Mapping and analyzing the distribution of the species in the genus *Tulipa* (Liliaceae) in the Ferghana Valley of Central Asia

Davron DEKHKONOV, Komiljon Sh. TOJIBAEV, Dilmurod MAKHMUDJANOV,
Nu-ree NA¹, Shukherdorj BAASANMUNKH², Ziyoviddin YUSUPOV,
Hyeok Jae CHOI^{2*} and Chang-Gee JANG^{1*}

National Herbarium, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan, Durmon yuli str.,
32, 100125, Tashkent, Uzbekistan

¹Department of Biology Education, Kongju National University, Gongju 32588, Korea

²Department of Biology and Chemistry, Changwon National University, Changwon 51140, Korea

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ABSTRACT: Tulips are bulbous geophytes that have considerable commercial value worldwide. This genus primarily originated in the Tien Shan and Pamir-Alai mountain ranges, which surround the Ferghana Valley. The Ferghana Valley is home to five sections of the genus *Tulipa* L., represented by 23 taxa (22 species). However, there is a lack of detailed information about the distribution of *Tulipa* species in the natural geographic area of the Ferghana Valley. Therefore, to address this knowledge gap, we comprehensively investigated the spatial distribution of all *Tulipa* species in the valley. To assess the spatial distribution, the entire area was divided into 32 squares consisting of four latitudinal and eight longitudinal zones. The results showed that latitudinal zones B and C with 15 and 13 taxa, respectively, along with five longitudinal zones (A5, B3, B4, C2, and C3) with 5 to 10 taxa were hotspots for this genus. Additionally, the spatial distributions of the species in terms of the corresponding state borders, mountain ranges, endemism, and conservation issues were assessed. The findings of this study provide comprehensive information about the distribution of *Tulipa* species to assist with conservation initiatives ultimately to ensure the survival of various species.

Keywords: endemism, *Tulipa*, Ferghana Valley, mapping, spatial distribution, species survival

The genus *Tulipa* L. (Liliaceae), known as “tulips,” has received substantial attention owing to its high economic value as an ornamental plant and research test species for taxonomy and hybridization processes. Wild tulip species are distributed across Central Asia, the Middle East, North China, Southern Europe, and North Africa (Zonneveld, 2009; Christenhusz et al., 2013; Everett et al., 2013). The Tien Shan and Pamir-Alai mountain ranges in Central Asia are considered to be the primary gene centers for the genus *Tulipa* (Botschantzeva, 1982; Zonneveld, 2009), whereas the Caucasus is considered to be a secondary gene center (Zonneveld, 2009). Currently, representative numbers of wild tulip species are unknown. However, numerous studies have estimated that the number of

species in the *Tulipa* genus ranges from 40 (Stork, 1984) and 50–60 (van Raamsdonk and De Vries, 1992, 1995) to approximately 100 (Hall, 1940; Botschantzeva, 1982; Prátov et al., 2006; Zonneveld, 2009; Christenhusz et al., 2013; Everett et al., 2013). The current global checklist mentions 580 species, of which 104 are accepted in the World Checklist of Selected Plant Families (2021).

The Ferghana Valley (FV) is 370 km long and 60–120 km (average 70 km) wide. The depression becomes high gradually from the west (330 m) to south (over 1,000 m) than sea level. The intermountain depression is framed by the high mountain ranges of Western Tien Shan in the north and the Pamir-Alai in the south. Western Tien Shan mountains system involves

*Author for correspondence: hchoi1975@changwon.ac.kr (H.J. Choi), cgjang@kongju.ac.kr (C.-G. Jang)

