Restoration of the Erythronium sibiricum (Fisch. et C.A. Mey.) Krylov coenopolulation in a nature reserve

Olga Klimova*, *Andrey* Egorov

The Federal Research Center of Coal and Coal Chemistry of SB RAS, 10, Leningradsky Prospekt, Kemerovo, 650065, Russia

Abstract. The article presents the results of a six-year study of the feasibility of maintaining the integrity of restored Siberian fawn lily coenopopulations after returning from the *ex-situ* system to the natural habitat. The restoration of the Siberian fawn lily coenopopulation in the disturbed part of the Barzassky Nature Reserve was the final stage of the biological reclamation of lands disturbed due to illegal economic activities. The source of planting material for restoration was fawn lily bulbs from the habitat zone destroyed during the development of a coal deposit within the boundaries of JSC Chernigovets. The bulbs were kept in artificial habitats of the Kuzbass Botanical Garden of the Federal Research Center of Coal and Coal Chemistry of SB RAS. Fawn lily seed material was obtained from the seed bank formed in the four years of plant development. In accordance with the restoration objectives, to completely restore a natural complex similar to the original appearance, the required volume of vegetative material amounts to 550 bulbs and of seed material – to 1050 seeds. The bulbs were planted in clumps of 5 m^2. The seeds were sown in furrows of 100 seeds in each. As a result, the rooting rate of the bulbs was about 86%, and the germination rate of the seeds equaled 85%. Bearing in mind that the planting material amount was increased during the work, the final result fully meets the required standards in terms of the number of Siberian fawn lily seedlings and sprouts. The methodological and technological techniques and approaches used during Siberian fawn lily cultivation and return to the *in-situ* system fully ensured the success of measures aimed at conserving vulnerable components of the regional biodiversity.

1 Introduction

The scientific and practical work on the restoration of the Siberian fawn lily (*Erythronium sibiricum* (Fisch. & C.A. Mey.) Krylov) coenopopulation in the disturbed part of the Barzassky State Nature Reserve is connected to the compliance with the Administrative

* Corresponding author: olia_1983kem@mail.ru

Rules of the Federal Service for Supervision of Natural Resources. These regulations concern the provision of public services for issuing permits for the taking of flora and fauna listed in the Red Data Book of the Russian Federation. The rules were approved by order of the Ministry of Natural Resources of Russia No. 60 of February 18, 2013, which states the need for the subsequent return of rare species to their natural habitats.

The experience of scientific and practical activities of the Kuzbass Botanical Garden of the Institute of Human Ecology of FRC SB RAS served as a methodological basis for restoring and maintaining the functional state of plants. This expertise was acquired as part of the undertaken work on the state task "Development of scientific foundations for assessing the state and restoration of floristic diversity *in situ* and *ex situ* in regions with a high ecosystem degradation level due to anthropogenic and technogenic impacts" and based on testing methods for Siberian fawn lily conservation. Plant relocation and the monitoring of their development and rooting processes were performed during practical work under conditions of the production cycle of JSC Chernigovets and LLC Gazprom Dobycha Kuznetsk.

The legal and regulatory framework of the undertaken activities is established by Order of the Government of Russia of June 30, 2021 No. 1090 "On federal state control (supervision) in the field of protection and use of protected areas" and by Ordinance of the Government of Russia of February 17, 2014 No. 212-r "On the Strategy for the conservation of rare and endangered species of animals, plants, and fungi in the Russian Federation for the period until 2030."

In the case under consideration, the restoration of the coenopopulation of Siberian fawn lily, a plant listed in the Red Data Book of Russia [1], on the disturbed territory of the nature reserve completed the biological stage of the reclamation of lands disturbed as a result of illegal economic activities.

2 Materials and Methods

The plant communities surrounding the restoration work area characterize the specific conditions of the phytocenotic environment and imply that the planned work can be successful. The phytocenotic and morphophysiological conditions of the surrounding phytosystems fully correspond to the species morphogenetic specializations of Siberian fawn lily, a plant which characterizes landscape units of the natural environment with considerable potential for species fidelity.

In 2019, 1600 Siberian fawn lily bulbs were planted on the territory of the Kuzbass Botanical Garden. The bulbs were planted in 16 plots ($1m^2$) characterized by various levels of illumination and different physiological states (young-, mature-, and old-aged). The plots were limited by boxes. Each box contained 100 bulbs. The basis for reserve coenopopulation formation was the need to preserve Siberian fawn lily obtained from the zone of its habitat destruction during the development of a coal field within the boundaries of JSC Chernigovets. The bulbs were obtained, transported, and planted on the basis of the Permit of Rosprirodnadzor of the Russian Federation.

The monitoring carried out in the experimental plots during the period of adaptation and development of the reserve population enabled the assessment of the success and prospects of *ex situ* rare species conservation.

In the process of natural aging, the number of individuals in different plots decreased from 32% to 58% over three years of observation as a result of senescence and death. Nevertheless, stable seed maturation and abundant seeding were recorded.

