Rare and endangered woody plants of the Sary-Chelek State Biosphere Reserve

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ABSTRACT

The research conducted in Sary-Chelek State Biosphere Reserve focuses on assessing the status of rare and endangered woody plants. Through field studies and literature analysis, the species composition, population size, and spatial distribution of these species were investigated. This article presents the results of an in-depth study of rare and endangered woody plants such as Semenov Fir (Abies semenovii B. Fedtsch.), Usunakhmat grape (Vitis usunachmatica Vass.), Crabapple (Malus sieversii (Ledeb.) M.Roem.), Nedzvetsky's Apple (Malus niedzwetzkyana Dieck.), and Persian Rowan (Sorbus persica Hedl.), found within the Sary-Chelek State Reserve. Extensive long-term field studies conducted by the authors have yielded substantial data on the status of rare species populations. The analysis of the obtained data, combined with a review of the literature, allowed for a detailed characterization of the ecological features of these rare woody plants. Based on the results, recommendations were developed for biodiversity conservation and effective strategies for protecting these species. Proposed measures include the establishment of special protected zones, monitoring population status restoring degraded ecosystems, and conducting educational outreach among the local community. These findings are significant for developing long-term management plans for the reserve and can be utilized in creating regional biodiversity conservation programs.

Keywords: Biodiversity, endangered tree species, environment protection, rare woody plants, Sary-Chelek State Reserve

INTRODUCTION

The Kyrgyz Republic is a mountainous, sparsely forested country located in the eastern part of the Central Asian region, with approximately 90% of its territory situated at an elevation of more than 1500 meters above sea level (Anon., 2023). According to data from the Global Forest Resources Assessment (FAO, 2020), 92% of the country's forests serve soil protection and water conservation functions. All forests in the Kyrgyz Republic are under state ownership and are considered a national asset. The total area of the state forest fund is 2619.7 thousand hectares. The forests of Kyrgyzstan represent a vast genetic reservoir of biodiversity and are one of the primary centers of origin for many modern cultivated plants. This is evidences by the fact that nearly all species of valuable fruit-bearing plants native to Central Asia are found here in their wild state. These forests serve as a gene pool for numerous species, not only of woody and shrub plants but also of herbaceous flora. Additionally, they provide a source of income for local communities and play an essential role in the national economy.

Given the vast biological diversity of vegetation, which holds significant scientific and practical value, the Sary-Chelek Nut-Fruit Reserve was established. This was done by decree №118 of the Council of Ministers of the Kyrgyz SSR on May 5, 1959, with the aim of preserving and promoting the further development of this unique ecosystem. In 1979, by the decision of the Presidium of the International Coordinating Council of the "Man and the Biosphere" Program of the UNESCO Council for Reserves and Protected Areas, the Sary-Chelek Reserve was included in the list of biosphere reserves worldwide (Arkit 2019; Sputnik, 2016). This network of protected areas, representing the world's major ecosystem types, is designed for the conservation of nature and for conducting scientific research in the interest of humanity. Additionally, this network will serve as a model for assessing human impact on the surrounding environment. In June 2016, by the decision of the UNESCO Commission, the Sary-Chelek Reserve was inscribed on the UNESCO World Heritage List (Bishkek, 2020). According to botanical-geographical zoning, Sary-Chelek Reserve is part of the Chatkal Floristic Region. The flora of the Reserve was first studied by Borlakov (1966) and the initial list of reserve's plant species was compiled. The flora of the reserve includes 62 families, 376 genera, and 969 plant species (Borlakov, 1966; Borlakov *et al*., 1971). According to data from the "Kyrgyz Forest and Hunting Management" State Institution (Bishkek, 2020) 677 species of higher plants grow within the reserve. Of these, 72 species are trees and shrubs belonging to 20 families. The reserve is home to 11 vulnerable plant species: 5 woody and shrub species and 6 herbaceous species, all of which are included in the Red Book of Kyrgyzstan. Rare and endangered plant species not only require an effective biodiversity conservation strategy but also demand thorough study of their bio-ecological characteristics. Research and the development of propagation methods for these plants contribute not only to the preservation of unique natural heritage but also lead to a shift in the principles of biological resource utilization, making them more sustainable and less depleting. The objects of this study are vulnerable woody and shrub species growing within the territory of the Sary-Chelek State Biosphere Reserve.