Chatkal (in the north-west), Kurama (in the north) and Ferghana (in the east) ranges. The elevation of the ranges varies from 1,200 to 3,500 m. Consequently, the south Alai and Turkistan ranges lie in the Pamir-Alai mountains system with 1,400–4,000 m in elevation. The central part of the area is covered by ring-shaped foothills with over 15 names (Chust-Pap, Namangan, Andijan, Akbel, and among others) (Baratov et al., 2002). The climate is continental with 41–45°C in summer and -2–5°C in winter. The average annual temperature is gradually decreased from the west to the east. Annual precipitation is 150 mm in average, and the quantity of rain gradually decreased from the west to the east. Absolute humidity is high than 30% in all the territory of the area. In the west, Khujand gateway (8–10 km width) forms an open corridor where arctic cold airflow comes with 4–5 km width. The FV has fast blowing winds (Kokand and Bekobod) with 15–25 m/s (Baratov et al., 2002).

The FV is a global hotspot for Central Asian bulbous geophytes. The total area of FV is small, and it harbors more than 60% of the species belonging to the genus *Allium* L. in the mountainous Central Asian province (Tojibaev et al., 2018). The flora of Uzbekistan contains 26 species of *Eremurus* M. Bieb (Tojibaev et al., 2018), of which 13 species grow in FV endemic to mountainous Central Asia (Kamelin, 1973). Species belonging to the genera *Tulipa*, *Gagea* Salisb., and *Juno* Tratt. show similar distributions (Tojibaev et al., 2018). In FV, 23 taxa (22 species) of tulips have been recorded. Tojibaev and Beshko (2014) produced updated distribution maps for all native tulips in Uzbekistan, reflecting several new locations of the taxa based on recent studies. However, efforts at the country level are not sufficient to assess the status of regional endemic species, which are distributed across different country boundaries. To facilitate effective conservation, knowledge of the geographical distribution of species is important for accurate categorization in the IUCN Red List or regional lists of threatened species. Moreover, the relationships between the present spatial distribution of the species and other geographic and environmental variables should be investigated to gain a deeper understanding of the present habitat range and climatic conditions favored by the various species (Doğan et al., 2011).

Most tulip habitats in Central Asia are threatened (Tojibaev and Beshko, 2014; Wilson et al., 2021). Therefore, comprehensive information on species distribution is urgently required, not only at the regional level but also across the complete geographic range, to support conservation initiatives. Thus, understanding the distribution patterns and conservation status of wild tulip species in critical hotspots and identifying key threats is essential to ensure their survival.

The aim of study is to map and analyze the spatial distribution of tulips in the natural geographic region of FV. We provide updated information on the geographical distribution of 23 *Tulipa* taxa across FV, which unites parts of the territories of three Central Asian countries—Kyrgyzstan, Tajikistan, and Uzbekistan. Spatial mapping was performed by dividing the area into 32 squares with four latitudinal and eight longitudinal zones. *Tulipa* distributions were analyzed in terms of administrative state borders, mountain ranges, endemism, and conservation issues. This information will serve as baseline data for future studies on changes in species distribution due to climate change or anthropogenic activities.

Materials and Methods

Study area

This study was conducted in the elliptical FV region of Central Asia (Fig. 1). The valley is bordered by the Chatkal range, which lies between 41.4 E–70.5 N and 41.93 E–72.07 N, on the northwest side. The eastern side of the valley gradually decreases in latitude and increases in altitude (between 41.41 E–73.32 N and 40.48 E–74.73 N) and includes parts of the Kurama and Ferghana mountain ranges of Kyrgyzstan. Furthermore, it is surrounded by the Alai mountain range on the southeast side (39.77 E–71.96 N), and the mountain ranges of Turkistan stretch from the south to the west (39.57 E–69.80 N). Additionally, the study area includes the Kurama mountain range that stretches from the west to the north, bordering northern Tajikistan and Uzbekistan and mountain ranges in the Kamchik pass of Uzbekistan. And also, the geographic information system data of protected areas (downloaded from the World Database on Protected Area, 2021; <https://protectedplanet.net/>) were used to determine the

Fig. 1. General topography of the Ferghana Valley in Central Asia.

extent to which species were included in the protected areas. Following some similar studies (e.g., Baasanmunkh et al., 2021) we also excluded the natural monuments of the study area.

