Introduction of ornamental herbaceous plants native to the Eurasian steppes in Laboratory of Ornamental Plants, at Main Botanical Garden of Russian Academy of Science

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Abstract. The steppes of Eurasia are promising donors for the introduction of ornamental plants. But when introduced to wetter regions, a number of species face the problem of their low ex situ stability. The purpose of the present work is to evaluate the results of the introduction of steppe species of ornamental herbaceous perennials in the Laboratory of ornamental plants (LOP) GBS RAS. The objects of the study are 84 species belonging to 53 genus from 23 families. In the introduction studies, two classical methods were used: the ecological-phytocenotic method and the method of generic complexes. To maintain the culture of some collections or their components, the method of ecotrons is also used. The analysis of the composition of the introduced species included in the modern collection fund of the LDR of the GBS RAS suggests that the most promising are groups of species with a wide response rate, which, in addition to steppe habitats, are confined to more remote ones. According to the results of long-term field experiments, the most stable species under long-term cultivation were identified. It is established that for a number of steppe species, long-term maintenance in culture is possible only with the use of a specially created substrate. Ex situ conservation of dry steppe species proper is extremely difficult and little practical. In MBG RAS Salvia stepposa Des.-Shost., Linum perenne L., Verbascum phoeniceum L., Dracocephalum ruyschiana L., Eremurus fuscus (O. Fedtsch.) Vved., Iris pumila L., I. scariosa Willd. ex Link, I. furcata Bieb., I. timofejewii Woronow, I. lutescens Lam. were short-lived in the culture.

1. Introduction

Steppes are unique landscape zones that cover vast areas, both in Russia and in Eurasia as a whole. Treeless communities of perennial xerophilic grasses are also found in North America and South America, Africa and Australia [1]. Due to such a significant geographical distribution, the steppes, as well as the adjacent landscapes – forest-stepe and semi-desert, form a single megaregion-Steppe Eurasia [2]. It is worth noting that the steppes are one of the most affected by anthropogenic impact, the landscape of the world [3]. Steppe cenoses are a valuable donor of ornamental plants that can be promising for the enrichment of cultural flora.

Russian steppe belt stretches from the south (steppe regions of the Crimea, Caucasus, Rostov district, etc.), across steppe areas of the Volga, Urals, Siberia, and to the Far East, significantly decreasing here. At the same time, one of the unique types of vegetation is the steppes of Central Yakutia, located at a great distance from the main area of the Siberian and Trans-Baikal steppes, but floristically and phytocenotically close to the steppes of the Trans-Baikal and Mongolia [4]. Note that
the phytocenoses characteristic of the steppe zone, in addition to highly specialized representatives, include a significant number of species with a wide response rate, going much further – in the taiga zone, forest-steppe, etc. At the same time, certain areas of steppe vegetation can occur locally in mosaic, where conditions acceptable for maintaining the vital activity of a number of steppe species are preserved (including under the influence of anthropogenic factors). Thus, one of the sources of expansion of the range of steppe plants is the embankments along the railway lines [5–7].

A special feature of the steppes is the different (depending on their location) annual precipitation (from 200 to 450 mm). Also in winter, these areas are characterized by low temperatures (usually below -20°C), often with a small height of snow cover, and in some regions, almost complete absence of it. At the same time, the steppes of European Russia are characterized by numerous thaws [8]. The flora of the steppes is unique: it is characterized by high resistance to extreme weather conditions – cold and snowless winters, frequent thaws, recurrent frosts, long periods of hot and dry weather. The adaptability of steppe plants to such difficult environmental conditions allows the use of a number of species with a wide response rate in urban landscaping. The experiments conducted to study the possibility of long-term cultivation of ornamental plants in container culture in the conditions of the city of Moscow confirmed the stability of individual species [9].

The introduction of steppe plants in the botanical gardens of Russia and the countries of the former USSR is carried out systematically and covers various introduction centers: Minsk, Kiev, Donetsk, Alma-Ata, Moscow, St. Petersburg, Volgograd, etc. [10–14]. At the same time, the success of the introduction of representatives of steppe communities depends both on the characteristics of the center of introduction (features the passage of phenological phases, the ability to seed and vegetative reproduction, resistance to pests and diseases, resistance to climatic conditions of the center of introduction), and on the peculiarities of the ecology of the introducers. According to the data of the VSPU Botanical Garden (Volgograd), when introducing local plant species, the most promising group was mesophilic meadow-steppe species (for example, *Paeonia tenuifolia* L., *Filipendula vulgaris* Moench.). Of the steppe species themselves, the most stable were the species-representatives of the upland indigenous communities (*Linum austriacum* L. etc.), characterized by good adaptability to adverse conditions [15]. At the same time, the introduction of plants to the Subarctic (the Polar-Alpine Botanical Garden) revealed a pattern associated with the greater success of the introduction of steppe species, compared with representatives of broad-leaved forests [16].