In 2020, an experiment was launched to renew Siberian fawn lily populations with seeds collected from plants of the model coenopopulations formed in the botanical garden.

The experiment confirmed the success of plant conservation under *ex situ* conditions. In total, about 1050 seeds (in weight fractions) were planted, and 998 seedlings were obtained.

Young Siberian fawn lily specimens and seed material obtained from adult plants are quite suitable as a donor source for restoring the species coenopopulation in the Barzassky Nature Reserve.

The territory of Siberian fawn lily removal (a license block of JSC Chernigovets) and the restoration area (the south-west the Barzassky State Nature Reserve) are part of the Barzas taiga phytogeographical region [2]. They have common features of soil-geographical and landscape-topographic conditions. The seed material is characterized by the unity of the genetically determined parameters corresponding to the ecological preference range of the gene pool of the individuals previously removed from their habitat.

Thus, the use of Siberian fawn lily individuals from the reserve population and the seed material from the seed bank formed in the Kuzbass Botanical Garden as a source material corresponds to the objectives of biodiversity conservation in the Barzassky Nature Reserve.

In accordance with the objectives of restoring a full-fledged and biologically productive Siberian fawn lily coenopopulation on the disturbed lands of the Barzassky State Nature Reserve and based on the peculiarities of the biology of the species, phytorestoration was performed in two ways. Firstly, Siberian fawn lily bulbs were transplanted (returned to their natural habitat). Secondly, fawn lily seeds were sown (seed regeneration).

The long-term research by L. L. Sedelnikova [3] established that in undisturbed land conditions, on average, 19 individuals/m^2 of fruit-bearing plants are formed. In the taiga zone of Kemerovo Oblast, in undisturbed habitats with an average population density of 39.6 individuals/m^2, 19.7 plants/m^2 of generative individuals develop. In disturbed habitats with moderate and average anthropogenic impact, the number of generative individuals varies from 7.4 to 9.1 plants/m^2 [4].

Under conditions of the Kuzbass Botanical Garden (KuzBG), the actual rooting rate of plants after their transfer from the original habitat amounted to 75.3% (taking into account the natural waste of old-aged forms).

The seed productivity of the specimens of the Siberian fawn lily reserve population (KuzBG) was 17–46 seeds/individual; the average value equaled 30 seeds/individual. The recorded seed germination rate amounted to 85.1%. The survival rate of seedlings was 95% (1050 seeds were planted in weight fractions, 998 specimens survived to the bud formation period).

Under stressful conditions during transplantation accompanied by an adaptation period and the necessary period of stratification for the restoration (recovery) of the natural Siberian fawn lily population, the productivity of 26 seeds/individual is taken into account for the calculation of the required number of mature individuals. Seeds are in deep endogenous resting state and can germinate at low positive temperatures close to 0°C [5].

In accordance with the biodiversity restoration objectives, it is necessary to restore 1600 specimens of Siberian fawn lily: 1200 specimens in plot No. 1 (1.6053 hectares, reclamation project 12TZP) and 400 specimens in plot No. 2 (0.6562 hectares, reclamation project 20TZP).

The objectives included restoring the reproductive nucleus of the coenopopulation on disturbed lands and ensuring seed regeneration of plants for the complete restoration of the natural complex close to the original appearance. Considering the results of studying the reserve Siberian fawn lily coenopopulation formed earlier, the necessary and sufficient volumes of vegetative and seed planting material were determined (Table).

Table. Estimated volume of Siberian fawn lily planting material

Plot No. 1				
Necessary quantity of specimens	Bulbs (quantity)	Rooting rate		Necessary volume
1200	400	75.3%		500 bulbs
	Seeds (quantity)	Germination	Survival rate	
	800	85.1 %	95 %	At least 970 seeds
Plot No. 2				
Necessary quantity of specimens	Bulbs (quantity)	Rooting rate		Necessary volume
400	150	75.3 %		200 bulbs
	Seeds (quantity)	Germination	Survival rate	
	250	85.1%	95 %	At least 310 seeds

Siberian fawn lily removal from the reserve population sites was performed after seed ripening, with the beginning of the dormant period (July). For transportation, the removed bulbs were placed basal plate down into small moisture- and air-permeable paper bags with a damp mulch mixture at the bottom, 10 bulbs in each bag. The bags were placed loosely in shipping boxes and transported from the place of removal to the planting site by road over a distance of 42 km.

To form a stable and self-developing coenopopulation under conditions of the emerging soil and vegetation cover and natural forest environment of the reclaimed area of the Barzassky State Nature Reserve, it is necessary to carry out integrated planting in the calculated proportions.

One of the important issues is the representativeness of the created population. For herbaceous small-bush and rosette-free plants, T. V. Elisafenko and O. V. Dorogina [6] recommend forming a clump with a close or slightly denser arrangement of individuals (relative to the natural one). Bulbs can be planted arbitrarily: in groups of 3–5 individuals, in rows at a distance of 5 to 10 cm, in zigzags or waves, depending on the microrelief of the clump formation site.