Field surveys

Extensive field surveys were conducted during the tulip-growing season from mid-March to August between 2016 and 2021 at different elevations ranging from 500 m to 3,600 m a.s.l. Different habitat types were surveyed to ensure a comprehensive representative geographical coverage. For that some areas investigated several times depending on blooming time of species and counting of full population of taxa. Growing in one area and habitat (for example, *T. ferganica* and *T. turkestanica*—in surrounds of Andijan city, *T. intermedia* and *T. scharipovii*—between Pap and Chust towns, *T. talassica* and *T. bifloriformis*—Rizaksay River Basin of Kurama range, *T. dubia* and *T. vvedenskyi*—Chodaksay River Basin of Kurama range, tract of Batagalyk) the blooming time of the species can be various that from above mentioned pairs the latter species blooms earlier. Another important factor is the amplitude of the vertical range of some tulip species. Such species as *T. bifloriformis*, *T. turkestanica*, *T. kaufmanniana*, *T. ferganica* and others grow from 500–700 to 2,500 m a.s.l., and, accordingly, the flowering time in a population starts from March and lasts until May–June. The habitats of these species were visited several times during one year.

The global positioning system coordinates of the specimens and their habitats were recorded. In addition to the field observations, previously published data (Botschantzeva, 1982; Tojibaev and Kadirov, 2010; Everett et al., 2013; Lazkov and Umralina, 2015), information from the Red Book of Kyrgyzstan (Kyrgyz Republic, 2006), Tajikistan (Republic of Tajikistan, 2017), and Uzbekistan (Khasanov, 2019), and the National Strategy and Action Plan and Sustainable Use of Biodiversity of the Republic of Tajikistan (Republic of Tajikistan, 2003, 2016) were used.

Subsequently, several new locations for the species, described in the following sections, were found in addition to the existing populations. Several researchers have visited some of these habitats within the last decade. More than 1,300 collected and deposited (in the National Herbarium of Uzbekistan, Tashkent, TASH) herbarium specimens were analyzed.

Analysis of the herbarium specimens

We examined over 3500 herbarium specimens of *Tulipa*, mainly stored in TASH, LE, and MW (Thiers, 2020). In addition, the Global Biodiversity Information Facility (2021) and Plantarium (2021, <http://www.plantarium.ru>) databases

were used as additional sources of information. Thus, data on herbarium vouchers were entered into the database of the Flora of Uzbekistan (Sennikov et al., 2016). In addition, the coordinates of the plant records were imported into ArcGIS 10.0, and transformed to a point map layer, with the WGS84 geographic coordinate system used as a reference datum.

Spatial distribution and grid mapping

Based on the results of previous studies (Tojibaev and Beshko, 2014), we determined the geographic locations of the species by using grid mapping to recognize the spatial distribution and multivariate analysis methods. The extensive geo-referenced data facilitated the mapping of the distribution of all *Tulipa* species in FV.

A novel grid-based mapping model was used for FV. The grid system was based on intervals of 40 min of latitude and longitude as the primary division for the recording of species. According to the grid system, the study area was divided into 32 grid squares with four latitudinal (A, B, C, and D) and eight longitudinal zones (Fig. 2A).

Species identification

Each species was identified based on the accepted species names according to Zonneveld (2009) and Tojibaev and Beshko (2014). Finally, taxonomic status was cross-checked by the World Checklist of Selected Plant Families (2021) and Plants of the World (Plants of the World Online, 2021). The IUCN criterion for species was followed by Tojibaev and Beshko (2014), Kyrgyz Republic (2006), and Republic of Tajikistan (2017).

