducing them into forest reclamation complexes.*

Keywords: *dendroflora; introduction; Kulunda arboretum; adaptation; conservation*

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Научная статья

ДЕНДРОЛОГИЧЕСКИЕ КОЛЛЕКЦИИ КУЛУНДИНСКОГО КЛАСТЕРА ФНЦ АГРОЭКОЛОГИИ РАН

А.А. Долгих, А.И. Беляев, А.Ш. Хужахметова

Обоснование. *В 2016 году Кулундинскому дендропарку присвоен статус особо охраняемой природной территории федерального значения. Многолетний массив данных об интродукционном потенциале древесных растений в коллекциях составляет основу для регулирования интродукционной работы и повышения эффективности мобилизации хозяйственно важных растений.*

Цель *– провести оценку современного состояния биоресурсных коллекций Кулундинского дендрария.*

Материалы и методы. *Объектами исследования являются генофонд Кулундинского дендропарка - 137 видов, форм и гибридов. Уточнение таксономического состава генофонда коллекций и обобщение экспериментальных данных инвентаризации (возраст, сохранность, параметры таксации, жизнеспособность, возобновление) осуществлялось с привлечением ведомственных материалов, баз данных.*

Результаты. *В Кулундинском дендрарии – кластере особо охраняемой территории федерального значения, проводят комплексные исследования за видами*

деревьев и кустарников в условиях интродукции. Уточнен таксономический состав коллекций, а также возраст, сохранность, таксационные и репродуктивные показатели интродуцентов. Анализ естественных ареалов интродукционных древесных растений выявил преобладание представителей европейской (28%) и североамериканской (19%) дендрофлоры. Дано соотношение коллекционного фонда по показателям жизненности. Выявлено, что 31,9% растений имеют хорошее состояние и перспективные для привлечения в программы по сохранению и рациональному использованию биологического разнообразия. На основе длительного комплексного изучения растений и опыта их интродукции (с 1977 года) выделена группа древесных видов, способная к инвазионному расселению за пределами коллекционных участков Кулундинского дендрария.

Заключение. *По материалам инвентаризации коллекционных участков Кулундинского дендрария уточнен состав деревьев и кустарников (137 таксонов, 52 рода, 24 семейства) и ранжирован по сохранности (от 50 до 100 %) и жизнеспособности (хорошая – 31,9%, удовлетворительная – 47,2%, неудовлетворительная – 22,2% видов). По результатам инвентаризации дендроколлекций выявлены виды, которые могут представлять инвазионную опасность. Прогнозируется естественная убыль видов из коллекций, что определяет актуальность задач сохранения генофонда адаптированных интродуцентов путем внедрения их в лесомелиоративные комплексы.*

Ключевые слова: *дендрофлора; интродукция; Кулундинский дендрарий; адаптация; сохранность*

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Introduction

Over the past hundred years of introduction, progress has been made in expanding the range of woody plants for protective afforestation [7; 9]. Introduction, as a scientific direction, ensures the search and introduction of new plants with valuable biological and economic properties to increase the biodiversity and productivity of degraded agroecosystems [2; 6; 13].

In the Kulunda steppe, the existing protective forest plantations with the participation of trees *Betula*, *Populus*, rarely *Pinus*, *Larix*, *Salix* have reached the age limit and are ineffective in reducing the impact of stress factors – unstable income rainfall during the growing season, combined with high air temperatures, active wind regime; low winter air temperatures [4; 5; 8].

Forest reclamation of degraded and technogenic landscapes with long-lived and pollution-resistant species is considered as a positive result of introduction activities [10; 11]. For example, the intensive ability of the introduced plants *Acer negundo* L., *Ulmus pumila* L. to regenerate (seed and vegetative) on soils of light granulometric composition contributes to the cessation of soil deflation under active wind conditions.

