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Abstract. About 300 species of natural flora are currently in the collection of the laboratory of rare plants of the Siberian Botanical Garden of Tomsk State University (TSU). 6 species of rare plants of the natural Siberian flora, included in the Red Book of the Tomsk Region, were the objects of this study: Aconitum anthoroideum DC., Allium obliquum L., Erythronium sibiricum (Fisch. et C.A. Mey.) Krylov, Potentilla erecta (L.) Raeusch., Primula macrocalyx Bunge, Thymus marschallianus Willd. Evaluation of their successful introduction was carried out using scales proposed by various authors. Its own unified scale for the introduction of rare and endangered plants of the natural flora of Siberia has been developed. It was established on the basis of the analysis that the species studied upon introduction into the southern taiga subzone of Western Siberia belong to medium resistant (Thymus marschallianus), resistant (Aconitum anthoroideum, Allium obliquum, Erythronium sibiricum, Potentilla erecta) and highly resistant (Primula macrocalyx).

1. Introduction

Creating collections of rare plants in botanical gardens is one of the effective ways to preserve biodiversity.

About 300 species of natural flora are currently in the collection of the rare plant laboratory of the Siberian Botanical Garden of Tomsk State University (TSU), including 15 species of Siberian flora included in the Red Book of the Russian Federation [1], 59 rare and endangered plant species represented in the Red Book of the Tomsk Region [2].

The 6 species of rare useful plants of Siberian natural flora included in the Red Book of Tomsk Oblast were the objects of our study: Aconitum anthoroideum DC., Allium obliquum L., Erythronium sibiricum (Fisch. Et CA Mey.) Krylov, Potentilla erecta (L.) Raeusch. , Primula macrocalyx Bunge, Thymus marschallianus Willd.

The introduction capabilities of plants are largely determined by their historical development, ecological plasticity associated with life form, range, degree of ecological specialization, intraspecific diversity [3–5]. The success of introducing one or another species is assessed by the general behavior of plants in the experiment and a set of biologically economic characters [6–8].

The most important criteria for the success of the introduction are: the passage of the full seasonal and ontogenetic cycles of plant development, the regular nature of fruiting and the formation of full seeds, winter hardiness, preservation of characteristic habitus, etc.

Some authors propose different scales for assessing the success of introductions [3, 5, 7, 9-16].

V.V. Bakanova [13] developed a working scale for assessing the success of the introduction of perennial herbaceous plants. Each point is a digital expression of the degree of success of the introduction of plants to new conditions for them. A higher sequence number indicates a higher success rate of species introduction. Success indicators were: resistance to adverse climatic factors, the presence of regular flowering and fruiting, the ability to self-sowing, self-dispersal.

In assessing the success of the introduction, N. V. Trulevich [5, 14] takes into account the peculiarities of rhythm, the ability to reproduce and resume, as well as the rate of ontogenesis, as a result of which he distinguishes the following groups: I Unstable - do not go through a full year cycle of shoot development, often die out in the early stages of ontogenesis; II Weak-tolerant - go through the full annual cycle of shoot development sporadically, do not resume on their own; III Medium tolerant - they go a full annual cycle of shoot development, are often characterized by an accelerated rate of ontogenesis, do not resume on their own; IV Sustainable - go a full annual cycle of shoot development, multiply successfully, can self-sow, but do not resume on their own; V Highly resistant - go through a full year cycle of shoot development, multiply intensively, can self-sow, and are capable of self-renewal.

This assessment system makes it much easier to summarize when the introducer works with more or less uniform source material on environmental features, phylogenetic relationship, life forms or on the type of wintering of the renewal buds.

G. P. Semenova [16, 17], evaluating the success of introducing rare species, takes into account frost resistance, winter hardiness, attitude to moisture, the stability of the seasonal rhythm of development, the duration of the life cycle, the activity of seed and vegetative propagation. The author has identified groups of promising, medium-perspective, unpromising and unpromising species.

Five signs that have the greatest practical value were taken into account on the scale of introduction assessment by V. N. Bylova, R. A. Karpisonova [9]: general habit, resistance against diseases and pests, ability to seed and vegetative propagation, winter hardiness.

A 3-point scale is used to evaluate each indicator, in which a score of 3 evaluates the best state of the plants by this characteristic, a score of 2 - average, a score of 1 - the worst. The summation of the scores for all indicators allows us to assign the view to one of the groups according to the success of the introduction: very promising - 12-15 points, promising - 9-11 points, unpromising - 5-8 points.

The scale proposed by V.N. Florea [10] allows for a more detailed analysis of the success of the introduction and the distribution of the studied species in ten stages of acclimatization. 5 indicators were taken into account on this scale: the possibility of reproductions, fruiting, flowering, winter hardiness, drought tolerance. Each indicator is evaluated on a ten-point scale, which allows to assess the state of plants at different stages of the experiment. The prospects of introducing one or another species are determined by the level of acclimatization (acclimatization stage).

