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RESEARCH ARTICLE

Rare species of *Tulipa* (Liliaceae) from Tashkent Botanical Garden

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Abstract

Biomorphological features of 14 rare *Tulipa* species listed in the Red Book of the Republic of Uzbekistan (*Tulipa affinis*, *T. carinata*, *T. ferganica*, *T. fosteriana*, *T. greigii*, *T. ingens*, *T. kaufmanniana*, *T. korolkowii*, *T. lanata*, *T. micheliana*, *T. scharipovii*, *T. tubergeniana*, *T. uzbekistanica* and *T. vvedenskyi*) were studied under ex situ conditions in the Tashkent Botanical Garden. It has been found, that all studied species successfully grow and bear fruits *ex situ*. All 14 species are able to autogamy; even solitary generative specimens regularly produce seeds. This feature significantly facilitates the further breeding of rare species of tulips. Considering the heterospermy and irregular quality of seedlings, the most rapidly developing individuals should be selected for cultivation and reintroduction.

Keywords

ex situ, geophytes, heterospermy, seed reproduction, threatened species

Introduction

The genus *Tulipa* L. is one of the most known and intensively studied genera of Monocots (Botschantzeva 1982; Ivaschenko 2005; Pratov et al. 2006; Coşkunçelebi et al. 2008; Pechenitsyn 2008; Tojibaev and Kadirov 2010; Peregrym et al. 2011; Beshko et al. 2013; Christenhusz et al. 2013; Everett 2013; Turktas et al. 2013; Tojibaev and Beshko 2015; Kashin et al. 2016; Ochirova et al. 2017; Sadyrova et al. 2017; Shomurodov and Abduraimov 2017; Xing et al. 2017; Khaleghi et al. 2018; Kritskaya et al. 2018; Tojibaev et al. 2018). Great research interest can be explained by tulips outstanding ornamental qualities and species diversity, wide distribution and attribution to the habit of bulbous geophytes.

According to the current estimation, the genus includes about 100 species (Zonneveld 2009; Veldkamp and Zonneveld 2011; Everett 2013). Several new species from various regions have been described over the past decade (Tojibaev 2009; Zonneveld 2009; Lazkov and Pashinina 2011; Epiktetov and Belyalov 2013; Stepanova 2013; Perezhogin 2014; Tojibaev et al. 2014).

At present, the flora of Uzbekistan contains 34 taxa of the genus *Tulipa* (Tojibaev and Beshko 2015). Most of them belong to the subgenus *Tulipa*, including *T. affinis* Botschantz., *T. carinata* Vved., *T. fosteriana* Irving, *T. greigii* Regel, *T. ingens* Hoog, *T. kaufmanniana* Regel, *T. lanata* Regel, *T. micheliana* Hoog, *T. mogoltavica* Popov & Vved., *T. tubergeniana* Hoog, and *T. vvedenskyi* Botschantz. They are large plants with a single bright flower, and their appearance meets the common opinion about tulips. These species glorify Central Asia across the world as the main center of tulips origin. Many of them (*T. fosteriana*, *T. greigii*, *T. kaufmanniana*, and *T. mogoltavica*) had a great impact on formation of current diversity of the cultivars (Marasek and Okazaki 2007, 2008; Marasek-Ciolakowska et al. 2009).

During past decades, the distribution area of many *Tulipa* species in Central and Western Asia and Transcaucasia have been decreased due to the intensive human impact. The main limiting factors are uncontrolled collecting of bulbs and blooming plants, overgrazing and habitat loss (Maunde et al. 2001; Sharipov et al. 2002; Ivashenko 2005; Varol and Mammadov 2006; Tojibaev and Kadirov 2010; Boboev T. and Boboev M. 2010; Dadasheva 2012; Lazkov and Umralina 2015). In this regard, the most threatened species are protected at the national level. In particular, the Red Data Book of Uzbekistan (2019) lists 20 species of tulips.