Some researchers M.M. Silantyeva et al. [12] also note the negative aspects of the introduction: «... over a ten-year observation period, the area of maple and mixed forests with the participation of *Acer negundo* increased almost 6 times. Monodominant maple forests and mixed forests with other invasive species are formed. This leads to a significant anthropogenic transformation of pine forests in the Altai Territory and a decrease in their nature-forming, socio-economic and environmental significance ...».

In this regard, a comprehensive study of the adaptive capabilities of trees and shrubs in an arid region is being carried out in order to solve the problems of their rational use, enriching the dendroflora of forest reclamation complexes [3]. A long-term array of data on the introduction potential of woody plants in the collections of the Kulunda Arboretum forms the basis for regulating introduction work and increasing the efficiency of mobilizing economically important plants.

Background – assess the current state of bioresource collections of the Kulunda Arboretum.

Materials and methods

In 2016, the Kulunda Arboretum was given the status of a specially protected natural area of federal significance, located on the lands of the West Siberian Agroforestry Reclamation Experimental Station - a branch of the Federal Research Centre of Agroecology, Complex Melioration, and Forest Reclamations of the Russian Academy of Science (WS ARES – a branch Federal Research Center of Agroecology of the Russian Academy of Sciences). The main activity of the institution is the introduction of woody plants, the selection of an assortment for protective afforestation and landscaping, the conservation of diversity and the enrichment of the flora. The objects of research are the gene pool of the Kulunda arboretum of the ZS AGLOS – 137 species, forms and hybrids (Fig. 1).

The soils of the cadastral area No. 22:23:010003:0014 (4.7 ha) are chestnut, light loamy (humus 0,6-2,7%). Group placement of plants (from 4 to 8 specimens) has been preserved to the present (Fig. 2).

Fig. 1. Zoning and location of the boundaries of the Kulunda Arboretum

Clarification of the taxonomic composition of the gene pool of collections and generalization of survey data (age, safety, taxation parameters, vitality) was carried out with the involvement of departmental materials of the WS ARES and thematic databases [1], which are interconnected and reflect the prospects of the objects of study in terms of a set of indicators.

To justify the practical use of introducers, they were grouped according to the method of renewal (self-sowing, vegetatively natural, artificially by seeds, artificially vegetatively). Accounting plots (1 m^2 each) were laid evenly under the canopy of plantations. When analyzing quantitative indicators obtained as a result of experiments and observations, standard statistical computer programs Statistica 12, Exel were used.

Juniperus sabina L. *Picea obovata* Ledeb.

Betula pendula Roth *Acer ginnala* Maxim.

Fig. 2. Exposition of trees and shrubs in the Kulunda Arboretum

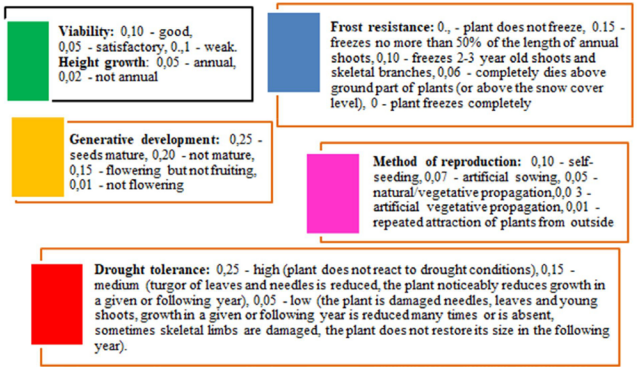


Fig. 3. Scales for assessing introducers

Winter hardiness, drought tolerance, flowering character, fruiting, etc. were determined according to the scales (Fig. 3).

Research results and their discussion

It has been established that the largest number of species, forms and hybrids belong to the Rosaceae (49) and Salicaceae (24) families in the structure of the gene pool of the Arboretum. The remaining families are represented by a small number of species – from 1 to 7 (Fig. 4).

