American Journal of Plant Sciences, 2026, 17(8), 799-811
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Field Seed Germination of the Medicinal Plant *Origanum tyttanthum* Gontsch. under Introduction Conditions in the Samarkand Region, Uzbekistan

Khurshida Boboyeva

Samarkand State University of Veterinary Medicine, Livestock and Biotechnologies, Samarkand, Uzbekistan
Email: urshidaboboyeva60@gmail.com

How to cite this paper: Boboyeva, K. (2026) Field Seed Germination of the Medicinal Plant *Origanum tyttanthum* Gontsch. under Introduction Conditions in the Samarkand Region, Uzbekistan. *American Journal of Plant Sciences*, **17**, 799-811.
https://doi.org/10.4236/ajps.2026.178048

Received: May 8, 2026
Accepted: August 23, 2026
Published: August 26, 2026

Abstract

Generative (seed-based) propagation is a key prerequisite for the successful introduction and cultivation of wild medicinal plants, yet field-level germination data for *Origanum tyttanthum* Gontsch., a medicinal species endemic to the mountainous regions of Central Asia, remain scarce. A three-year field trial (2021-2023) was carried out on irrigated typical grey soils (sierozems) of the Samarkand region to determine how sowing date, sowing depth, and short-term seed storage affect the field germination of *O. tyttanthum* seeds. Seeds sown in mid-October (200 seeds m^{-2}) produced the highest germination rate (89.5 ± 2.19%), significantly exceeding rates obtained from early-October, late-October, and all three spring sowing dates tested (50.1 - 82.6%). Sowing depth strongly and inversely affected germination: shallow sowing at 0.5 cm gave the highest germination (89.0 ± 2.17%), while germination declined progressively with depth and was completely suppressed at 4 cm. Seeds were also subjected to a 40 - 45-day cold, moist-sand stratification prior to sowing to overcome physiological dormancy typical of Lamiaceae seeds. These results indicate that mid-October sowing at a shallow depth of approximately 0.5 cm, combined with pre-sowing stratification, provides the most favorable regime for field establishment of *O. tyttanthum* and can inform agrotechnical recommendations for the introduction, cultivation, and *ex situ* conservation of this medicinal species in arid and semi-arid regions of Central Asia.

Keywords

Origanum tyttanthum, Seed Germination, Sowing Date, Sowing Depth, Stratification, Medicinal Plant, Introduction, Central Asia

1. Introduction

The conservation of biological diversity and the rational use of natural resources are among the most pressing global challenges of the present day, and the propagation and seed-based cultivation of wild-growing medicinal plant species play a central role in addressing this challenge [1]. Uzbekistan is regarded as one of the principal centers of medicinal plant diversity in Central Asia, hosting several hundred documented medicinal species, a substantial proportion of which are still collected from wild populations rather than cultivated [2] [3]. Bringing such species into cultivation reduces pressure on natural populations, provides a predictable and standardized source of raw material for the pharmaceutical industry, and supports the broader national goals of import substitution and export-oriented plantation-scale cultivation of medicinal raw materials.

Origanum tyttanthum Gontsch. (small-flowered mountain oregano) is a perennial aromatic and medicinal species of the family Lamiaceae, native to the mountainous and foothill regions of Uzbekistan, where it has long been used in traditional medicine for its anti-inflammatory, spasmolytic, and antiseptic properties. Successful introduction of this species into cultivation depends first and foremost on establishing a reliable method of generative (seed) propagation, since seed-based propagation is generally more scalable and less labor-intensive than vegetative methods for large-scale plantation establishment [4]-[7]. However, seed germination in Lamiaceae species is frequently constrained by small seed size, physiological dormancy, and pronounced sensitivity to sowing depth, sowing date, and pre-sowing treatment [8]-[12].

A growing body of international research has addressed these constraints in related Origanum and other Lamiaceae taxa. Studies on *Origanum elongatum*, a Moroccan endemic closely related to *O. tyttanthum*, have shown that germination is highly sensitive to temperature, salinity, and pH, with optimal germination occurring at moderate temperatures (15 - 20˚C) and declining sharply under saline or high-temperature conditions [13] [14]. Comparable sensitivity to abiotic factors has been documented for other medicinal Lamiaceae genera, including Salvia [15] and Thymus, underscoring the broader relevance of controlled sowing conditions for successful field establishment across the family.

Sowing depth is a particularly critical determinant of seedling emergence in small-seeded species. A meta-analysis of thirteen annual species under semi-arid Mediterranean conditions demonstrated that the decline in germination with burial depth is markedly steeper for small-seeded than for large-seeded species, with near-complete inhibition typically occurring within the first few centimeters of burial [16]. Similar depth sensitivity was reported for the *Lamiaceae* species Salvia verbenaca, in which even a shallow burial depth of 2 cm completely inhibited germination in both varieties studied [15], and for Dalmatian sage (Salvia officinalis), whose seedling emergence likewise declined sharply with increasing sowing depth (as reviewed in [15]). These findings are broadly consistent with the general seed ecology principle that smaller seeds possess more limited carbohydrate reserves to support hypocotyl elongation through the soil profile, making shallow sowing essential for reliable emergence [8].