In the second half of XX century, the unique *ex situ* collection of *Tulipa* has been created in the Tashkent Botanical Garden; there were several thousand of specimens of more than 100 species, collected mainly from natural habitats (Botschantzeva 1982). Unfortunately, in 1980s, the exposition was gradually desolated and completely lost.

In the past few years, the reconstruction of the *ex situ* collection Uzbekistan rare native plant species became extremely urgent for biodiversity conservation at national and global level. This study began in 2010 within the framework of State Research Projects (Turgunov et al. 2019).

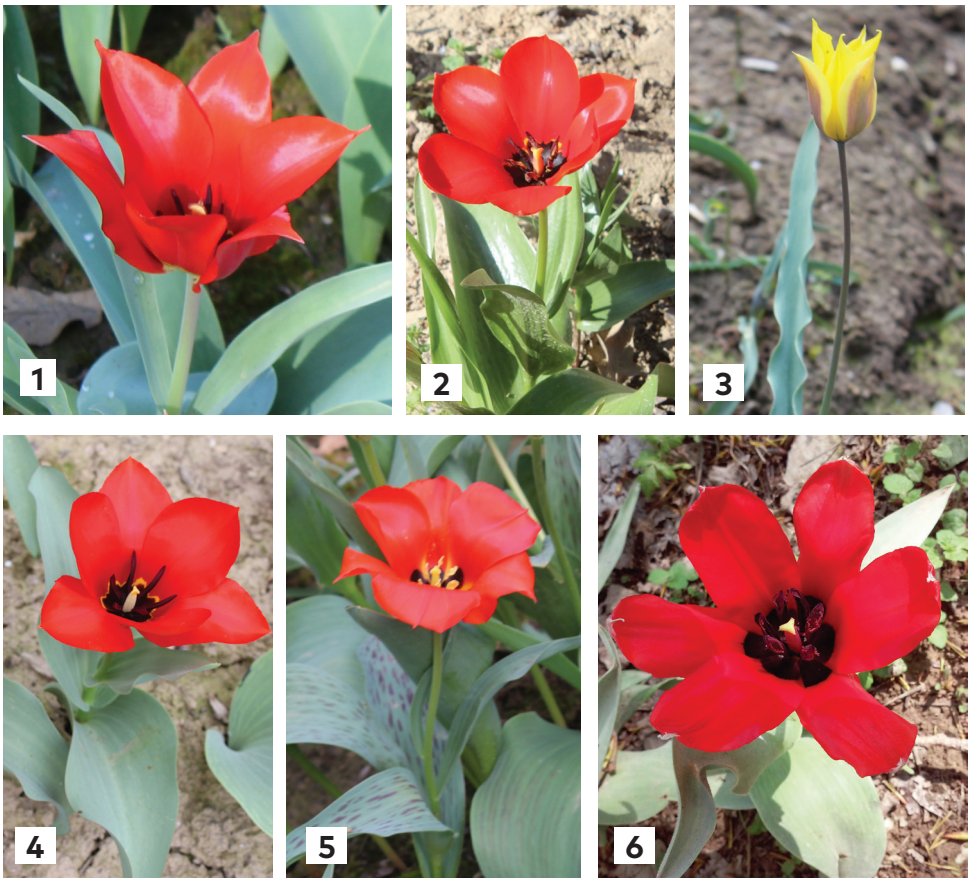
Material and methods

The research objects were the rare species of *Tulipa* included in the Red Data Book of Uzbekistan (2019). National categories of threatened species are following: 0 – extinct species; 1 – endangered, disappearing species; 2 – rare species; 3 – reducing, near threatened species. Accepted scientific names of species are given according to the international taxonomical databases, International Plant Names Index (www.ipni.org) and Catalogue of Life (www.catalogueoflife.org). The descriptions of ecology and geographical distribution of species were given in accordance with published data (Vvedensky 1941; Vvedensky and Kovalevskaya 1971; Botschantzeva 1982; Pratov et al. 2006; Tojibaev and Kadirov 2010; Beshko et al. 2013; Tojibaev and Beshko 2015) and own observations.

