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Article

Role of Endemism and Other Factors in Determining the Introduction Success of Rare and Threatened Species in Tashkent Botanical Garden

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Abstract: Although rare and threatened species are maintained in many botanical gardens around the world, detailed reports on the success or failure of their introduction appear infrequently, which makes it difficult to understand the major constraints of growing imperilled species in botanical garden living collections. Though intuitively, a level of endemism appears to be important, its role as a predictor of species cultivation success in the garden living collections has never been tested. This paper summarizes the experience of the Tashkent Botanical Garden in creating and maintaining living collections of rare and threatened species of Uzbekistan, trying to understand the role of endemism and other factors in the success and failure of these species cultivation. We found that out of 100 rare and threatened species introduced, the cultivation of 26 failed. Most of these species were endemic to the country, occupying soil types and habitats different from those of the garden site. However, surprisingly, the introduction of many analogous species has been successful. This implies that some narrow endemics can be successfully grown in botanical gardens, but to predict which can and which cannot is impossible, and there are no alternatives to introduction trials. Overall, the large number of rare and threatened species for which introductions were successful confirms the important role of ex situ conservation in preserving critically endangered biodiversity and should stimulate further work in this direction. The future efforts of the garden staff will focus on two major objectives: (i) collecting seeds of endangered species that have so far skipped attention or their collection missions have not been successful; and (ii) propagating those species that have proven cultivation success and using the propagated material for in situ actions.

Keywords: ex situ; plant conservation; biodiversity; Uzbekistan flora

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1. Introduction

Many species have restricted ranges and those species with "small range, narrow habitat specificity" are called endemics [1]. Endemics usually have higher probabilities of extinction than widespread species [1–5] and for this reason, ex situ conservation of endemics is particularly important. Modern botanical gardens are a vital component of plant conservation [6–10], and many of them not only significantly contribute to gaining knowledge of threatened species biology, but also actively support in situ conservation by collecting and propagating plant material that is used for the creation of new populations [6,11–16]. Of particular importance can be the contribution of botanic gardens to the conservation of local (and especially endemic) flora in biodiversity hotspots, where protected areas can safeguard the future for only a fraction of the regional plant biodiversity. Uzbekistan covers a substantial part of the Mountains of Central Asia biodiversity hotspot [17] which is extremely rich in endemics. There are 871 species and subspecies of vascular plants endemic to this area, of which 69 are national endemics of Uzbekistan [18]. This dictates the important role of not only in situ, but also ex situ conservation in this region, given that the number of protected areas and their total territory in Uzbekistan as well as the actual protection level of these areas are inadequate to protect the existing in the region biodiversity [19]. Despite the widespread recognition of the importance of maintaining living collections of rare and endangered endemics in botanical gardens, the role of species endemism as a predictor of the success of species cultivation is not clear.

Tashkent Botanical Garden, founded in 1950, has a long history of successful growing in its collections of numerous local species. By 1989, more than 2500 species of Central Asian flora, many of which were rare and threatened species, have been preserved in the garden's living collections. Sadly, many of these collections were lost in the years following the collapse of the Soviet Union and for the past 20 years, the garden staff has been recreating once-existing and creating new collections of endangered species. Initially, the living collections of Tashkent Botanical Garden were created without the goal of supporting in situ actions (reinforcement or translocation). Currently, the garden living collections are specifically dedicated to this goal.

In this study, we summarize the many years of experience of the Tashkent Botanical Garden in creating and maintaining living collections of rare and threatened species from Uzbekistan trying to understand the factors determining the success or failure of these species cultivation. Among the analyzed factors, the role of endemism was of particular importance. On the one hand, endemic species which usually are narrow specialists, are expected to have less chance of success in cultivation than widely distributed species. On the other hand, to the best of our knowledge, there has not yet been a comparative study on the success of growing live collections of endemic vs. non-endemic species. This knowledge will be crucial to understanding the prospects and limitations of ex situ conservation in Uzbekistan with the implications of this knowledge for Central Asia and elsewhere.

