Some results of the functioning of the Natural Botanical Garden in the Republic of Bashkortostan

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Abstract. In the Republic of Bashkortostan, since 2005, in the Natural Botanical Garden (Kushnarenkovsky district, Mountain Gurovskaya), experiments have been carried out on the introduction of rare and endangered plant species of regional flora into a new natural environment as close as possible to the ecological and phytocenotic conditions of their habitats. To date, the following areas of work have been worked out: creation of collections for the study and conservation of gene pools for 20 rare species (families Alliaceae, Fabaceae, Paeoniaceae and other); creation of long-term self-renewable reserve populations to preserve the gene pool of specific natural populations for Hedysarum razoumovianum, Globularia punctata, Oxytropis hippolyti; creation of uterine plots in order to obtain mass planting and sowing material for reintroduction work for Allium nutans; experience of evacuation to the territory of the Natural Botanical Garden of plants from natural populations doomed to destruction for A. obliquum and Iris pseudacorus. The collections include economically valuable species: ornamental, food, melliferous and medicinal. These plant collections can be used for demonstration and educational purposes.

1. Introduction
The Republic of Bashkortostan (RB) has a high potential in agricultural production. Agricultural land occupies more than 50% of its total area, and the area of arable land among them is 58.9%. The Republic is one of the largest regions for the production of livestock products. Land plowing and livestock grazing are the main anthropogenic factors that limit the spread of rare and endangered plant species (REPS), and for some of them they pose a threat to existence due to the destruction and degradation of their natural habitats.

According to the latest data, there are currently 232 species of rare higher vascular plants growing on the territory of the Republic of Bashkortostan that need protection [1]. One of the most important directions for the conservation of the REPS gene pool is the creation of collections and nurseries in botanical gardens (BG) and their comprehensive study. Since 1950, this role in the Republic of Bashkortostan has been successfully performed by the South Ural Botanical Garden-Institute of the Ural Federal Research Center of the Russian Academy of Sciences (SUBGI) (Ufa). To date, more than 80 rare plant species of Bashkortostan have passed through the introduction [2]. However, there are limitations with the introduction of REPS: a low diversity of habitats on the territory of the BG, limited areas, laboriousness of creating and other. The maintenance of collections also requires certain financial costs: maintenance of staff, water use and other. It is also important to note that only dark gray forest soils are presented in the SUBGI, which are unsuitable for the introduction of many REPS, especially for numerous steppe and petrophytic species (for example, species of the genera Astragalus L., Hedysarum L., Oxytropis DC.). Even with successful introduction on soils unusual for them, these
species greatly change their ecological and biological features compared to those in natural conditions: a sharp reduction in life expectancy is observed, phenophases shift, seed productivity increases, plants often reach atypical sizes and other. [3-4]. These data are difficult to extrapolate to natural populations, which greatly complicates their use in the development of effective methods for the protection of REPS. It seems problematic to place large collections in the BG, especially the maintenance of those collections for which massive research work has already been completed.

In connection with the foregoing, since 2005, we have been conducting experiments to test the possibility of mass introduction of REPS into a new natural environment as close as possible to the ecological and phytocenotic conditions of their natural habitats. A compact area with natural vegetation, where introduction experiments are carried out, we conditionally called the Natural Botanical Garden (NBG) "Gurovskaya Gora" (Bashkortostan, Kushnarenkovsky district, Mountain Gurovskaya). The growth of plants outside their native habitats has long been known: both from spontaneous invasions of alien species into natural communities, and those deliberately transplanted by humans. There are also reports in the literature on the creation of artificial populations outside the boundaries of the natural range of the species in similar natural conditions [5-7]. Researchers also note the high cost, laboriousness, and sometimes failure of these experiments [8]. For our experiments, a fairly large forest-steppe area was selected in the vicinity of Ufa, which has a wide variety of habitats (stony and meadow steppes, broad-leaved forests, swamps, a stream and other), with different soils and exposures. Prior to the start of introduction work, the authors, together with colleagues, previously studied the floristic composition and vegetation of the site. In 2009, a botanical natural monument of republican significance was officially established here (an area of 210.0 ha), where a permit for the introduction of REPS, as well as various restrictions on the economic use of natural complexes, were registered in the protection regime.

The main purpose of the experiments is to study the possibility of “transferring” some of the tasks that are solved in the conditions of classical BG: creating large collections of species from different geographical locations, conducting various experiments on the introduction of REPS, establishing nurseries to obtain mass planting and seed material for reintroduction, providing sites for evacuation of species from various construction sites, creation of educational and demonstration collections (including not only REPS, but also, for example, useful plants) and other species, as well as the complete lack of plant care (watering, weeding, thinning, pest control and other).