Sowing date and pre-sowing seed treatment are two further agrotechnical factors known to strongly influence field establishment. In hazelnut (Corylus avellana), outdoor sowing date was shown to affect seedling emergence the following spring, with early autumn sowing immediately after seed collection producing the best results, while extended warm and cold moist stratification further enhanced germination synchrony and rate [17]. Analogous stratification-related improvements in germination have been documented for numerous other medicinal plant seeds, for which appropriate storage conditions, duration, and pretreatment are critical for preserving seed viability and maximizing subsequent germination [18]. Seed dormancy itself is now understood within a formal hierarchical classification framework distinguishing physiological, morphological, morphophysiological, physical, and combinational dormancy classes, which provides a useful conceptual basis for interpreting the germination responses of insufficiently studied species such as *O. tyttanthum* [8].

Despite this substantial body of comparative evidence for related taxa, no field-based, quantitative data on the combined effects of sowing date, sowing depth, and stratification on seed germination of *Origanum tyttanthum* have previously been reported. The present study was therefore designed to determine, under the irrigated typical grey soil (sierozem) conditions of the Samarkand region, (i) how autumn versus spring sowing date affects field germination, and (ii) how sowing depth affects field germination of *O. tyttanthum* seeds, in order to establish an evidence-based agrotechnical recommendation for the generative propagation of this medicinal species.

The Samarkand region lies within the arid-to-semi-arid continental climatic zone of Central Asia, where medicinal plant cultivation is carried out predominantly on irrigated typical grey soils (sierozems). These soils are characterized by comparatively low humus content, a mechanical composition dominated by loams, and a calcium- and magnesium-saturated exchange complex, properties that are broadly representative of long-irrigated arable land across the wider Fergana and Zarafshan valley systems of Uzbekistan [19]. Because soil texture, aeration, and moisture retention strongly influence the depth to which small seeds can be reliably sown, and because seasonal soil temperature dynamics govern the timing of dormancy release, the sierozem soils and continental climate of the Samarkand region provide an appropriate but previously untested setting in which to evaluate the sowing-date and sowing-depth responses of *O. tyttanthum*.

Beyond its regional importance, the broader global market for medicinal and aromatic plant raw material continues to expand, and cultivated material is increasingly preferred over wild-collected material because it offers more predictable yield, quality, and chemical composition, and eliminates the risk of species misidentification or adulteration that can arise with wild-harvested plant material. Realizing these advantages for *O. tyttanthum*, however, first requires a dependable, field-validated protocol for generative propagation—the central gap that the present study seeks to address.

It is worth noting that the wider three-year introduction trial from which the present dataset was drawn also incorporated three row-spacing schemes (45 × 30 cm, 60 × 30 cm, and 90 × 30 cm), intended to evaluate the effect of planting density on subsequent vegetative growth, canopy closure, and raw-material yield. Because seedling emergence itself is governed primarily by seed-to-soil contact, sowing depth, and near-surface soil moisture rather than by the spacing between sowing rows, the present analysis focuses specifically on sowing date and sowing depth as the two factors most directly relevant to the germination stage; the influence of row-spacing scheme on later developmental stages of *O. tyttanthum* will be addressed in a separate report once the full three-year growth and yield dataset has been compiled.

2. Materials and Methods

2.1. Study Site and Plant Material

The field trials were conducted over three consecutive years (2021-2023) at an experimental site in Pastdargom District, Samarkand Region, Uzbekistan, within the Zarafshan River basin, on irrigated typical grey soils (sierozems) with relatively limited water supply. Prior to establishment of the trial, soil samples from the 0 - 30 cm layer at the experimental site were analyzed and contained 0.898% humus, 0.092% total nitrogen, 0.122% total phosphorus, and 2.10% total potassium (mobile forms: 8.67 mg/kg $N\text{-}NO_3$, 22.65 mg/kg P_2O_5, 175 mg/kg K_2O); the underlying 30 - 50 cm layer contained 0.762% humus, 0.065% total nitrogen, 0.096% total phosphorus, and 1.76% total potassium. Bulk density ranged from 1.27 - 1.33 g/cm^3 in the 0 - 30 cm layer at the start of the growing season. Soil pH, electrical conductivity, and the seasonal irrigation schedule were not recorded as part of this study and are recommended as measurements for future trials. Mature, fully ripened seeds of *Origanum tyttanthum* Gontsch. were hand-collected from naturally occurring plants in the foothill areas of the Samarkand region at the end of the growing season and cleaned of plant debris and empty seed coats prior to use.