2. Materials and Methods

Uzbekistan is located in Central Asia between latitudes 37° and 46° N and longitudes 56° and 74° E. Approximately 12% of the country's total area is mountains and foothills and the rest of the territory is plains. The main mountainous regions are located in the north-eastern (Ugam, Chatkal, Kurama, Fergana ranges), south-eastern (Turkestan and Alay), and southern (Hissar, Zeravshan, Babatag ranges) parts of the country. The climate is continental, with significant daily temperature fluctuations, hot summers, dry warm autumns, and moderately cold winters. The average summer temperature is around +40 °C, while the average temperature in winter is around −23 °C.

Tashkent Botanical Garden is located at an altitude of 480 m above sea level. The recorded absolute minimum and maximum temperature is −25.8 °C and +44.6 °C, respectively. The average number of days with temperature above 0 °C, 5 °C, and 10 °C is 327, 263, and 213, respectively. The average precipitation is 380 mm, which falls mainly in the autumn–winter–spring period. The average annual humidity is 59%, which in summer drops to 22%. According to the FAO classification, the soil at Tashkent is calcic xerosol (Xk). The city is located on a plain, but very close to the foothills that border the Western Tian Shan mountains. Phytogeographically, Tashkent and the surrounding area belong to the Middle Syrdarya region [20].

Living collections were created with plants grown from seeds or adults collected in the field during local expeditions. Seeds were sown in the open ground. Adult plants were planted in late fall or early spring. The planted individuals did not receive any special care except for weeding. For annuals and biannuals, an introduction was considered successful if the plants were producing viable seeds. For other life forms, the introduction of a species was considered successful if the plants could be maintained for more than 3 years with the regular fruiting and production of viable seeds, and the plants showed no signs of senescence.

The introduced species were classified by their level of endemism, life form, and phytogeographic region (Figure 1), soil type (Figure 2), and habitat in which they occur (Table 1).

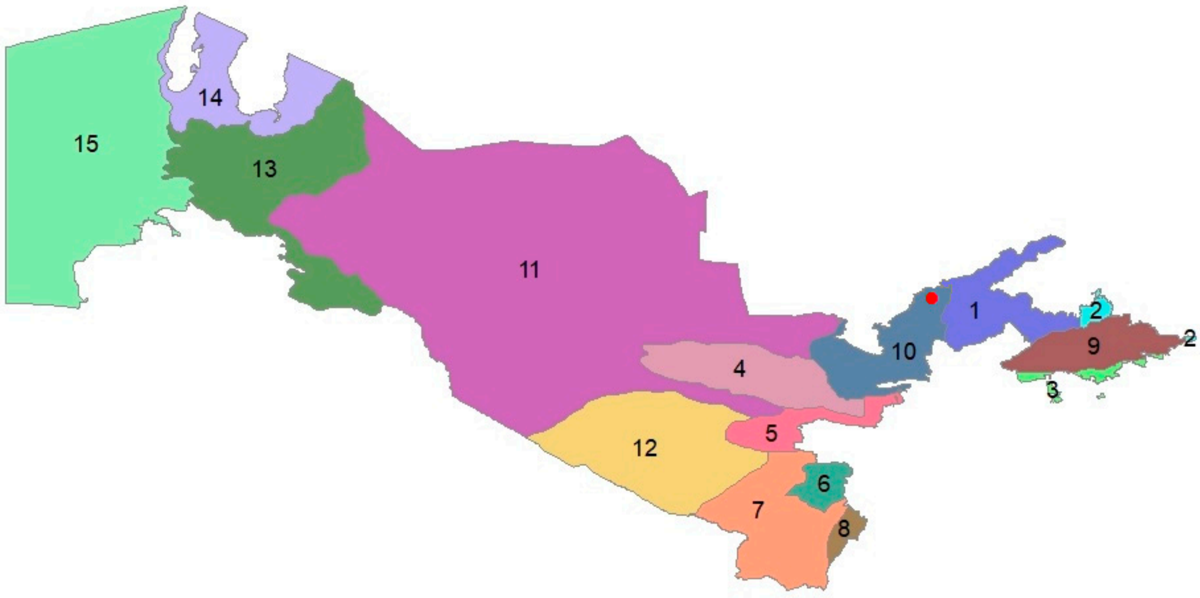

Figure 1. Phytogeographic regions of Uzbekistan according to Tojibaev et al. [20]: 1—Western Tien Shan, 2—Fergana, 3—Fergana–Alai, 4—Nurata, 5—Kuhistan, 6—Gissaro–Darvaz, 7—South-Western Gissar, 8—Near-Pjandzh, 9—Upper-Syrdarya, 10—Middle Syrdarya, 11—Kyzylkum, 12—Bukhara, 13—South Near-Aral, 14—Aral, 15—Ustyurt. Red dot denotes a location of the Tashkent Botanical Garden.

