

A comprehensive review on propagation techniques of the medicinal herb *Ocimum tenuiflorum* L.

Thi-Hoan Luong¹, Dang-Minh-Chanh Nguyen^{2*}

¹National Institute of Medicinal Materials, 3B Quang Trung Street, Cua Nam Ward, Hanoi, Vietnam

²Nafods Research and Development Institute for Agriculture, 162A Nguyen Tuan Street, Thanh Xuan Ward, Hanoi, Vietnam

Received 28 July 2025; revised 4 November 2025; accepted 6 November 2025

Abstract:

Ocimum tenuiflorum L. (holy basil) is an economically important medicinal plant widely valued for its diverse therapeutic properties and applications in traditional medicine, food, cosmetics, and pharmaceuticals. The growing global demand for holy basil and its essential oil has driven interest in efficient propagation methods to ensure a consistent supply of high-quality planting materials. This review provides a comprehensive analysis of sexual propagation, clonal propagation, and tissue culture techniques, critically evaluating their advantages, limitations, and scalability for commercial production. Key production bottlenecks, including low seed germination uniformity, limited rooting efficiency in cuttings, and high tissue culture costs, are identified, and strategies are proposed to optimise propagation efficiency and reduce costs. These insights provide a foundation for future breeding programs, sustainable cultivation, and industrial applications of *O. tenuiflorum*.

Keywords: clonal propagation, holy basil, *Ocimum tenuiflorum*, sexual propagation, tissue culture.

Classification numbers: 3.1, 3.5

1. Introduction

Ocimum tenuiflorum L. (holy basil), a perennial shrub belonging to the family Lamiaceae, is a highly valued medicinal and aromatic plant widely used in traditional medicine, pharmaceuticals, cosmetics, and functional foods. Rich in bioactive compounds, particularly essential oils, *O. tenuiflorum* has demonstrated diverse therapeutic properties, including anti-inflammatory, antimicrobial, antioxidant, anticancer, and anti-ulcer activities [1-3]. The essential oil content of *O. tenuiflorum* typically ranges from approximately 0.3% in fresh material to 0.5% in dried leaves, with eugenol (>70%), methyl eugenol (≈12%), and β-caryophyllene identified as the predominant constituents [4]. Recent comprehensive phytochemical and pharmacological analyses of *Ocimum* species have revealed considerable diversity in essential oil composition, emphasising the major roles of eugenol, methyl eugenol, and β-caryophyllene in determining biological activity [5]. These findings highlight the economic and therapeutic significance of producing high-quality, chemically consistent plant material through standardised and reliable propagation techniques.

The global holy basil essential oil market was valued at approximately USD 14.5 million in 2024 and is projected to grow at a compound annual growth rate

(CAGR) of 10.1% through 2033, reflecting rising demand in the pharmaceutical, nutraceutical, and personal care industries [6]. The growing commercial utilisation of *O. tenuiflorum* and its essential oil underscores its expanding economic importance and the need for efficient, large-scale propagation systems. Several studies have reported that the commercial cultivation of *O. tenuiflorum* has generated significant economic benefits for farming communities in India, Egypt, and other producing countries [7, 8]. Originating in India, this species is now widely cultivated across Asia, North America, and Europe, with key production regions in the United States, Canada, Iran, Thailand, and Vietnam [2, 3, 8].

In Vietnam, holy basil is increasingly cultivated in provinces (before the administrative merger) such as Quang Tri, Nghe An, Thanh Hoa, Ha Nam, Bac Giang, and Phu Tho to supply raw materials for medicine, healthcare products, cosmetics, and natural perfume production [9, 10]. However, large-scale production faces several critical challenges. Among these, the lack of genetically uniform, high-quality planting materials remains a major bottleneck, as the species is primarily propagated through seed sowing. While this method is simple and inexpensive, it often results in genetic variability, inconsistent seedling quality, and lower essential oil yields.