METHODS

The research was conducted through surveys of local residents, reserve staff, and on-foot expeditions. During the studies, the habitat conditions of vulnerable species were identified. General information on the distribution of the studied species was collected, and a standard geobotanical description was carried out. The description involved the individual examination of each identified specimen, with coordinates recorded using a Garmin eTrex 10 GPS navigator. To assess species vulnerability, the IUCN categories and criteria were used (Anon., 2024). In accordance with the methodology of the International Union for Conservation of Nature, the geographic distribution, population size, and habitats of the species were specified. Within the territory of the Sary-Chelek Reserve, five species of rare and endangered woody plants *viz*., Semenov Fir (*Abies semenovii* B. Fedtsch.), Usunakhmat Grape (*Vitis usunachmatica* Vass.), Nedzvetsky's Apple (*Malus niedzwetzkyana* Dieck.), Crabapple (*Malus sieversii)* and Persian Rowan (*Sorbus persica* Hedl.) were taken for the study.

RESULTS AND DISCUSSION

Semenov Fir (*Abies semenovii* B. Fedtsch.)
It is listed in the IUCN Red List as *Abies sibirica subsp.semenovii*. According to IUCN classification and criteria, it was originally categorized as Critically Endangered (CR), but in 2010 it was reclassified as Least Concern (LC) (IUCN Red List of Threatened Species,a). In the Red Book of the Kyrgyz Republic, it is listed as a vulnerable species (VU) (Anon. 2016), while in the Red Book of Woody Plants of Central Asian it holds a critically endangered

status (CR B1ab(v)) (Anon., 2009). The results of molecular-genetic studies (nuclear markers: allozymes and AFLP, chloroplast markers: SSR) clearly indicate that Semenov Fir is a distinct species with a limited distribution range (Semerikova and Semerikov, 2011; Semerikova *et al*.,2012; Semerikova (2016); Orlova *et al*., 2016) which necessitates more active conservation measures. Despite this, in the IUCN Red List, Semenov Fir (*Abies semenovii* B. Fedtsch.) is still listed as a subspecies of Siberian Fir (*Abies sibirica subsp. semenovii*). The factors contributing to the vulnerability of *A. Semenovii* include not only increased anthropogenic pressure but also competition from other coniferous and deciduous species.

Semenov Fir. is a narrow endemic of the western Tien Shan, found only in Kyrgyzstan, primarily in the Aksy and Toktogul districts of the Jalal-Abad region. Small populations of this species also occur on the slopes of the Talas range (Besh-Tash Gorge). The total area of its range is 4326.7 hectares, of which 279.1 hectares are located within the Sary-Cheleek State Biosphere Reserve. In the Sary-Chelek State Biosphere Reserve, Semenov Fir grows at various altitudes, with the lower limit of its range at 1,250 meters above sea level (Bak-Chop area) and upper limit at 2,600 meters above sea level (Makmal area). Under natural conditions, Semenov Fir regenerates by seeds, although occasional rooting of lower branches, forming new shoots upon contact with the soil, has also been observed. In the Sary-Chelek Reserve, optimal conditions for seed regeneration of the fir occur in stands located at altitudes between 1,600 and 2,000 meters above sea level, particularly on north-facing slopes.

Usunakhmat Grape (*Vitis usunachmatica* Vass.)

It is listed in the Red Book of Kyrgyzstan with the status of vulnerable (VU). It grows in the lowest part of the reserve on a southern slope. The fruits, ranging from 5 to 10mm in diameter, vary in color from black-violet and pink to greenish-pink and green, with juicy flesh. The taste ranges from sweet to sweet-and-sour, sometimes with a slight astringency. The seeds are pear-shaped in reverse. In the conditions of the Sary-Chelek State Biosphere Reserve, the plant flowers in mid-May, and the fruits ripen in the third decade of August. Seed-based regeneration has been observed.

Crabapple *Malus sieversii* (Ledeb.)