Results

Species richness

We identified 23 taxa (22 species) of *Tulipa*, divided into five sections in the FV flora (Table 1). Among these, two species (*T. scharipovii* and *T. intermedia*) are endemic to Uzbekistan, followed by four species (*T. zonneveldii*, *T. anadroma*, *T. neustruevae*, and *T. jasquesii*), which should be classified as endemic to Kyrgyzstan, and 20 taxa (more than 87% of all taxa) that are endemic to mountainous Central Asia. Moreover, 18 taxa were listed in the Red Book of Kyrgyzstan (Kyrgyz Republic, 2006), Tajikistan (Republic of Tajikistan, 2017), and Uzbekistan (Khasanov, 2019). The threat categories of *Tulipa* species and species richness in the grid squares of FV are listed in Table 1. In addition, we photographed representative of 17 taxa (16 species) of *Tulipa* during the field surveys from FV, which are shown in Fig. 3.

Table 1. Checklist, red list assessment, and distribution of the *Tulipa* species in the Ferghana Valley.

No.	Taxon (Photo)	Status in the national Red (Data) Books and by the IUCN criteria	Grid distribution
Sect. <i>Lanatae</i> (Raamsd.) Zonn.			
1	<i>T. affinis</i> Botschanz. (Fig. 3A)	Uzbekistan-3 (reducing), VU, B1b (ii, iii, iv) 2b (ii, iii, iv); Tajikistan-EN; Kyrgyzstan-VU	C2, C3, D2, D3
Sect. <i>Kopalkowskiane</i> Raamsd. ex Zonn. & Veldk.			
2	<i>T. scharipovii</i> Tojibaev (Fig. 3M)	Uzbekistan-2 (rare), EN, B1b (ii, iii, iv) 2b (ii, iii, iv)	B4
3	<i>T. intermedia</i> Tojibaev & J.de Groot (Fig. 3G)	Uzbekistan-2 (rare), EN, B1b (ii, iii, iv) 2b (ii, iii, iv)	B4, C3
4	<i>T. talassica</i> Lazkov (Fig. 3N)	DD	B3, B4
5	<i>T. korolkowii</i> Regel (Fig. 3I)	Uzbekistan-3 (reducing), NT; Tajikistan-EN; Kyrgyzstan-VU	B3, B4, C2, C3, C4, D2
6	<i>T. korolkowii</i> f. <i>rosea</i> Vved. (Fig. 3I-inset)	Tajikistan-VU; Kyrgyzstan-EN	C2, C3, C4, D3, D4
7	<i>T. lehmanniana</i> Mercklin (Fig. 3J)	Uzbekistan-3 (reducing), NT; Tajikistan-EN	C2, C3
8	<i>T. ferganica</i> Vved. (Fig. 3E)	Uzbekistan-2 (rare), VU B2b (ii, iii, iv)	A5, B4, B5, B6, B7, B8, C5, C6, C7, D5
9	<i>T. zonneveldii</i> J.de Groot & Tojibaev	–	A5
10	<i>T. platystemon</i> Vved.	Kyrgyzstan-VU	C8
Sect. <i>Vinistriatae</i> (Raamsd.) Zonn.			
11	<i>T. greigii</i> Regel (Fig. 3F)	Uzbekistan-3 (reducing), VU, A2cd B1b (ii, iii, iv) 2b (ii, iii, iv); Tajikistan-VU; Kyrgyzstan -EN	B3, C2
12	<i>T. vvedenskyi</i> Botschantz. (Fig. 3P)	Uzbekistan-3 (reducing), EN, B1b (ii, iii, iv) 2b (ii, iii, iv)	B3
13	<i>T. mogoltavica</i> Popov & Vved. (Fig. 3L)	Uzbekistan- VU, B1b (ii, iii, iv) 2b (ii, iii, iv); Tajikistan-CR	B3, C1, C2, C3
14	<i>T. micheliana</i> Hoog (Fig. 3K)	Uzbekistan-3 (reducing), NT; Tajikistan-CR	C2
Sect. <i>Spiranthera</i> Vved. ex Zonn. & Veldk.			
15	<i>T. dubia</i> Vved. (Fig. 3D)	Uzbekistan-3 (reducing); VU, B1b (ii, iii, iv) 2b (ii, iii, iv)	A3, A4, B3, B4
16	<i>T. anadroma</i> Botschantz.	Kyrgyzstan – VU	A5, B8
17	<i>T. kaufmanniana</i> Regel (Fig. 3H)	Uzbekistan-3 (reducing), NT; Tajikistan-CR; Kyrgyzstan – VU	A4, B2, B3, B4
Sect. <i>Biflores</i> A.D.Hall ex Zonn. & Veldk.			
18	<i>T. bifloriformis</i> Vved. (Fig. 3B)	Uzbekistan-NT, Tajikistan-EN	A6, B3, B4, C2, C5, D5
19	<i>T. turkestanica</i> (Regel) Regel (Fig. 3O)	Uzbekistan-LC	B3, B6, C1, C2 C3, C5
20	<i>T. dasystemon</i> (Regel) Regel (Fig. 3C)	Uzbekistan-3 (reducing), VU, B1b (ii, iii, iv) 2b (ii, iii, iv)	A3, A6, A7, B3, B9, D5
21	<i>T. dasystemonoides</i> Vved.	Uzbekistan-EN, B1b (ii, iii, iv) 2b (ii, iii, iv)	A5, C6, D2, D5
22	<i>T. neustruevae</i> Pobed.	–	A5, B8
23	<i>T. jacquesii</i> Zonn.	–	A6