*Corresponding author: Email: ndmchanh75@gmail.com

To meet the increasing market demand and ensure sustainable cultivation, it is essential to develop and optimise efficient propagation techniques, including sexual propagation, vegetative propagation, and tissue culture. A systematic evaluation of each method's strengths, limitations, and practical applications is required to identify strategies that balance cost-effectiveness and product uniformity.

Despite the growing economic and medicinal significance of *O. tenuiflorum*, there has been no comprehensive review systematically comparing available propagation techniques and assessing their industrial applicability. This review addresses this gap by (i) synthesising current research on propagation methods, (ii) analysing the advantages and limitations of each approach, and (iii) proposing future perspectives to enhance propagation efficiency. These insights aim to serve as a valuable reference for researchers, farmers, and industry stakeholders involved in the sustainable production and commercialisation of holy basil.

2. Propagation techniques

2.1. Sexual propagation by seeds

Seed propagation is one of the simplest and most widely practised methods for *O. tenuiflorum*. Successful seed-based propagation depends on several factors affecting germination such as temperature, viability, and dormancy status [11]. While inexpensive and technically simple, seed propagation often produces variable seedlings that differ in morphology and bioactive compound content, leading to inconsistent yield and oil quality.

Results summarised in Table 1 demonstrate that different pre-sowing treatments significantly influenced the germination percentage, seedling vigour, and radicle emergence rate of *O. tenuiflorum* seeds. Among the tested methods, gibberellic acid (GA_3) seed soaking (0.05-0.1% for 24 h) under alternating temperatures of 20-30°C resulted in the highest germination rate (>90%), superior seedling vigour, and the fastest radicle emergence, as reported by S. Singh, et al. (2024) [12]. These findings are consistent with the established role of GA_3 in breaking seed dormancy by promoting α -amylase activity, which facilitates starch hydrolysis and enhances embryo growth.

Following GA_3 treatment, KNO_3 priming (0.4%) combined with green LED illumination in a plant factory system showed germination rates above 85% [13, 14]. KNO_3 is known to act as an osmopriming agent, improving water uptake and providing nitrate signals that stimulate cytokinin biosynthesis, which in turn promotes seed germination. Interestingly, seedling vigour was further enhanced under green LED light, likely due to its effects on phytochrome-mediated photomorphogenesis. These

Table 1. Effects of different pre-sowing treatments on germination of *O. tenuiflorum*.

Method/treatment	Key parameters (concentration, temperature, duration, spectrum)	Environment	Reported effect on germination/seedling vigour	References
GA_3 seed soaking	GA_3 0.05-0.1% for 24 h; alternating 20-30°C	Controlled chamber	Highest germination >90% and greatest seedling vigour; fastest radicle emergence	[12]
KNO_3 priming+LED light spectrum	KNO_3 0.2-0.4%; LED spectra (white, green, red/blue)	Plant factory with artificial lighting (PFAL) system	0.4% KNO_3 under green LED enhanced germination (>85%) and seedling growth	[13, 14]
Hot-water treatment	Hot water treatment at 25°C for 5 min	Seed germination and seedling growth experiment	Improved germination and seedling growth responses depending on <i>Ocimum</i> species	[15]
Mechanical scarification	Gentle sandpaper abrasion before sowing	Nursery/lab tests	Germination 65-75% depending on seed lot; results inconsistent across cultivars	[15]
Acid scarification (H_2SO_4)	Immersion 30-60 sec, then rinsing in distilled water	Laboratory	Marked increase (80-90%) but requires strict safety control and timing	[15]
Combined treatments (GA_3 + KNO_3 or hot water)	Alternating temperature regimes with combined treatments	Growth chamber	Synergistic effects; combined treatments consistently outperformed single ones	[12, 15]
Thermal treatment	Exposure to 50°C for 2 h (before sowing)	Laboratory	Highest germination rate at 50°C; higher temperatures reduced viability	[10]
Temperature regime optimisation	20-40°C gradient tested on multiple cultivars	Growth chamber	Maximum germination occurred at 30°C (88%) in CIM-Angana and 25°C (72%) in CIM-Ayu; at 40°C, most seedlings were abnormal	[16]
Baseline (control)	Untreated seeds under ambient lab conditions	Laboratory	Lower germination (50-70%); slower and uneven seedling emergence	[12, 15]

findings suggest that integrating nutrient priming with optimised light spectra could represent a scalable, controlled-environment strategy for large-scale propagation of *O. tenuiflorum*.

