Flowering Biology And Phenological Rhythms Of Phlomoides Anisochila And Phlomoides Sogdiana In The Nuratau Mountains

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ABSTRACT

The study presents a comparative analysis of flowering biology and phenological rhythms of the rare and endemic species Phlomoides anisochila (Pazij & Vved.) Salmaki and Phlomoides sogdiana (Pazij & Vved.) Salmaki under the natural conditions of the Nuratau Mountains. Field observations were conducted during 2019–2023 in ten subpopulations, with detailed seasonal and daily flowering records obtained in five subpopulations of each species. Flower opening, duration of individual flowers, total flowering period, vegetation onset, bud formation, seed maturation, air temperature and relative humidity were recorded using established phenological and reproductive-biology methods. The results show that P. sogdiana starts vegetation slightly earlier and flowers from late April to the first decade of May, while P. anisochila generally starts flowering in the first decade of May. The total flowering period was 16–21 days in P. sogdiana and 14–17 days in P. anisochila. Maximum daily flower opening occurred around 12:00–14:00, and the dynamics were more closely associated with increasing air temperature than with relative humidity. The vegetation period lasted 150–155 days in P. sogdiana and 155–160 days in P. anisochila. The field results also indicate that the previously published June–July flowering period for P. anisochila does not correspond to the current phenological pattern in the studied populations. These findings provide a basis for monitoring, conservation planning and ex situ propagation of the two species.

KEYWORDS: Phlomoides anisochila, Phlomoides sogdiana, flowering biology, phenology, daily flowering rhythm, endemic species, Nuratau Mountains.

INTRODUCTION

Phenological timing is one of the most informative biological characteristics of a plant species because it reflects the interaction between inherited developmental programs and the seasonal course of environmental conditions. The dates of vegetation onset, bud formation, flowering, fruiting and dormancy influence reproductive success, seed production, population renewal and ultimately the persistence of a species in its natural habitat. For rare and geographically restricted plants, phenological data are particularly important because even relatively small shifts in temperature or moisture regime may alter the coincidence between flowering and pollinator activity, shorten the effective reproductive period, or change the time available for seed maturation. Classical approaches to plant phenology therefore remain highly relevant for modern conservation biology [1, 2].

The genus Phlomoides Moench belongs to Lamiaceae and includes a number of mountain species with distinct ecological and morphological adaptations. Modern molecular studies have supported the taxonomic recognition of Phlomoides as a separate genus and clarified its relationships within Phlomideae [8, 9]. In Uzbekistan, P. anisochila and P. sogdiana are especially important from a conservation perspective. P. anisochila is a narrowly distributed endemic associated with the Nuratau Mountains, while P. sogdiana is an endemic of Uzbekistan with a wider but still geographically limited distribution. Both species occur mainly on dry, stony and gravelly mountain slopes, where seasonal development is constrained by continental climatic conditions and rapid summer desiccation.

Despite the taxonomic and floristic interest in the genus, the flowering biology of P. anisochila and P. sogdiana has remained insufficiently documented. Earlier floristic sources provide information on morphology and distribution [3], while studies of Phlomoides reproductive structures have focused largely on seed and nutlet morphology [5]. The dissertation-based field programme conducted in the Nuratau area made it possible to follow the complete phenological sequence of both species over several years and to compare their daily and seasonal flowering dynamics. Preliminary results on the phenology of these taxa have also been reported by Xolbo'tayeva [6], whereas their phytocenotic position in the Nuratau vegetation was described by Xolbo'tayeva and O'ralov [7].

The aim of the present research article is to compare the flowering biology and phenological rhythms of P. anisochila and P. sogdiana under natural conditions, to identify the environmental range associated with maximum flower opening, and to determine the timing of the principal developmental phases from vegetation onset to seed maturation and seasonal dormancy. Particular attention is given to interspecific differences that may be relevant to population monitoring and conservation practice.

