EISSN 2997-7185

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AMERICAN JOURNAL OF BIOLOGY AND NATURAL SCIENCES

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American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBB
ISSN: 2997-9331

Efficiency of Propagation and Cultivation Methods of *Linum Usitatissimum* L.

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Received: 2025 19, Feb
Accepted: 2025 28, Mar
Published: 2025 17, Apr

Annotation: In recent years, numerous researchers in our country have been deeply engaged in scientific studies. In particular, investigations into flax (Linum usitatissimum) seeds have shown promising and high-yielding results. This article presents a scientific analysis of the efficiency of propagation and cultivation technologies of common flax (Linum usitatissimum L.) under various agrobiological conditions of the Republic of Uzbekistan. The study was conducted in different natural-climatic regions, including Tashkent city (Botanical Garden), Jizzakh region (Sharof Rashidov and Zomin districts), and Navoi region (Khatirchi district). The ontogenetic developmental stages of the plant and corresponding agro-technical practices were studied. The results showed that various methods applied during the latent, virginal, and generative stages of flax significantly influenced seedling emergence, growth dynamics, fruit formation rate, and seed productivity. The scientific outcomes of the research contribute to the effective propagation of this species under local conditions, its adaptation to the climate, and its potential to substitute imports through the production of medicinal and technical raw materials.

Keywords: Linum usitatissimum, flax, ontogenesis, propagation methods, agrotechnology, introduction, generative stage, seed productivity, rainfed lands, Botanical Garden.

INTRODUCTION

Over the past two decades, despite the expanding scope of conservation efforts, the global biodiversity crisis continues to intensify. The sustainable management of biological resources and their rational utilization require prompt and decisive actions aimed at preserving individual species and ecosystems. To achieve these goals, it is essential to strengthen national and international capacities for systematic biodiversity monitoring and research. Equally important are strategies to enhance the functional performance of natural ecosystems and to develop effective local measures for in-situ conservation, as well as the preservation of biological and genetic resources under ex-situ conditions [1].

According to the 2020 data from the State Customs Committee of Uzbekistan, more than 900 tons of products such as black cumin (*Nigella sativa*), common flax (*Linum usitatissimum*), and Persian cumin (*Elwendia persica*) are imported annually into the country. As a result, over one million USD in foreign currency is spent each year on these imports [2]. Given the growing demand for these highly medicinal plants both globally and domestically, there is a pressing need to establish plantations and develop efficient cultivation technologies. Producing export-oriented products and promoting import substitution has become a national priority [3].

In light of these challenges, practical scientific research is being carried out under the A-FA-106 project titled “Establishment of Plantations of *Nigella sativa*, *Linum usitatissimum*, and *Elwendia persica* in the Rainfed Foothill Regions of Uzbekistan” for the period of 2021–2023. The aim is to organize plantations of medicinal plants in various rainfed areas of the country and, based on analysis of their bioecological characteristics across different regions, develop innovative cultivation technologies and sustainable plantation models [4].

This research investigates the bioecological and morphobiological features of these medicinal plants under the natural conditions of Uzbekistan's rainfed lands. The study also involves comparative analyses conducted at the "Introduction of Medicinal Plants" laboratory of the Tashkent Botanical Garden to assess raw material quality indicators and adaptive capabilities of the plants grown in different agroecological zones [5].

RESEARCH METHODOLOGY. The present study was conducted to examine the bioecological characteristics, ontogenetic development, and cultivation efficiency of medicinal plants such as ***Linum usitatissimum*** (common flax) under rainfed conditions of Uzbekistan. Research was carried out within the framework of the practical project A-FA-106 titled “Establishment of Plantations of ***Nigella sativa***, ***Linum usitatissimum***, and ***Elwendia persica*** in the Rainfed Foothill Regions of Uzbekistan” during the period of 2021–2023.

Study Areas

Field research was performed in various natural and climatic zones of Uzbekistan, specifically:

- **Sharof Rashidov district (Molguzar area)** and **Zomin district (Pishaghar Forest section)** of Jizzakh region;
- **Khatirchi district** of Navoi region;

- **Experimental plots of the "Introduction of Medicinal Plants" laboratory** at the Tashkent Botanical Garden (used as a control site for comparison).

These locations represent typical rainfed foothill landscapes, providing diverse agroecological settings for the evaluation of flax cultivation.

Plant Material and Sampling

Ten model plants of *Linum usitatissimum* were selected and observed at different stages of ontogenetic development. The study focused on the latent, virginal, juvenile, and generative phases of growth. Key morphological and ecological parameters were recorded, such as:

- ✓ Germination characteristics and seedling vitality in the latent and virginal stages;
- ✓ Leaf formation, root system structure, and growth dynamics during the juvenile stage;
- ✓ Flowering intensity, fruit formation, and seed yield during the generative stage.