2.2. Seed Stratification

A portion of the collected seed was subjected to cold, moist stratification prior to sowing to overcome physiological dormancy typical of many Lamiaceae seeds [8]. Seeds were mixed with moist river sand at a layer thickness of 4 - 5 cm and a substrate moisture content of 25 - 30%, and held under these conditions for 40 - 45 days at ambient autumn/winter temperatures. During stratification, water uptake by the seed coat promotes structural changes that facilitate subsequent imbibition and radicle emergence. This procedure is intended to improve germination in seeds with physiological dormancy, consistent with stratification-related improvements documented for the seeds of other medicinal and aromatic plant species [17] [18] [20] [21]. A replicated, non-stratified control treatment was not included in the present trial, so the magnitude of the stratification effect specific to *O. tyttanthum* could not be quantified here and is recommended as a priority for future controlled trials.

2.3. Experimental Design: Sowing Date

To evaluate the effect of sowing date, stratified seeds were sown in the field at six dates spanning the autumn and spring sowing seasons of the 2021-2022 trial cycle: three autumn dates (5, 15, and 20 October 2021) and three spring dates (1, 5, and 15 March 2022). At each date, 200 full, mature seeds were sown per 1 m^2 plot, with the trial conducted in four replicates per date, following the row-spacing schemes (45 × 30 cm, 60 × 30 cm, and 90 × 30 cm) used across the wider three-year introduction trial. The number of emerged seedlings per plot was counted at the completion of the germination period, and germination rate was expressed as the mean percentage (± standard error, SE) of the 200 sown seeds that produced a visible seedling.

2.4. Experimental Design: Sowing Depth

To evaluate the effect of sowing depth, 100 full, mature seeds were sown at each of six depths (0.3, 0.5, 1, 2, 3, and 4 cm) under otherwise uniform field conditions, with the trial conducted in four replicates per depth, and results expressed as mean percentage germination (± SE).

2.5. Data Analysis

Both the sowing-date and sowing-depth trials were conducted in four replicates per treatment. Germination rate for each treatment is reported as the mean percentage of sown seeds producing a visible seedling across these four replicates, together with the standard error of the mean. Because the present dataset represents the first sowing cycle of a longer-term, multi-year introduction trial, and additional replicate years are still in progress, formal analysis of variance (ANOVA) was not performed on the data reported here; treatment differences are described qualitatively on the basis of non-overlapping standard errors and consistent directional trends across dates and depths. We recommend that subsequent seasons of this trial, and future replicated studies of this kind, incorporate a formal ANOVA or mixed-model analysis with sowing date, sowing depth, and year as fixed or random effects, respectively, to allow rigorous statistical inference.

3. Results

3.1. Effect of Sowing Date on Field Germination

Field emergence of *O. tyttanthum* seeds was strongly dependent on sowing date (**Table 1**, **Figure 1**). Among the autumn sowing dates, seeds sown on 5 October 2021 produced a mean germination rate of 52.0 ± 1.47%, corresponding to 104.0 seedlings per 1 m^2 out of 200 seeds sown. Germination increased sharply for the mid-October sowing date (15 October 2021), reaching 89.5 ± 2.19% (179.0 seedlings per 1 m^2)—the highest germination rate recorded in the entire trial. Seeds sown at the end of October (20 October 2021) produced an intermediate germination rate of 82.6 ± 1.79% (165.2 seedlings per 1 m^2). Sowing later than the third decade of October coincided with the onset of the cold season, after which further seed germination in the field ceased until spring.

Germination rates recorded for the three spring sowing dates (1, 5, and 15 March 2022) were consistently lower than those of the mid- and late-October dates, ranging from 60.65 ± 1.49% (121.3 seedlings per 1 m^2) for the earliest spring date down to 50.05 ± 1.59% (101.0 seedlings per 1 m^2) for the latest spring date tested—a pattern of progressive decline with delayed spring sowing that mirrored, in reverse, the earlier decline observed with delayed autumn sowing.

Table 1. Effect of sowing date on the field germination of *Origanum tyttanthum* Gontsch. seeds (n = 200 seeds per date).

Season	Sowing date	Germinated seeds per 1 m^2 (no.)	Germination rate (% ± SE)
Autumn	5 Oct 2021	104.0	52.0 ± 1.47
Autumn	15 Oct 2021	179.0	89.5 ± 2.19
Autumn	20 Oct 2021	165.2	82.6 ± 1.79
Spring	1 Mar 2022	121.3	60.65 ± 1.49
Spring	5 Mar 2022	112.1	56.05 ± 2.95
Spring	15 Mar 2022	101.0	50.05 ± 1.59

Note: values are means ± standard error (SE) based on six 1 m^2 replicate plots per sowing date. Data are from the 2021 (autumn) and 2022 (spring) sowing cycle of the ongoing three-year (2021-2023) introduction trial.