2. Materials and methods

The NBG is located on Mountain Gurovskaya, which is a section of an erosion hill - a fragment of the ancient bedrock bank of the river Belaya, rising about 40 m above the adjacent plains. The mountain is composed of layers of Permian rocks, exposed on eroded slopes with clays, siltstones, marls, limestones, which increases the variety of stations. Landslide and karst landforms are also represented here. The main soils are dark gray forest and degraded chernozems to varying degrees. The predominant types of natural vegetation are degraded meadow steppes and forests (oak, mixed broad-leaved, birch, spruce and pine plantations). The location of the mountain and its surroundings (arable lands stretching for long distances, paddocks and grazing areas, roads and other) minimize the "departure from culture" of introduced species.

From 2005 to 2021, on the territory of the NBG, various experiments on the introduction of REPS were laid almost every year. Occasionally, not rare useful plant species (medicinal, ornamental) were introduced. The mobilization material was mainly seeds and seedlings, less often adult plants obtained in the BG (introduction through introduction). Less commonly, seeds and plants were transferred from natural populations. Sowing seeds and transplanting plants was carried out in holes or shallow trenches (turf and large stones were previously removed). In the experiments, sowing was usually carried out in 15-30 holes in the amount of 5 to 100 pcs. seeds. The distance between the holes was usually 50-70 cm. Various variants of experiments were tested (spring and autumn sowing, surface sowing and with seeding into the soil, sowing of scarified seeds and without scarification and other). The locations of the experiments were fixed using a satellite GPS navigator. Usually once or twice a
year (rarely once every 2 years) counts of numbers, ontogenetic conditions, and biometric indicators of plants were carried out.

The methodological recommendations on the reintroduction of plants of domestic and foreign scientists were used in the work [9-11].

3. Results and discussions

In the NBG "Gurovskaya Gora" the introduction of REPS and their observation have been carried out for more than 15 years, and today it seems possible to draw preliminary conclusions about the results of the work carried out. Below are considered 4 directions of the REPS introductory experiment, in which positive results were obtained.

1. Creation of REPS collections for their study and conservation of their gene pool.

About 50 plant species were introduced into the NBG "Gurovskaya Gora" during the entire observation period from 2005 to 2021. In experiments on 20 species (4 species of *Hedysarum* L., 3 species of *Dianthus* L., 3 species of *Linum* L., 2 species of *Oxytropis* DC., *Crambe tataria* Sebeok., *Paeonia hybrida* DC. and other), generative plants were obtained that bloom annually and bear fruit, in some species annual self-seeding is observed.

In all experiments, the main adverse factor was the lack of moisture in the soil (short-term and long-term droughts), to which young plants (from seedlings to immature plants) are especially sensitive. Often plants exist only 1-4 years. When sowing a large number of seeds (50-100 pcs. per hole), mainly legumes (species of the genera *Hedysarum* L., *Oxytropis* DC.), a seed bank is formed in the soil, thanks to which seedlings are observed throughout the growing season (more often after rains) and for several years. Autumn sowing was preferable to spring sowing.

Other significant unfavorable factors are the flooding of seeds and plants with soil during rains, especially often on eroded steep slopes, as well as damage by phytophages (figure 1) and (figure 2) (for example, in *Crambe tataria*, up to the complete destruction of crops). Obviously, these factors are also limiting in natural populations.

2. Creation of long-term self-renewing reserve populations to preserve the gene pool of a specific natural population.

![Figure 1. Artificial population of *Hedysarum razoumovianum* in the Natural Botanical Garden (July 2017, phenophase: end of flowering - beginning of fruiting).](image1)

![Figure 2. Artificial population of *Allium nutans* in the Natural Botanical Garden (September 2021, phenophase: fruiting - seed ripening and shedding).](image2)
To create such collections, a sufficient area and distance from other experiments are required to prevent overpollination. The best result in this direction was obtained for *Hedysarum razoumovianum* Fisch. ex Helm. [12] and *Globularia punctata* Lapeyr. In the first case, an artificial population has existed since 2005 (figure 1), in the second case, since 2012. In both populations, an increase in their area and number is observed, already fruit-bearing self-sowing plants have appeared, it is also noted that plants of the 3rd-4th generations are from mothers at a distance of 8-10 m. In the experiment with *Oxytropis hippolyti* Boriss. the artificial population exists since 2005, the number is kept at a low but stable level (about 20 individuals), no increase in area is observed. There are two artificial populations of *Allium nutans* L. (figure 2), in which self-seeding, active vegetative reproduction and an increase in the number of generative shoots are observed.