Methods of Analysis

- **Ontogenetic and biomorphological features** were studied using the method of A.I. Rudenko.
- **Morphological characteristics** of the plant were determined according to A.A. Fedorov.
- **Floral morphology** was analyzed following the methodology of Z.G. Bespalova.
- **Seed germination tests** under laboratory conditions were carried out based on the methodological guide by T.T. Rakhimova.
- **Seasonal growth rhythms** and developmental phases were identified using the methods of I.V. Borisova and I.N. Beydeman, which distinguish between vegetative and generative phases of growth.

Data Processing

The collected data were statistically analyzed to determine correlations between ecological conditions and plant productivity, as well as to assess the influence of agro-technical practices on the growth, development, and yield of flax in different locations.

The experiments were conducted using a comparative analysis approach under field conditions specific to rainfed (non-irrigated) areas. The selected regions reflect variations in soil composition, precipitation levels, altitude, and microclimatic conditions. These differences enabled a broader understanding of the adaptability and ecological plasticity of *Linum usitatissimum*. To ensure consistency and minimize external variability, uniform agronomic practices were applied across all sites, except for the specific variables under study. Experimental plots were established in randomized blocks, and data were collected from repeated replicates to ensure statistical accuracy. Soil samples were collected from each experimental site prior to planting and analyzed for pH level, salinity, nitrogen-phosphorus-potassium (NPK) content, organic matter percentage, and texture class. Climatic data such as temperature, humidity, and precipitation were recorded throughout the growing season using nearby meteorological stations to correlate growth parameters with environmental influences. One of the objectives was to evaluate the potential for the introduction and acclimatization of *Linum usitatissimum* into non-native regions of Uzbekistan. For this purpose, the physiological responses of the plant (such as drought tolerance, phenological shifts, and reproductive success) were carefully observed and compared to those grown in the Tashkent Botanical Garden — considered an optimal reference environment. Several propagation techniques were tested, including direct seed sowing, seed pre-treatment with biostimulants (e.g., humic acids, microelements), and seedling transplantation in controlled nursery environments prior to field planting. The efficiency of these methods was evaluated based on seedling emergence rate, early vigor, pest resistance, and final seed yield per hectare. All collected data were subjected to statistical analysis using software tools such as Microsoft Excel and SPSS. The analysis included descriptive statistics (mean, standard deviation), ANOVA (Analysis of Variance), and correlation and regression analysis to determine relationships between environmental factors and plant productivity.

Results and Discussion.

Over the past twenty years, despite increasing efforts and measures, the global crisis of biological diversity continues to persist. The sustainable management of biological resources and their rational use requires urgent and decisive actions to preserve specific species and ecosystems [6]. This entails strengthening the capacity for studying biological diversity on both national and international scales, systematically monitoring it, improving the functional activity of natural ecosystems, and establishing effective local measures for conserving biological and genetic resources both in situ and ex situ. According to the State Customs Committee of Uzbekistan's 2020 data, over 900 tons of products – including Nigella sativa (black seed), Linum usitatissimum (flax), and Elwendia persica (cumin) – are imported annually into the country, while over one million USD worth of currency flows out of the Republic. This highlights the necessity of establishing plantations for these highly valuable medicinal plants and developing effective methods for cultivating them, thereby reducing dependency on imported products. This research, aligned with the A-FA-106 project "Establishing Plantations of Nigella sativa, Linum usitatissimum, and Elwendia persica in the Steppe Regions of Uzbekistan" (2021-2023), is dedicated to the creation of medicinal plant plantations in the steppe regions of Uzbekistan, focusing on their bioecological properties and analyzing the quality indicators of raw materials. The research aims to develop innovative technologies for plant production and provide recommendations for sustainable plantation establishment in the future [7].

The scientific research on the bioecological properties of these plants was conducted across various steppe areas of Uzbekistan, including the Jizzakh region's Sh. Rashidov district (Molguzar), Zomin district (Pishagar Forest Department), and Khatirchi district of Navoi region. The experimental studies were carried out in the Tashkent Botanical Garden's "Medicinal Plant Introduction" laboratory. The research methods used to study the ontogenetic bio-morphological characteristics of the plants were based on the techniques of A.I. Ruденко , A.A. Fedorov, Z.G. Besspalova, and T.T. Rakhimova [8]. These methods allowed for a comprehensive analysis of various developmental stages of the plants, from seed dormancy to full maturation [9].

