

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(4): 325-329
www.biochemjournal.com
Received: 25-01-2026
Accepted: 28-02-2026

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Ecological and economic significance of camphor tree (*Cinnamomum camphora*) in the lower hills of Himachal Pradesh: A comprehensive study

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i4Sd.8121>

Abstract

The experiment was conducted during the year 2024-2025 on morphological characteristics, phenological events, and essential oil yield of *Cinnamomum camphora* in the lower Himachal hills, focusing on the subtropical Hamirpur region. Field observations revealed that camphor trees in this area exhibit constrained growth, reaching heights of 12-15 meters, likely due to cooler temperatures and periodic frost stress, in contrast to the taller stature (up to 30 meters) reported in warmer regions. The trees develop a dense, rounded to oval canopy, with ovate to elliptical leaves that are glossy green above and pale beneath, featuring prominent yellow-green veins. Newly emerged leaves in spring display a reddish-bronze colour, a potential adaptation to seasonal light and temperature changes. Crushed leaves emit a strong camphor odour, indicative of abundant oil glands, and the inflorescence comprises axillary or terminal panicles. Fruits are initially green, turning black at maturity. Phenological monitoring documented a synchronized annual cycle: leaf budding occurs in February-March, leaf maturation in March-April, flowering in April-May, and fruit ripening from August to October. This timing aligns with local climatic patterns, optimizing growth and reproductive success in the region's subtropical environment. Essential oil extraction from fresh leaves, upon hydro-distillation, yielded oil content ranging from 1.20% to 1.55%. This yield is within the lower reported range for the species and may reflect environmental constraints such as frost or suboptimal soil conditions. The study highlights the species' adaptability to cooler subtropical climates and its potential for small-scale essential oil production in Himachal Pradesh. Further research on genetic diversity and environmental influences is recommended to optimize cultivation and maximize economic returns.

Keywords: Camphor, essential oil, hydrodistillation, morphology, yield

1. Introduction

The camphor tree (*Cinnamomum camphora*), a resilient evergreen of the Lauraceae family, is native to East Asia but widely naturalized in India's subtropical regions, including the lower hills of Himachal Pradesh (300-900 m elevation). India is home to 26 *Cinnamomum* species, with 12 endemics to the Northeast and South. Distributed across states such as Karnataka, Kerala, West Bengal, Assam, Tamil Nadu, and Uttar Pradesh, the camphor tree is valued for its aromatic wood, medicinal uses, and essential oils.

Locally known as "Kapoor ka Ped" or "Karpura," *C. camphora* is deeply embedded in the ethnobotanical traditions of Himachal's lower hills, where communities like the Gaddis, Gujjars, and Pahari farmers use it in traditional medicine, rituals, ceremonies and in agroforestry plantations. In districts such as Hamirpur, Bilaspur and Una, the tree aids soil stabilization, supports biodiversity and provides camphor oil for pharmaceuticals, aromatherapy and religious practices. Despite its benefits, species invasive potential and competition with native flora require careful management and scientific attention.2.

Taxonomic Hierarchy of *Cinnamomum* Species

Rank	Classification
Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Order	Laurales
Family	Lauraceae
Genus	Cinnamomum

2. Ethnobotanical and Medicinal Uses

The camphor tree is a vital component of the ethnobotanical, cultural, and ecological landscape of Himachal Pradesh's lower hills. Camphor is used for its medicinal applications, spiritual significance, and agroforestry integration and conservation challenges, providing a foundation for understanding its multifaceted role in the region. In Himachal Pradesh, *Cinnamomum camphora* has been integral to folk medicine, with local *Vaidyas* utilizing its leaves, bark, and essential oil for treating respiratory infections, rheumatic pain, and skin disorders (Negi *et al.*, 2018) ^[11]. These applications, often involving camphor mixed with mustard oil as a topical analgesic or burned as a fumigant, are rooted in Ayurvedic traditions. The tree's antimicrobial and anti-inflammatory properties, attributed to its volatile compounds, are well-documented in indigenous knowledge systems (Gupta *et al.*, 2016) ^[8]. However, contemporary scientific studies validating these uses are sparse, highlighting a gap that warrants further pharmacological investigation (Chen *et al.*, 2010) ^[11].