Critically Endangered – CR, Endangered – EN, Vulnerable – VU, Near Threatened – NT, Least Concern – LC.

Mapping of species distribution

We analyzed the species richness of all tulips based on grid cells, as shown in Fig. 2. Based on the results, the taxa in the grid cells had different species compositions; 19 grid cells represented one to three taxa of *Tulipa*. Five grid cells (A5, B3, B4, C2, and C3) showed high species richness, ranging from five to ten taxa. Furthermore, the western and northwestern parts of FV showed high species richness. The spatial distribution (Fig. 2) and taxa numbers (Table 1) are summarized herein.

Through field surveys in 2016–2021 over 1,300 collected and deposited herbarium specimens were analyzed, and 19 tulip species were identified. As a result, 16 new areas of *T. scharipovii* (5), *T. intermedia* (3), *T. vvedenskyi* (2), *T. dubia* (1), *T. bifloriformis* (3), and *T. ferganica* (2) populations were georeferenced.

The spatial distribution of the taxa by section is shown in Fig. 2. Distribution maps compiled by sections show the spatial differences in the Tien Shan (*Spiranthera* and *Vinistriatae*,

Fig. 2. Spatial distribution of the *Tulipa* taxa in the Ferghana Valley. **A.** Numbers in the grid cells represent the taxon names given in Table 1. **B–F.** Distribution of sections: **B.** *Biflores*. **C.** *Kopalkowskiane*. **D.** *Lanatae*. **E.** *Spiranthera*. **F.** *Vinistriatae*.

except *T. micheliana*) and Pamir-Alai species (*Lanatae*). Sect. *Kopalkowskiane* and sect. *Biflores* species were widespread throughout the study area. The northern and eastern parts of the area mainly included species (*Kopalkowskiane* and *Biflores*) with yellow and white tepals. Species with red tepals were mainly present in the western and southwestern parts of the valley, considered hotspots (B3 and C2–3) for tulips.