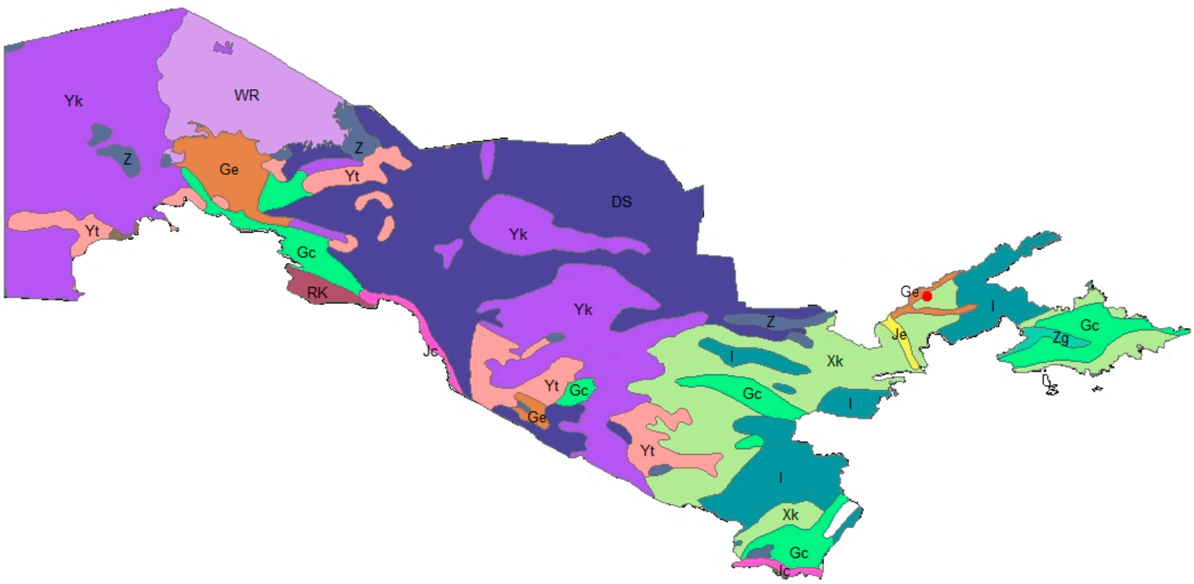

Figure 2. Soil types of Uzbekistan according to FAO classification: DS—dunes or shifting sands, Gc—calcaric gleysoils, Ge—eutric gleysoils, I—lithosols, Jc—calcaric fluvisols, Je—eutric fluvisols, RK—rock debris or desert detritus, WR—inland water, Xk—calcic xerosols, Yk—calcic yermosols, Yt—takyric yermosols, Z—solonchaks, Zg—gleyic solonchaks, Zt—takyric solonchaks. Red dot denotes a location of the Tashkent Botanical Garden.

Table 1. Rare and threatened species introduced in the Tashkent Botanical Garden, and the information about the introduced material type, cultivation success, life form, and native environment (altitude range, habitat, soil type, and phytogeographic region).