3. Cultural and Spiritual Significance

The camphor tree holds profound spiritual importance in Himachali culture, particularly in Hindu rituals performed at temples like Jwalamukhi and Chintpurni, where camphor (*kapoor*) is burned during *aarti* to symbolize purity and divine connection (Kumar *et al.*, 2012) ^[3]. Its use in warding off evil spirits through scented pouches reflects a blend of Hindu and animistic beliefs prevalent in the region (Bhagwat and Rutte, 2006) ^[6]. Sacred groves (*Devban*) in Kangra, often harboring camphor trees, serve as bio-cultural sanctuaries, where spiritual reverence supports biodiversity conservation (Sharma and Devi, 2017) ^[12]. These practices underscore the tree's role in maintaining cultural and ecological heritage.

4. Agroforestry and Ecological Benefits

In agroforestry systems of Una and Bilaspur, camphor trees are planted alongside crops like citrus and mango, leveraging their allelopathic properties to deter pests and reduce chemical pesticide use (Sharma *et al.*, 2019) ^[13]. The use of camphor leaves as mulch and branches as firewood enhances soil moisture retention and resource availability (Kumar and Thakur, 2015) ^[10]. However, the commercial demand for camphor oil has driven over-exploitation, threatening wild populations (Cunningham, 2001) ^[7].

5. Conservation Challenges and Indigenous Strategies

The camphor tree faces threats from deforestation and climate change, which jeopardize its survival in Himachal Pradesh (Berkes, 2008) ^[5]. Indigenous conservation

practices, including taboos against felling camphor trees in *Devban* forests and seasonal harvesting restrictions, have historically protected this species (Bhagwat and Rutte, 2006) ^[6]. Integrating these traditional strategies with modern reforestation efforts could enhance conservation outcomes, preserving both the species and Pahari cultural heritage.

Keeping in view, this study examines the growth dynamics, essential oil yield, and pathways for sustainable use of camphor trees in the region. It aims to fill existing research gaps and outlines livelihood strategies for local communities that align with conservation priorities. By integrating ecological insights with practical applications, the research supports both biodiversity preservation and community well-being.

6. Materials and Methods

6.1. Study area

The study was conducted in the lower hill region of Himachal Pradesh, India, specifically in the Hamirpur area where *Cinnamomum camphora* is found both naturally and in plantations. The research sites were situated at elevations ranging from 500 to 800 meters above sea level. This region experiences a subtropical climate, receiving an average annual rainfall of 1466 mm, typically spread over about 127 rainy days each year. The annual temperature generally ranges from 11 °C to 28 °C, although extremes as low as 2 °C and as high as 41 °C have been observed. For sampling, mature and healthy *Cinnamomum camphora* trees were randomly selected within the specified elevation range. At each site, five individual trees were chosen, ensuring that each tree was at least 20 meters apart from the others to avoid clonal repetition.

Morphological data were collected during the peak growing season (April to June). The following vegetative and reproductive traits were recorded:

Vegetative Traits:

- Leaf length and width (cm)
- Leaf shape, margin, apex, and base:
- Reproductive Traits
- Inflorescence type and length (cm): Recorded during the flowering season.
- Flower colour, number of petals, and diameter (mm)
- Fruit type, size (mm), and number per inflorescence
- Photography and Herbarium Preparation

6.2. Determination of essential oil

6.2.1. Plant material collection and preparation

- Fresh leaves of *Cinnamomum camphora* (L.) was collected from randomly selected trees in the Neri region, Hamirpur, Himachal Pradesh, India. Collection was performed during the months of May-August in this region, preferably in the morning hours to minimize loss of volatile compounds due to sun exposure. For each tree, healthy, mature leaves (avoiding very young or senescent leaves) were collected. A representative sample size (e.g., 500 g per tree) was harvested. Immediately after collection, leaves were transported to the laboratory in breathable bags to prevent fermentation or degradation. Leaves were thoroughly cleaned to remove any dirt, dust, or foreign matter.

6.2.2. Essential oil extraction by hydrodistillation

A standard Clevenger-type essential oil distillation apparatus (for oils lighter than water) was used.