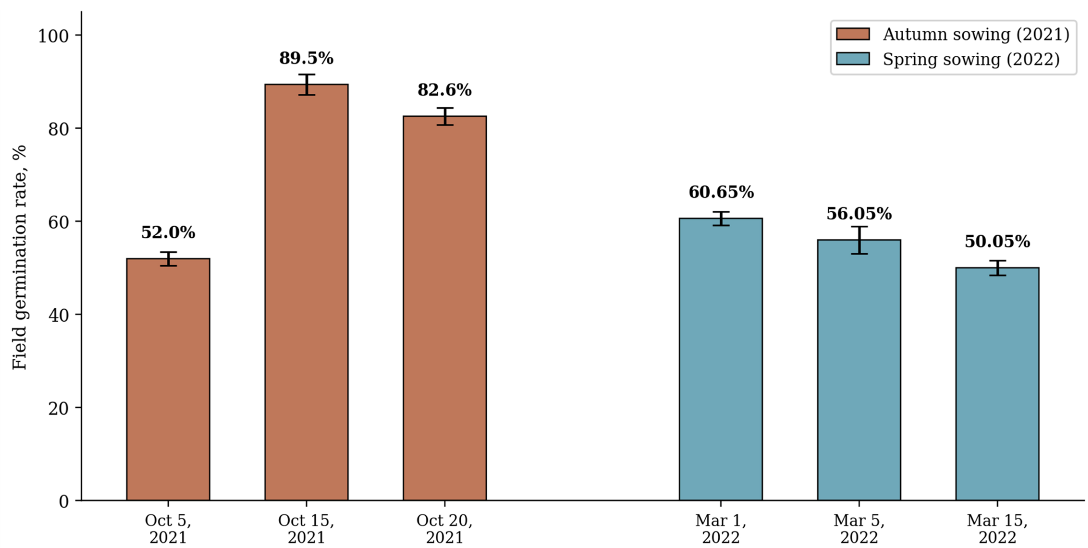

Figure 1. Field germination rate of *Origanum tyttanthum* Gontsch. seeds as a function of sowing date. Bars show means ± SE for six autumn and spring sowing dates (n = 200 seeds per date).

3.2. Effect of Sowing Depth on Field Germination

Sowing depth exerted a strong, inverse effect on the field germination of *O. tyttanthum* seeds (Table 2, Figure 2). Germination increased from 59.0 ± 1.46% at the shallowest depth tested (0.3 cm) to a maximum of 89.0 ± 2.17% at 0.5 cm, then declined progressively with increasing depth: 75.5 ± 1.80% at 1 cm, 50.3 ± 1.51% at 2 cm, and only 10.1 ± 2.97% at 3 cm. No seedlings emerged from seeds sown at 4 cm. This pattern describes a clear, non-monotonic optimum, with germination peaking at a shallow depth of approximately 0.5 cm and falling off sharply on either side of this optimum.

Table 2. Effect of sowing depth on the field germination of *Origanum tyttanthum* Gontsch. seeds (n = 100 seeds per depth).

Sowing depth (cm)	Germinated seeds per 100 sown (no.)	Germination rate (% ± SE)
0.3	59.0	59.0 ± 1.46
0.5	89.0	89.0 ± 2.17
1.0	75.5	75.5 ± 1.80
2.0	50.3	50.3 ± 1.51
3.0	10.1	10.1 ± 2.97
4.0	0	0

Note: values are means ± standard error (SE) based on replicate plots per depth treatment.

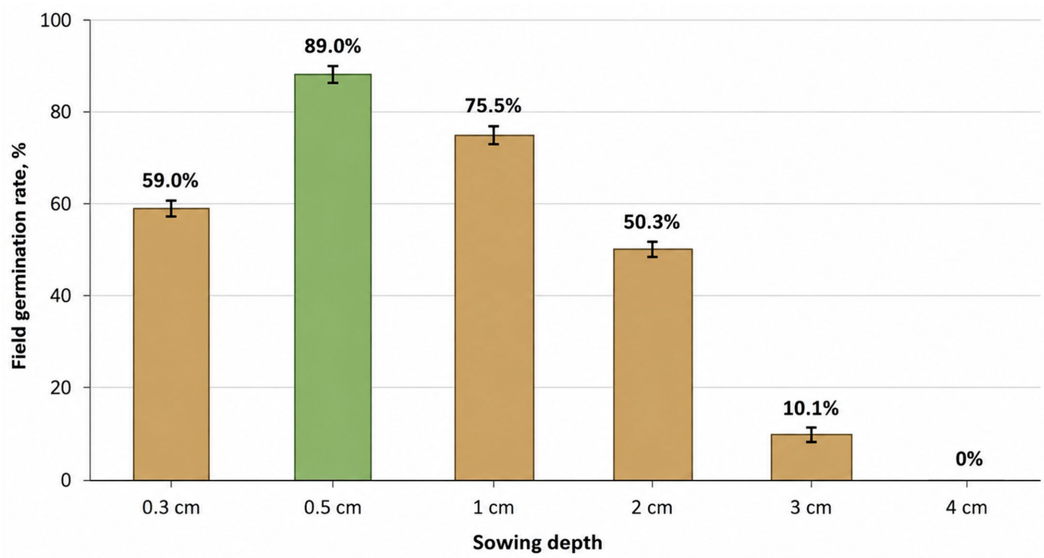

Figure 2. Field germination rate of *Origanum tyttanthum* Gontsch. seeds as a function of sowing depth. Bars show means ± SE (n = 100 seeds per depth); germination was completely suppressed at 4 cm.