Species	Family	Introduced Material	Introduction Success	Endemism	Life Form	Habitat Type	Soil Type	Phytogeographic Region
Acantholimon ekatherinae *	Plumbaginaceae	Seeds/adults	Yes	U	Subshr	A	I	1
Acantholimon margaritae *	Plumbaginaceae	Seeds/adults	Yes	U	Subshr	M	I	1
Acantholimon nuratavicum *	Plumbaginaceae	Seeds	Yes	U	Subshr	M	I	4
Acantholimon subavenaceum *	Plumbaginaceae	Seeds	Yes	U	Subshr	M	I	4
Aconitum talassicum *	Ranunculaceae	Seeds/adults	Yes	CA	Per	M, A	I, Gc	1, 5, 7
Aconitum seravschanicum	Ranunculaceae	Adults	No	CA	Per	M, A	I	6
Adonis chrysocyathus	Ranunculaceae	Adults	No	-	Per	A	I	3
Allium decoratum *	Amaryllidaceae	Seeds/adults	No	U	Per	A	I	7
Allium giganteum *	Amaryllidaceae	Seeds/adults	Yes	-	Per	F, M	Xk, Gc	7, 8
Allium praemixtum *	Amaryllidaceae	Seeds/adults	Yes	U	Per	M	I, Xk	4
Allium pskemense *	Amaryllidaceae	Seeds/adults	Yes	CA	Per	M	I	1
Alliumisakulii *	Amaryllidaceae	Seeds/adults	Yes	CA	Per	M	I, Xk	3, 4
Allium stipitatum	Amaryllidaceae	Seeds/adults	Yes	U	Per	M	I	4
Allium oshaninii	Amaryllidaceae	Adults	No	CA	Per	F, M	I	7, 6, 8, 5, 1
Acanthophyllum gypsophiloides *	Caryophyllaceae	Seeds	Yes	CA	Per	M	I	1
Acanthophyllum tadshikistanicum	Caryophyllaceae	Seeds	Yes	CA	Per	F	I	8
Andrachne vvedenskyi *	Phyllanthaceae	Seeds/adults	Yes	U	Subshr	F	I	7
Anemone baissunensis *	Ranunculaceae	Seeds/adults	Yes	CA	Per	F, M	Xk	7
Anemone bucharica *	Ranunculaceae	Seeds/adults	Yes	CA	Per	M	I, Xk	7
Anemone narcissiflora	Ranunculaceae	Seeds/adults	No	CA	Per	M, A	I	1
Astragalus belolipovii *	Fabaceae	Seeds	Yes	U	Per	M	I	4
Astragalus bucharicus *	Fabaceae	Adults	No	U	Per	M	I	8
Astragalus rhacodes *	Fabaceae	Seeds	Yes	U	Subshr	M	I	3
Astragalus terrae-rubrae *	Fabaceae	Seeds	No	U	Per	M	I	7
Astragalus willisii *	Fabaceae	Seeds	No	U	Per	M	I	7
Aulacospermum popovii *	Apiaceae	Seeds	No	U	Per	M	I	1
Bryonia melanocarpa *	Cucurbitaceae	Seeds/adults	No	CA	Per	D, P	Yk, Ds	4, 10, 11
Bunium vaginatum *	Apiaceae	Seeds/adults	Yes	CA	Per	M	I	1
Argyrolobium aegacanthoides *	Fabaceae	Adults	No	U	Subshr	M	I	7
Capparis spinosa var. herbacea *	Capparaceae	Seeds	No	U	Per	F, M	I	8
Cephalopodum hissaricum *	Apiaceae	Seeds	No	CA	Per	M	Xk	7
Cleome gordjaginii *	Cleomaceae	Seeds	Yes	CA	Ann	F	I, Xk	7
Colchicum kesselringii *	Colchicaceae	Adults	Yes	CA	Per	P, F, M, A	I	1, 4, 5, 7
Corydalis sewerzovii	Papaveraceae	Seeds/adults	Yes	U	Per	(F) M	I, Xk	1, 7, 11
Crambe gordjaginii *	Brassicaceae	Seeds	No	U	Per	F	I	7
Crocus alatavicus	Iridaceae	Adults	Yes	CA	Per	M	I, Xk	1, 10
Crocus korolkovii	Iridaceae	Seeds/adults	Yes	CA	Per	F, M	I, Xk	7, 4, 5