6.3 Procedure

- **Loading the Still:** A precisely weighed quantity of prepared *Cinnamomum camphora* leaf material (500 gm) will be placed into the round-bottom flask.
- **Adding Water:** Distilled water will be added to the flask in a specific ratio to the plant material (3L water for 500 g plant material). The plant material should be fully immersed.
- **Assembly:** The Clevenger trap will be securely connected to the round-bottom flask. The condenser will then be attached to the top of the Clevenger trap. All joints will be greased lightly to ensure a tight seal.
- **Cooling System:** The condenser cooling system (circulating chiller or cold-water tap) will be activated to ensure efficient condensation of vapours.
- **Heating:** The heating mantle will be set to gradually heat the flask. The temperature will be carefully monitored to ensure gentle boiling and continuous steam generation. Violent boiling should be avoided to prevent material degradation or foaming.
- **Distillation Duration:** The distillation process will typically be carried out for a specific duration (7 hrs) after the first drop of distillate is observed (Verma *et al.*, 2024) ^[15]. This duration may be optimized in preliminary runs by monitoring the volume of oil collected over time until no further increase is noted.
- **Collection:** As steam and essential oil vaporize, they will pass into the condenser, condense into liquid, and drip into the Clevenger trap. The essential oil, being lighter than water, will float on top of the aqueous distillate (hydrosol) in the calibrated arm of the trap. The excess hydrosol will automatically return to the distillation flask.
- **Separation and Measurement:** After the distillation is complete, heating will be stopped, and the apparatus will be allowed to cool down. The volume of the separated essential oil in the calibrated Clevenger trap will be carefully recorded.
- **Oil Transfer:** The essential oil will be carefully transferred from the Clevenger trap using a Pasteur pipette into a pre-weighed amber glass vial.
- **Drying:** Traces of water in the essential oil will be removed by adding a small amount of anhydrous sodium sulphate (Na₂SO₄) or magnesium sulphate (MgSO₄). The vial will be gently swirled and left to stand for approximately 1-2 hours.
- **Storage:** The dried essential oil will be decanted into a new, clean, pre-weighed amber glass vial, sealed tightly, labelled, and stored in a refrigerator (4 °C) or freezer (-20 °C) until further analysis to prevent degradation.

6.4 Calculation of essential oil yield

The essential oil yield will be calculated on a fresh weight basis using the following formula:

$$\text{Essential Oil Percentage} = \frac{\text{Amount of Essential Oil produced}}{\text{Total Amount of material used}} \times 100$$

7. Results and Discussion

7.1 Morphological Characteristics of *Cinnamomum camphora* in Lower Himachal Hills

- Growth Habit:** In the subtropical Hamirpur region, camphor trees (*Cinnamomum camphora*) exhibited constrained growth, with heights ranging from 12 to 15 meters, likely due to cooler temperatures and periodic frost stress. The canopy was observed to be dense and rounded to oval in shape. Leaves were ovate to elliptical, with glossy green upper surfaces and pale green undersides displaying prominent yellow-green veins. In spring, newly emerged leaves appeared reddish-bronze. When crushed, leaves released a strong camphor odour due to the presence of oil glands. The inflorescence consisted of axillary or terminal panicles. Fruits were berry-like, green in their immature stage, and black at maturity.
- Phenological events:** The following phenological stages were recorded in the *Cinnamomum camphora* tree :
 - **Leaf Budding:** Emergence of new, red-bronze leaves in February-March.
 - **Leaf Maturation:** The leaves colour changed from red-bronze to green over a 25-30 day period in March-April.
 - **Flowering:** Appearance of greenish-yellow flower panicles in April-May.
 - **Fruiting:** Fruits ripened between August and October.
- Essential oil percentage:** Fresh leaves were harvested from randomly selected, middle-aged *Cinnamomum camphora* trees in the Neri region of Hamirpur, Himachal. The leaves were immediately transported to the laboratory and subjected to hydro-distillation for 7 hours using a Clevenger apparatus to extract the essential oil.

The heating mantle was initially set to 100 °C to boil the water in which the leaves were submerged, and then reduced to 40 °C for entire duration of the extraction i.e. upto 7 hrs. The essential oil content recovered from the leaves ranged from 1.20% to 1.55%, representing the natural variability among the individual trees sampled in the region. A loose cotton plug was inserted into the apparatus opening immediately below the condenser to minimize the loss of camphor vapours.

The vapours produced were directed into a condenser equipped with an inlet and outlet. The condenser facilitated cooling, resulting in the condensation of the vapours into camphor oil and an aqueous distillate. In the measuring tube, camphor oil floats and formed a distinct layer above the distillate.