Thermal treatments also improved germination efficiency. Hot water treatment at 25°C for 5 min enhanced germination and seedling growth responses in *Ocimum* species, including *O. tenuiflorum* [15]. Similarly, thermal pretreatment at 50°C for 2 h yielded a marked improvement in germination rates, with T.H. Luong, et al. (2019) [10] reporting optimal performance at this

temperature. These findings suggest that moderate heat stress likely softens the seed coat, enhances water permeability, and accelerates metabolic activation. However, the beneficial effect of heat treatment is likely temperature- and duration-dependent, and excessively intense thermal treatments may adversely affect seed viability. Therefore, optimisation of both temperature and exposure duration is necessary to maximise germination while avoiding heat-induced damage to the seeds.

Recent studies have also highlighted the benefits of combined dormancy-breaking techniques. Treatments that integrate GA₃ soaking with KNO₃ priming or hot water exposure consistently produced better germination and seedling vigour compared with single treatments, suggesting a synergistic effect among hormonal, chemical-, and temperature-based methods [12, 15]. Additionally, temperature-regime experiments showed that germination of *O. tenuiflorum* was favoured at moderate temperatures, with maximum germination occurring at 30°C in CIM-Angana (88%) and at 25°C in CIM-Ayu (72%), whereas exposure to 40°C resulted in abnormal development of most seedlings [16].

In summary, GA₃ soaking and KNO₃ priming are the most effective and reproducible strategies for improving *O. tenuiflorum* germination and establishing uniform seedlings for large-scale production. However, integrating these treatments with controlled environmental conditions, including temperature optimisation and LED-assisted germination systems, can further enhance success. These findings are highly relevant for commercial propagation where uniform seedlings directly contribute to higher biomass accumulation and increased essential oil yield.

2.2. Clonal propagation by stem cutting

Clonal propagation through stem cuttings is a simple and cost-effective method that produces uniform progeny genetically identical to the mother plant. The success of rooting depends on multiple factors, including the cultivar, the physiological stage of the mother plant, environmental conditions, and the application of plant growth regulators (PGRs) [18].

Several studies have demonstrated that the application of auxins, particularly indole-3-butyric acid (IBA) and indole-3-acetic acid (IAA), significantly enhances rooting performance. For instance, treating cuttings with IBA at 1000 ppm increased rooting success up to 90%, indicating its strong influence on root initiation [19]. Similarly, Y.J. Lim, et al. (2013) [20] reported that both the type of cutting and auxin concentration are critical: 20 cm-long apical cuttings treated with IAA achieved the highest rooting rate (82.48%), whereas IBA treatment resulted in a moderate rate (62.28%). Moreover, 20 cm middle cuttings treated with IAA at 2000 ppm showed superior growth compared to apical cuttings, demonstrating that cutting position affects overall plant performance.

Table 2. Effects of different approaches in clonal propagation by stem cutting of *O. tenuiflorum* and related *Ocimum* species.

Approach/treatment	Substrate used	Hormonal/biostimulant treatment	Rooting success (%)	Shoot growth/survival (%)	
Stem cuttings treated with auxin	Inert medium (perlite:vermiculite, 1:1)	IBA+NAA, basal quick-dip	100	-	[21]
Stem cuttings treated with plant-derived biostimulant	Inert medium (perlite:vermiculite, 1:1)	Plant-derived biostimulant	100	-	[21]
Apical cuttings	Sand	IBA 1000 ppm	75	82	[9]
Stem cuttings		NAA under different light conditions	-	-	[20]

Note: NAA: 1-Naphthaleneacetic acid; IBA: indole-3-butyric acid.

