Potential Crops for Herbal Sector





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CSIR-Institute of Himalayan Bioresource Technology
Palampur (H.P.) 176061, India
Phone: +91 - 1894-230411, Fax: +91 - 1894-230433
Email: director@ihbt.res.in;
Web: https://www.ihbt.res.in

Contributed by: Scientists and Staff

Compiled by: Dr. Sukhjinder Singh

Design by: Sh. Pabitra Gain

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Introduction

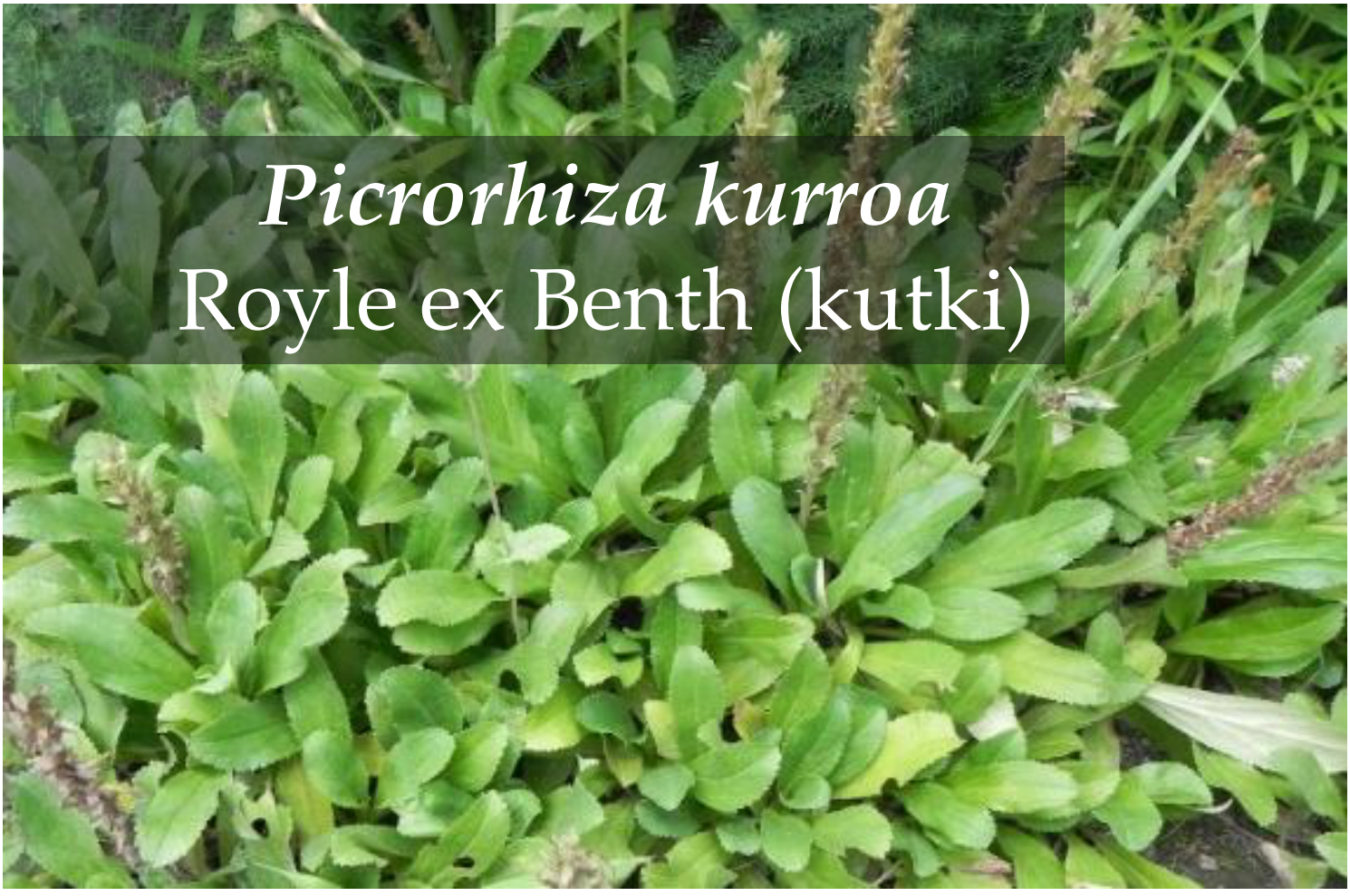
Indian Ayurveda health treatment is most likely the oldest medical care system in the world. The history of using herbs for health purposes is very old and has been mentioned in ancient religious works known as 'Vedas'. Practice of herbal healing is believed to be mentioned during 3000 BCE in Rig Veda. The bifurcation of Ayurveda into eight divisions on the basis of different parts and functions of the human body and its organs has been elaborated in Atharva Veda. In ancient times, Vedic Brahmins were acting as herbal healers and India was the leader in this kind of herbal health care system. In spite of systematic therapies, there are some specific herbal therapies developed by individuals which are also used for treating different diseases. However, the formulations developed by such individuals were kept secret and were passed on only in the family system from the older to the new generation.