When introducing steppe plants to wetter regions, there is a problem of low stability of a number of species: first of all, highly specialized xerophytic steppe plants. According to R.A. Rotov [17], when introduced in the conditions of the Main Botanical Garden (MBG RAS) plants, the formation and development history of which is associated with xerophytic growing conditions, often react negatively to an increase in precipitation and a change in the soil moisture regime. At the same time, the prospects of introducing meadow-steppe and petrophilic-steppe species with high ecological plasticity are noted [18]. When introducing such taxa, the change of xerophilic conditions to more mesophilic ones, as a rule, causes an increase in habitus, an increase in the intensity of flowering and productivity of plants.

The purpose of this study is to evaluate the results of the introduction of steppe species of ornamental herbaceous perennials in the Laboratory of Ornamental plants (LOP) MBG RAS.

## 2. Materials and Method

The work was carried out on the basis of the collection fund of the LOP of the MBG RAS.

84 species were used as objects of research. At the same time, all the studied samples are represented by species associated with steppe communities: both steppe ones themselves and in steppe phytocenoses.

To form, maintain and expand the collections of steppe plants in the collection fund of the LOP of the MBG RAS, two classical methods of introduction are used on a permanent basis. This is the method of generic complexes [19], the essence of which is to form – in the conditions of a specific point of introduction – the maximum possible sample of species and varieties belonging to a particular
genus. The ecological-phytocenotonic method is based on the involvement in the introduction experiment of taxa with similar ecological characteristics and/or species confined to a certain geographical area [20].

At the same time, to maintain some collections or their components in the culture, the ecotron method is used, the main idea of which is a partial, but as complete as possible imitation of the edaphic conditions necessary for the normal growth and development of plants [21].

Latin plant names are given by IPNI (International Plant Names Index) [22].

3. Results and Discussion

In modern conditions, one of the basic directions of research in the LOP of the MBG RAS is the enrichment of the regional cultural flora of ornamental plants, including by identifying the most promising species-representatives of the temperate zone of the Earth during the introduction experiment. At the same time, the introduction of representatives of the steppe flora is carried out from the first years of the garden's foundation [23, 24]. The plants found in steppe communities are represented in the modern collection fund: 84 species of 53 genus from 23 families (figure 1) [25]. This group includes both the steppe species proper and the species found in the steppe communities of Eurasia. At the same time, the number of genus is dominated by three families: Asteraceae, Lamiaceae and Ranunculaceae, and the greatest species diversity belongs to four families: Asteraceae, Lamiaceae, Ranunculaceae and Campanulaceae. The wide taxonomic composition is due to a long-term introduction search aimed at identifying the most promising species of steppe flora.

![Figure 1](image-url)

**Figure 1.** Distribution of genus by family in the modern collection fund of the LOP MBG RAS (in ornamental plants of representatives of steppe communities).

Note: The families of plants: 1. – Asteraceae, 2. – Lamiaceae, 3. – Ranunculaceae, 4. – Campanulaceae, 5. – Rosaceae, 6. – Caryophyllaceae, 7. – Scrophulariaceae, 8. – Poaceae, 9. – Asparagaceae, 10. – Alliaceae, 11. – Liliaceae, 12. – Apocynaceae, 13. – Brassicaceae, 14. – Polygonaceae, 15. – Crassulaceae, 16. – Euphorbiaceae, 17. – Asphodelacea, 18. – Geraniaceae, 19. – Apiaceae, 20. – Hemerocallidaceae, 21. – Linaceae, 22. – Paeoniaceae, 23. – Plumbaginaceae
The analysis of the composition of the introduced species included in the modern collection fund of the LOP of the MBG RAS [25] allows us to note that the most promising groups of species are those with a broad response rate, which, in addition to steppe habitats, are confined to more mesophilic communities – settled forests, meadow steppes, dry meadows, rocky scree. Ex situ conservation (in the conditions of the central part of Russia) The nature of the dry steppe species is extremely complex and little implemented in practice.

Most xerophilic steppe plants, when introduced in the conditions of central Russia, fall out as a result of wetting, in some cases (especially mountain-steppe species) – the rot of plants during the autumn-winter and early-spring periods. At the same time, some steppe species proved to be quite stable and durable under cultivation in Central Russia. These are Echinops humilis M. Bieb., Galetella sedifolia (L.) Greuter, Clematis integrifolia L., Crambe cordifolia Steven, Crambe tataria Sebeck, Euphorbia lamprocarpa Prokh. and Veronica spicata L.. For Crambe cordifolia, Cr. tataria and Euphorbia lamprocarpa are noted for self-seeding. Stable in ex situ conditions are ephemero-phyllous-representatives of the genus Allium L. and Tulipa L. It should be noted that during the introduction experiment, the plants were cultivated on ordinary garden soils without changing the agricultural background.

For a number of steppe species (for example, Goniolemon tataricum (L.) Boiss., Adonis wolgensis Steven ex DC), long-term maintenance in culture in the conditions of central Russia is possible only with the use of a specially created substrate. In addition, in such species as Gypsophila paniculata L. and Thymus serpyllum L., the formation of self-seeding is possible if special drained substrates are selected. At the same time, Thymus serpyllum on wetter soils is unstable to competition with local weed species.