It is listed in the Red Book of Kyrgyzstan with the status of Least Concern (LC), indicating a lower level of vulnerability (Anon.2016). It is included in the IUCN Red List and the Red Book of Woody Plants of Central Asia, classified as a vulnerable (VU) under criterion (IUCN Red List of Threatened Species (b); Anon.2009). This polymorphic fruit species is one of the secondary forest-forming species in the nut-fruit forests of Kyrgyzstan. According to DNA studies, it is the progenitor of many modern apple varieties (Velasco *et al.*, 2010). The tree reaches a height of 3 to 5 meters and has a compact crown. It grows throughout the reserve at altitudes ranging from 1,200 to 2,000 meters above sea level. In the reserves, depending on the growing conditions, it blooms from the third decade of April to the first half of May. The fruits ripen from the second half of August to mid-September. It reproduces by seeds and root suckers. In the Sary-Chelek State Biosphere Reserve, the population of Crabapple (*Malus sieversii* (Ledeb.) M.Roem.) remains stable. Observations indicated that degradation of this species is not occurring, which signifies favorable ecological conditions within the reserve. Effective conservation measures and the absence of significant anthropogenic impacts contribute to maintaining a healthy population of Crabapple.

Nedzvetsky's Apple (*Malus niedzwetzkyana* Dieck.)

It is a very rare, endemic, and endangered species. It is listed in the IUCN Red List with the status of Endangered (EN) due to critically low population numbers (IUCN

Red List of Threatened Species (c). It is also included in the Red Book of Woody Plants of Central Asia with the Status of Endangered (EN B2ab (iii,v)), indicating a high degree of extinction threat for this species (Annon., 2009). In the Red Book of Kyrgyzstan, it is assessed as Vulnerable (VU), highlighting the need for conservation measures (Anon., 2016). The bark of perennial branches has a reddish-brown hue, while in one-year-old branches it appears dark purple. The branches are thornless. The leaves are dense, oblong or obovate in shape, dark green with a reddish tint, and range from 7 to 10 cm in length. The flowers are light pink or purple. The fruits are small, spherical, slightly elongated, and either red or violet-red, with a waxy coating and pinkish-red flesh. In the Sary-Chelek State Reserve, *Malus niedzwetzkyana* Dieck. is found at altitudes ranging from 1,255 meters (Dendrosad) to 2,000 meters (Kyla-Kol) above sea level. It occurs as individual trees or in small clusters consisting of three to sixteen trees. At lower altitudes (1,200-1,300 meters above sea level) *Malus niedzwetzkyana* individuals are rare and appear as isolated trees. The majority of Nedzvetsky's apple trees are found at elevations between 1,400 and 1,700 meters above sea level, within the belt of walnut-fruit forests

During field studies in the reserve, 52 specimens of *Malus niedzwetzkyana* were identified across various slope exposures. According to the data presented in Figure 1, the vast majority of individuals (60%) are concentrated on southeast-facing slopes, while only 2% are found on south-facing slopes. This uneven distribution is likely due to the more favorable microclimatic conditions on southeast exposures, which promote optimal photosynthesis and reduce the risk of plant overheating.

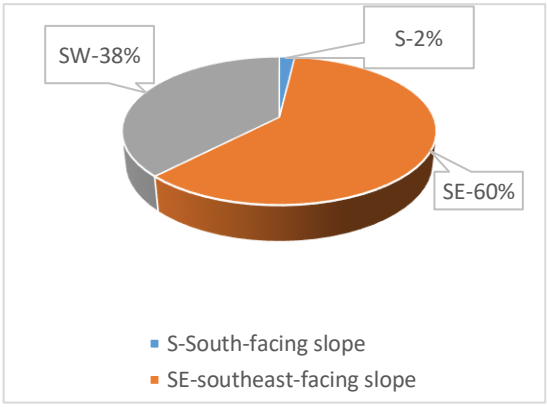

Fig.1: Distribution of *Malus niedzwetzkyana* Dieck. Individuals by slope exposure

Nedzvetsky's apple (*Malus niedzwetzkyana* Dieck.) is recognized for its diverse flesh colors, including light pink, pinkish-red, and deep red hues (Fig. 2).