Table 1. *Cont.*

Species	Family	Introduced Material	Introduction Success	Endemism	Life Form	Habitat Type	Soil Type	Phytogeographic Region
Dianthus uzbekistanicus *	Caryophyllaceae	Seeds	Yes	U	Per	M	I	5, 7
Dionysia hissarica *	Primulaceae	Seeds	No	U	Subshr	M	I	6
Dipcadi turkestanicum *	Asparagaceae	Adults	No	U	Per	M	Gc	7
Dorema microcarpum *	Apiaceae	Seeds	Yes	CA	Per	(F) M	I, Xk	2, 3
Eremurus aitchisonii *	Asphodelaceae	Seeds/adults	Yes	-	Per	P, A	I, Xk	5, 6, 7, 12
Eremurus alberti *	Asphodelaceae	Seeds/adults	Yes	-	Per	F	Xk, Z	7, 8
Eremurusambigens	Asphodelaceae	Seeds/adults	Yes	CA	Per	F	Xk, Gc	7, 8
Eremurus baissunensis *	Asphodelaceae	Adults	No	U	Per	F	I, Xk	7
Eremurus lactiflorus *	Asphodelaceae	Seeds/adults	Yes	CA	Per	F, M	I, Xk	1, 4
Eremuruskorolkovii *	Asphodelaceae	Adults	No	U	Per	P	Yk, Yt, Z	11
Eremurusluteus *	Asphodelaceae	Seeds/adults	Yes	-	Per	F, M	I	7
Eremurusnuratavicus *	Asphodelaceae	Seeds/adults	Yes	U	Per	F, M	I	4
Eremurusrobustus *	Asphodelaceae	Seeds/adults	Yes	CA	Per	F, M	I, Xk	1, 4, 5, 7, 10, 12
Eremurus stenophyllus	Asphodelaceae	Seeds/adults	Yes	-	Per	F, A	I, Xk, Gc	6, 7
Eremurussuworowii *	Asphodelaceae	Seeds/adults	Yes	-	Per	F, M	I, Xk	6, 7, 8
Eversmannia botschantzevii *	Fabaceae	Seeds	Yes	U	Shrub	F	I	7
Ferula gigantea	Apiaceae	Seeds	Yes	-	Per	F, M	I, Gc	6 or 8
Fritillaria eduardii *	Liliaceae	Seeds/adults	Yes	-	Per	M	I	6
Gladiolus italicus *	Iridaceae	Seeds/adults	Yes	-	Per	F, M	I	7, 6
Heliotropium bucharicum *	Heliotropiaceae	Seeds	Yes	U	Ann	M	I	7
Incarvillea olgae *	Bignoniaceae	Seeds	Yes	CA	Per	M	I	3
Iris hippolyti *	Iridaceae	Adults	No	U	Per	D, F	Yk	4
Iris magnifica *	Iridaceae	Seeds/adults	Yes	U	Per	F	Gc, I	5
Iris orchioides *	Iridaceae	Seeds/adults	Yes	CA	Per	F, M	I, Xk	1, 10
Iris svetlanae *	Iridaceae	Seeds/adults	Yes	U	Per	F, M	I, Xk	5, 7, 12
Lagochilus inebrians *	Lamiaceae	Seeds	Yes	U	Subshr	P	Xk	4
Lepidolopha fedtschenkoana *	Asteraceae	Seeds	Yes	U	Subshr	M	I	7
Lipskya insignis *	Apiaceae	Seeds	Yes	CA	Per	F	I, Xk	7
Malacocarpus crithmifolius *	Zygophyllaceae	Seeds	Yes	-	Shrub	P	Yk	15
Nanophyton botschantzevii	Amaranthaceae	Seeds	No	U	Shrub	M	I	1
Onobrychis tavernierifolia *	Fabaceae	Seeds	Yes	-	Ann	P	Yt	11
Ostrowskia magnifica *	Campanulaceae	Seeds/adults	Yes	-	Per	M	I	6
Moluccella bucharica *	Lamiaceae	Seeds/adults	No	U	Subshr	F, M	I	7
Oxytropis tachtensis	Fabaceae	Seeds	Yes	-	Per	M	I	4, 5
Oxytropis seravschanica	Fabaceae	Seeds	Yes	CA	Per	A	I	5
Paeonia intermedia *	Paeoniaceae	Seeds/adults	Yes	-	Per	M	I	1, 6, 7
Physochlaina alaica *	Solanaceae	Adults	Yes	U	Per	M	I, Xk	3
Prangos tschimganica	Apiaceae	Seeds	Yes	U	Per	M	I	1
Rhus coriaria *	Anacardiaceae	Seeds/adults	Yes	-	Shrub	F, M	I	1, 6
Rubia laevissima *	Rubiaceae	Seeds	No	CA	Subshr	M	I	1
Salvia korolkowii *	Lamiaceae	Seeds/adults	Yes	U	Subshr	F, M	I	1
Salvia lilacinocoerulea *	Lamiaceae	Seeds/adults	Yes	U	Per	M	I	7