Distillation was terminated when no further camphor oil was extracted. The apparatus was allowed to cool to a lukewarm temperature over approximately 10 minutes. The aqueous distillate was decanted into a separate beaker, and the camphor oil was collected in another beaker. The isolated camphor oil solidified within 10 minutes under ambient conditions, attributed to its inherent sublimation properties.



8. Discussion

The study on *Cinnamomum camphora* in the subtropical Hamirpur region of the lower Himachal hills provides significant insights into its morphological adaptations, phenological patterns, and essential oil yield under local environmental conditions. The constrained growth of camphor trees, with heights ranging from 12 to 15 meters, likely resulted from cooler temperatures and periodic frost stress, which are characteristic of the region's subtropical climate. This reduced stature contrasts with reports from warmer subtropical or tropical regions, where camphor trees often attain greater heights (up to 20-30 meters) (Smith *et al.*, 1998) ^[4]. The dense, rounded to oval canopy observed aligns with the species' typical growth habit, facilitating efficient light capture and potentially serving as a protective mechanism against frost damage. The ovate to elliptical leaves, with glossy green upper surfaces and pale green undersides displaying yellow-green veins, suggest efficient photosynthetic capacity and structural adaptations to the local climate. The reddish-bronze hue of newly emerged leaves in spring, transitioning to green, indicates a phenological adaptation to seasonal light and temperature changes, potentially protecting young leaves from herbivorous animals or excessive solar radiation (Jones, 2005) ^[2].

The phenological events recorded—leaf budding in February-March, leaf maturation in March-April, flowering in April-May, and fruit ripening in August-October—reflect a well-synchronized cycle with the region's climatic patterns. The early spring leaf budding coincides with rising temperatures and increased photoperiod, optimizing growth

during favourable conditions. The 25-30 day leaf maturation period suggests a rapid transition to photosynthetic efficiency, critical in a region with a relatively short growing season due to cooler winters. Flowering in April-May aligns with the availability of pollinators, while fruit ripening in late summer to early autumn ensures seed dispersal before the onset of cooler temperatures. These phenological patterns are consistent with studies in other subtropical regions, though the timing in Hamirpur appears slightly earlier, possibly due to microclimatic variations (Kumar *et al.*, 2012) ^[3].

The essential oil content of 1.20% to 1.55% extracted from fresh leaves via hydro-distillation is within the lower range reported for *Cinnamomum camphora* (1.0%-2.5%) across different regions (Chen *et al.*, 2010) ^[1]. The variability observed among individual trees may be attributed to genetic differences, soil nutrient availability, or micro-environmental factors such as light exposure and water availability in the Neri region. The strong camphor odor released upon crushing leaves, due to the presence of oil glands, underscores the species' commercial potential for essential oil production. However, the relatively low oil yield compared to tropical populations may reflect environmental stress, such as frost or suboptimal soil conditions, limiting oil biosynthesis. The use of the Clevenger apparatus for extraction, with controlled temperatures (90 °C initially, then 40 °C), ensured efficient recovery while minimizing thermal degradation of volatile compounds, supporting the reliability of the reported oil content.

In a similar study, steam distillation of *Cinnamomum camphora* leaves yielded essential oil in the range of 0.8-1.2% (v/w), which is consistent with earlier findings (Arora *et al.*, 2004) ^[16].

These findings highlight the adaptability of *Cinnamomum camphora* to the subtropical conditions of the lower Himachal hills, despite environmental constraints like frost stress. The species' morphological and phenological traits suggest a robust capacity to thrive in cooler subtropical climates, while the essential oil yield indicates potential for small-scale commercial exploitation, though optimization of cultivation practices could enhance oil production. Future studies should focus on genetic diversity among local populations and the impact of soil and climatic factors on oil yield to further elucidate the species' ecological and economic potential in the region.

9. Conclusion

The essential oil content of 1.20%-1.55% from fresh leaves, extracted via hydro-distillation, indicated moderate commercial potential, though lower than in tropical regions, possibly due to environmental constraints. These findings underscore the adaptability of *Cinnamomum camphora* to the subtropical conditions of Hamirpur and suggest opportunities for further research into optimizing its cultivation and essential oil production for economic benefits.

10. Conflict of Interest

The authors declare no competing interests.

11. Acknowledgement

The authors gratefully acknowledge the College of Horticulture and Forestry (COHF), NERI, Dr. YS Parmar

University of Horticulture and Forestry (Dr. YSPUHF) Nauni Solan for providing the necessary facilities and support to carry out the experiment.

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