3.3. Comparison of Sowing-Date and Sowing-Depth Results

Sowing date and sowing depth were evaluated in two separate experimental series rather than in a combined factorial design, so the present study cannot test for a statistical interaction between these two factors or directly demonstrate that a particular combination of date and depth maximizes emergence. Considered side by side, however, the two series show a similar qualitative pattern: the highest germination rate within each series was recorded at an intermediate treatment level rather than at either extreme—mid-October sowing among the six dates tested (89.5%), and a shallow 0.5 cm depth among the six depths tested (89.0%). This parallel is presented here as a descriptive observation rather than as evidence of a shared underlying mechanism or a tested joint optimum, and later sowing dates together with greater sowing depths were both associated with lower germination in their respective series. A factorial trial that varies sowing date and sowing depth simultaneously would be required to test directly whether their effects interact and whether a specific combination of the two maximizes field emergence, and we recommend this as a priority for future work.

4. Discussion

The present results demonstrate that both sowing date and sowing depth are major determinants of field establishment success in *Origanum tyttanthum*, a pattern broadly consistent with findings for other small-seeded Lamiaceae and related taxa. The superior performance of mid-October sowing over both early-October and spring sowing suggests that *O. tyttanthum* seeds benefit from a period of natural, in-soil overwintering that is functionally analogous to the artificial cold, moist stratification applied in this study. A comparable benefit of early autumn sowing, immediately following seed collection, was reported for hazelnut (Corylus avellana), in which sowing date strongly affected the following spring's seedling emergence and interacted with warm and cold moist stratification treatments to maximize dormancy breakage [17]. The progressive decline in germination observed here with delayed spring sowing (from 60.65% at the earliest date to 50.05% at the latest) may similarly reflect a narrowing window of favorable soil moisture and temperature conditions as the spring season advances, consistent with the general sensitivity of sowing-date responses to prevailing soil temperature and moisture documented across a wide range of crop and wild species.

The pronounced, inverse relationship between sowing depth and germination observed in this study is consistent with a substantial body of seed ecology literature on small-seeded species. In a comparative study of thirteen annual Mediterranean species, the decline in germination with burial depth was found to be considerably steeper for small-seeded than for large-seeded species, reflecting the more limited carbohydrate reserves available to small seeds for supporting hypocotyl elongation through the soil profile [16]. An essentially complete inhibition of germination at greater sowing depths, closely paralleling the results obtained here for *O. tyttanthum* at 4 cm, has likewise been reported for the related Lamiaceae species Salvia verbenaca, in which even a shallow burial depth of 2 cm was sufficient to fully suppress germination in both varieties examined [15]. Because Origanum seeds are very small and possess minimal endosperm reserves, the optimal sowing depth identified in the present study (approximately 0.5 cm) is well within the range typically recommended for small-seeded Lamiaceae taxa, and depths beyond 2 - 3 cm should be avoided in practical cultivation.

The use of cold, moist-sand stratification in the present study, motivated by the physiological dormancy known to affect the seeds of many wild Lamiaceae species, is consistent with the broader recognition that seed dormancy in many wild Lamiaceae species is physiological in nature and can be substantially alleviated by an appropriate period of cold stratification [8]. Similar stratification-related improvements in germination performance have been documented for other medicinal and aromatic plants, and appropriate storage and pre-treatment protocols are now recognized as essential components of seed-based propagation programs for wild medicinal species more broadly [18] [20] [21]. Seed-associated microbiota may further influence germination and seedling vigor in Origanum species; recent work on Origanum heracleoticum has revealed a diverse endophytic bacterial community residing within the seed coat that may be vertically transmitted to seedlings and could represent an additional, currently unexplored factor shaping field establishment success in this genus [22] [23].

From an applied perspective, these findings have direct relevance for the introduction and domestication of *O. tyttanthum* as a cultivated medicinal crop in Uzbekistan. Successful domestication of wild aromatic Lamiaceae species elsewhere has similarly depended on establishing reliable seed-based propagation protocols as a first step, as illustrated by long-term domestication programs for Agastache species in Mexico [4] and for numerous wild medicinal and aromatic plants in the eastern Mediterranean region. Given that Uzbekistan hosts substantial reserves of wild medicinal plant diversity that remain largely uncultivated [2] [3], the sowing-date and sowing-depth recommendations established here provide a practical, evidence-based starting point for scaling up *O. tyttanthum* propagation on irrigated sierozem soils.