Table 1. *Cont.*

Species	Family	Introduced Material	Introduction Success	Endemism	Life Form	Habitat Type	Soil Type	Phytogeographic Region
Salvia submutica *	Lamiaceae	Seeds	Yes	U	Per	M	Xk, I	4
Spirostegia bucharica *	Plantaginaceae	Seeds	No	CA	Biann	F	I	7
Sternbergia lutea *	Amaryllidaceae	Seeds/adults	No	-	Per	M	I	7
Tulipa affinis *	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk, Yk	4, 11, 5
Tulipa bifloriformis	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk, Ge	1, 2, 10
Tulipa buhseana	Liliaceae	Seeds/adults	Yes	CA	Per	P	Xk, Yk,	4, 10, 11, 15
Tulipa carinata *	Liliaceae	Seeds/adults	Yes	U	Per	M, A	I, Xk	6, 7
Tulipa ferganica *	Liliaceae	Seeds/adults	Yes	U	Per	F	Gc, I, Xk	2, 3, 9
Tulipa fosteriana *	Liliaceae	Seeds/adults	Yes	U	Per	F, M	I	5
Tulipa greigii *	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk, Ge	1, 10
Tulipa ingens *	Liliaceae	Seeds/adults	Yes	CA	Per	M	I, Xk	5, 6, 7
Tulipa kaufmanniana *	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk, Ge	1
Tulipa korolkowii *	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk, Ge, Yk, Gc	1, 3, 4, 5, 6, 7, 8
Tulipa lanata *	Liliaceae	Seeds/adults	Yes	CA	Per	F, M	I, Xk, Gc	6, 7,8
Tulipa micheliana *	Liliaceae	Seeds/adults	Yes	CA	Per	P, F	I, Gc, Yk, Xk	4, 5, 7, 11, 12
Tulipa orythioides *	Liliaceae	Seeds/adults	Yes	U	Per	F, A	I	6, 7
Tulipa scharipovii *	Liliaceae	Seeds/adults	Yes	U	Per	F	Gc, Xk	1, 2
Tulipa tschimganica	Liliaceae	Seeds/adults	Yes	U	Per	F, M	I	1
Tulipa tubergeniana *	Liliaceae	Seeds/adults	Yes	CA	Per	F, M	I, Gc, Xk	6, 7, 8
Tulipa turkestanica	Liliaceae	Seeds/adults	Yes	CA	Per	P, M	I, Xk	1, 3, 4, 5, 6, 7, 9, 10, 11, 12
Tulipasogdiana	Liliaceae	Adults	No	CA	Per	P	Yk	11, 12, 13, 15
Tulipauzbekistanica *	Liliaceae	Seeds/adults	Yes	U	Per	M	I	7
Tulipavvedenskyi *	Liliaceae	Seeds/adults	Yes	U	Per	F, A	I	1
Zeravschania regeliana *	Apiaceae	Seeds	Yes	U	Per	M	I	7
Zygophyllum bucharicum *	Zygophyllaceae	Seeds/adults	No	CA	Shrub	F	Jc	7

Abbreviations: * included in the latest edition of *Red Book of Uzbekistan* [21]. Life form: ann—annual, biann—biannual, per perennial, subshr—subshrub, shr—shrub. Endemism: U—endemic to Uzbekistan, CA—endemic to Central Asia,—non-endemic. Habitat type: D—desert, P—plain, F—foothills, M—mid mountain, A—alpine.

3. Results

There are documented results of introduction in the Tashkent Botanical Garden from 1950 until 2022 for a total of 100 rare and threatened species. Of these, 83 are listed in the latest edition of the *Red Book of Uzbekistan* [21]. The other 17 species not listed in the latest edition of the *Red Book* were listed in the previous editions and therefore are considered rare. In fact, these species as well as many others not included in the *Red Book* can be truly threatened because species categorization in Uzbekistan has never involved the formal IUCN criteria. The majority of the species are endemic to Central Asia (87), of which 47 are endemic to Uzbekistan (Table 1).