As summarised in Table 2, auxin treatment and the choice of rooting substrate can substantially influence the rooting performance of *Ocimum* cuttings. In *O. tenuiflorum*, T.H. Luong, et al. (2019) [9] evaluated apical cuttings rooted in sand with IBA treatment and reported 75% rooting success and 82% shoot growth or survival, demonstrating the feasibility of using apical cuttings for clonal propagation of this species. These results also indicate that auxin-assisted stem cutting can provide a practical alternative to seed propagation for maintaining selected plant material. However, rooting performance may vary depending on cutting type, physiological condition, rooting substrate, and auxin concentration.

Supporting evidence from a related *Ocimum* species was reported by H.J. Kim, et al. [21], who obtained 100% rooting in *O. basilicum* cuttings treated with either auxin or a plant-derived biostimulant when propagated in an inert perlite-vermiculite (1:1, v/v) substrate. These findings highlight the potential of combining appropriate rooting substrates with exogenous treatments to promote adventitious root formation. Nevertheless, because the results in [21] were obtained with *O. basilicum*, they should be considered complementary evidence rather than directly transferable results for *O. tenuiflorum*.

Overall, the available evidence suggests that rooting success in *Ocimum* can be improved through appropriate auxin treatments, suitable rooting substrates, and optimised culture conditions. However, responses vary according to species, explant or cutting type, physiological maturity, rooting medium, and treatment concentration. Therefore, propagation protocols developed for *O. basilicum* or other *Ocimum* species should be experimentally validated before being applied to *O. tenuiflorum*. For commercial production, the integration of optimised stem-cutting and *in vitro* propagation protocols may provide complementary approaches for producing uniform planting material and supporting a sustainable supply of raw materials for medicinal and essential-oil applications.

2.3. Tissue culture propagation (in vitro)

Tissue culture-based micropropagation offers a highly efficient and reliable method for producing genetically uniform, disease-free, and high-quality planting material of *O. tenuiflorum*. This approach overcomes the limitations of conventional seed germination and stem cutting propagation, which are often constrained by low germination rates, seasonal dependence, and inconsistent rooting success. *In vitro* techniques have been widely applied for large-scale commercial production, germplasm conservation, and genetic improvement of medicinal plants [19].

The success of *in vitro* propagation largely depends on several factors, including the explant type, nutrient medium composition, PGRs, and environmental conditions such as light, temperature, and humidity [22]. In *O. tenuiflorum*, nodal segments, shoot tips, and leaf explants are commonly used as starting materials due to their high morphogenic potential and reduced contamination risk [23].

Table 3. Effects of different approaches in propagation via tissue culture of *O. tenuiflorum*.

Explant type	PGR combination	Shoots/explant	Rooting success (%)	Reference
Nodal explants cultured	Half-strength MS medium; IBA 1.0 mg/l	9.57	80.1	[19]
Nodal explants, purple-leaf morphotype	BA 0.5 mg/l	5.01±0.11	-	[23]
Nodal explants, green-leaf morphotype	BA 1.0 mg/l	7.03±0.10	-	[23]
Nodal segments of <i>O. sanctum</i>	BAP 2.0 mg/l + NAA 0.5 mg/l	9.0	-	[24]
Shoot tips of <i>O. sanctum</i>	BAP 2.0 mg/l + NAA 0.5 mg/l	7.0	-	[24]
Nodal explants with lateral buds of <i>O. basilicum</i>	Airlift bioreactor	-	-	[25]

Note: BA/BAP: 6-benzylaminopurine; NAA: α -naphthaleneacetic acid; MS: Murashige and Skoog medium.

The results summarised in Table 3 indicate that explant type and PGR composition are major determinants of *in vitro* multiplication efficiency in *Ocimum*. Among the studies directly conducted on *O. tenuiflorum*, S. Saha, et al. (2016) [23] demonstrated that nodal explants were highly responsive to cytokinin-based media. The highest shoot multiplication was 5.01±0.11 shoots per explant in the purple-leaf morphotype on medium containing 0.5 mg/l BA, whereas the green-leaf morphotype produced 7.03±0.10 shoots per explant on medium containing 1.0 mg/l BA. These differences between morphotypes suggest that genotype or physiological characteristics of the source material may influence the response to PGRs. The study further confirmed the genetic stability of the regenerated plants based on RAPD and ISSR analyses, supporting the suitability of nodal explants for clonal propagation of *O. tenuiflorum* [23].