Following 14 species are breeding now in the Tashkent Botanical Garden:

1. *Tulipa affinis* Botschantz. (Fig. 1). Endemic to the Northwestern Pamir-Alay (Kyrgyzstan, Tajikistan and Uzbekistan). Distribution in Uzbekistan: Turkestan and Malguzar ranges, Nuratau Mountains. Habitat: fine earth and stony slopes, rock ledges, among shrubs and juniper stands, in the lower and middle mountain belt, rarely in foothills (700–2200 m a.s.l.). Occurs sporadically, singly or in small groups, sometimes forms populations of several hundred plants. Seed propagation. UzbRDB 3 (UzbRDB is the abbreviation for the Red Data Book of Uzbekistan 2019). Material was collected on the Nuratau Mountains.
2. *T. carinata* Regel (Fig. 2). Endemic to the Southwestern Pamir-Alay (Tajikistan, Turkmenistan, Uzbekistan and Afghanistan). Distribution in Uzbekistan: Kughitang and Hissar ranges, Baysun Mountains. Habitat: fine earth and stony slopes, rock ledges, in the middle mountain belt (1500–2800 m a.s.l.). Occurs sporadically, singly. Seed propagation. UzbRDB 3. Material was collected on the Baysun Mountains.
3. *T. ferganica* Vved. (Fig. 3). Endemic to the Fergana Valley (Kyrgyzstan, Tajikistan and Uzbekistan). Distribution in Uzbekistan: Chatkal, Fergana and Alay ranges. Habitat: clayey and stony slopes of foothills, lower and middle mountain belt (700–2000 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 2. Material was collected on the Kurama Ridge.
4. *T. fosteriana* Irving (Fig. 4). Endemic to the Western Pamir-Alay (Tajikistan, Uzbekistan). Distribution in Uzbekistan: Zeravshan Range. Habitat: fine earth and stony slopes, rock ledges, in the middle mountain belt (1500–2500 m a.s.l.). Occurs sporadically, singly or in small groups. Seed and vegetative propagation. UzbRDB 2. Material was collected on the Zeravshan Ridge.
5. *T. greigii* Regel (Fig. 5). Endemic to the Western Tien Shan (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan). Distribution in Uzbekistan: Ugam, Pskem, Karzhantau, Chatkal, Kurama ranges. Habitat: clayey, rarely stony slopes of foothills, lower and middle mountain belt (500–1700 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 3. Material was collected on the Chatkal Ridge.