A distribution of introduced species among the five life forms was highly dissimilar. Most introduced species were non-arboreal perennials (78), followed by subshrubs (13). Only five introduced species were shrubs, three were annuals and one was a biannual. Of the introduced 100 species, the introduction of 26 failed. The highest number of introduction failures had shrubs and subshrubs (40.0 and 30.8%, respectively). There was a similar probability of failure for perennials and annuals/biannuals (22.9 and 25.0%, respectively) (Table 2).

The largest number of species in cultivation represented Liliaceae (21) and Asphodelaceae (11), with only one and two failures, respectively, and Fabaceae (10) with four failures. Apiaceae and Amaryllidaceae were represented by eight species, each with two and three failures, respectively. They were followed by Iridaceae (7), Ranunculaceae (6), Lamiaceae (5), Plumbaginaceae (4), Caryophyllaceae (3), and Zygophyllaceae (2). For all these families, except Ranunculaceae, the number of failures did not exceed one. As for Ranunculaceae, cultivation of three species of this family failed. Other families were represented by a single species.

Among the four habitats, plains (the habitat type of the botanic garden location) had the smallest proportion of failures (18.7%), followed by mid mountains and foothills (20.8 and 20.9%, respectively). The highest proportion of failures was detected for desert and alpine mountain zones (100 and 30.8%, respectively), although the sample size for the desert habitat was very small (only two species), which could influence the result (Table 2).

The soil type was found to be an important predictor of introduction success: the species occupying soil type Xk (the soil type of the botanic garden location) had a much smaller proportion of failures (5.1%) than the species occupying other soil types (37.7%). The same effect was found for the phytogeographic region: the species occupying Middle Syrdarya (the region where the botanic garden is located) had a much smaller proportion of failures (12.5%) than the species growing in other regions (27.2%).

In terms of endemism, the smallest proportion of failures was detected for non-endemic species (11.8%), followed by Central Asian endemics (i.e., those occurring not only in Uzbekistan, but also in Turkmenistan, Tajikistan, Kyrgyzstan, or Kazakhstan) (24.4%), while failures were the most frequent among Uzbek endemics (32.6%). The largest number of failures was recorded for Uzbek endemics from South-Western Gissar, Western Tien Shan, and Near-Pjandzh phytogeographic regions (6, 3, and 2, respectively). Three regions had one recorded species introduction failure (Gissaro–Darvaz, Nurata, and Kyzylkum). In terms of soil, the pattern was highly similar with the phytogeographic regions: most of Uzbek endemics which introduction failed only grow on the soil type I (10 out of 15 species); this type predominates in South-Western Gissar and Western Tien Shan.

Table 2. A relationship between species introduction success/failure and the five analyzed factors (endemism, life form, habitat type, soil type, and phytogeographic region).

Analyzed Factors	Results of Species Introduction (Number of Species) Success	Failure
Endemism		
Non-endemic	15	2
Endemic to Central Asia (Uzbekistan + other CA countries)	31	9
Endemic to Uzbekistan	32	15
Life form		
Shrub	3	2
Subshrub	9	4
Perennial	64	19
Annual or biannual	3	1
Habitat type		
Desert	0	2
Plain	13	3
Foothills	34	9
Mid mountains	57	15
Alpine	9	4
Soil type		
Xk	37	2
Other types	38	23
Phytogeographic region		
Middle Syrdarya	7	1
Other regions	67	25