Materials And Methods

The study was based on long-term field observations carried out from 2019 to 2023 in the Nuratau Mountains, including sites around Uxum village and the Nuratau State Reserve. Phenological observations were conducted in ten subpopulations where P. anisochila and P. sogdiana occurred naturally. Detailed flowering-biology observations were organized in five subpopulations of each species. The studied habitats represented dry gravelly and stony mountain slopes and plant communities typical of the middle mountain belt. For P. sogdiana, monitored localities included areas near Po'dak, Boloi Aftoda and Sop; P. anisochila was observed in the Tikchasoy–Novi Olim and Loloyi areas. The field design was intended to capture both interannual variation and local differences among subpopulations.

Reproductive observations followed the approach used for studying flowering and pollination of plants [1]. Ten individuals of comparable size were selected for each species in the detailed monitoring plots. During the flowering period, the number of newly opened flowers was recorded at regular intervals over the day. The sequence of reproductive development was monitored from bud formation through initial opening, full anthesis, wilting and flower fall. Air temperature and relative humidity were measured with a psychrometric instrument at the same observation times. Flower opening was evaluated under clear, cloudy and rainy conditions in order to distinguish the role of short-term weather variation.

Phenological observations were organized according to the standard sequence proposed for plant and plant-community phenology [2]. The following phases were recorded: end of winter dormancy, beginning of vegetation, leaf development, bud formation, beginning of flowering, mass flowering, end of flowering, fruit and seed formation, seed maturation, drying of the

above-ground shoots and completion of vegetation. Generative individuals were used as reference plants for multi-year comparisons. The duration of the total vegetation period and the interval from vegetation onset to flowering were calculated from repeated observations.
The study was comparative and field-based; results are therefore presented as observed ranges and year-specific dates. Historical flowering information for P. anisochila in the Red Data Book of Uzbekistan [4] was used as a reference for assessing whether current multi-year observations confirm or differ from earlier records.

Results And Discussion

Seasonal flowering showed a stable but distinct pattern. P. sogdiana entered the flowering phase earlier. Across five monitored subpopulations, flowering began from the third decade of April to the first days of May and lasted 16–21 days. P. anisochila generally started flowering in the first decade of May and its total flowering period was shorter, 14–17 days. Multi-year observations from 2020–2022 confirmed this interspecific difference despite annual shifts of several days. The vegetation of P. sogdiana also began earlier, usually from the last decade of February to the first decade of March, whereas P. anisochila started active vegetation mainly in the first decade of March. Thus, the earlier reproductive transition of P. sogdiana is consistent with its slightly shorter overall vegetation cycle.

Table 1. Seasonal flowering dates of P. sogdiana and P. anisochila (2020–2022)

Species	Year	Vegetation onset	Flowering onset	Mass flowering	Flowering end / duration
P. sogdiana	2020	03 Mar	30 Apr	07 May	20 May / 21 d
P. sogdiana	2021	01 Mar	26 Apr	05 May	12 May / 16 d
P. sogdiana	2022	04 Mar	01 May	09 May	18 May / 18 d
P. anisochila	2020	06 Mar	04 May	12 May	20 May / 17 d
P. anisochila	2021	05 Mar	05 May	11 May	18 May / 14 d
P. anisochila	2022	07 Mar	06 May	13 May	22 May / 17 d

Daily flowering rhythm was also similar in general pattern but differed in quantitative detail. Both species were day-flowering plants. Under clear weather, flower opening intensified as temperature rose during the morning and reached a maximum around midday or early afternoon. In P. sogdiana, no newly opened flowers were observed at 08:00 when the temperature was 21.2 °C and relative humidity was 59%. Flower opening increased at 10:00 and 12:00 and reached the highest recorded value at 14:00, when four flowers opened at 27.3 °C and 47% relative humidity. By 16:00, only one flower opened despite a temperature of 27.9 °C. In P. anisochila, one flower opened at 08:00, two at 10:00, three at 12:00, and the maximum of five flowers was recorded at 14:00 at 24.9 °C and 40% relative humidity. The number fell to one by 16:00. These observations demonstrate a pronounced daily rhythm rather than continuous flower opening.