Geographical analysis

Tojibaev and Karimov (2012) provided the first checklist of bulbous geophytes of FV including *Tulipa* species. Tojibaev and Karimov's (2012) contribution presented checklist of four endemic species of *Tulipa* (taxon numbers: 2, 8, 16, and 22 in Table 1) distributed in FV. In addition, in the current work the list of endemic species updated and endemic species reached

Fig. 3. Some representative *Tulipa* species in the Ferghana Valley. **A.** *T. affinis*. **B.** *T. bifloriformis*. **C.** *T. dasystemon*. **D.** *T. dubia*. **E.** *T. ferganica*. **F.** *T. greigii*. **G.** *T. intermedia*. **H.** *T. kaufmanniana*. **I.** *T. korolkowii* (inset: f. *rosea*). **J.** *T. lehmanniana*. **K.** *T. micheliana*. **L.** *T. mogoltavica*. **M.** *T. sharipovii*. **N.** *T. talassica*. **O.** *T. turkestanica*. **P.** *T. vvedenskyi*.

Fig. 4. Distribution of *Tulipa* taxa by latitudinal (A) and longitudinal (B) zones of the Ferghana Valley.

Fig. 5. Distribution of *Tulipa* taxa by mountain ranges (A) and administrative state borders (B) of the Ferghana Valley.

to nine (taxon numbers: 2, 3, 6, 8, 9, 10, 16, 22, and 23 in Table 1).

Previously published data (Tojibaev et al., 2018) included 19 species of *Tulipa* provided comprehensive information on the geographical distribution of the species in the botanical-geographical zones of FV. Based on these previous records and the results of the field surveys conducted as part of this study. Information on tulip diversity in FV was updated adding *T. talassica*, *T. platystemon*, *T. vvedenskyi*, and *T. jacquesii* to the previous list. As mentioned previously, 23 taxa were identified in FV, of which 12 were in the administrative regions of Kyrgyzstan (taxon numbers: 1, 7, 8, 9, 10, 16, 17, 18, 20, 21, 22, and 23 in Table 1), 11 in Tajikistan (taxon numbers: 1, 5, 6, 7, 8, 11, 13, 14, 17, 18, and 19 in Table 1), and 11 in Uzbekistan (taxon numbers: 2, 3, 4, 8, 11, 12, 15, 17, 18, 19, and 20 in Table 1), respectively.

The species distributions in the latitudinal and longitudinal

zones are presented in Fig. 4. The results indicate that zones B (15 taxa) and C (13 taxa) had high species diversity. Zones A (10 taxa) and D (6 taxa) had comparatively lower species diversity. Species richness in the longitudinal zones was also analyzed. Consequently, zones B3 (10 taxa), B4 (8 taxa), C2 (9 taxa), and C3 (7 taxa) were observed to be hotspots for tulips. Eight latitudinal zones (A2, 8, 9, C9, and D6–9) had no tulips.

According to the distribution in the mountain ranges, Tien Shan included 19 taxa (10, 12 and 5 in the Chatkal, Kurama and Ferghana mountain ranges, respectively, and 7 taxa in both ranges), whereas 14 taxa were included in Pamir-Alai (10 and 5 in Turkistan, and Alay ranges, respectively, and 3 taxa throughout these ranges). Moreover, 11 and 5 taxa were endemic only to the Tien Shan and Pamir-Alai mountain ranges, respectively, and 4 species (*T. korolkowii*, *T. ferganica*, *T. dasystemon*, and *T. bifloriformis*) were common across both

Fig. 6. Distribution of endemic *Tulipa* taxa of the Fergana Valley by mountain ranges.

mountain ranges (Fig. 5A).

According to the administrative state borders, 8 taxa (*T. affinis*, *T. korolkowii* f. *rosea*, *T. ferganica*, *T. greigii*, *T. kaufmanniana*, *T. bifloriformis*, *T. turkestanica*, and *T. dasystemon*) were the most widespread and were present either in all the three countries or in any two countries (Fig. 5B). Furthermore, 5 taxa (*T. scharipovii*, *T. intermedia*, *T. talassica*, *T. vvedenskyi*, and *T. dubia*), 4 taxa (*T. korolkowii*, *T. lehmanniana*, *T. mogoltavica*, and *T. micheliana*), and 6 taxa (*T. zonneveldii*, *T. platystemon*, *T. anadroma*, *T. dasystemonoides*, *T. neustruevae*, and *T. jacquesii*) were the least widespread, occurring only in Uzbekistan, Tajikistan, and Kyrgyzstan, respectively. However, these distribution patterns could change through the discovery of new species locations in future investigations.

