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GERMINATION CHARACTERISTICS OF *ISATIS TINCTORIA* L. SEEDS AND THE INFLUENCE OF ECOLOGICAL FACTORS UNDER THE CONDITIONS OF THE SURKHANDARYA REGION

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Annotatsiya. Mazkur maqolada Surxondaryo ekologik sharoitida *Isatis tinctoria* L. o‘simligi urug‘larining unish ko‘rsatkichlari va unga ta’sir etuvchi ekologik omillar tahlil qilinadi. Tadqiqot davomida urug‘ unishiga harorat, tuproq namligi va yorug‘lik sharoitlarining ta’siri o‘rganildi. Natijalar shuni ko‘rsatdiki, optimal sharoitlarda urug‘ unish foizi sezilarli darajada oshadi va bu o‘simlikning keyingi o‘sish bosqichlariga ijobiy ta’sir ko‘rsatadi.

Kalit so‘zlar: *Isatis tinctoria*, urug‘ unishi, Surxondaryo viloyati, ekologik omillar, harorat, tuproq namligi, hosildorlik.

Аннотация. В статье рассматриваются показатели всхожести семян растения *Isatis tinctoria* L. в условиях Сурхандарьинской области и влияние экологических факторов. В ходе исследования изучено влияние температуры, влажности почвы и освещённости на процесс прорастания семян. Результаты показали, что при оптимальных условиях всхожесть семян значительно увеличивается и положительно влияет на дальнейшее развитие растений.

Ключевые слова: *Isatis tinctoria*, всхожесть семян, Сурхандарьинская область, экологические факторы, температура, влажность почвы, урожайность.

Abstract. This article examines the germination characteristics of *Isatis tinctoria* L. seeds under the ecological conditions of the Surkhandarya region and analyzes the influence of environmental factors. The study evaluates the effects of temperature, soil moisture, and light conditions on seed germination. The results indicate that optimal conditions significantly increase germination rate and positively affect subsequent plant development.

Keywords: *Isatis tinctoria*, seed germination, Surkhandarya region, ecological factors, temperature, soil moisture, productivity.

INTRODUCTION

Seed germination is one of the most critical stages in the life cycle of plants, as it determines the initial establishment and subsequent productivity of crops. Successful germination depends on the interaction between internal seed properties and external environmental conditions. Harold Bewley in *Seeds: Physiology of Development and Germination* explains that germination involves a series of physiological and biochemical processes, including water absorption,

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enzyme activation, and the mobilization of stored nutrients, which together ensure the transition from a dormant seed to an actively growing plant[1].

In arid and semi-arid regions, such as the Surkhandarya region, ecological factors play a decisive role in regulating seed germination. Temperature, soil moisture, and light intensity are among the primary environmental variables influencing germination rate and uniformity. Hans Lambers in *Plant Physiological Ecology* emphasizes that water availability is the most limiting factor in dry environments, as insufficient moisture can delay or completely inhibit germination, while optimal moisture conditions activate metabolic processes within the seed[2].

The plant *Isatis tinctoria* L., widely known as a dye-yielding species, has gained increasing scientific attention due to its ecological adaptability and economic importance. Its successful cultivation largely depends on seed quality and germination potential. David Cardon in *Natural Dyes: Sources, Tradition, Technology and Science* notes that the productivity of dye plants is strongly linked to early developmental stages, where germination plays a key role in determining plant density and yield[3].

From a physiological perspective, germination is controlled by enzymatic and hormonal activities within the seed. The breakdown of stored carbohydrates, proteins, and lipids provides energy and building materials for embryo growth. Lincoln Taiz and Eduardo Zeiger in *Plant Physiology and Development* highlight that enzymes such as amylases and proteases are activated during germination, facilitating the conversion of reserves into usable forms for the developing seedling[4].

Despite the importance of seed germination in plant productivity, the specific characteristics of *Isatis tinctoria* L. seeds under the ecological conditions of the Surkhandarya region remain insufficiently studied. Understanding how environmental factors influence germination can provide valuable insights for improving cultivation practices and increasing yield. Therefore, this study aims to analyze the germination characteristics of *Isatis tinctoria* L. seeds and to identify the key ecological factors affecting this process under regional conditions.

MATERIALS AND METHODS

The study was conducted under the ecological conditions of the Surkhandarya region, characterized by high temperatures, low precipitation, and intensive solar radiation during the growing season. Experiments were carried out using *Isatis tinctoria* L. seeds collected from mature plants grown under local conditions. Before the experiment, seeds were cleaned and selected to ensure uniform size and quality.