Comparable responses have also been reported in *O. sanctum*. M.A.H.M. Jamal, et al. (2016) [24] found that nodal

segments were more responsive than shoot tips, with the highest multiplication rate reaching 9 shoots per explant on MS medium supplemented with 2.0 mg/l BAP and 0.5 mg/l NAA. Shoot tips produced a maximum of 7 shoots per explant under the same PGR combination. These findings further support the importance of pre-existing meristematic tissues, particularly nodal segments, for efficient axillary shoot multiplication in *Ocimum*.

The role of culture systems in scaling up propagation should also be considered. S. Kintzios, et al. (2004) [25] demonstrated the feasibility of using a 5-l airlift bioreactor for the culture of nodal explants with lateral buds and leaf-derived suspension cultures of *O. basilicum*. Although this study was conducted on a different *Ocimum* species and did not provide a direct quantitative comparison with conventional micropropagation of *O. tenuiflorum*, it provides evidence that bioreactor systems may facilitate the scale-up of tissue-culture processes in the genus *Ocimum*. Therefore, the application of bioreactor technology to *O. tenuiflorum* represents a promising direction for future research rather than an already established industrial propagation system.

Table 4. Comparison of different propagation techniques for *O. tenuiflorum*.

Criteria	Seed propagation	Clonal propagation (stem cuttings)	Tissue culture (<i>In vitro</i>)
Genetic uniformity	Low; high variability in morphology, yield, and oil composition	High; maintains true-to-type traits	Very high; produces genetically stable clones
Germination/Rooting success	Variable and affected by seed quality and environmental conditions	Generally high under optimised rooting conditions and PGR treatment	High multiplication and regeneration responses can be obtained under optimised culture conditions
Multiplication rate	Low; one seed produces one plant	Moderate; limited by the number of suitable cuttings	Very high; multiple shoots can be produced from a single explant through repeated subculture
Disease management	Risk of seed borne pathogens	Risk of disease transfer from mother plants	Produces disease free plants
Technical requirement	Minimal infrastructure; farmer friendly	Requires basic nursery setup and rooting management	Requires sterile laboratories, trained personnel, and advanced facilities
Cost effectiveness	Low cost, highly accessible	Moderate cost; suitable for nurseries	High initial cost but cost-effective for large-scale production
Scalability	High for bulk cultivation, but uniformity compromised	Limited scalability due to labour intensity	Highly scalable with automation and bioreactor integration
Suitable applications	Germplasm conservation, basic cultivation, breeding programs	Elite cultivar multiplication, medium-scale production, phytochemical uniformity	Industrial scale essential oil production, pharmaceutical grade propagation, germplasm preservation
Time required to obtain plantable seedlings	Depends on seed germination and seedling establishment	Depends on rooting and acclimatisation	Depends on multiplication, rooting, and acclimatisation stages; generally requires a controlled multi-stage process
References	[10, 12, 16]	[9, 18, 19, 21]	[23-25]

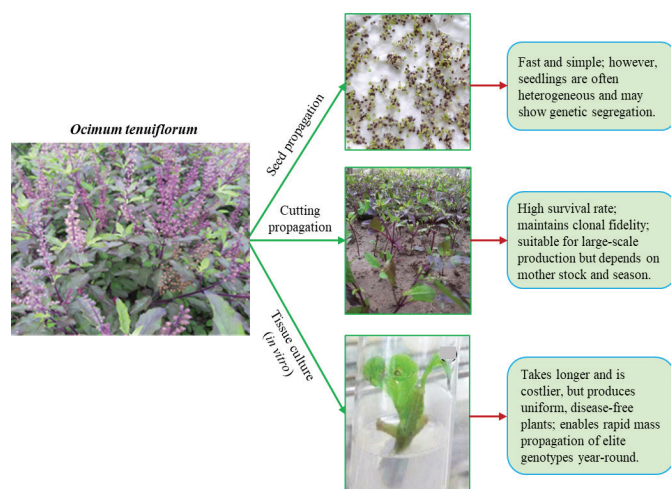


Fig. 1. Schematic diagram of propagation methods of *Ocimum tenuiflorum* L. (compiled by the authors based on the literature reviewed in this study).