The plants' morphobiological characteristics during ontogenesis were studied across ten model plant samples. During the latent phase, the seeds exhibited dormancy, while in the virginal stage, their viability was evaluated, followed by observations of leaf shape and size, root formation, and juvenile stage leaf appearance. In the generative phase, various parameters such as the number of branches, flower formation, and seed count in fruits were observed [10].

Additionally, the seasonal growth and development of the plants were monitored using the methodologies of I.V. Borisova and I.N. Beydeman. These methodologies allowed for the observation of vegetative and generative cycles. During the vegetative phase, parameters such as the onset of growth, leaf appearance, and size were measured, while in the generative phase, observations of flowering, fruiting, and seed maturation were conducted. The environmental factors, particularly soil moisture content and temperature, were found to be crucial in influencing the plants' growth and productivity, with soil moisture identified as the primary factor influencing seed production. In terms of environmental adaptation, the cultivation of Nigella sativa, Linum usitatissimum, and Elwendia persica in Uzbekistan's steppe regions was compared to the optimal conditions in the Tashkent Botanical Garden. This comparison helped to establish baseline data for understanding the plants' bioecological properties in both native and introduced environments.

Experimental trials were conducted in steppe regions, with seeds of Linum usitatissimum and Nigella sativa sown at depths of 1.5-2 cm in the first decade of February. The ontogenetic stages of these plants were observed and classified as latent (se), virginal (v), and generative (g). The timing of seed germination and the subsequent development of the plants were studied in detail. For instance, the germination period in Molguzar and Pishagar conditions was recorded in late February, while in the Tashkent Botanical Garden, germination occurred in the first decade of March. The latent period for both species was observed to be almost identical, with a 3-5 day difference between them. The study also included the analysis of vegetative stages, focusing on the growth of the first and second leaves, which appeared in the plants after 8-9 days in the steppe regions and 2-3 days later in the Botanical Garden. The juvenile phase was marked by the appearance of the third and fourth leaves, with the plants' height recorded in various conditions. In Molguzar and Pishagar, plant heights reached 4-5 cm, while in Khatirchi and the Botanical Garden, plant heights were 3-4 cm and 5-6 cm, respectively.

This detailed analysis of the plants' growth and bioecological characteristics, including soil moisture, temperature, and environmental adaptation, will contribute significantly to the development of effective plantation systems for these medicinal plants in Uzbekistan's steppe regions. The research highlights the importance of these species in ensuring sustainable local production and reducing the reliance on imported medicinal plant products. The generative phase of the plant begins with the formation of buds in the upper part of the plant. Flower formation occurs at the end of the first decade of May, with plant heights reaching an average of 30–40 cm in the Molguzar, Khatirchi, and Pishagar regions, and 45–50 cm in the conditions of the Botanical Garden. The number of leaves per plant is typically between 70 and 80, with the main root averaging 15–20 cm in length and up to 6–8 secondary and tertiary lateral roots. The period during which buds form and fully develop averages 10–12 days. The onset of flowering is observed in mid-May, with plant heights ranging from 30.8 to 42.7 cm in the Molguzar, Khatirchi, and Pishagar conditions. On the loamy soils, each plant produces 8 to 12 flowers, while in the Botanical Garden conditions, 15 to 20 flowers are formed.

The overall flowering period in loamy soils is observed at the end of May, while in the Botanical Garden, it begins in early June. The total duration of the flowering process averages 25–30 days. The fruiting process begins in the first decade of June on loamy soils, whereas in the Botanical Garden, it starts in the second decade of June. The maturation of fruits is directly correlated with the seed formation process, with seed formation taking an average of 10–12 days. In each fruit capsule, an average of 10–15 seeds with a size of 0.1–0.2 mm are formed.

Throughout the phenological observations, differences in the plant's vegetative cycle and phase durations, as well as its biometric indicators, were identified. In the case of the common flax variety, bud formation is typically observed in the first decade of May, though in some cases, it is influenced by external environmental factors and may occur in mid-May. The earliest flowering is observed on May 20, with the latest flowering occurring by May 30. The fruiting process lasts from the beginning of June until the end of the month.

Conclusion.

In the first year of the introduction study of common flax (*Linum usitatissimum*), the plant completes its full growth and development cycle, transitioning into the generative phase, which includes the flowering process and subsequent seed formation. The vegetative period of the plant in loamy soils lasts approximately 134–138 days, while in the conditions of the Botanical Garden, it extends to 140–145 days. The plant responds to various environmental factors, particularly the relative humidity of the air, with specific observations under different conditions. In the Botanical Garden, the relative humidity averages around 50–51%, while in loamy soils, it ranges from 40–45%, which is associated with the onset of flowering.