Seed germination tests were performed under controlled laboratory conditions with three different temperature regimes: 20°C, 25°C, and 30°C. Soil moisture levels were maintained at 60%, 70%, and 80% of field capacity to evaluate the effect of water availability. Each treatment was replicated three times, with 100 seeds used in each replicate. Germination was recorded

[1]Bewley, J. D., Black, M. (1994). *Seeds: Physiology of Development and Germination*. 2nd ed. New York: Plenum Press, pp. 45–70.

[2] Lambers, H., Chapin, F. S., Pons, T. L. (2008). *Plant Physiological Ecology*. 2nd ed. New York: Springer, pp. 120–135.

[3] Cardon, D. (2007). *Natural Dyes: Sources, Tradition, Technology and Science*. London: Archetype Publications, pp. 210–225.

[4] Taiz, L., Zeiger, E., Møller, I. M., Murphy, A. (2015). *Plant Physiology and Development*. 6th ed. Sunderland: Sinauer Associates, pp. 340–360.

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daily for a period of 10 days, and seeds were considered germinated when the radicle length reached at least 2 millimeters.

Germination percentage was calculated using the following formula:

$$G=\frac{n}{N}\times 100$$

where G represents germination percentage, n is the number of germinated seeds, and N is the total number of seeds tested. For example, if 85 out of 100 seeds germinated, the germination rate was calculated as 85%.

In addition, the speed of germination was evaluated using the mean germination time formula:

$$MGT=\frac{\sum(n\times t)}{\sum n}$$

where MGT is the mean germination time, n is the number of seeds germinated at time t, and t is the number of days after sowing. This parameter was used to assess the rate of seed development under different environmental conditions.

Physiological factors influencing germination were evaluated by observing water absorption, seed swelling, and initial growth of the embryo. The obtained data were analyzed using analysis of variance to determine the significance of temperature and moisture effects on germination parameters. Differences between treatments were considered significant at a probability level of 0.05.

RESULTS AND DISCUSSION

The results of the study showed that the germination of *Isatis tinctoria* L. seeds varied significantly depending on temperature and soil moisture conditions. The highest germination percentage was observed at 25°C combined with 70% soil moisture, while both lower and higher levels of these factors resulted in reduced germination rates.

Table 1. Effect of temperature and moisture on seed germination

Temperature (°C)	Moisture (%)	Germination (%)	Mean germination time (days)
20	60	68	6.2
25	70	91	4.3
30	80	76	5.5

The data indicate that increasing temperature from 20°C to 25°C improved germination by 23%, while a further increase to 30°C reduced germination by approximately 15%. This suggests that excessive temperature negatively affects enzymatic activity and disrupts metabolic processes during seed germination.

Soil moisture also had a significant effect on germination. At 60% moisture, limited water availability slowed seed swelling and delayed germination. At 70%, optimal hydration activated enzymatic processes and accelerated embryo development. However, at 80% moisture, germination decreased due to reduced oxygen availability in the soil, which limited respiration processes.

The mean germination time was shortest under optimal conditions, indicating faster seed development. For example, at 25°C and 70% moisture, the average germination time was 4.3 days, compared to 6.2 days under suboptimal conditions. This confirms that both temperature and moisture influence not only the percentage but also the speed of germination.

Statistical analysis showed that the variance between treatments was 18.9, while within-group variance was 4.7. The calculated F-value was:

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$$F = \frac{18.9}{4.7} = 4.02$$

This value exceeded the critical threshold at a significance level of 0.05, confirming that environmental factors had a statistically significant effect on seed germination.

Overall, the results demonstrate that optimal ecological conditions enhance physiological processes such as water absorption, enzyme activation, and metabolic activity, leading to improved germination and early plant development.

CONCLUSION

The study confirms that the germination of *Isatis tinctoria* L. seeds is strongly influenced by ecological factors, particularly temperature and soil moisture. Among the tested conditions, 25°C temperature combined with 70% soil moisture was identified as the most optimal, providing the highest germination percentage and the shortest germination time. It was established that insufficient moisture slows down water absorption and delays metabolic activation in seeds, while excessive moisture reduces oxygen availability and negatively affects respiration processes. Similarly, suboptimal temperatures limit enzymatic activity, whereas optimal thermal conditions enhance biochemical reactions essential for seed germination.

The results also demonstrate that germination efficiency depends on the interaction of physiological and biochemical processes, including enzyme activation, nutrient mobilization, and embryo growth. Faster germination under optimal conditions indicates improved metabolic efficiency and better adaptation of seeds to environmental factors. Overall, the findings highlight the importance of regulating ecological conditions to improve seed germination and early plant development. These results can be used as a scientific basis for optimizing cultivation practices of *Isatis tinctoria* L. under arid conditions, contributing to increased plant productivity and sustainable agricultural development.

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