Table 2. Daily flower-opening rhythm and associated microclimatic conditions

Species	08:00	10:00	12:00	14:00	16:00	Peak conditions
P. sogdiana	0 21.2°C / 59%	2 24.2°C / 55%	3 27.0°C / 47%	4 27.3°C / 47%	1 27.9°C / 45%	12:00–14:00
P. anisochila	1 19.1°C / 57%	2 19.7°C / 59%	3 21.5°C / 45%	5 24.9°C / 40%	1 22.0°C / 50%	14:00

The field records suggest that temperature was the more immediate driver of flower opening during the day. Flowers opened more actively in clear weather, whereas low temperature, cloudiness and rain sharply reduced or stopped the process. Relative humidity changed simultaneously with temperature, but maximum opening did not correspond to the highest humidity values. Instead, the strongest flower-opening activity occurred when the air had warmed and relative humidity had declined to approximately 40–47%. This pattern does not imply that humidity is biologically irrelevant; rather, within the observed daily range, rising temperature was more consistently associated with anthesis. The daily concentration of flower opening around midday may also increase overlap with the activity period of insect pollinators, a potentially important consideration for species with restricted populations.

The duration of an individual flower also differed between the species. A flower of P. sogdiana remained open for approximately 4–7 days, whereas a flower of P. anisochila remained open for about 3–6 days. The somewhat longer flower life and longer seasonal flowering period of P. sogdiana may contribute to a wider temporal window for pollination. By contrast, the shorter flowering interval of P. anisochila means that adverse weather during a relatively narrow period may have a stronger effect on reproductive success. This interpretation is consistent with the broader dissertation findings showing lower reproductive performance and more restricted populations in P. anisochila, although the present article focuses specifically on flowering and phenology rather than seed productivity.

The annual phenological sequence was relatively compressed in both species. From the onset of vegetation to flowering, the interval was approximately 60–65 days. After flowering, seed formation began in late May or early June in P. anisochila and in the second to third decades of May in P. sogdiana. Seed maturation lasted about 25–30 days. As seeds matured, shoots changed from green to yellowish tones, leaves lost chlorophyll, and the above-ground parts progressively dried. By the third decade of June or the beginning of July, the active above-ground season was essentially completed. The total vegetation period was 150–155 days in P. sogdiana and 155–160 days in P. anisochila. These short seasonal cycles are consistent with adaptation to dry continental mountain environments, where plants must complete reproduction before the most severe summer drought.

A particularly important result concerns the timing of P. anisochila flowering. The 2019 Red Data Book of Uzbekistan reports flowering in June–July [4], information linked to earlier herbarium and floristic records. However, the 2019–2022 field observations used in this study showed that flowering in the monitored Nuratau populations occurred mainly in the first and second decades of May. By June and July, vegetation was already approaching completion and above-ground shoots were drying. This discrepancy should not be interpreted as an error in the historical material; rather, it indicates that current field monitoring provides a more precise description of the present phenological calendar in the studied populations. It also demonstrates why conservation assessments should be periodically updated using direct, multi-year observations.

The comparison reveals a common spring-active ecological strategy with species-specific timing. P. sogdiana starts vegetation and flowering somewhat earlier, keeps individual flowers open for longer, and may flower for up to three weeks. P. anisochila flowers later and completes flowering within about two weeks. For rare mountain plants, differences of only several days may change exposure to rainfall, heat events and pollinator activity; consequently, these data define useful windows for monitoring and seed collection.

Conclusion

Long-term field observations showed that P. anisochila and P. sogdiana have closely related but distinguishable flowering and phenological rhythms in the Nuratau Mountains. P. sogdiana flowers from late April or early May for 16–21 days and individual flowers remain open for 4–7 days; P. anisochila generally flowers in the first decade of May for 14–17 days and individual flowers remain open for 3–6 days. In both species, maximum flower opening is concentrated around midday and early afternoon and is more consistently associated with rising air temperature than with relative humidity. The total vegetation period is 150–155 days in P. sogdiana and 155–160 days in P. anisochila, while seed maturation takes about 25–30 days. Importantly, current field observations place P. anisochila flowering much earlier than the June–July period reported in older conservation literature. Monitoring should therefore be concentrated from late April through May, with seed collection planned for the subsequent maturation period. The results can refine phenological descriptions and support population monitoring, propagation and conservation of these endemic taxa.

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