3. Creation of uterine plots in order to obtain mass planting and sowing material for reintroduction work.

In 2005 and 2006, 2 experiments on seed propagation of *Allium nutans* L. were included in the NBG for subsequent use in reintroduction work in natural populations. 20 seeds were sown in 60 holes. Seeds were obtained from plants introduced into the BG. Seeds germinated within 2-4 years. Between 2013 and 2016 in these experiments, 457 plants were obtained, which were used in reintroduction work to restore the number of natural critical populations of this species on the eastern spurs of the Southern Urals (mountain Ayan, mountain Yumurgyr). In the wells, from 10 to 14 plants of various ages and ontogenetic states, from juvenile to virginal, rarely generative, were found. It took 10-12 years from sowing seeds in the nursery to obtaining flowering plants in the reintroduction plots. The survival rate of plants in experiments with the transplantation of live plants into natural habitats was 82-90%. By 2021, single plants left in the holes after the removal of the reintroduction material, due to vegetative propagation, have grown so much that a mass planting material has been formed suitable for further reintroduction work using the rhizome division method. However, the method of growing planting material from seeds proved to be ineffective for other types of onions - *A. obliquum* L. and *A. hymenorhizum* Ledeb. Their seedlings could not withstand competition with natural species, and also, possibly, died in large numbers from a lack of moisture in the soil, and were not found in the experiments for 3-5 years after sowing.

4. The experience of evacuating the REPS to the territory of the NBG from populations doomed to destruction.

At present, if it is often necessary to evacuate REPS, for example, from construction zones, the question arises of the place for plant transplantation. In this case, the NBG, in the presence of large areas and studied habitats on their territory, can play an important role in the temporary or permanent placement of evacuated plants. Thus, in 2018, in connection with the reconstruction of oil pipelines in the vicinity of Ufa, it became necessary to evacuate the rare species *Iris pseudacorus* L., included in the Red Data Book of the Republic of Bashkortostan, from the construction sites. In agreement with the Ministry of Natural Resources of the Republic of Bashkortostan, about 230 individuals of *I. pseudacorus* were transplanted to the territory of the NBG and adjacent areas (marshy meadows, outskirts of karst bogs, streams and other). In some plants, flowering and fruiting were noted the next year after transplantation; today, partial loss of plants is noted.

Also in 2014, 30 *A. obliquum* plants were successfully evacuated from the landslide zone in the natural population in the vicinity of the village of the NBG. Bishkain in the Aurgazinsky district of the Republic of Bashkortostan.

In addition, plants from the BG are periodically transplanted into the NBG. Only in 2020, a large number of adult plants of more than 10 species were transplanted (*Alceae rugosa* Alef., *Gypsophila rupestris* Kuprian., *Paeonia anomala* L., *Paeonia hybrida* Pall. and other).

4. Discussion

More than 15 years after the start of introduction work in the NBG "Gurovskaya Gora", it seems possible to draw some preliminary conclusions about the advisability of creating the NBG in the Republic of Bashkortostan. On the territory of the NBG, it is possible to conduct a number of
scientific experiments carried out in classical BG. The NBG, which has a large area and a wide variety of habitats, can be widely used to create collections (including self-renewing artificial populations) of a large number of species. The NBG areas are convenient for growing mass planting material for the purpose of further reintroduction work in nature. In addition, temporarily or permanently rare species that grow in critical habitats can be evacuated to the NBG. REPS collections can be used for demonstration and educational purposes.

However, the NBG, unlike classical BG, have a number of disadvantages and cannot completely replace them. During dry periods, there is a mass death of seedlings; therefore, many experiments can be resumed only in wet years. Due to the remoteness of the experiments, the constant control and accounting of crops is complicated. For example, since dead plants can be replaced by new seedlings in holes during the season (and this happens more than once), it is impossible to take into account the overall germination of seeds. Therefore, we use the conditional concept of “plant survival or survival”, meaning the proportion of plants that survived the juvenile and immature ontogenetic states, out of the total number of sown seeds, expressed as a percentage. Usually it is no more than 5%.

The recreational factor also causes noticeable damage to the NBG: almost every year, the local population and vacationers dig up and collect ornamental and food plants (onions, irises and other) on experimental sites.

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