6. *T. ingens* T.M. Hoog (Fig. 6). Endemic to the Western Pamir-Alay (Tajikistan, Turkmenistan and Uzbekistan). Distribution in Uzbekistan: Zeravshan, Hissar, Kugitang ranges. Habitat: fine earth and stony slopes, rock ledges, in the middle mountain belt (1500–2500 m a.s.l.). Occurs sporadically, singly or in small groups, rarely forms large populations. Seed propagation. UzbRDB 3. Material was collected on the Hissar Ridge.
7. *T. kaufmanniana* Regel (Fig. 7). Endemic to the Western Tien Shan (Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan). Distribution in Uzbekistan: the Ugam, Pskem, Karzhantau, Chatkal, Kurama ranges. Habitat: clayey, gravelly and stony slopes of foothills, lower and middle mountain belt (700–2500 m a.s.l.). Occurs sporadically, singly or in small groups, sometimes forms populations of several hundred plants. Seed and vegetative propagation. UzbRDB 3. Material was collected on the Chatkal Ridge.
8. *T. korolkowii* Regel (Fig. 8). Endemic to the mountainous Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan). Distribution in Uzbekistan: surroundings of Tashkent, Kurama, Pistalitau, Turkestan, Zeravshan, Hissar, Kughitang, Babatag ranges, Nuratau and Zirabulak-Ziadin Mountains, Baysun Mountains. Habitat: outcrops of variegated beds, clayey, gravelly and stony slopes of foothills, lower and middle mountain belt (400–2200 m a.s.l.). Occurs sporadically, singly or in small groups, sometimes forms populations of several hundred plants. Seed propagation. UzbRDB 3. Material was collected on Nuratau Mountains and Hissar Ridge.
9. *T. lanata* Regel (Fig. 9). Endemic to the Pamir-Alay (Tajikistan, Turkmenistan, Uzbekistan). Distribution in Uzbekistan: Hissar, Kughitang, Babatag ranges, Baysun Mountains. Habitat: outcrops of variegated beds, clayey, rarely stony slopes of lower and middle mountain belt (1000–2200 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 3. Material was collected on the Hissar Ridge.
10. *T. micheliana* T.M. Hoog (Fig. 10). Western Pamir-Alay, Kopetdag (Tajikistan, Turkmenistan, Uzbekistan and Iran). Distribution in Uzbekistan: Pistalitau, Malguzar, Zeravshan, Hissar, Kughitang ranges, Nuratau and Zirabulak-Ziadin Mountains. Habitat: clayey and stony slopes of foothills and lower mountain belt (400–1500 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 3. Material was collected on the Hissar Ridge.
11. *T. scharipovii* Tojibaev (Fig. 11). Endemic to the Fergana Valley, national endemic. Distribution in Uzbekistan: piedmont plains and southern foothills of the Chatkal and Kurama ranges. Habitat: saline, loess and skeleton soils in foothills (700–900 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 2. Material was collected on the Kurama Ridge.
12. *T. tubergeniana* T.M. Hoog (Fig. 12). Endemic to the Southwest Pamir-Alay (Tajikistan, Uzbekistan). Distribution in Uzbekistan: Hissar, Kughitang, Babatag ranges, Baysun Mountains. Habitat: Habitat: outcrops of variegated beds, clayey slopes, among pistachio stands, in foothills and lower mountain belt, rarely in



Figures 1–6. **1** *Tulipa affinis*. **2** *Tulipa carinata*. **3** *Tulipa ferganica*. **4** *Tulipa fosteriana*. **5** *Tulipa greigii*. **6** *Tulipa ingens*.

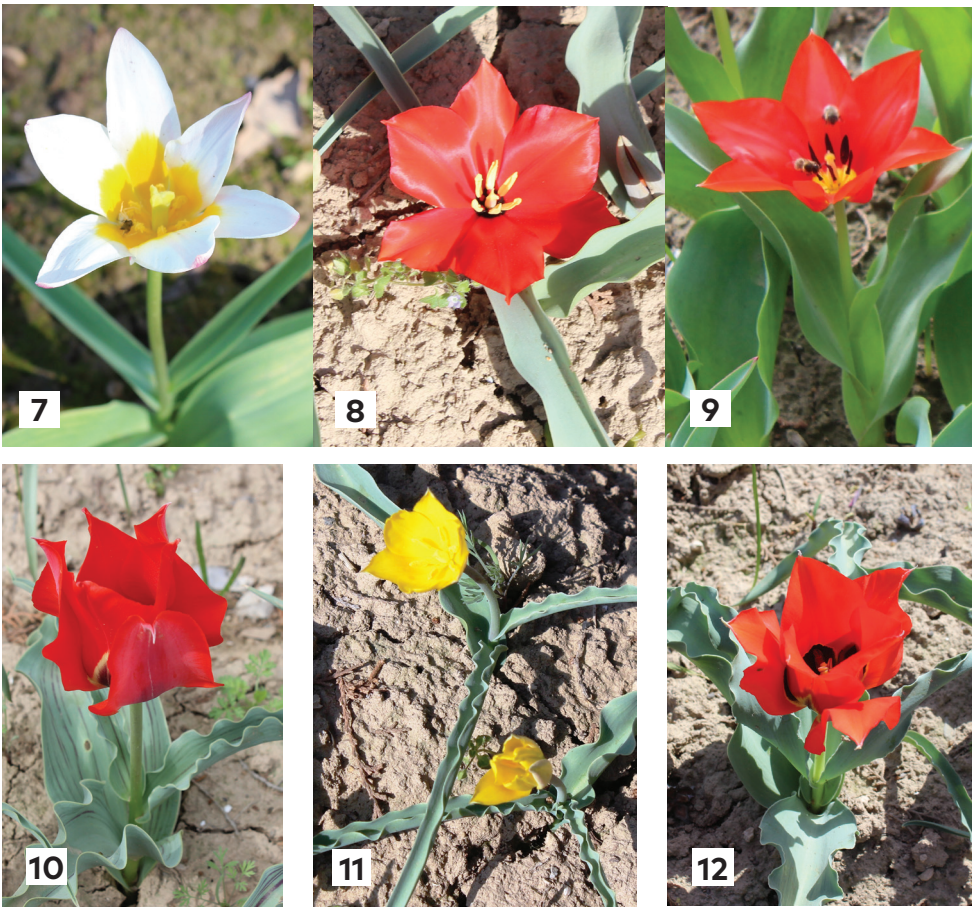
middle mountain belt (500–1800 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 3. Material was collected on the Baysun Mountains.