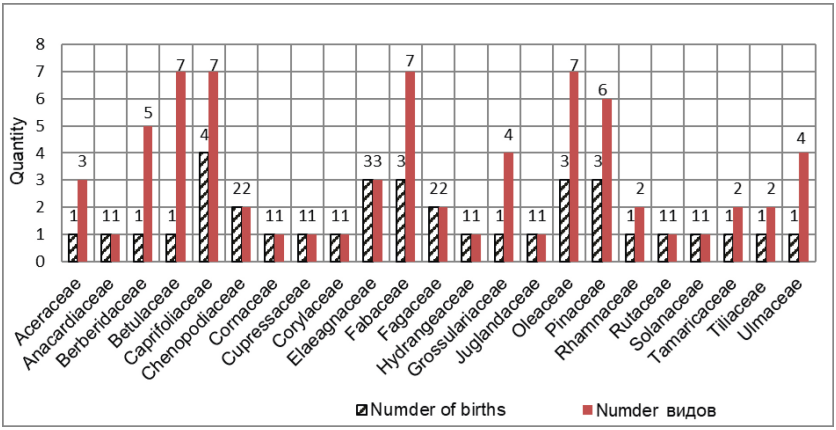


Fig. 4. Systematic composition of dendrological collections

A significant part of the introduced species are representatives of the European (28%) and North American (19%) dendroflora (Fig. 5).

Trees introduced into dry steppe conditions grow differently than in the forest zone. In the forest, they develop slowly, with the gradual extinction of the physiological functions of the plant organism. Previously, it was found that under new conditions, trees become fast-growing [10], there is a limited height of different species – up to 10-14 m (on average 6-9 m). Shrubs in the dry steppe reach their maximum height at the age of 15-20 years. Most trees have had little growth in recent years.

Technological elements and activities for the enrichment of dendroflora should take into account changes in the ecological environment and the impact of climate change on plant organisms, their longevity. Collectible plants of the age group (up to 40 years old) account for about 10% with a survival rate of 50% (mountain pine) to 100% (*Picea schrenkiana* subsp (Rupr.) Bykov, *Picea omorika* (Pane.) Purk., *Lonicera albertii* Regel, *Cotoneaster multiflorus* Bunge,

Crataegus pinnatifida Bunge) (Fig. 6). All plant species in this age group are in good condition, with the exception of *Viburnum sargentii* Koehne.

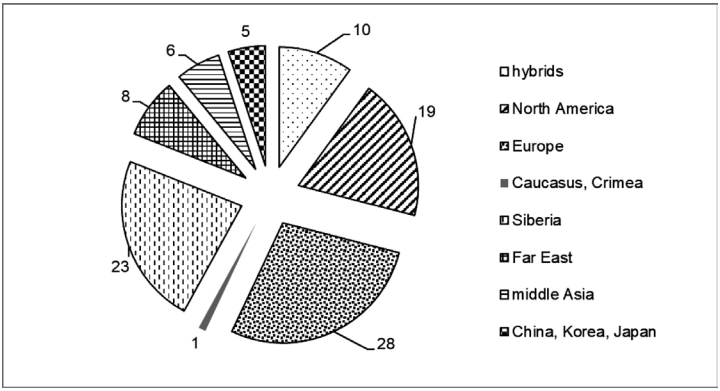
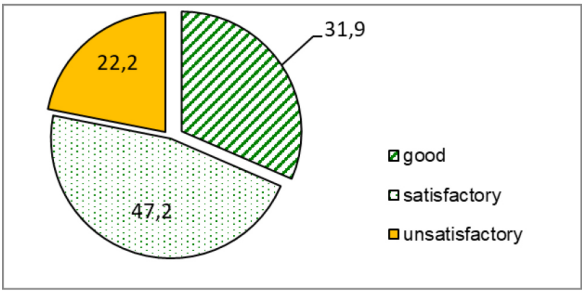
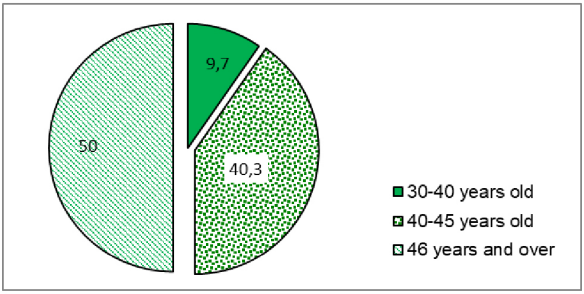