The acclimatization stage is calculated by the formula: A = R + F + Fl + H + D, where A is the acclimatization step; R is the indicator of reproduction; F - an indicator of fruiting; Fl - an indicator of flowering; H - an indicator of winter hardiness; D is an indicator of drought tolerance. The acclimatization rate is calculated according to the scale: I - A from 0 to 5; II - A from 6 to 10; III - A from 11 to 15; IV - A from 16 to 20; V - A from 21 to 25; VI - A from 26 to 30; VII - A from 31 to 35; VIII - A from 36 to 40; IX - A from 41 to 45; X - A from 46 to 50.

2. Results and discussion

The scales developed by V. N. Bylov, R. A. Karpisonova [9] and V. N. Floria [10] were taken as a basis for assessing the prospects in the culture of the studied species.

Assessment of the success of the introduction of the studied species on the scale proposed by the staff of the Main Botanical Garden [9] is shown in table 1.

Table 1. Assessment of the success of the introduction and prospects in the culture of the studied species.

Species	WH	SP	VP	Dd	H	A	Pr
Aconitum anthoroideum	3	3	1	3	3	13	VP
Allium obliquum	3	3	1	3	3	13	VP
Erythronium sibiricum	3	3	1	3	3	13	VP
Potentilla erecta	3	3	2	3	3	14	VP
Primula macrocalyx	3	3	2	3	3	14	VP
Thymus marschallianus	3	3	2	3	3	14	VP

Note – WH – winter hardiness; SP – seed propagation; VP – vegetative propagation; Dd - damage by diseases and pests; H – general habitus; A - comprehensive assessment; Pr – promising (VP – very promising).

All studied species are winter hardy. Loss after overwintering was not observed during the observation period, only Thymus marschallianus withering was observed in the early spring due to the high level of snow cover (the fall in some years reached 20%). All studied species are characterized by high seed productivity (3 points). Erythronium sibiricum (2 points) is characterized by limited seed production due to low temperatures in the spring, which hinder the successful seed setting.

As regards vegetative propagation ability, studied species belong to plants with low vegetative propagation ability (Aconitum anthoroideum, Allium obliquum, Erythronium sibiricum) and medium (Potentilla erecta, Primula macrocalyx, Thymus marschallianus).

Plants of the studied species are characterized by resistance to pests and diseases. However, minor damage by fungal diseases (Aconitum anthoroideum) and pests (Potentilla erecta, Primula macrocalyx) is possible in some years.

All studied species retain their inherent habitus under introduction, an increase in the size and number of flowers and leaves was noted for some species compared to plants from natural populations.

Studied species are assigned to very promising plants according to the results of a comprehensive introduction assessment (13–14 points) (table 1).

An analysis of 6 studied rare species was carried out according to the acclimatization steps proposed by V.N. Florea [10] (table 2).

Table 2. Success rates for the introduction of the studied species.

Species	R	F	Fl	WH	D	A	Acclimatization stage
Aconitum anthoroideum	9	7	8	10	9	43	IX
Allium obliquum	7	8	8	10	10	43	IX
Erythronium sibiricum	8	8	8	10	6	40	VIII
Potentilla erecta	7	7	10	10	9	43	IX
Primula macrocalyx	9	8	8	10	7	42	IX
Thymus marschallianus	8	9	9	10	9	45	IX

Note – R – reproduction indicator; F – fruit indicator; Fl – flowering indicator; WH – winter hardiness indicator; D – drought tolerance indicator; A – acclimatization stage.

The species we studied were possibly assigned to plants that have low self-seeding (7 points) - Allium obliquum, Potentilla erecta; giving moderate self-seeding and stable offspring (8 points) - Erythronium sibiricum, Thymus marschallianus; able to give abundant self-seeding and stable offspring (9 points) - Aconitum anthoroideum, Primula macrocalyx.

We divided the species according to the features of fruiting into plants with regular, but not plentiful fruiting (7 points) - Aconitum anthoroideum, Potentilla erecta; plants characterized by regular

and abundant fruiting (8 points) - Allium obliquum, Erythronium sibiricum, Primula macrocalyx; plants periodically tying the fruit from repeated flowering (9 points) - Thymus marschallianus.

We divided the studied species by the nature of flowering into plants with regular and abundant flowering (8 points) - Aconitum anthoroideum, Allium obliquum, Erythronium sibiricum, Primula macrocalyx; plants with irregular repeated flowering (9 points) - Thymus marschallianus; plants with repeated flowering (or a very long flowering period) (10 points) - Potentilla erecta.

We attributed all the studied species in the degree of winter hardiness to plants that are not damaged by spring and autumn frosts and winter freezing temperatures.