13. *T. uzbekistanica* Botschantz. et Sharipov (Fig. 13). Narrow endemic to the Kurukdagana mountains (surroundings of the pass Tally and basin of river Tarkapchigay) in the western spurs of Hissar Range, national endemic. Habitat: grey saliferous clays, outcrops of variegated beds, in the middle mountain belt (1400–1700 m a.s.l.). Occurs sporadically, singly or in small groups. Seed propagation. UzbRDB 1. Material was collected on the Kurukdagana mountains.
14. *T. vvedenskyi* Botschantz. (Fig. 14). Endemic to the Western Tien Shan (Tajikistan, Uzbekistan). Distribution in Uzbekistan: Kurama and Chatkal ranges (mainly basin of the river Akhangaran). Habitat: the skeleton soils, screes and outcrops of bed rocks in the middle mountain belt (1600–2000 m a.s.l.). Occurs singly or in small groups, sometimes forms populations of several hundred

plants. Seed and vegetative propagation. UzbRDB 3. Material was collected on the Kurama Range.

The bulbs and seeds of tulips were collected in 2010–2018 in natural habitats and planted in the Tashkent Botanical Garden, where cultivated without the watering and with minimal maintenance. Species were identified using "Flora of Uzbekistan" (Vvedensky 1941) and "Conspectus Florae Asiae Mediae" (Vvedensky and Kovalevskaya 1971).

Turgunov et al. (2019) described the soil and climatic conditions of the Tashkent Botanical Garden in detail and we presented here only some basic characteristics. The Garden is located at the elevation of 480 m a.s.l. The soil is a typical old irrigated gray soil. The climate is continental, warm temperate with hot dry summer and moderately cold winter (Csa) (Kottek et al. 2006). The average temperature of January is… +1.4°C, average temperature of July is…+27.6°C, the absolute mini-



Figures 7–12. 7 *Tulipa kaufmanniana*. **8** *Tulipa korolkowii*. **9** *Tulipa lanata*. **10** *Tulipa micheliana*. **11** *Tulipa sharipovii*. **12** *Tulipa tubergeniana*.

Figures 13–14. 13 *Tulipa uzbekistanica*. **14** *Tulipa vvedenskyi*.

mum of temperature is…-25.8°C, the absolute maximum is…+44.6°C. Average annual relative air humidity is 59%, in July it decreases to 22%. Annual rainfall is 420 mm and most precipitation occurs in winter-spring period.

The following indicators of fruit bearing plants were considered: ovule number (potential seed productivity - PSP), seeds number per fruit (real seed productivity - RSP), and seeds-ovules ratio (seed production coefficient - SPC).