Fig. 2: Variation in flesh color of *Malus niedzwetzkyana* fruit

Some fruits exhibit a uniform deep red flesh, while others display a gradient from lighter pink to more intense red. This characteristic not only enhances the aesthetic

appeal of Nedzvetsky's apple but also provides invaluable material for fruit breeders in developing cultivated varieties with red fruits and red flesh. Fruit ripening in *Malus niedzwetzkyana* Dieck occurs at different times depending on the altitude. At lower elevations (Dendrosad, 1,255 meters above sea level), fruit ripening takes place in September, while at an altitude of 2,000 meters above sea level (Kyla-Kol), ripening is observed by the end of September.

The number of viable seeds in the fruits of *Malus niedzwetzkyana Dieck* varies from 4 to 15. According to Firsov *et al.*, (2019), this variability is attributed to the unevenness of fertilization processes and the subsequent development of ovules. Some ovules are eliminated at early stages, while the development of other seeds may cease after fertilization. Additionally, the morphological formation of seeds within a single fruit is often heterogeneous. Through morphometric analysis of the seeds *Malus niedzwetzkyana Dieck*, it was determined that the average weight of one thousand seeds is 23.3g. The viability of the seeds, assessed using the indigo carmine staining methods, revealed that the percentage of viable seeds is 82%.

The Persian Rowan *(Sorbus persica* Hedl)

One of the rare and endangered species occurring within the territory of the Sary-Chelek State Biosphere Reserve is the Persian Rowan. It is an endemic species that is infrequently encountered and is listed in the Red Book of Kyrgyzstan with a status of (VU) as a vulnerable species (Anon. 2016). In the Red Book of Woody plants of Central Asia, it is classified as a species of least concern (Anon. 2009). In the Sary-Chelek State Biosphere Reserve, Persian rowan (*Sorbus persica* Hedl.) is found at altitudes ranging from 1,876 to 1,962 meters, both in groups and as solitary specimens. It grows on various slopes with varying degrees of steepness. The primary concentration of Persian rowan is observed on the northeastern and northwestern slopes, predominantly along the southern shores of the Sary-Chelek and Tuyuk-Kol lakes (Fig. 3). Most of the trees are of seed origin and fall into the mature or old-growth categories. Typically, the rowan forms small clusters consisting of 10-20 trees in limited areas.

Fig. 3: P1~P14 – Habitat locations of the identified Persian rowan in Sary-Chelek State Reserve

Persian Rowan (*Sorbus persica* Hedl.) is characterized by simple leaves measuring 5–8.5 cm in length and 3.5–5 cm in width. The leaf margin exhibits 4–6 lobes with either blunt or pointed tips, and the base tapers in a wedge shape. The leaf blade is elliptical or

elongated-elliptical, appearing almost glabrous on the upper surface, while the underside is covered with a white, woolly pubescence. The leaf margins feature oblique triangular teeth, and the petioles are hairy, measuring 1–2 cm in length. The inflorescence of the Persian Rowan is characterized by a complex umbel bearing numerous small white flowers. The diameter of the inflorescence varies from 6 to 12 cm. The flowers emit a characteristic scent that attracts pollinating insects. The fruit is a berry, either spherical or ellipsoid in shape, with a smooth, orange-red skin. The morphological and flavor characteristics of the fruits can very significantly among populations. The plant exhibits polymorphic life forms, ranging from tree to shrub. The heigh of the trees can reach between 5 and 12 meters. In the conditions of the Sary-Chelek State Biosphere Reserve, the fruits of the Persian rowan mature at the end of October. Notably, the seed productivity is low, with a clean seed yield of only 3.4% of the total fruit mass. The fruits often contain underdeveloped seeds or empty seed cavities. The average weight of 1,000 seed is 27.7±4.8 g.

CONCLUSION

The study of rare and endangered tree species in the Sary-Chelek State Biosphere Reserve has revealed several important characteristics. The findings highlight the necessity of developing and implementing comprehensive conservation measures to preserve the biodiversity of the reserve. Such measures include the establishment of special protected zones, monitoring the status of rare species populations, restoring disturbed ecosystems, and conducting educational outreach among the local population. The conservation of rare and endangered tree species is not only of scientific importance but also holds practical value, as these species represent vital genetic resources and play a key role in maintaining ecological balance.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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