Fig. 5. Distribution of the gene pool by origin (%)



a



b

Fig. 6. Grouping of introduced species (in %) according to their vitality (a) and age (b)

According to the inventory of trees and shrubs of other age categories (from 40 to 50 years old), the following species are in good condition: *Larix sibirica* Ledeb., *Picea obovata* Ledeb., *Pinus sylvestris* L., *Pinus sibirica* Du Tour, *Caragana frutex* (L.) C.Koch., *Viburnum lantana* L., *Ribes alpinum* L., *Quercus robur* L., *Tilia cordata* Mill., *Amelanchier spicata* (Lam) C.Koch., *Cotoneaster melanocarpus* Lodd., *Spiraea trilobata* L., *Berberis vulgaris* L., *Amygdalus ledebouriana* Schlecht., *Rosa acicularis* Lindl., *R. alaica* Juz., *Crataegus* (*altaica* Lge., *arnoldiana* Sarg., *maximowiczii* C. K. Schneid.).

Studies of a large collection under similar experimental conditions in a limited area for a comparative assessment of growth processes and breeding efficiency make it possible to establish the degree of adaptation and the manifestation of diagnostic features that indicate compliance or non-compliance with new habitat conditions. According to the quantitative and qualitative indicators of fruiting for the purposes of agroforestry, shrubs of the genera *Amelanchier, Crataegus, Cotoneaster, Rosa, Spiraea* with a high degree of adaptation were identified (Table 1). A different level of fruit weight indicator variability has been established - from low (*Pyrus ussuriensis, Cotoneaster lucidus*), medium (*Amelanchier spicata, Padus virginiana, Sorbus schneideriana, Crataegus arnoldiana, C. maximowiczii*), high (*Cotoneaster multiflorus, Aronia melanocarpa, Rosa acicularis*) to high (*Crataegus sanguinea*) and very tall (*Cotoneaster melanocarpus*).

Table 1.

Characteristics of fruits and seeds of tree species

Plant name	Weight of 1000 fruits, g		Weight of 1000 seeds, g	
	average value for 2019-2021 (deviation from the average for 2016-2018)	2022	average value for 2019-2021 (deviation from the average for 2016-2018)	2022
Pyrus ussuriensis	1666,8 (+243,7)	1546,0	47,52 (-3,12)	31,0
Amelanchier spicata	563,5 (-55,5)	532,5	3,94 (-0,44)	6,0
Padus virginiana	518,2 (+25,0)	627,5	76,30 (-41,5)	96,0
Cotoneaster melanocarpus	339,4 (-127,3)	297,5	15,00 (-0,3)	17,0
C. lucidus	352,7 (-7,5)	338,0	17,00 (1,4)	22,0
C. multiflorus	329,8 (+18,0)	316,0	14,70 (-0,1)	12,0
Sorbus schneideriana	242,0 (-0,5)	215,5	2,70 (-0,2)	5,0
Aronia melanocarpa	739,2 (-4,8)	763,0	2,80 (0,2)	3,0
Crataegus arnoldiana	1622,0 (+11,0)	1565,5	59,70 (-27,1)	46,0
C. sanguinea	594,7 (+8,9)	510,5	35,60 (1,7)	22,3
C. maximowiczii	753,8 (+29,4)	774,5	43,90 (2,6)	32,0
Rosa acicularis	1056,6 (-24,1)	1000,0	14,90 (0,7)	13,0