When determining the average weight of air-dried seed, the sample size was 20. The seeds and bulbs were weighed using the electronic scales OHAUS Explorer Pro EP 214 C.

Results and discussion

All studied species are bulbous geophytes and ephemeroids. In the conditions of the Tashkent Botanical Garden, their vegetation begins in early spring or even in winter and ends with the advent of the hot period in the end of April–May. The vegetation period is 2.5–3 months.

The species can be grouped as follows:

- early-flowering: blooming begins in the first half of March, when the sum of daily average temperatures since the beginning of vegetation reaches 200–300°C (*T. kaufmanniana*, *T. uzbekistanica*);
- mid-flowering: blooming begins in the second half of March with the sum of daily average temperatures of 300–350°C (*T. affinis*, *T. carinata*, *T. ferganica*, *T. fosteriana*, *T. korolkowii*, *T. lanata*, *T. scharipovii*, *T. tubergeniana*, *T. greigii*);

- late-flowering: blooming begins in April when the sum of daily average temperatures reaches 370–400°C (*T. ingens*, *T. micheliana*, *T. vvedenskyi*).

Under *ex situ* conditions, the size of tulip bulb enlarges that leads to an increase of plant height, the number and size of leaves, and the size of flower. Some species can form more than one flower as well as one or two auxiliary buds and bulblets (Table 1).

Among studied species, *T. carinata* reaches the largest size under the conditions of introduction: the reproductive shoot is up to 53 cm high, the lower leaf is up to 35 cm long and 17.5 cm wide, the flower is up to 17.5 cm in diameter, and the flower stalk is up to 1.2 cm in diameter.

The most affordable way for *Tulipa* species propagation is the seed reproduction, which provides the heterogeneity of the offspring. Despite a rather long pre-generative period, a regular sowing with a small number of seeds provides in 4–5 years an annual yield of planting material sufficient for reintroduction. Our observations showed that all 14 species are able to autogamy; even solitary generative specimens regularly produce the seeds. This feature significantly facilitates the further breeding of rare tulip species *ex situ*.

The mature seeds of tulips are flat and located in a trilocular capsule; two piles in each locule. Among 14 studied species, *T. korolkowii* and *T. scharipovii* produce the least amount of seeds (about of 100), whereas the highest seed numbers were registered in *T. carinata*, *T. fosteriana*, *T. greigii*, *T. kaufmanniana* and *T. micheliana* – up to 350 seeds. Other species produce less than 200 seeds.

Using *T. kaufmanniana* as an example, we studied parameters of seed productivity and weight, formed in different capsule parts. The capsule dimensions among

Table 1. Some morphological features of *Tulipa* species under *ex situ* conditions in the Tashkent Botanical Garden.

Species	Maximum quantity		Vegetative reproduction presence
	leaves	flowers	
Tulipa affinis	5	1	+
T. carinata	6	1	+
T. ferganica	3	2	–
T. fosteriana	6	2	+
T. greigii	7	2	–
T. ingens	6	2	–
T. kaufmanniana	5	2	+
T. korolkovii	4	2	–
T. lanata	5	1	+
T. micheliana	5	2	–
T. scharipovii	3	1	–
T. tubergeniana	5	1	–
T. uzbekistanica	5	1	–
T. vvedenskyi	6	2	+

the plants of the same population were almost equal (6–6.5 x 2.2–2.3 cm). The seed location in each pile can be determined as follows:

- central – about 0.6 cm;
- distal (the lower and upper parts of a capsule) – about 0.6 cm each;
- middle (between the central and distal positions) – about 1 cm each (Table 2).

We registered one common pattern in all the cases: the distal capsule parts were characterized by the least seed production rate and average seed weight (Table 2). We also found small seeds in the middle capsule parts. In the capsule, the largest seeds were formed in the central and middle parts while the smallest seeds were located in the distal and middle parts (capsules 2 and 5). It is known, that tulip ovules are situated in the middle part of ovary and developed faster than peripheral ones. The farther the ovule is located from the middle part, the more expressed its development delay (Pechenitsyn 2008).