Some species of steppe plants – Salvia stepposa Des.-Shost., Linum perenne L., Verbascum phoeniceum L., Dracocephalum rayschiana L., Eremurus fuscus (O. Fedtsch.) Vved. – proved to be short-lived in culture.

In the genus Iris L. to the group of unstable in ex situ conditions includes steppe species – Iris pumila L., I. scariosa Willd. ex Link, I. furcata Bieb., I. timofejewii Woronow, I. lutescens Lam., which in culture are typical juveniles [26]. Therefore, in general, the experience of the introduction of species representatives of this species in the conditions of Central Russia and more northern territories (north-west of Russia) was negative [27–29]. G.I. Rodionenko [30] explains this trend by the fact that they have a narrow specialization to the living conditions formed during the evolutionary process. The limiting factors, respectively, are excessive humidity (both soil and air) and the lack of the sum of active temperatures during the growing season.

Most of the samples of ornamental plants found in the steppes presented in the collection fund of the LOP of the MBG RAS are species with a wide response rate and, often, with a wide geographical distribution. Thus, among the more promising taxa for introduction into the cultural flora of the region, it is necessary to note the species-representatives of various grass steppes, settled meadows, forest-steppe phytocenoses, as well as species entering the steppe communities.

Among the exotic species with a wide norm of reaction, a part of the modern collection Fund LOP MBG after years of introduction trials, should be sustained in long-term cultivation of the species: Artemisia pontica L., Clematis integrifolia L., Paeonia tenuifolia L., Hemerocallis minor Mill., Pyrethrum balsamita (L.) Willd., Phlomoides tuberosa (L.) Moench, Phlomis russeliana Lag. ex Benth., Aconogonon divaricatum (L.) Nakai ex Mori, Clematis recta L., Filipendula vulgaris Moench, Asparagus officinalis L., Euphorbia semivillosa Prokh., Veronica incana L. It is also worth noting the species for which mass self-seeding was noted: Anemone sylvestris L., Eryngium planum L., Anthemis tinctoria L., Echinops ritro L., Echinops sphaerocephalus L., Melica altissima L., Sanguisorba minor Scop., Sanguisorba officinalis L., Aconogonon alpinum (All.) Schur.

A number of steppe species with a wide response rate are not currently included in the collection fund of the LOP [23, 24]. But it should be noted that within the framework of many years of introduction work, these species showed a fairly high stability and decorative effect and were dropped from the collections due to the influence of extreme climatic conditions (low-snow frosty winters,
excessive moisture in spring and autumn). Therefore, in our opinion, their re-introduction into the culture can be considered appropriate.

One of the interesting, but difficult to maintain in ex situ conditions (in central Russia) generic complexes is *Stipa* L.. It should be noted that in the introduction work on the basis of the collection fund of the LOP of the MBG RAS, according to the literature sources [23], as well as information from the journals of phenological observations for the 1970s – 1980s, 4 species were studied: *Stipa* gigantean Lag. (listed in the collection for more than 10 years), *S. capillata* L., *S. pennata* L., *S. pulcherrima* C. Koch. Among the representatives of the genus Iris, this group includes representatives of the subgenus *Xyridion* [31]. In the LOP of the MBG RAS, the introduction work with this group of irises is traditionally focused on high and medium stemmed species *Iris sintenisis* Janka, *I. sogdiana* Bunge, *I. graminea* L., *I. carthaliniae* Fomin, *I. spuria* L., *I. pseudonotha* Galushko, *I. notha* M. Bieb., *I. musulanica* Fomin (*I. klattii* Kem.-Nat.), *I. halophila* Pall., *I. monnieri* D.C., *I. ochroleuca* L. (*I. orientalis* Mill.), *I. aurea* Lindl. (*I. crocea* Jacq.) [23, 24, 32]. In general, they can be recommended for cultivation in the north-west [33] and in the central part of Russia. But at the same time, weather factors that have a significant impact on the duration of their cultivation at a particular point of introduction are waterlogging of the soil (especially in the autumn period), lack of active temperatures, warm winters, as well as, possibly, early and prolonged spring drought.

4. Conclusion
Currently, the collection fund of the Laboratory of Ornamental Plants of the Russian Academy of Sciences includes 84 species of steppe plants belonging to 53 genus and 23 families. At the same time, the most promising for ex situ cultivation in the soil and climatic conditions of Central Russia, according to the results of our research, are mesophilic meadow-steppe species. In the future, one of the most important directions for expanding the collection fund of the Laboratory of Ornamental plants of the Russian Academy of Sciences will be the active use in the introduction studies of mesophilic species found in steppe phytocenoses. It is worth noting that the resistance of steppe plants to moisture deficiency and at the same time high frost resistance, with high decorative properties, suggest that a number of species – *Aconogonon alpinum*, *Aconogonon divaricatum*, *Clematis integrifolia*, *Clematis recta*, *Crambe cordifolia*, *Euphorbia lamprocarpa*, *Euphorbia semivillosa*, *Galatella sedifolia*, *Geranium sanguineum*, *Phlomoides tuberosa*, *Prunella grandiflora*, *Sanguisorba officinalis* – are promising for introduction to mass urban landscaping.

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