Several limitations of the present study should be acknowledged. First, the germination data reported here correspond to the initial (2021 autumn / 2022 spring) sowing cycle of the ongoing three-year introduction trial; germination outcomes for the subsequent autumn 2022 and 2023 sowing cycles were not available for inclusion in the present analysis and should be reported separately once complete, to confirm the consistency of the observed sowing-date effect across years with differing weather conditions. Second, because inferential statistical testing (e.g., ANOVA) was not performed on the present dataset, the treatment comparisons reported here should be regarded as descriptive rather than confirmatory; we recommend that future replicated trials of this species formally test sowing date, sowing depth, and year effects, and their interactions, using appropriate mixed-model or analysis-of-variance approaches. Third, the row-spacing schemes (45 × 30 cm, 60 × 30 cm, and 90 × 30 cm) used across the wider introduction trial were not evaluated as an independent factor in the present analysis and represent a priority for future investigation, given their likely relevance for optimizing plant density and long-term stand productivity. Finally, the present study addressed only field emergence; subsequent research should extend these findings to seedling survival, vegetative growth, and, ultimately, essential oil yield and composition under the sowing regimes identified here as optimal.

5. Practical Recommendations for Propagation

On the basis of the present findings, three practical recommendations can be made for the generative propagation of *O. tyttanthum* under conditions comparable to those of the Samarkand region. First, freshly collected or short-term-stored seed should be subjected to cold, moist-sand stratification for approximately 40 - 45 days prior to sowing, as this practice is recommended for overcoming physiological seed dormancy in Lamiaceae species. Second, field sowing should be scheduled for mid-October wherever local climatic conditions permit, since this timing produced the highest germination rate observed in the present trial and allows seeds to undergo a period of natural overwintering broadly analogous to artificial stratification. Third, seeds should be sown shallowly, at a depth of approximately 0.3 - 0.5 cm, and under no circumstances deeper than 2 cm, since deeper sowing sharply reduced and ultimately eliminated germination. Where mechanized sowing equipment is used, calibration to achieve consistent shallow placement is likely to be more important for this species than for larger-seeded crops, given the steepness of the depth-response relationship documented here.

These recommendations are broadly consistent with agrotechnical guidance developed for other small-seeded medicinal Lamiaceae taxa, for which shallow, surface, or near-surface sowing combined with adequate but not excessive soil moisture is generally advised [14] [15]. At the same time, the present results should be treated as provisional pending confirmation across the remaining years of the ongoing introduction trial and, ideally, formal statistical validation through replicated, randomized field experiments incorporating sowing date, sowing depth, and year as explicit experimental factors.

The steepness of the observed depth response may also reflect specific properties of the irrigated sierozem soils on which the trial was conducted. These soils are characterized by a loam-dominated mechanical composition and a tendency toward surface crusting following irrigation or rainfall, particularly where organic matter content is low [19]. Surface crusting can impede the emergence of small-seeded species even under otherwise favorable moisture and temperature conditions, since the mechanical resistance offered by a crusted surface layer may exceed the limited force that a small, energy-poor hypocotyl can exert during emergence. Under such conditions, seeds sown very close to the surface (0.3 - 0.5 cm) are more likely to avoid this constraint than seeds sown at greater depth, which must additionally overcome the crust from below after elongating through several centimeters of soil. This soil-specific mechanism, in combination with the more general seed-size-related constraints on hypocotyl elongation discussed above [8] [16], likely contributes jointly to the sharp decline in field germination beyond 1 cm reported here.

Looking beyond field emergence, an important direction for future work is to determine whether the sowing regime that maximizes germination also maximizes downstream indicators of crop quality, such as seedling vigor, survival to flowering, biomass accumulation, and essential oil content and composition [24] [25]. In many Lamiaceae species, early-season vigor established at the seedling stage carries forward into later differences in canopy development and secondary metabolite accumulation, so it cannot simply be assumed that the sowing date and depth identified here as optimal for germination will also prove optimal for raw-material yield; this question can only be resolved by following the same experimental cohorts through to harvest in subsequent seasons of the ongoing trial.

6. Conclusion

This study provides the first field-based, quantitative assessment of how sowing date and sowing depth affect the seed germination of *Origanum tyttanthum* Gontsch. under irrigated typical grey soil (sierozem) conditions in the Samarkand region of Uzbekistan. Mid-October sowing produced the highest field germination rate (89.5%), substantially exceeding both earlier and later autumn sowing dates as well as all spring sowing dates tested. Shallow sowing at approximately 0.5 cm depth maximized germination (89.0%), while germination declined sharply with increasing depth and was fully suppressed at 4 cm. Pre-sowing cold, moist-sand stratification for 40 - 45 days was applied to overcome physiological seed dormancy, consistent with practices recommended for other medicinal Lamiaceae species; the specific magnitude of this effect for *O. tyttanthum* was not quantified in the present trial and should be established in future controlled comparisons. Taken together, these findings indicate that a combination of mid-October sowing, shallow sowing depth (0.3 - 0.5 cm), and pre-sowing stratification represents the most favorable agrotechnical regime for the generative propagation of *O. tyttanthum*, and they provide a practical foundation for scaling up the introduction and cultivation of this medicinal species in the arid and semi-arid regions of Central Asia.

