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Features of introduction of *Dactylorhiza fuchsii* (Druce) Soó in the conditions of the Astana botanical garden

This article presented the initial results of experimental work aimed at establishing an introduction population from living specimens of *Dactylorhiza fuchsii* in the Astana Botanical Garden (ABG). In the flora of Central Kazakhstan, there are 17 species from the family Orchidaceae, with only one species, *Dactylorhiza fuchsii*, listed in the Red Book of Kazakhstan. Propagation and cultivation of orchids under introduction conditions for species conservation and potential reintroduction into their natural habitat have become increasingly relevant. Knowledge of orchid habitats and their ecological preferences is essential for their proper conservation and the development of introduction methods. As a result of a three-year study of the introduction of *Dactylorhiza fuchsii*, it has been established that this population exhibits moderate survival rates of generative and vegetative individuals. Over the results of three years, a total of 3 individuals were accounted for (21 % of those initially planted). The age composition consists of two ontogenetic states: 2 individuals in the generative (g) state and 1 in the vegetative (v) state. Ontogenetic states of *Dactylorhiza fuchsii* were determined based on morphological characteristics of above-ground organs, including leaf number, size of the lower leaf, and number of veins in it. Non-flowering individuals were categorized as generative.

Keywords: introduction, *Dactylorhiza fuchsii,* Astana Botanical Garden, population, Red Book, Central Kazakhstan Upland, conservation.

Introduction

Since the establishment of the collection of natural flora at the Astana Botanical Garden, special attention has been given to cultivating rare and endangered species, as well as those with shrinking ranges and populations, of the flora of Kazakhstan. This effort is also in response to the pressing task of preserving the gene pool of the local regional flora. Protected plants in the Akmola region include species listed in the Red Data Book of Kazakhstan, which require constant monitoring and observation within the region. This includes *Dactylorhiza fuchsia* [1].

Dactylorhiza fuchsii is successfully cultivated in the botanical gardens of Moscow, St. Petersburg, Yekaterinburg, and others [2, 3]. However, the introduction of this species in the conditions of the Central Siberian Botanical Garden has proven to be less promising [4]. *D. fuchsii* grows well in cultivation (both in partial shade and open areas) without requiring special substrates. This species can be easily propagated in vitro using mature seeds, and the seedlings develop well. The plants adapt easily when transplanted into non-sterile conditions. They typically flower in the 5th to 6th year after sowing [5, 6]. There is report about incidental reintroduction experiment with this species. A single individual was planted in the Podolsk district of the Moscow region on a hayfield with dry loamy soil. Over 8 years, the plant spread within a 15-meter radius in atypical habitat conditions for the species due to self-seeding. A total of 23 individuals were found, 7 of which was flowering [7].

The first experiments to establish an introduction population of *D. fuchsii* at the Main Botanical Garden of the Russian Academy of Sciences were conducted in 1958. At that time, 20 individuals were brought from the Moscow region and planted in a plot of broad-leaved forest. Long-term observations were carried out to study their seasonal development rhythms. Individual specimens from these original samples still exist to this day [8].

The family Orchidaceae represents a diverse and globally significant group of plants with high conservation requirements and priority status. The issue of the disappearance of orchids growing within the flora of the Central Kazakhstan Uplands is particularly acute. Due to limited germination, mycorrhizal specificity, and pollinator specialization, orchids are particularly vulnerable to changes in ecosystem balance, especially

alterations in moisture content, light regimes, nutrient availability, and competitive pressures [9]. Changes in habitat or their complete destruction have led to the extinction or decline in the population and distribution of many orchid species, resulting in legal protection and/or inclusion in the Red Data Book [10]. A study and compilation of a checklist for Orchidaceae in the northern part of Kazakhstan was conducted based on herbarium materials, field research, and literature [11].

In the flora of the Central Kazakhstan Uplands, there are 17 species from the family Orchidaceae [1], including 6 species of the genus *Dactylorhiza* [12], of which only one species, *Dactylorhiza fuchsii*, is listed in the Red Data Book of Kazakhstan [1]. In light of this, the propagation and cultivation of orchids under introduction conditions are becoming increasingly relevant for species conservation and the potential for subsequent reintroduction into their natural habitats [13]. Therefore, understanding the habitat and ecological preferences of orchids is essential for their proper conservation and the development of introduction methods.

