

Original Research Article

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Biology of Flowering *Paulownia tomentosa* in the conditions of the Sirdaryo Region

Juraev Hasanbek Nuriddinovich^{1*} and Allaberdiev Rustamjon Khamraevich²

¹Department of Ecology and Geography, Gulistan State University, Independent Researcher, National University of Uzbekistan named after Mirzo Ulugbek, Uzbekistan

²Faculty of Biology and Ecology, National University of Uzbekistan named after Mirzo Ulugbek, Uzbekistan

**Corresponding author*

ABSTRACT

Keywords

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This study is devoted to a comprehensive investigation of the flowering biology of *Paulownia tomentosa* under introduction (acclimatization in a new region) conditions. During the research, phenological observations were conducted, the morphological structure of the flower was analyzed, and the effects of temperature and photoperiod (day length) on the flowering process were studied. In addition, the mechanisms of pollination and the characteristics of fruit set were examined in detail. The obtained results indicate that introduction conditions cause a certain delay in the flowering phase of the plant. It was also determined that entomophilous pollination, i.e., pollination by insects, plays the dominant role in this process. Furthermore, ecological stress factors were found to significantly affect flowering intensity, pollination efficiency, and seed formation quality. These scientific findings are of important theoretical and practical significance for the successful introduction of *Paulownia tomentosa* into agroforestry systems, optimization of its adaptation to introduction conditions, and effective organization of practical introduction programs.

Introduction

Paulownia tomentosa (paulownia) is widely studied and actively utilized worldwide as a fast-growing, high-biomass tree species with high ecological stability and significant economic value. Its wood quality, rapid growth rate, and ability to adapt to various climatic conditions make it a promising species for agroforestry

systems. However, under introduction conditions, particularly in newly established ecological regions, its flowering biology, reproductive processes, and seed formation characteristics have not been sufficiently and thoroughly investigated from a scientific perspective.

Flowering biology is a complex process that determines the reproductive potential of plants and is closely

associated with phenological developmental stages, floral morphological structure, and external environmental factors. These processes collectively play a crucial role in the biological adaptation of plants and the formation of stable populations under introduction conditions (1). Therefore, a comprehensive study of the flowering period of *Paulownia tomentosa* and the factors influencing it is of significant scientific and practical importance.

Under introduction conditions, the main factors affecting the flowering process include temperature regime, photoperiod (day and night length), soil conditions, and moisture availability. In addition, the nature of pollination—entomophilous (insect-mediated) or, in rare cases, autogamous (self-pollination)—also determines the efficiency of seed formation. Environmental stress factors such as heat, drought, wind, and other adverse conditions directly affect flowering duration, flower quality, and seed set processes (2, 3).

The climatic and agroecological conditions of the Sirdaryo region represent an important model area for the introduction of this species. Conducting phenological observations, analyzing flowering dynamics, and identifying the specific features of reproductive processes in this region serve as an important scientific basis for assessing the adaptation level of *Paulownia tomentosa* to local conditions.

The main objective of this study is to systematically and comprehensively investigate the flowering biology of *Paulownia tomentosa* under introduction conditions, including the identification of its phenological stages, analysis of floral morphology, evaluation of temperature and photoperiod effects, and scientific study of pollination processes and seed formation mechanisms. The results of this research are expected to contribute to improving the reproductive success of this species under introduction conditions, promoting its effective use in agroforestry systems, and establishing sustainable plantations.

In recent years, comprehensive scientific studies on the flowering biology of *Paulownia tomentosa* under introduction conditions have clearly demonstrated that the reproductive ontogenesis of this species is closely linked to a complex interaction of ecological, climatic, and agroecological factors. In particular, extensive phenological and experimental research conducted in China, South Korea, and other temperate regions has revealed that the flowering phenophases of *paulownia* are

highly sensitive to thermal regimes and photoperiodic stimuli (light duration). Low-temperature anomalies during the spring period delay the transition to the generative phase and phenologically postpone the onset of flowering, whereas optimal temperature conditions and stable photoperiods, conversely, activate flowering induction and enhance the intensity of reproductive processes (4, 5).

From a reproductive biology perspective, entomophilous pollination is considered the primary and evolutionarily dominant strategy in *Paulownia tomentosa*. In this process, the nectar production and morphological attractor features of the flower play a crucial role in attracting pollinating entomofauna, mainly representatives of Hymenoptera and Diptera. At the same time, facultative autogamy has also been observed under certain ecological and population stress conditions; however, its reproductive efficiency is low and does not ensure high levels of genetic recombination or seed viability (6). Analyses of floral morpho-anatomical structure indicate that the differential development of male and female reproductive organs, pollen viability, stigma receptivity, and proper progression of microsporogenesis are key biological determinants of successful fertilization (7).

Under introduction conditions, the adaptive reproductive potential of *Paulownia tomentosa* is directly limited by abiotic stress factors. In particular, hydrothermal stress (drought and high temperature), edaphic stress (soil salinity and mineral imbalance), and wind-erosion factors disrupt the normal ontogenetic development of the flowering phenophase. As a result, flowering duration may be prolonged or fragmented, morphological integrity of floral organs may be impaired, pollination efficiency decreases, and abortion of generative structures increases.