4. Discussion

Although rare and threatened species are maintained in many botanical gardens around the world, detailed reports on the success or failure of their cultivation appear infrequently, making it difficult to understand the major limitations of growing imperiled species in botanical garden living collections. For the countries of the former Soviet Union, we found such reports only for Armenia [22] and different parts of Russia [23–25]. In Central Asia, such reports were previously published by Belolipov [26] and Tursunov and Sharipov [27]. The authors of these two papers presented the results of the introduction of rare and threatened species of Central Asia in the Tashkent Botanical Garden. More data have accumulated over the past 30 years, and this report greatly expands on previous knowledge. However, the difference between our report and these two reports is that it is limited to species native to Uzbekistan only. This was motivated by the specific objective of our study, different from the two mentioned above: to identify species that can be cultivated in the Tashkent Botanical Garden for propagation and the introduction in situ in Uzbekistan. Moreover, the data presentation in Tursunov and Sharipov [27] had serious shortcomings. The authors of this article stated that 150 species of rare and endangered plants from Central Asia were successfully introduced into the Tashkent Botanical Garden, of which 66 represented the flora of Uzbekistan. Unfortunately, they did not provide a complete list of species, and their analysis of introduction success based on the rarity categories and habitat types did not distinguish Uzbek species from those that occur only outside the country. This significantly devalues their conclusions when they speak of a probability of the successful introduction of species representing different habitat types and rarity categories. In fact, their rarity categories combined rarity and level of endemism, and a rare endemic plant in their analysis could be endemic to Uzbekistan or any other Central Asian country. A comparison of the environmental requirements (which are usually not known) of such endemics with respect to the prospects of creating their living collections in the Tashkent Botanic Garden located in Uzbekistan is problematic because even if endemics from different countries of Central Asia occupy a similar altitude or soil type, they experience different regional climates. This problem was not present in our analysis because only species with known records of occurrence in Uzbekistan were analyzed.

In our work, of the five factors which effects have been checked (endemism, life form, phytogeographic region, habitat, and soil type), life form had the weakest effect on the cultivation success/failure. This is due, at least in part, to the very unequal representation of different life forms among the introduced species. All other four factors were important in determining the cultivation success. Country endemics that grow in different, compared to the garden location, broadly defined phytoregions, habitats and soils have the least chance of success. In contrast, the species that also grow outside the country have much better prospects for successful cultivation, even if they occupy phytoregions, habitats, and soils that are different from the garden location.

Previously, Tursunov and Sharipov [27] came to the conclusion that species occupying mid-mountain slopes, intermountain valleys, and the adjoining them forests have the best chance for successful introduction in the Tashkent Botanical Garden, while species from the alpine zone have the least chance. These conclusions are consistent with the results of our analysis. Poor prospects for successful cultivation, according to these authors, also have species from sandy deserts, and species from variegated clays and gypsum soils have intermediate chances. The last two specific soil substrates are common in South-Western Gissar with lithosols, where most of the species which introduction failed are found.

An important finding of our study was that species endemic to Uzbekistan in general have a lower chance of success compared to those species that also grow outside the country. This means that many Uzbek endemics have very narrow environmental requirements that are difficult or impossible to meet in a garden even if the garden shares a common climate with these species. Nevertheless, although many rare and threatened species introduced to the Tashkent Botanical Garden are narrow endemics occupying specific habitats in terms of microclimate, soil type, altitude, and vegetation, their introduction was successful. All of these species were producing viable seeds and new cohorts, and their collections could be maintained in the garden for many years upon the removal of competing local weeds. The latter turned out to be decisive for the success of the cultivation. This confirms the important role of ex situ conservation for preserving critically endangered biodiversity and should stimulate further work in this direction. The future efforts of the garden staff will focus on three main objectives: (i) collecting seeds of imperiled species that have so far skipped attention or their collection missions have been unsuccessful; (ii) seed banking with duplicate lots of seeds sent abroad to provide the best chances of survival for those species in which cultivation in the garden failed; and (iii) propagating those species that have proven cultivation success and using the propagated material for in situ actions. We are currently propagating several of these species (*Fritillaria eduardii*, *Iris orchioides*, six species of *Tulipa*, and two species of *Eremurus*) and identifying the most appropriate locations in the protected areas of Uzbekistan to create new populations of these species. Contrary to the previous procedures of the garden staff, the propagated material will not be grown in the garden for more than three years and will be used exclusively for in situ introduction.

5. Conclusions

Narrow endemics, as a rule, have lower chances of successful cultivation in botanical garden living collections than non-endemics, but many local endemics grow well in such collections, and, therefore, the introduction trials of rare and threatened endemics are certainly warranted. It is important that living collections be used to propagate material that will be utilized for in situ actions.

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