One of the main objectives of botanical gardens is preservation genetic diversity and promoting sustainable use of plants and ecosystems. As a result of habitat disturbance, plants may face the threat of extinction or serious genetic erosion. Plant genetic diversity, which plays a crucial role in human development, is decreasing. Excessive use of medicinal, food, and ornamental plants growing in natural conditions leads to depletion of their populations. In 1994, the International Council of Botanical Gardens for Plant Conservation, with support and financial assistance from the International Plant Genetic Resources Institute, United Nations Educational, Scientific and Cultural Organization (UNESCO), Food and Agriculture Organization (FAO) of the United Nations, United Nations Environment Program (UNEP), and World Wide Fund for Nature (WWF), developed measures. According to the "Strategy of Botanical Gardens for Plant Conservation" [14], botanical gardens today are regarded as centers for the conservation and study of plants, where the introduction and cultivation of rare plants are seen as methods for their preservation. Establishing collections of rare plants in botanical gardens are serving not only as insurance and material for research but also as an opportunity for educational outreach and sometimes as a primary source for restoring disappearing species in nature. In essence, botanical gardens fulfill a triple function: conservation, propagation, and education. The development of methods for objective assessment of population status and identification of mechanisms for the resilience of rare orchid species can only be achieved through comprehensive study of their biological characteristics, ecological preferences, population structure and dynamics, and consortial relationships with other components of the biocoenosis. A systematic approach to studying rare orchid species allows for predicting the subsequent development of specific populations and devising the most effective conservation measures for each species.

Thus, threat of anthropogenic changes to the vegetation cover of the Central Kazakhstan Uplands, there is an unprecedented need for the introduction studies of the rare medicinal plant *Dactylorhiza fuchsii*.

The aim of this study is to conduct introduction research on *Dactylorhiza fuchsii* in the conditions of the Astana Botanical Garden.

Experimental

Introduction studies of new species, forms, cultivars of plants, or their transfer from the wild into cultivation are being conducted for the first time at the Astana Botanical Garden (ABG) in Astana.

The climate of Astana is sharply continental, characterized by dry summers and cold, snowy winters. The warm season lasts for 4 months, from May to September, with maximum daily average temperatures exceeding 19 °C. The hottest month is July, with an average maximum temperature of 26 °C and a minimum of 14 °C. The cold season spans 3.8 months, from November to March, with minimum daily average temperatures below -4 °C. The coldest month in Astana is January, with an average maximum temperature of -20 °C and a minimum of -11 °C.

Traditional methods of introduction research were employed [15]. Plant emergence records and phenological observations will be conducted using the methodologies developed by B.I. Ivanchenko (1962) [16] and B.A. Dospechov (1968) [17].

D.fuchsii (Druce) Soo is a meadow-forest species found in Kazakhstan within floristic regions classified under 22 altitudinal zones. It inhabits habitats with moist meadow-like moisture, growing in both open spaces and shady forests depending on light availability. It prefers neutral soil acidity and nutrient-rich soils. The population of *D.fuchsii* is declining due to habitat destruction and the collection of generative shoots for bouquets. This species has been listed in the Red Book of Kazakhstan (2014).

The initial material for introduction research consisted of plant samples collected in the territory of the Kokshetau National Park (Fig. 1).

Figure 1. Populations of *Dactylorhiza fuchsii* in the territory of Kokshetau National Park

The original material was sourced exclusively from natural habitats in the form of live plants. Significant importance was placed on the age, phenological phase, and overall condition of the transplanted plants. In the first year, all introductants were placed in the primary introduction plot. All samples were kept under uniform conditions: meadow-chernozem soil with added sand, and standard agronomic practices (watering, weeding, and loosening) were applied. Observations on experimental plants were conducted from 2021 to 2023 by measuring biometric parameters such as plant height, inflorescence size, flower dimensions, and so on.

Results and Discussion

Observations of the phenorhythm of the test plants in different environmental conditions demonstrate the adaptability of individuals to changing external factors and the completeness of passing through ontogenetic stages. Therefore, phenological data are one of the most important indicators in plant introduction.