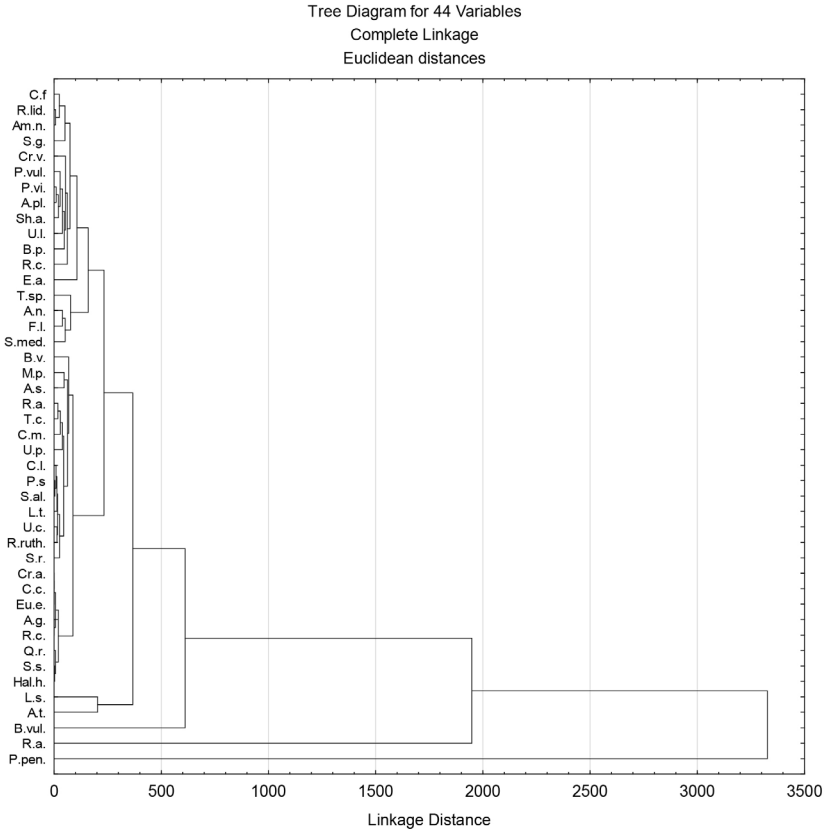
Seed indicators had a lower level of variability: from very low (*Aronia melanocarpa,* the coefficient of variation – 4,7%), low (*Cotoneaster multiflorus* – 12,47%) to medium (other species – 15,23-23,34%). It has been established that the amplitude of plasticity in different species is not the same. That is, the wider the range of plasticity, the more effective the adaptability of a given species to various environmental factors. Species that are capable of regenerating by self-seeding may be an invasive hazard. According to the results of the inventory of dendrocollections, species (*Acer - ginnala, negundo, tataricum, Ulmus parvifolia, Malus pallasiana, Berberis vulgaris, Amelanchier spicata, Crataegus pinnatifida*) were identified, which are found in more than 35,0% of the total number of registration sites (more than 30 specimens / site), as well as outside the dendro collections and are represented by pre-generative individuals (Table 2).

Table 2.

Number of individuals and their distribution in dendrological collections

Genus	Number of plants		Presence of plants (number of accounting sites)
	шт.	%	
Acer	7595	69,48	24
Amelanchier	127	1,16	15
Berberis	256	2,34	23
Cerasus	56	0,52	3
Chamaecytisus	279	2,56	10
Cotinus	93	0,85	6
Cotoneaster	90	0,82	20
Crataegus	123	1,12	15
Malus	315	2,89	31
Padus	195	1,78	6
Populus	89	0,81	3
Quercus	144	1,32	13
Rhamnus	65	0,59	7
Ribes	75	0,68	8
Spiraea	182	1,67	9
Ulmus	452	4,13	19
Others (36 genera)	796	7,28	52
Total	10932	100	

The second group according to the invasive status includes 9 species that are actively dispersed. A significant part of the introduced species (about 28,0%) forms local populations, sometimes found outside the arboretum (the third group). Clustering the results of assessing the ability of woody plants to regenerate made it possible to identify five clusters that united the accounting sites according to the similarity of species composition and frequency of occurrence (Fig. 7).