Discussion

Endemism and distribution by ranges

Remarkable results were observed in relation to species endemism (Fig. 6). The distribution of endemics by mountain ranges was as follows: eleven taxa of Tien Shan (five in Kurama, one in Ferghana and two in Chatkal), and 5 taxa of Pamir-Alai (four in Turkistan and one in Alai ranges). Furthermore, 7 taxa (*T. korolkowii*, *T. lehmanniana*, *T. ferganica*, *T. bifloriformis*, *T. turkestanica*, *T. dasystemon*, and *T. dasystemonoides*) inhabited both mountain ranges.

In the Red Book of Kyrgyzstan (Kyrgyz Republic, 2006), *T. anadroma* and *T. platystemon* were shown to be endemic in the Chatkal and Alai ranges, respectively. In addition, the species were found in the Fergana range ([https://www.gbif.org/](https://www.gbif.org/occurrence/1233582509)

<https://www.gbif.org/occurrence/1233582509> and <https://www.plantarium.ru/page/image/id/563334.html>) and should, therefore, be accepted as endemics of FV.

Ecology and conservation issues

The high degree of human activity and climate change impacts are causing a decrease in plant species and habitats including wild tulips. Currently, the FV presents 11 protected areas with four types (including nature monuments). Only 8 out of the 23 *Tulipa* taxa had at least one observation in a protected area of FV (Table 2). In terms of preserving wild tulip populations, the most significant protected area is the Sary-Chelek Reserve and as well other Reserves are located in Kyrgyzstan. The Sary-Chelek Reserve is the oldest protected area in Central Asia. At least 4 taxa out of 23 grow here. The main distribution area of *T. zonneveldii* falls on this reserve and adjacent area. *T. ferganica* and *T. turkestanica* have been found in almost all protected areas within Kyrgyzstan, whereas 74% of tulip species were not within any protected area. A critical situation is observed with strict endemic species of the northern foothills of the FV, such as *T. scharipovii* and *T. intermedia*. All known populations of these species grow in a zone of human activity and all populations are highly fragmented. Due to Table 2 total area of protected area is 978.45 km² that is 4.4% of them of total area (22,000 km²). Therefore, the existing situation requires optimization and new approaches to solve the problem of insufficient conservation programs in the region. Creation of new important plant areas (IPA) in the hotspot zones of endangered species of the valley can be considered new approach of conservation program.

The Red Book of Uzbekistan (Khasanov, 2019), Tajikistan

Table 2. List of protected areas in the Ferghana Valley with *Tulipa* diversity.

Name	Area (km ²)	Country	Protected species
Aktash Reserve	150	Tajikistan	<i>T. bifloriformis</i> , <i>T. kaufmanniana</i> , <i>T. vvedenskyi</i>
Sary-Chelek Reserve	238.33	Kyrgyzstan	<i>T. anadroma</i> , <i>T. ferganica</i> , <i>T. neustruevae</i> , <i>T. zonneveldii</i>
South Kyrgyz Nature Park	180	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>
Kara-Shoro Nature Park	143.4	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>
Kyrgyz Ata Nature Park	111.72	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>
Yassin Wildlife Refuge	50	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>
Gulchin Wildlife Refuge	5	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>
Akbuurin Wildlife Refuge	100	Kyrgyzstan	<i>T. ferganica</i> , <i>T. turkestanica</i>

(Republic of Tajikistan, 2017), and Kyrgyzstan (Kyrgyz Republic, 2006) included 19, 19, and 12 *Tulipa* taxa, respectively. Among the 19 taxa listed in the Red Book of Uzbekistan, 8 were protected in six nature reserves, and 7 occurred in two national parks. Furthermore, among the 12 endangered taxa of Kyrgyzstan, 3 (2 in nature reserves and 1 in a wildlife area) were protected. In Tajikistan, 9 out of the 19 taxa require special protection efforts at different levels (3, 4, and 2 taxa at the global, regional, and national levels, respectively).