Data Availability Statement

The germination datasets generated and analyzed during the reported sowing-date and sowing-depth trials are available from the corresponding author upon reasonable request. Data from the subsequent (autumn 2022 and 2023) sowing cycles of the ongoing three-year introduction trial will be made available following completion and separate reporting of that work.

Conflicts of Interest

The author declares no conflict of interest.

References

[1] Rakhmonov, V., Turdalieva, K., Bobokandov, N., Kobulova, B., Mustanov, S., *et al.* (2026) The Effect of Biotechnological Treatment Using Vascular Aquatic Plants Azolla (*Azolla caroliniana*) and Duckweed (Lemna Minor) on Changes in Polluted Water Parameters. *International Journal of Agriculture and Biosciences*, **15**, 1095-1108. https://doi.org/10.47278/journal.ijab/2026.023

[2] Hamrayeva, M., Bobokandov, N., Rakhmonov, V., Isomov, E., *et al.* (2025) Effect of Different Lighting Environments on the Biomass and Dry Matter Content of Raw Materials of *Chelidonium majus* L. (Papaveraceae) under Cultural Conditions. *International Journal of Agriculture and Biosciences*, **14**, 908-916.

[3] Isikov, V.P., Rabotyagov, V.D., Khlypenko, L.A., *et al.* (2009) Introduction and Breeding of Aromatic and Medicinal Plants: Methodological Aspects. Nikitsky Botanical Garden, 110 p.

[4] Isomov, E., Nomozova, Z., Djumayeva, G., Bobokandov, N. and Tashpulatov, Y. (2024) Anatomical Structure of Vegetative Organs of Artichoke Green Gold Variety (in Medium Saline Soil Conditions). *E3S Web of Conferences*, **510**, Article 01008. https://doi.org/10.1051/e3sconf/202451001008

[5] Semenzato, G., Faddetta, T., Falsini, S., Del Duca, S., Esposito, A., Padula, A., *et al.* (2022) Endophytic Bacteria Associated with *Origanum heracleoticum* L. (Lamiaceae) Seeds. *Microorganisms*, **10**, Article 2086. https://doi.org/10.3390/microorganisms10102086

[6] Semenzato, G. and Fani, R. (2024) Endophytic Bacteria: A Sustainable Strategy for Enhancing Medicinal Plant Cultivation and Preserving Microbial Diversity. *Frontiers in Microbiology*, **15**, Article 1477465. https://doi.org/10.3389/fmicb.2024.1477465

[7] Stefanakis, M.K., Giannakoula, A.E., Ouzounidou, G., Papaioannou, C., Lianopoulou, V. and Philotheou-Panou, E. (2024) The Effect of Salinity and Drought on the Essential Oil Yield and Quality of Various Plant Species of the Lamiaceae Family (*Mentha spicata* L., *Origanum dictamnus* L., *Origanum onites* L.). *Horticulturae*, **10**, Article 265. https://doi.org/10.3390/horticulturae10030265

[8] Abduraimov, O.S., Li, W., Shomurodov, H.F. and Feng, Y. (2023) The Main Medicinal Plants in Arid Regions of Uzbekistan and Their Traditional Use in Folk Medicine. *Plants*, **12**, Article 2950. https://doi.org/10.3390/plants12162950

[9] Rakhmonov, V., Turdalieva, K., Bobokandov, N., Isomov, E., *et al.* (2025) Intensive Cultivation of Vascular Aquatic Plants in the Conditions of the Central Regions of Uzbekistan and Preparation of Feed for Herbivorous Fish. *International Journal of Agriculture and Biosciences*, **14**, 1088-1097.

[10] Stoian, V.A., Gâdea, Ș., Vidican, R., Balint, C., Stoian, V., Vâtcă, A., *et al.* (2024) Seed Priming Methods Tested on *Salvia officinalis* L. Germination According to BBCH Scale. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **52**, Article 13676. https://doi.org/10.15835/nbha52213676

[11] Tiwari, R.S., Chandra, K.K., Dubey, S. and Tripathi, S. (2022) Influence of Packaging Materials and Storage Conditions on Seed Germination Ability and Biochemical Changes in Some Medicinal Plants of Indian Forests. *Frontiers in Forests and Global Change*, **5**, Article 868237. https://doi.org/10.3389/ffgc.2022.868237