C.f. – *Cerasus fruticosa*, *R.lid.* – *Chamaecytisus lindemanni*; *C.c.* – *Cotinus coggygria*, *Am.n.* – *Amygdalus nana*; S.g. – *Spiraea crenata*, *Cr.v.* – *Crataegus pinnatifida*, *P.vul.* - *Padus avium*, *P.vi.* - *Padus virginiana*, *A.pl.* – *Acer platanoides*, *Sh.a.* - *Shepherdia argentea*, *U.l.* – *Ulmus laevis*, *B.p.* – *Betula pendula*, *R.c.* – *Rhamnus cathartica*, *R.c.* – *Rhamnus cathartica*, *E.a.* - *Elaeagnus angustifolia*, T. sp. – hybrids *Populus,* A.n. – *Acer negundo*, *F.l.* - *Fraxinus lanceolata*, *S. med.* – *Spiraea media*, *B.v.* – *Berberis vulgaris*, *M.p.* – *Malus pallasiana*, *A.s.* – *Amelanchier spicata*, *R.a.* – *Ribes aureum*, *T.c.* – *Tilia cordata*, *C.m.* – *Cotoneaster melanocarpus*, *U.p.* – *Ulmus pumila*, *C.l.* – *Cotoneaster lucidus*, *P.s.* – *Prunus spinosa*, *S. a.* – *Symphoricarpos albus*, *L.t.* – *Lonicera tatarica*, *U.p.* – *Ulmus propinqua*, *S.r.* – *Sumbucus racemosa*, *Cr.a.* – *Crataegus altaica*, *Eu.e.* – *Euonymus europea*, *A.g.* – *Acer ginnala*, *Q.r.* – *Quercus robur*, *S.s.* – *Sorbus sibirica*, *Hal.h.* – *Halimodendron halodendron*, *L.s.* – *Larix sibirica*, *A.t.* – *Acer tataricum*, *R.ac.* – *Rosa aciacicularis*, *P.pen.* – *Padus pensylvanica*

Fig. 7. Cluster analysis of accounting sites by renewal and species composition

It has been established that the best renewal was observed in shrubs than in trees. On 48% of the accounting plots there is a renewal, which is represented

by 4 to 10 species (clusters II, IV), the rest of the clusters are accounting plots with a renewal of up to 3 species (clusters I and III, V).

Ranking of introducers according to their prospects, taking into account significant features, made it possible to distinguish three groups: promising (48,9%); with a good level of prospects (36,0%); acceptable level (10,0%); unpromising (5,0% of species) for the technology of enrichment of the dendroflora of forest reclamation complexes.

Promising economically valuable species are a priority for conservation and rational use in forest reclamation complexes and technologies for improving the agroforest landscapes of the Kulunda steppe in desertification conditions.

Conclusion

Based on the materials of the inventory of the collection plots of the Arboretum WS ARES, the composition of trees and shrubs was specified (137 taxa, 52 genera, 24 families). It has been established that the largest number of species, forms and hybrids belong to the Rosaceae (49) and Salicaceae (24) families. A significant part of the plants in the collection is represented by European (28%) and North American (19%) dendroflora taxa. The gene pool was ranked in terms of safety (from 50 to 100%) and vitality (good - 31.9%, satisfactory – 47,2%, unsatisfactory – 22,2% of species). According to the results of the inventory of dendrocollections, species that may represent an invasive danger have been identified. Pre-generative individuals of *Acer - ginnala, negundo, tataricum, Ulmus parvifolia, Malus pallasiana, Berberis vulgaris, Amelanchier spicata, Crataegus pinnatifida* are found in a significant part of the territory of the Kulunda arboretum, as well as outside it. Proper control over their movement and continuation of field studies while monitoring introduced populations are required. A natural loss of species from collections is predicted, which determines the relevance of the tasks of preserving the gene pool of adapted introducers by introducing them into forest reclamation complexes.

Conflict of interest information. The authors declare that there is no conflict of interest.

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