Despite rigorous conservation measures, *Tulipa* species populations are declining because of various factors. The main threats to these species in FV are as follows:

1. Limited protected areas (especially in Tajikistan and Uzbekistan) (Tojibaev and Karimov, 2012). Anthropogenic effects, such as uncontrolled development and climate change have increased the threats to *Tulipa* populations and their habitats. Further, protected areas have not been designated in the Uzbekistan region of the valley to preserve the representative plant diversity; however, four state nature monuments (category 3 of protected areas), with a total area of less than 4 ha, are exceptions. An effective way to address this issue is to identify Important Plant Areas, specific key sites that require efficient management and protection because of the high wild plant diversity (Anderson, 2002; Plantlife International, 2004).

2. Poorly managed livestock and overgrazing (Tojibaev and Beshko, 2014; Wilson et al., 2021). Animal husbandry is another key cause of tulip population decline. *Tulipa scharipovii*, *T. intermedia*, *T. bifloriformis*, and *T. talassica* suffer the most from grazing because these species usually occur in the low and mid-elevations of mountains and foothills. The magnitude of the decline is rapidly increasing due to the easy accessibility of these areas for grazing and the lack of control measures.

3. Loss of natural habitat due to rapid urbanization, rural expansion, fragmentation of natural habitats, and mining

(Tojibaev and Beshko, 2014; Wilson et al., 2021). FV is one of the most densely populated regions of Central Asia, resulting in increasing pressure on the existing natural habitats of many wild plants, particularly tulips.

4. Uncontrolled horticultural and floricultural demands (Tojibaev and Beshko, 2014; Wilson et al., 2021). The horticultural history of *Tulipa* and the uncontrolled demand for tulips worldwide have increased the collection and trade of these plants for ornamental purposes. This commercial activity is a threat to wild tulip populations and is believed to have caused extinctions and population declines in the past (Mauder et al., 2001; Wilson et al., 2021).

5. Recently published studies have shown that climate change will pose a significant threat to wild tulip populations because most species are currently distributed in mountainous regions of Central Asia (Wilson et al., 2021).

Conclusion

The spatial distribution maps and endemism patterns of 23 tulip taxa (22 species) were investigated based on grid cells in FV. Two latitudinal zones, B (15 taxa) and C (13 taxa), and five longitudinal zones (A5, B3, B4, C2, and C3), with taxa numbers ranging between 5 and 10, were observed as hotspots for the *Tulipa*. Furthermore, species belonging to the *Kopalkowskiane* and *Biflores* sections were widely distributed; species belonging to the *Spiranthera* and *Vinistriatae* sections occurred in Tien Shan, and species belonging to the *Lanatae* section were widespread in the Pamir-Alai mountain range. Understanding the distribution patterns of wild tulip species in critical hotspots and identifying the key threats can provide significant insight into their conservation status and help ensure their survival. The comprehensive information on *Tulipa* species distribution in FV provided by this study can contribute to various conservation initiatives.

ORCID: Davron DEHKONOV <https://orcid.org/0000-0002-2762-5268>; Komiljon Sh. TOJIBAEV <https://orcid.org/0000-0003-2846-5777>; Dilmurod MAKHMUDJANOV <https://orcid.org/0000-0002-3137-7308>; Nu-ree Na <https://orcid.org/0000-0003-1437-2393>; Shukherdorj BAASANMUNKH <https://orcid.org/0000-0003-4224-9376>; Ziyoviddin YUSUPOV <https://orcid.org/0000-0003-2278-542X>; Hyeok Jae CHOI <https://orcid.org/0000-0001-6315-0071>; Chang-Gee JANG <https://orcid.org/0000-0002-3013-9068>

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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