Overall, auxin-cytokinin balance plays a pivotal role in optimising shoot induction and rooting. While BAP remains the most commonly used cytokinin, combining it with IBA or NAA at low concentrations produces superior results. Callus-mediated regeneration, although useful for somatic embryogenesis, was comparatively less efficient due to slower shoot elongation rates [18].

3. Analysis, evaluation, and application orientation

Variation in essential oil composition among propagated plants may result from somaclonal variation or culture-induced stress. These observations reinforce the need for optimised propagation systems that preserve both genetic identity and metabolic uniformity.

The efficient propagation of *O. tenuiflorum* is crucial for ensuring the sustainable production of high-quality planting material for medicinal, nutraceutical, and industrial purposes. A comparative assessment of three primary propagation techniques, namely sexual propagation by seeds, clonal propagation by stem cuttings, and tissue culture, was carried out to evaluate their efficiency, limitations, and potential applications as summarised in Table 4 and Fig. 1.

Seed propagation remains the simplest and most economical technique, suitable for germplasm conservation and breeding but limited by low germination rates and high trait variability [10, 12, 16].

Clonal propagation ensures uniformity and consistency in essential oil content, ideal for elite cultivar multiplication, though its scalability is constrained by labour intensity and disease risk [9, 19, 21].

Tissue culture offers an efficient approach for the rapid multiplication of *O. tenuiflorum*, particularly through direct regeneration from nodal explants. Studies on *O. tenuiflorum*

and related *Ocimum* species have demonstrated high shoot multiplication responses under optimized PGR combinations [23, 24]. Bioreactor-based systems have also shown potential for scaling up micropropagation in *Ocimum*, although their application to *O. tenuiflorum* requires further validation [25]. However, tissue culture requires sterile facilities, specialised equipment, and skilled technical personnel, resulting in higher initial costs than conventional propagation methods.

Consistency in essential oil composition is crucial for pharmaceutical and food-grade applications. Studies have shown that variations in propagation techniques and environmental conditions can alter metabolite profiles among *Ocimum* species [5]. Thus, optimising propagation protocols that preserve chemotype stability is essential to maintain product quality across cultivation cycles.

To enhance production efficiency and scalability, an integrated propagation strategy is recommended. The first step involves using seed propagation for the selection of elite genotypes to maintain genetic diversity and identify plants with desirable traits. In the second step, *in vitro* micropropagation can be applied to rapidly multiply disease-free and high-value clones while maintaining uniformity in morphology and phytochemical composition. In the final step, large-scale field production can be achieved economically by using stem cutting propagation, which enables the distribution of uniform planting material to farmers and nurseries.

This integrated approach combines the strengths of all three techniques, thereby improving the quality, consistency, and scalability of *O. tenuiflorum* cultivation. It provides a sustainable framework that balances genetic diversity, phytochemical stability, cost-effectiveness, and production efficiency, supporting both small-scale growers and industrial producers.

4. Conclusions

The optimal propagation method for *O. tenuiflorum* depends on production objectives, available resources, and intended applications. Seed propagation is simple and economical but limited by genetic variability among seedlings. Stem cutting propagation with IBA treatment provides higher uniformity and survival rates, making it suitable for nursery-level production. In contrast, tissue culture propagation is more resource-intensive yet ensures genetic stability and produces disease free plants that meet the requirements of high value industrial uses.

Future studies should focus on optimising substrate composition, hormonal combinations, and seasonal conditions, as well as developing standardised and cost-effective tissue culture protocols. The integration of conventional propagation with controlled environment cultivation and bioreactor-assisted micropropagation will be essential to achieve sustainable, large-scale production of high-quality *O. tenuiflorum* planting materials.