Specific part/parts of a plant e.g. leaves, flowers, seeds, roots, barks, stems, etc. are used for preparing specific herbal medicines. Even in the present era, herbal medicines have an important role in India. A similar practice of herbal care is also very common in China, South East Asia and Africa. In a survey of 123 countries conducted by World Health Organization (WHO) in 2001 it was revealed that recognition and regulation procedures for traditional medicine (TM) vary from country to country. However, there is increasing popularity of traditional medicine in the world due to affordability and verified efficacy in number of important health cures. Traditional medicine has been given varying legal recognition by different countries.

Herbal crops are essential for variety of uses in food, medicine, and other industries. They provide natural substitutes for manufactured goods with possible health and environmental benefits. They are an important part of both conventional and contemporary healthcare systems and are a rich source of nutrients, antioxidants, and therapeutic chemicals.

CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur is actively involved in the study, research and utilization of Himalayan bioresources such as medicinal and aromatic plants particularly focusing on herbal plants. The studies include various aspects such as cataloging biodiversity, understanding their biological and chemical properties, and developing technologies for their conservation and sustainable use.

Institute has established nurseries for high-value medicinal plants such as *Ginkgo biloba*, *Picrorhiza kurroa* etc. and has a strong track record of transferring technologies developed in-house to industries, promoting commercialization and economic development.



Picrorhiza kurroa Royle ex Benth (kutki)

Dr. Rakesh Kumar and Ms Sumedha Thakur
(Agrotechnology Division)

1. Health benefits and applications in medicine

Picrorhiza kurroa Royle ex Benth (kutki) is a significant Himalayan alpine medicinal plant. Kutki, as it is commonly known in Indian medicine, is a key ingredient in about 2000 plant-based medications. This plant's roots and rhizomes are the source of the crude medication (Raut et al., 2022). The plant, often referred to as Hun-hung lien, has a role in Chinese medicine. *P. kurroa* is known for its bitter flavor, which is frequently associated with its therapeutic benefits. Glycosides, alkaloids, cucurbitacins, iridoids, phenolics, and terpenes are among the phytoconstituents found in *P. kurroa* that have demonstrated encouraging pharmacological potential. The chemicals of importance in terms of chemistry are picroside-I and picroside-II, which are iridoid glycosides. Chronic constipation, burning sensation, recurrent chronic fever, jaundice, allergies, tuberclosis, prediabetes, obesity, cholagogue, skin, heart, liver, breathing, digestion and blood issues are among the conditions for which *P. kurroa* is used (Almeleebia et al., 2022). The plant has anti-microbial, anti-bacterial, anti-mutagenic, cardio-protective, anti-cancer, anti-malarial, anti-diabetic, anti-ulcer, anti-inflammatory, hepato-protective, anti-oxidant, anti-periodic properties (Debnath et al., 2020). Although the plant material has historically been taken from the wild, overexploitation and habitat degradation have caused its status to drastically decline in recent years.

2. Economic impact and market demand

The global annual demand for this herb is 500 tons, while the supply is only 375 tons, with India contributing just 75 tons per year (Thani et al. 2018). In 2023, the market value of *P. kurroa* extract worldwide was estimated to be about USD 2.09 billion. It is expected to grow to USD 2.71 billion by 2030, indicating a compound annual growth rate (CAGR) of roughly 3.8% during 2024-2030 (MMR, 2024). Moreover, nations such as India, Nepal, and China as well as emerging markets in Europe and North America are experiencing a rising demand for *P. kurroa* extracts.



Picrorhiza demonstration field in UK



Picrorhiza demonstration field in HP

3. Raw material availability and conservation status

In India, the availability of *P. kurroa* as a raw material remains a significant concern due to overreliance on wild harvesting and limited cultivation. According to a 2021 study by the High-Altitude Plant Physiology Research Centre, the total picrosides in Uttarakhand's cultivated plants range from 0.14 to 5.68% for picroside-I and from 0.70 to 7.05% for picroside-II. Crucially, substantial levels of picroside-I (~4.54%) and picroside-II (~5.52%) were also accumulated by leaves and stolons, indicating that non-rhizome portions may lessen the strain on wild populations. The results indicated that the supply of leaves may meet market demands, which will aid in species conservation and elite accession will be utilized for further multiplication. As a result, *P. kurrooa* mass cultivation ought to be encouraged (Attri et al., 2021). Micropropagation protocols developed by CSIR-IHBT in 2023 deliver >85% survivability of tissue-cultured plants planted in natural habitats offered a scalable way to meet raw material demand.