Under conditions of phytorestoration of the disturbed area of the reserve, 5 clumps were formed in plot No. 1 with a planting density of 20–22 bulbs/m^2 for each clump. The clumps were placed in wind shade along the transition zone from the surviving scrub (the south-easterly end of the restoration site) to the open (non-forested) part of the site towards the forest stands in the north-easterly part of the site. The area of each clump is 5 m^2.

In plot No. 2, 2 clumps were planted according to the same pattern. They were located in the open space along the remaining scrub in a south-westerly direction.

The bulbs were planted two weeks after the end of the biological stage of the site reclamation, as well as natural compaction and consolidation of the humus-accumulative soil horizon.

Since they lack a protective tunic, the bulbs were planted within 24 hours after being removed from soil. When planting, holes were made into which the bulbs were carefully placed, their basal plate down. The top of the bulbs was covered with a thin soil layer which was lightly compacted. The soil layer above the bulb equaled at least 8 centimeters. In total, the planting depth is twice the bulb height. It is not advisable to press Siberian fawn lily bulbs into soil as this can damage the planting material integrity.

Simultaneously with bulb planting, the seeds were sown in shallow furrows (5 cm deep), 100 seeds in each, followed by covering them with a thin layer of soil and its light compaction. Winter covering and frost protection of spring seedlings are not required.

3 Results and Discussion

The initial assessment of repopulation and restoration efficiency was undertaken in the first ten days of May 2024. By this time, seedlings (sprouts) of Siberian fawn lily seeds and bulbs had already been observed. In plot No. 1, 246 seedling specimens (57%) corresponded to individuals of the adult virginal state (V). Their leaf blade is large, 10–15 cm long, 5–7 cm wide, with 10–12 parallel veins; the leaf petiole length ranges from 9 to 11 cm. 126 specimens (29.4%) were individuals of the young generative state (g1) with two leaf blades and a developed above-ground elongated shoot. 58 specimens (13.5%) were individuals of the mature generative state (g2). This age state differs from the young generative state only in a more powerful leaf blade, which is 15–20 cm long and 6–8 cm wide. The leaves are opposite, the first leaf is elliptic, the second – oblong. The flowers are 3–4 cm long with a thick pedicel. In plot No. 1, the total number of sprouting Siberian fawn lily bulbs was 428 specimens, which corresponds to 85.6% of the number of planted bulbs and exceeds the required number for population restoration. In plot No. 2, the highest percentage of sprouts from the bulbs is also characterized as individuals of the virginal state – 49% (86 specimens). 62 specimens (35%) were individuals of the young generative state, and 27 specimens (16 %) – individuals of the mature generative state. The total number of sprouts in plot No. 2 was 175 specimens with the required quantity of 150 specimens (Table). The number of seedlings in plot No. 1 was at least 820±10 plants, in plot No. 2 – at least 270±10. The seedlings were 4–6 cm long.

As a result of the scientific and practical work on the restoration of the Siberian fawn lily coenopopulation on the Barzassky Nature Reserve adjacent territory, it was established that in the first year the survival rate of fawn lily bulbs was 86%, and the seed germination rate equaled 85%. These data fully satisfy the requirements for the quantitative composition volume of Siberian fawn lily individuals to restore a community close to the original appearance of the natural complex.

Acknowledgments. The work was carried out within the framework of state task 0286-2024-0022 (Project AAAA-A21-121011590010-5 “Development of scientific foundations for assessing the state and restoration of floristic diversity *in situ* and *ex situ* in regions with a high ecosystem degradation level due to anthropogenic and technogenic impacts”).

References

1. *Red data book of the Russian Federation (plants and mushrooms)* (Tov. nauchn. izdaniy KMK, Moscow, 2008)
2. A. V. Kuminova, *Vegetation of Kemerovo Oblast* (OGIZ, Novosibirsk, 1950)
3. L. L. Sedelnikova, *Siberian fawn lily: Biology, distribution, use* (Akademich. Izd-vo Geo, Novosibirsk, 2018)
4. A. N. Kupriyanov, O. A. Kupriyanov, Features of ontogenesis and state of *Erythronium sibiricum* (Fisch. et C.A. Mey.) Kryl. populations depending on the degree of anthropogenic impact, Flora i Rastitelnost Antropogenno Nareshennikh Territoriy, **8**, 18–25 (2012)
5. L. L. Sedelnikova, Organogenesis and rhythms of development of geophytes during

introduction, in: Theoretical and applied aspects of plant introduction as a promising direction for the development of science and national economy. Materials of the International Scientific Conference dedicated to the 75th anniversary of the founding of the Central Botanical Garden of the National Academy of Sciences of Belarus. Vol. 1, 284–286 (Minsk, 2007)

6. T. V. Elisafenko, O. V. Dorogina, *Methodological recommendations for the introduction and restoration of natural populations of rare and endangered plant species* (Primula, Kemerovo, 2021)