The first introduction experiments to establish a population of *D. fuchsii* were conducted in the shaded conditions of the Astana Botanical Garden in 2021. Seven individuals were transported from the Ormandybulak Forestry, Kokshetau National Park, and planted on September 15, 2021 (Fig. 2).

However, the individuals of *D.fuchsii* did not establish themselves. In 2022, work on creating an introduction population of this species was continued. On the adjacent territory near the building of the Astana Botanical Garden, an area of 1x1 m² was planted with 14 individuals (Fig. 3). After planting, all individuals were labeled and mapped for subsequent observations. The plants consisted of 7 generative (g) individuals and 7 vegetative (v) individuals. Due to weather conditions in 2023, changes in phenological terms were noted. The first flowering of the rare species was observed on June 13, with mass flowering beginning in the third decade of June. The end of flowering of this ephemeral species was noted from June 25–28.

Figure 2. Planting of *Dactylorhiza fuchsii* in 2021 at the territory of Astana Botanical Garden

Figure 3. Introduced plants in 2022-2023, territory of ABG

The specimens brought from natural populations of the rare species (Table) showed a low degree of adaptation to the new conditions, characterized by incomplete phenological stages of development in the introduction conditions (up to the budding stage, but no flowering occurred).

T a b l e

Morphological parameters of introduced plants of *Dactylorhiza fuchsii* in ABG

Biometric indicators	Plant 1	Plant 2	Plant 3
Leaf length, cm	13	5	10
Leaf width, cm	1.4	0.7	1,6
Leaf length, cm	7	4	10.5
Leaf width, cm	1.5	1	2

The main developmental phases, both in the wild and on the collection plot, occurred at the same time.

Observations of the seasonal phenological rhythms of the rare *D.fuchsii* showed that the duration of vegetation depends on weather conditions and can vary from 7 to 30 days. From 2022 to 2023, flowering of the species was not observed.

The record of individuals in 2023 showed that the population amounted to 3 individuals (21 % of those planted). The age composition of this group was represented by two ontogenetic states: generative (g) — 2 individuals (14 %) and virgin (v) individuals — 1 (7.1 %), and they did not bloom. We cannot assess the survival rate of the plants in the first years because orchids are capable of entering a state of secondary dormancy, caused by various factors. According to M.G. Vakhrameeva [18], the duration of the secondary dormancy state in *D. fuchsii* individuals ranges from 1 to 3 years, and in some cases, up to 4 years. The ontogenetic states of *D. fuchsii* are determined by the morphological characteristics of the above-ground organs: the number of leaves, the size of the lower leaf, and the number of veins in it. We classified non-flowering individuals as generative. Khomutovsky M.I. (2012) reports that species of the genus *Dactylorhiza* behave differently under cultivation conditions. One of the most resilient plants in open ground conditions is *D. fuchsii*, which annually flowered and set fruits with viable seeds. Vegetative reproduction of tuberous species is more frequently observed in populations at the edges of their ranges in extreme conditions. Additionally, *D. fuchsii* (both vegetative and generative) successfully passed all phenological phases. However, due to the lack of pollinators in the greenhouse, the tested specimens did not set fruits [19].

D.fuchsii is capable of surviving and spreading in urban habitats [20].

As a result of the initial introduction of *Dactylorhiza* species at the Altai Botanical Garden, four species of the genus *Dactylorhiza* (*D. fuchsii*, *D. incarnata*, *D. maculata*, and *D. umbrosa*) were introduced. *D. incarnata* proved to be more plastic and adaptable to cultivation conditions, as indicated by increased inflorescence length, number of flowers per inflorescence, and dimensions of basal leaves in terms of length and width. Due to the high nutrient content in the soil, the number of flowers per inflorescence increased for all four species. Additionally, plant height decreased for all species due to receiving more sunlight [21].

Conclusions

Therefore, the rare species considered in this article has shown resilience under introduction conditions at the Astana Botanical Garden. The conditions provided by the botanical garden are favorable for this species; it is possible to predict normal survival of the introduced population in this area in the coming years. Regarding the population growth due to the appearance of young individuals, data will only become available in a few years.