Analyzed the weight of different age seedlings bulbs, we revealed that studied species considerably differ by the rates of bulb development. The majority of one-year seedlings of *T. affinis* had the bulbs weighing 26–50 mg, whereas the bulbs of *T. vvedenskyi* weighed 101–200 mg. In the second-year plants, this difference between two species was less pronounced: the majority of bulbs of both species weighed 101–300 mg. However, the amplitude of bulb weight variability increased considerably: in *T. affinis* it is ranged from 20 to 500 mg, and in *T. vvedenskyi* – from 40 to 800 mg (Fig. 15).

We also established that development of a certain part of two-year seedlings sharply delays, but other plants accelerate their development. While the largest bulbs of one-year seedlings were by 5–6 times heavy than the smallest ones, the weights of largest and smallest bulbs among two-year plants differed by 20 times.

Conclusion

Thus, our long-term research showed that all studied rare species of *Tulipa* successfully grow and bear fruits ex situ in Tashkent Botanical Garden. Even in cultural landscapes some specimens of *T. carinata*, *T. ferganica*, *T. fosteriana*, *T. ingens* and *T. lanate* that grow under protection of thorny shrubs or liana, can survive for decades. These rare species can live for a long time *ex situ*, with the minimum care, periodic digging and clearing the bulbs from the died scales.

Revealed heterospermy is linked with the ovules development in the ovary and location of forming seeds. The growth wild tulip sseedlings up to generative conditions, *ex situ* breeding of rare species in numbers sufficient for the reintroduction are rather labour-consuming and long processes. Therefore, considering the heterospermy and irregular quality of seedlings, the most rapidly developing individuals should be selected for cultivation and reintroduction, whereas the slow developed must be ignored.

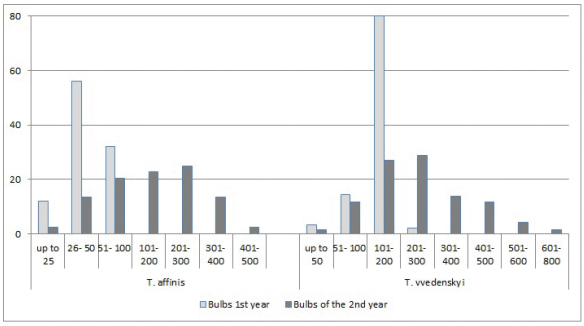


Figure 15. Distribution of bulbs of different-age seedlings of *Tulipa* species by weight, %.

Table 2. Seed productivity and average seed weight of *T. kaufmanniana* in various locations.

№	PSP			RSP			SPC, %			Seed weight, mg		
	Cent	Mid	Dist	Cent	Mid	Dist	Cent	Mid	Dist	Cent	Mid	Dist
1	54	151	92	46	128	44	85.2	84.8	47.8	9.4± 0.30	8.9± 0.29	7.0± 0.26
2	66	175	102	52	102	24	78.8	58.3	23.5	7.1± 0.23	6.6± 0.20	5.2± 0.18
3	52	133	91	50	125	54	96.2	94.0	59.3	9.0± 0.27	9.1± 0.30	7.4± 0.27
4	54	146	99	50	132	49	92.6	90.4	49.5	7.0± 0.22	6.3± 0.22	5.3± 0.21
5	53	170	53	50	158	22	94.3	92.9	41.5	7.1± 0.21	6.4± 0.20	5.9± 0.20
M±m	55.8± 2.58	155.0 ±7.77	87.4± 8.85	49.6± 0.98	129.0 ±8.93	38.6 ±6.57	90.4± 3.96	84.1± 6.64	44.3± 5.94			

Seed location: Cent – central, Mid – middle, Dist – distal. PSP – potential seed productivity, RSP – real seed productivity, SPC – seed production coefficient. Underlined values significantly different from that of central and middle location (P<0.05).

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