CRediT author statement

Thi-Hoan Luong: Conceptualisation, Methodology, Data analysis, Software, Data curation, Investigation, Original draft preparation, Writing; Dang-Minh-Chanh Nguyen: Conceptualisation, Methodology, Data analysis, Writing - Reviewing and Editing.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

References

- [1] M. Gupta, B. Kapoor, R. Gupta, et al. (2021), "Plants and phytochemicals for treatment of peptic ulcer: An overview", *South African Journal of Botany*, **138**, pp.105-114, DOI: 10.1016/j.sajb.2020.11.030.
- [2] D. Singh, P.K. Chaudhuri (2018), "A review on phytochemical and pharmacological properties of holy basil (*Ocimum sanctum* L.)", *Industrial Crops and Products*, **118**, pp.367-382, DOI: 10.1016/j.indcrop.2018.03.048.
- [3] P. Chutimanukul, H. Jindamol, A. Thongtip, et al. (2022), "Physiological responses and variation in secondary metabolite content among Thai holy basil cultivars (*Ocimum tenuiflorum* L.) grown under controlled environmental conditions in a plant factory", *Frontiers in Plant Science*, **13**, DOI: 10.3389/fpls.2022.1008917.
- [4] D.T. Loi (2015), *Vietnamese Medicinal Plants and Remedies*, Medical Publishing House, 1274pp (in Vietnamese).
- [5] O.O. Ferreira, R. Kumar, L.R.R. da Silva, et al. (2025), "Phytochemistry, pharmacological insights, and food science applications of natural bioactive compounds from *Ocimum* species with a focus on essential oils", *Food Front.*, **6**, pp.2081-2107, DOI: 10.1002/fft.2496.
- [6] Spherical Insights (2024), *Global Basil Seed Market Size, Share, and COVID-19 Impact Analysis, by Type (Sweet Basil Seed, Holy Basil Seed, Scented Basil Seed, and Purple Basil Seed), by Application (Cultivation Basil Seeds, Medicinal Basil Seeds), by Distribution Channel (Supermarkets & Hypermarkets, Online Store, Specialty Stores, Others), and by Region (North America, Europe, Asia-Pacific, Latin America, Middle East, and Africa), Analysis and Forecast 2023-2033*, Spherical Insights & Consulting, accessed 2 October 2025.
- [7] M.E. Ibrahim, M.A. Mohamed, H.E. Wahba (2016), "Introduction of *Ocimum tenuiflorum* plant to the Egyptian cultivation", *International Journal of Pharm Tech Research*, **9**, pp.18-24.
- [8] K. Bhattarai, R. Bhattarai, D.R. Pandey, et al. (2024), "A comprehensive review of the phytochemical constituents and bioactivities of *Ocimum tenuiflorum*", *The Scientific World Journal*, **2024(1)**, pp.1-26, DOI: 10.1155/2024/8895039.
- [9] T.H. Luong, N.N. Hoang, T.C. Nghiem, et al. (2019), "Propagating purple basil (*Ocimum tenuiflorum*) by cuttings", *Journal of Agriculture and Rural Development*, **1**, pp.24-29 (in Vietnamese).
- [10] T.H. Luong, N.N. Hoang, D.M.C. Nguyen (2019), "Study on propagation of *Ocimum tenuiflorum* by seeds", *Journal of Vietnam Agricultural Science and Technology*, **1(98)**, pp.64-69 (in Vietnamese).
- [11] S. Tomar, P. Tiwari, I. Kale, et al. (2024), "Revitalising Tulsi growth: Impact of pre-germination treatments on seed quality and seedling performance in Uttar Pradesh's semi-arid zones", *International Journal of Advanced Biochemistry Research*, **8(8)**, pp.987-992, DOI: 10.33545/26174693.2024.v8i8m.1912.
- [12] S. Singh, A. Bhuker, S. Kumar, et al. (2024), "Effects of dormancy-breaking treatments on seed quality parameters in medicinal herb Tulsi (*Ocimum tenuiflorum* L.)", *Seed Research*, **51(1)**, pp.43-49, DOI: 10.56093/sr.v51i1.154668.