Based on a three-year monitoring of the introduced *D. fuchsii* population, it has been determined that this population exhibits moderate survival rates among pre-generative individuals. Virgin individuals show the highest survival rates. The census in 2023 revealed that the population consisted of 3 individuals (21 % of those planted). The age composition includes 2 generative (g) and 1 virgin (v) individuals.

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А.Е. Халымбетова, С.К. Мухтубаева, С.А. Абиев, Ж.А. Адамжанова

Астана ботаникалық бағы жағдайында *Dactylorhiza fuchsii* (Druce) Soó интродукциялау ерекшеліктері

Мақалада алғаш рет Астана қаласының Астана ботаникалық бағында (АББ) *Dactylorhiza fuchsii* тірі өсімдіктерінен интродукциялық популяцияны құру бойынша эксперименттік жұмыстың нәтижелері келтірілген. Орталық Қазақстан ұсақ шоқыларының флорасында *Orchidaceae* тұқымдасының 17 түрі бар және тек бір түрі — *D. fuchsii* Қазақстанның Қызыл кітабына енгізілген. Түрлерді сақтау үшін

орхидеяларды интродукциялық жағдайда көбейту және өсіру, оларды кейін табиғи тіршілік ортасына бейімделу мүмкіндігі үлкен өзектілікке ие. Орхидеялардың тіршілік ету ортасы мен экологиялық бейімділігін білу оларды дұрыс сақтау және енгізу әдістерін әзірлеудің міндетті шарты болып табылады. *D. fuchsii* интродукциясындағы өсімдіктердің жағдайын үш жылдық бақылау нәтижесінде, бұл популяция генеративті және виргинильді дарақтардың орташа өмір сүруімен сипатталатыны анықталды. Үш жыл ішінде жеке дарақтарды есепке алу 3 дарақты құрады (жерсіндірілгені 21 %). Жас құрамы екі онтогенетикалық жағдаймен сипатталады: 2 (g) және 1 (v). *D. fuchsii* онтогенетикалық күйлері жерүсті мүшелерінің морфологиялық белгілерімен анықталады: жапырақ саны, төменгі жапырақ өлшемдері және ондағы жіпшелер саны. Гүлденбеген дарақтарды біз генеративті күйге жатқыздық.

Кілт сөздер: интродукция, *Dactylorhiza fuchsii,* Астана ботаникалық бағы, популяция, Қызыл кітап, Орталық Қазақстанның ұсақ шоқылары, сақтау.

А.Е. Халымбетова, С.К. Мухтубаева, С.А. Абиев, Ж.А. Адамжанова

Особенности интродукции *Dactylorhiza fuchsii* (Druce) Soó в условиях Астанинского ботанического сада

В статье впервые приведены результаты экспериментальной работы по созданию интродукционной популяции из живых растений *D. fuchsii* в Астанинском ботаническом саду города Астаны. Во флоре Центрально-Казахстанского мелкосопочника насчитывается 17 видов из семейства *Orchidaceae* и только один вид — *Dactylorhiza fuchsii* занесен в Красную книгу Казахстана. Размножение и выращивание орхидных в интродукционных условиях для сохранения видов и возможности последующего возвращения их в естественную среду обитания приобретают большую актуальность. Знание среды обитания и экологических предпочтений орхидей является необходимым условием для их надлежащего сохранения и разработки методов интродукции. В результате трехлетнего мониторинга состояния растений в интродукции *D. fuchsii* установлено, что данная популяция характеризуется средней приживаемостью генеративного и виргинильного особей. Учет особей за три года составил 3 особи (21 % от высаженных). Возрастной состав представлен двумя онтогенетическим состоянием: 2 (*g*) и 1 (*v*). Онтогенетические состояния *D. fuchsii* определены по морфологическим признакам надземных органов: число листьев, размеры нижнего листа и число жилок в нем. Нецветущие особи мы отнесли к генеративным.

Ключевые слова: интродукция, *Dactylorhiza fuchsii,* Астанинский ботанический сад, популяция, Красная книга, Центрально-Казахстанский мелкосопочник, сохранение.

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