For annual plants, such as the studied flax species, the duration of flowering phases is influenced by external environmental factors, particularly air humidity. Accordingly, a reduction or extension of the flowering phase has been observed depending on these environmental indicators. This finding is consistent with earlier research on the influence of environmental factors on plant development.

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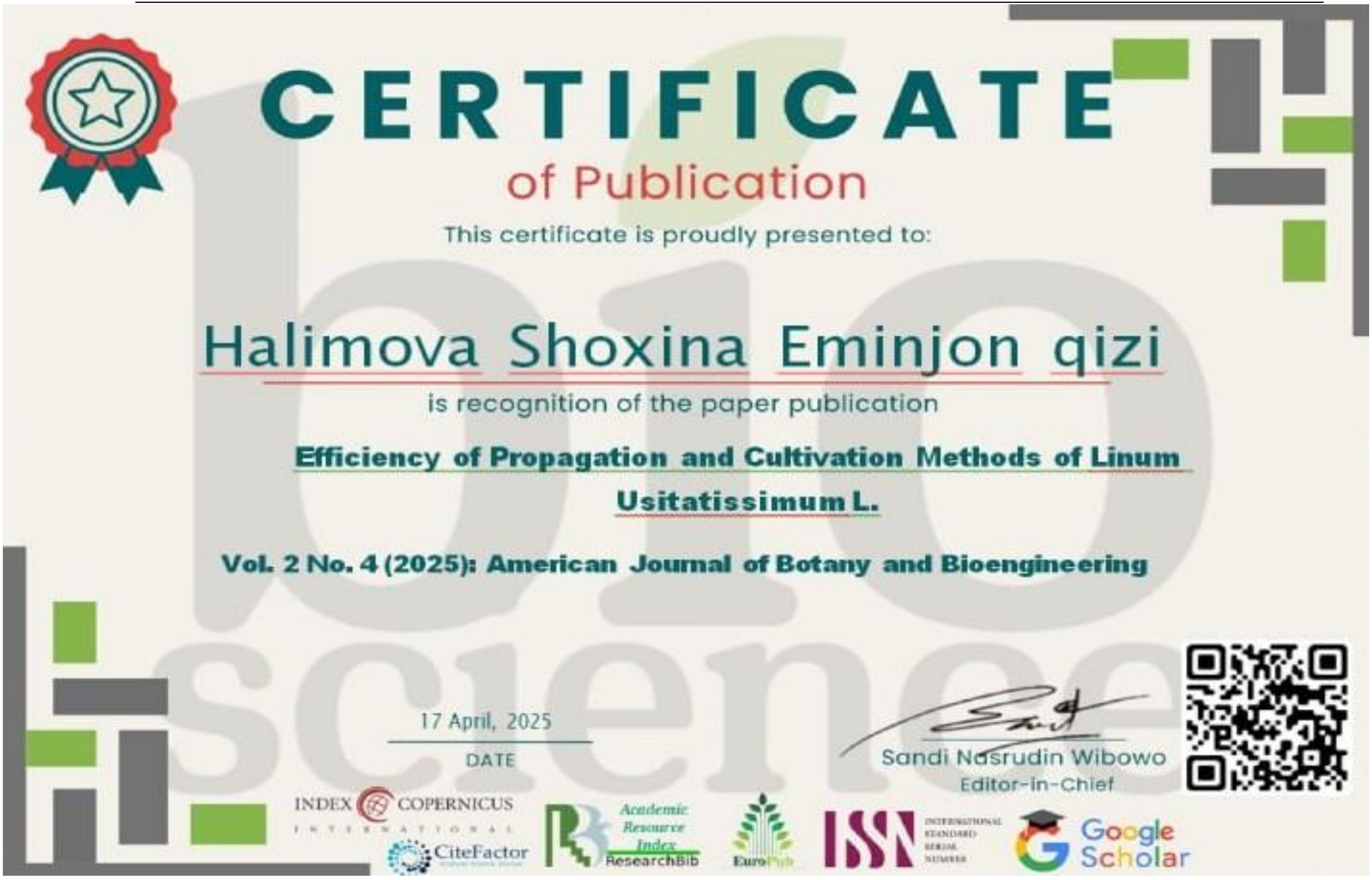

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Efficiency of Propagation and Cultivation Methods of Linum Usitatissimum L.

Vol. 2 No. 4 (2025): American Journal of Botany and Bioengineering

17 April, 2025
DATE

Sandi Nasrudin Wibowo
Editor-in-Chief