We divided the studied species by resistance to dry weather into plants in which leaves and generative shoots dry out during fruiting (6 points) - Erythronium sibiricum; plants whose leaves dry on vegetative shoots (7 points) - Primula macrocalyx; plants in which partial drying of leaves on generative shoots is noted (9 points) - Aconitum anthoroideum, Potentilla erecta, Thymus marschallianus; Allium obliquum is assigned to plants that normally tolerate all dry periods (10 points).

It was revealed as a result of a comprehensive assessment that the model species are at the VIII (Erythronium sibiricum) and IX (all other species) acclimatization stages (table 2).

The conducted studies suggest that the studied species under cultural conditions in the subzone of the southern taiga of Western Siberia show high adaptive capabilities, which indicates their significant environmental plasticity. They are winter hardy, characterized by high rates of seed reproduction, resistant to diseases, retain a characteristic habitus in the culture and are promising for creating sustainable agropopulations.

As a result of the analysis of the scales for assessing the stability of species under the conditions of introduction, we established that most of them do not always allow taking into account all the signs characterizing the resistance of rare and endangered plant species that have specific developmental biology and need special growing conditions. In this regard, we made an attempt to develop our own unified scale of introduction assessment of rare and endangered plants of the natural Siberian flora, taking into account the currently available developments of various authors (table 3).

Our proposed introduction assessment scale includes six main sections: the passage of the main stages of ontogenesis; seed and vegetative propagation; damage by diseases and pests; winterization / soaking in the winter-spring period; exactingness to growing conditions. For each section, the species can be evaluated by four points (maximum score - 4, minimum - 1). Summing up the scores for all indicators makes it possible to attribute the species to one of the stability groups under the conditions of introduction: 24–22 points are highly resistense, 21–19 are stable, 18–16 are medium stable, 15–13 are low stable, 12–6 are unstable. This scale, unlike the scales previously proposed by other authors, allows one to take into account the features of the introduction of species of the Siberian flora in connection with their ecological and biological characteristics.

Analysis of the studied species on the proposed scale is shown in table 4.

Table 3. Unified scale for the introduction assessment of the species of natural flora of Siberia.

I	Passage of the main stages of ontogenesis
	1 – dies in the early stages of development
	2 – it is in a state of vegetation, does not enter the reproductive phase of development
	3 - the plant goes through all stages of ontogenesis, but in a shorter period than in nature (behaves like a juvenile)
	4 – ontogenesis is similar to natural
II	Seed propagation
	1 – the plant does not bloom in the conditions of culture, or blooms, but does not set fruit
	2 – bears fruit, but does not produce viable seeds, or has very low seed productivity
	3 – bears fruit and has viable seeds, but self-seeding is absent
	4 – gives viable self-seeding

III Vegetative propagation
1 – the plant does not propagate vegetatively
2 – only artificial vegetative propagation is possible
3 – capable of natural vegetative propagation
4 – actively propagated vegetatively
IV Damage by diseases and pests
1 – the whole plant or its generative sphere is substantially damaged
2 – the vegetative sphere is significantly damaged
3 – damaged, but quickly restored, or damaged slightly
4 – the plant is not damaged
V Aging / Soaking in the winter-spring period
1 – plants die annually
2 - plants are severely damaged, can die in some years
3 – plants are damaged, but are quickly restored, single individuals can die
4 – plants are not damaged or almost not damaged
VI Demanding on growing conditions
1 – plants are highly specialized, need to develop special cultivation technologies
2 – plants are demanding on growing conditions, they need strict adherence to individual agricultural practices
3 – plants require compliance with traditional methods of cultivation
4 – plants are unpretentious, preserved in a culture without special care

Table 4. Success indicators for the introduction of the studied species in the south of the Tomsk region according to the developed scale.

Species	I	II	III	IV	V	VI	Total score	Degree of stability
Aconitum anthoroideum	4	4	2	3	4	3	20	stable
Allium obliquum	4	3	2	4	4	3	20	stable
Erythronium sibiricum	4	4	1	4	4	4	21	stable
Potentilla erecta	4	4	2	3	4	3	20	stable
Primula macrocalyx	4	4	2	4	4	4	22	highly stable
Thymus marschallianus	4	4	2	4	2	2	18	medium stable

Based on a comprehensive assessment, the studied species were found to be medium- stable (Thymus marschallianus), stable (Aconitum anthoroideum, Allium obliquum, Erythronium sibiricum, Potentilla erecta) and highly stable (Primula macrocalyx) plants in the culture (table 4).

3. Conclusion

The studied species under the conditions of introduction in the subzone of the southern taiga of Western Siberia undergo a full cycle of ontogenesis, which is similar to the natural one; most species produce viable self-seeding; capable of only artificial vegetative propagation; practically not damaged by pests and diseases; resistant to aging and soaking in the winter-spring period and do not require strict adherence to agricultural technology. Thus, the creation of highly efficient agropopulations is possible for these species.

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