[12] Turdaliev, A., Askarov, K., Abakumov, E., Makhkamov, E., Rahmatullayev, G., Mamajonov, G., *et al.* (2023) Biogeochemical State of Salinized Irrigated Soils of Central Fergana (Uzbekistan, Central Asia). *Applied Sciences*, **13**, Article 6188. https://doi.org/10.3390/app13106188

[13] Bobokandov, N. (2024) Ecological Analysis of *Leontice* L. Species Distributed in the Navoi Region, Kyzyl-Kum Desert (Uzbekistan). *American Journal of Plant Sciences*, **15**, 307-315. https://doi.org/10.4236/ajps.2024.155022

[14] Carrillo-Galván, G., Bye, R., Eguiarte, L.E., Cristians, S., Pérez-López, P., Vergara-Silva, F., *et al*. (2020) Domestication of Aromatic Medicinal Plants in Mexico: Agastache (Lamiaceae)—An Ethnobotanical, Morpho-Physiological, and Phytochemical Analysis. *Journal of Ethnobiology and Ethnomedicine*, **16**, Article No. 22. https://doi.org/10.1186/s13002-020-00368-2

[15] Batbat, A., Habbadi, K., El Hachlafi, N., El Allaoui, N., Yahyaoui, H., Ferioun, M., *et al*. (2024) Unveiling Germination Conditions for Origanum Elongatum: Strategic Insights into Temperature, Salinity, and pH for Agricultural Propagation and Conservation Management. *Ecological Frontiers*, **45**, 352-361. https://doi.org/10.1016/j.ecofro.2024.10.015

[16] Baskin, J.M. and Baskin, C.C. (2004) A Classification System for Seed Dormancy. *Seed Science Research*, **14**, 1-16. https://doi.org/10.1079/ssr2003150

[17] Belmehdi, O., El Harsal, A., Benmoussi, M., Laghmouchi, Y., Skali Senhaji, N. and Abrini, J. (2018) Effect of Light, Temperature, Salt Stress and Ph on Seed Germination of Medicinal Plant Origanum Elongatum (Bonnet) Emb. & Maire. *Biocatalysis and Agricultural Biotechnology*, **16**, 126-131. https://doi.org/10.1016/j.bcab.2018.07.032

[18] Javaid, M.M., Florentine, S., Ali, H.H. and Weller, S. (2018) Effect of Environmental Factors on the Germination and Emergence of *Salvia verbenaca* L. Cultivars (Verbenaca and Vernalis): An Invasive Species in Semi-Arid and Arid Rangeland Regions. *PLOS ONE*, **13**, e0194319. https://doi.org/10.1371/journal.pone.0194319

[19] Libus, O.K., Rabotyagov, V.D., Kutko, S.P. and Khlypenko, L.A. (2004) Essential Oil and Spicy-Aromatic Plants. Aylant, 270 p.

[20] Khojimatov, O.K., Khamaraeva, D.T., Khujanov, A.N. and Bussmann, R.W. (2020) An Overview of Ethnomedicinal Plants of Uzbekistan. *Ethnobotany Research and Applications*, **20**, 1-19. https://doi.org/10.32859/era.20.08.1-19

[21] Limón, Á. and Peco, B. (2016) Germination and Emergence of Annual Species and Burial Depth: Implications for Restoration Ecology. *Acta Oecologica*, **71**, 8-13. https://doi.org/10.1016/j.actao.2016.01.001

[22] Farashah, H.D., Tavakkol Afshari, R., Sharifzadeh, F. and Chavoshinasab, S. (2011) Germination Improvement and α-Amylase and β-1,3-Glucanase Activity in Dormant and Non-Dormant Seeds of Oregano (*Origanum vulgare*). *Australian Journal of Crop Science*, **5**, 421-427.

[23] García-Caparrós, P., Romero, M.J., Llanderal, A., Cermeño, P., Lao, M.T. and Segura, M.L. (2019) Effects of Drought Stress on Biomass, Essential Oil Content, Nutritional Parameters, and Costs of Production in Six Lamiaceae Species. *Water*, **11**, Article 573. https://doi.org/10.3390/w11030573

[24] Nazir, R., Qadir, R.U., Yousuf, M., Sultan, P., Nawchoo, I.A. and Hassan, Q.P. (2024) Exploring the Efficacy of Hormonal Treatments and Pre-Sowing Techniques on Seed Germination of Salvia Rosmarinus Spenn. *Journal of Applied Research on Medicinal and Aromatic Plants*, **42**, Article 100564. https://doi.org/10.1016/j.jarmap.2024.100564

[25] Pipinis, E., Stampoulidis, A., Milios, E., Kitikidou, K., Akritidou, S., Theodoridou, S., *et al*. (2018) Effects of Seed Moisture Content, Stratification and Sowing Date on the Germination of Corylus Avellana Seeds. *Journal of Forestry Research*, **31**, 743-749. https://doi.org/10.1007/s11676-018-0852-x