- [13] A. Thongtip, K. Mosaleeyanon, S. Korinsak, et al. (2022), "Promotion of seed germination and early plant growth by KNO₃ and light spectra in *Ocimum tenuiflorum* using a plant factory", *Scientific Reports*, **12**, DOI: 10.1038/s41598-022-11001-5.
- [14] A. Thongtip, K. Mosaleeyanon, S. Janta, et al. (2024), "Assessing light spectrum impact on growth and antioxidant properties of basil family microgreens", *Scientific Reports*, **14**, DOI: 10.1038/s41598-024-79529-2.
- [15] S.S. Gahire, S.R. Rathod (2023), "Seed germination and plant growth in *Ocimum* varieties by physical treatment methods", *International Journal for Multidisciplinary Research*, **5(6)**, DOI: 10.36948/ijfmr.2023.v05i06.10762.
- [16] B. Kumar, E. Gupta, R. Yadav, et al. (2014), "Temperature effects on seed germination potential of holy basil (*Ocimum tenuiflorum*)", *Seed Technology*, **36(1)**, pp.75-79.
- [17] U.H. Bhat, M. Uddin, A.S. Chishti, et al. (2024), "Enhancing growth, vitality, and aromatic richness: Unveiling the dual magic of silicon dioxide and titanium dioxide nanoparticles in *Ocimum tenuiflorum* L.", *Frontiers in Plant Science*, **6(15)**, DOI: 10.3389/fpls.2024.1335965.
- [18] H.E. Haddaji, M. Akoudad, A. Skalli, et al. (2024), "Exogenous gibberellin improves the yield and quality of basil (*Ocimum basilicum* L.) and chervil (*Anthriscus cerefolium* L.) plants grown under salinity stress conditions", *Plant Science Today*, **11(2)**, DOI: 10.14719/pst.2666.
- [19] V.G. Gaddagut, R.V. Talluri, P.A. Rao (2015), "In vitro propagation of *Ocimum tenuiflorum* var. CIM AYU from nodal explants", *Journal of Applied BioScience Research*, **6**, pp.1-7.
- [20] Y.J. Lim, S.H. Eom (2013), "Effects of different light types on root formation of *Ocimum basilicum* L. cuttings", *Scientia Horticulturae*, **164**, pp.552-555. DOI: 10.1016/j.scienta.2013.09.057.
- [21] H.J. Kim, K.M. Ku, S.H. Choi, et al. (2019), "Vegetal-derived biostimulant enhances adventitious rooting in cuttings of basil, tomato, and chrysanthemum via brassinosteroid-mediated processes", *Agronomy*, **9(2)**, DOI: 10.3390/agronomy9020074.
- [22] G. Baby, M. Greeshma, M. Rafeekher, et al. (2024), "Advances in micropropagation techniques for aquascaping plants: A comprehensive review", *Archives of Current Research International*, **24(11)**, pp.14-22, DOI: 10.9734/acri/2024/v24i11944.
- [23] S. Saha, T. Dey, S. Adhikari, et al. (2016), "Effects of plant growth regulators on efficient plant regeneration efficiency and genetic stability analysis from two *Ocimum tenuiflorum* L. morphotypes", *Rendiconti Lincei. Scienze Fisiche e Naturali*, **27(4)**, pp.609-628, DOI: 10.1007/s12210-016-0538-2.
- [24] M.A.H.M. Jamal, I.H. Sharif, M.M. Shakil, et al. (2016), "In vitro regeneration of a common medicinal plant, *Ocimum sanctum* L. for mass propagation", *African Journal of Biotechnology*, **15(24)**, pp.1269-1275, DOI: 10.5897/AJB2015.15200.
- [25] S. Kintzios, H. Kollias, E. Straitouris, et al. (2004), "Scale-up micropropagation of sweet basil (*Ocimum basilicum* L.) in an airlift bioreactor and accumulation of rosmarinic acid", *Biotechnology Letters*, **26(6)**, pp.521-523, DOI: 10.1023/B:BILE.0000019561.89044.30.