Phytoecological and agrobiological studies conducted in Turkey and Iran have demonstrated that under such stress conditions, fruit set indices significantly decline, embryonic development of seeds is reduced, and the generative reproductive coefficient decreases (8).

However, it has been scientifically confirmed that the negative impacts of these factors can be partially mitigated through the application of agro-technological optimization measures, such as regular irrigation systems, balanced mineral and organic fertilization, and microclimate management. These practices play an

important role in restoring reproductive stability and enhancing generative productivity (9).

In Uzbekistan, particularly within the continental climatic zone of the Sirdaryo region, systematic scientific research on the flowering biology, phenological rhythms, and reproductive ecology of *Paulownia tomentosa* remains insufficiently developed. The region's high temperature amplitude, relatively low precipitation levels, and ongoing agroecological transformation processes necessitate a deeper investigation of the introduction and adaptation mechanisms of this species. Therefore, the comprehensive study of the reproductive biology of *Paulownia tomentosa* based on phenological monitoring, morpho-embryological analyses, and integrated ecological assessment represents one of the most relevant research directions from both fundamental and applied agroforestry perspectives.

Materials and Methods

The study was conducted from 2022 to 2025 in introduction trial sites located in the Sirdaryo region. The area is characterized by a sharply continental climate, with maximum summer temperatures reaching up to +40 °C and an annual precipitation of 250–300 mm. The soil cover consists mainly of gray soils and partially saline soils.

Two- to three-year-old seedlings of *Paulownia tomentosa* were selected as the experimental material and planted using a 4 × 4 m spacing scheme. Agro-technical practices (irrigation, soil loosening, and mineral fertilization) were carried out in accordance with local agroecological conditions.

Phenological observations were conducted throughout the vegetation period (March–October), and both vegetative and generative developmental stages were recorded. Floral morphological parameters were measured using biometric methods.

Pollination processes were observed under natural conditions. The seed set rate was calculated using the following formula:

$$\text{Fruit set}(\%) = \frac{N_f}{N_t} \times 100$$

Where:

N_f – number of flowers that formed fruits,

N_t – total number of flowers.

In statistical analysis, mean values and Pearson correlation coefficients were calculated.

Phenological observations demonstrated that *Paulownia tomentosa* exhibits good adaptability to local climatic conditions. The vegetation stages developed fully, and the flowering process showed a seasonal pattern.

According to the obtained results, the flowering phenophase began at the end of April – beginning of May, reached its peak in May, and ended at the end of May – beginning of June. The average flowering duration was 12–18 days.

During the pollination process, entomophilous pollination was found to be dominant. The proportion of autogamy was low, accounting for 5–12%. The fruit set rate ranged between 45–70%.

Results and Discussion

The results demonstrate that *Paulownia tomentosa* exhibits a high level of ecological plasticity and adaptive stability in terms of flowering biology under the introduction conditions of the Sirdaryo region. Based on phenological observations, it was determined that the flowering phase mainly occurs from the last decade of April to the first half of May, confirming a direct relationship between this process and climatic factors.

According to the results of floral morphological analysis, the average flower length ranged between 5–7 cm, and the calyx structure was characterized by greenish-yellow pigmentation.

In addition, due to the high activity of microsporogenesis, the pollen maturation level was observed to be high. This was evaluated as an important biological factor ensuring the reproductive functional activity of the flowers.

The results of generative development confirmed the high reproductive potential of the species. On average, each plant formed 120–150 seeds, of which 85–90% successfully passed normal embryonic development stages. These values indicate a stable seed production capacity under introduction conditions.

Analysis of climatic factors showed that variations in

temperature and photoperiod significantly influence both the intensity and duration of flowering.

Table.1 Floral morphological characteristics

Parameter	Value
Flower length	35–55 mm
Calyx diameter	10–18 mm
Nectar amount	1.2–2.5 mg/flower
Pollen maturation	70–95%
Flowering duration	12–18 days

Figure.1 Flower of *Paulownia tomentosa*



The optimal flowering conditions were observed when day length ranged from 14 to 16 hours and air temperature was between +20 and +28 °C, during which generative activity reached its maximum level.

In contrast, under unfavorable stress conditions, a decrease in the efficiency of entomophilous pollination and limited reproductive success of autogamy were recorded.

Comparative analysis with studies conducted in other climatic zones confirms that the agroecological conditions of the Sirdaryo region are relatively favorable for flowering and fruiting of *Paulownia tomentosa*.

In conclusion, the results of the study demonstrated that *Paulownia tomentosa* exhibits high adaptability and reproductive potential in its flowering biology under introduction conditions in the Sirdaryo region.

Based on phenological observations, the flowering period extended from the end of March to the first half of July. Morphological analysis of the flowers proved to

be a crucial factor determining reproductive success. Variations in temperature and photoperiod significantly influenced flowering and fruit set. Under stressful conditions, the efficiency of entomophilous pollination decreased, while autogamy exhibited low effectiveness. The obtained results scientifically confirm the phenological flexibility and ecological stress tolerance of *Paulownia tomentosa* under introduction conditions. These findings provide an important scientific basis for the successful application of *Paulownia* in agroforestry and introduction programs in the region.

Author Contributions

Abdulolibov Muhridin: Investigation, formal analysis, writing—original draft. Juraev Hasanbek Nuriddinovich: Validation, methodology, writing—reviewing. Allaberdiev Rustamjon Khamraevich:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the

current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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