Inflorescence



Leaves



Fresh rhizomes



Dry rhizomes

4. Agrotechnology

Propagation

Both sexual and asexual methods of kutki propagation are possible, using seeds, rhizomes, and stolon segments. In general, seeds harvested from wild sources in September do well when sown right away in temperatures that are rather hot (15–20°C). One hectare of plantation can be established with 3 kg of newly collected seeds. Sowing is done in March-April in beds at an intermediate elevation (2200m) and in May in alpine regions for seed-based crop production. Lower altitude seeds are seeded in polyhouses in November and December, and harvested seedlings are moved to nursery beds for up to six months in the winter before being moved to higher altitudes in the spring. An area of one acre may support roughly 4,000 plants (Patial et al., 2012). So-grown nurseries are moved onto the fields at 30 x 15 cm intervals, which can support 2-3 lakh plants in a hectare.



Nursery raising



Transplantation in field

Rhizome or stolons are propagated by taking pieces of 5-7 cm length, dipping them in water or a solution of plant growth regulators, such as IBA, and then planting them in the field. These segments are best planted in April or May, but they can also be planted in September or October as the latter months yield greater results. Stolon cuttings planted horizontally at 7.5 cm depth and 30 x 30 cm spacing provide the highest rootstock yield per hectare (Thakur et al., 2010; Sharma, 2013).

Climate

P. kurroa thrives in climates that are cool, shady, and moist. Its high death rate is caused by heavy, protracted rainfall. For optimal development and productivity, modest shrub canopies or other confined gloomy regions are ideal. Although it can be grown between 1800 and 2800 meters above sea level, the yield may be reduced at lower elevations.

Soil preparation

The ideal soil type for *P. kurroa* is sandy, loamy soil. Its cultivation requires a place that is rich in organic carbon, has a thick layer of humus or litter, and has a high moisture content. For it to be grown well, water must drain well.

Planting density and nutritional requirement

In both types of propagation, plants are planted 30 × 15 cm apart. Since seedlings or stolon cuttings are planted 30 cm apart, roughly 2,22,222 plants are required for one hectare of land. However, it has been discovered that a planting distance of 5-10 cm is preferable for plant survival if the planting is done during the wet season since dense planting prevents both weed competition and soil erosion. The application of nutrients is well received by *Picrorhiza*. Before transplanting, it is advised to add roughly 20 t ha^{-1} of well-decomposed FYM. Given that it is a perennial crop, additional FYM dosages could be applied throughout the winter (Kumar et al., 2012). Digging 6 inch-deep trenches for manuring is advised throughout the winter or prior to transplanting (during the wet season) (Patial et al., 2012). When biofertilizers were used in conjunction with FYM or vermicompost, they produced the best results (Thakur et al., 2013).

Harvesting

When sown by seed, the crop can yield economically after three to four years, but when planted by nodal cutting or rhizome, the crop yields after two years. Since active contents are at their maximum during the reproductive phase, the crop should only be harvested after this phase is over. Plants in alpine regions finish their reproductive phase in September or October, but plants at lower elevations finish their reproductive phase in September. This indicates that different elevations have varying times for this phase to be completed. The rhizomes are separated and cleaned after the plants are removed to prepare for harvesting.

5. Cultivars developed at CSIR-IHBT

Kumar et al., (2012) found that under the western Himalayan conditions Picroside -I (P-I) content varied from 0.20% to 4.14% and P-II varied from 0.83% to 7.29% in different accessions. Higher P-I in rhizome was found in IHBT- PK-16 (4.14%). Rhizomes reported higher amount of P- II in comparison to P-I while comparing 18 accessions of *P. kurrooa* for growth and marker compound accumulation.

6. Stakeholders and purpose of collaboration

To encourage the sustainable cultivation and protection of *P. kurroa* a variety of stakeholders work together, including pharmaceutical corporations and local farmers. By combining market connections, enhanced agricultural techniques, and scientific research, these partnerships aim to create a sustainable value chain. While industry partners provide market assurance and quality compliance, farmers can benefit from access to high-quality planting material, technical assistance, and training. The current collaborative effort brings together key stakeholders from diverse backgrounds with the shared purpose of promoting the sustainable cultivation and value addition of medicinal and aromatic plants, particularly *Picrorhiza kurroa*, a high-value herb known for its hepatoprotective, anti-inflammatory, and immunomodulatory properties. This initiative involves Mr. Nand Lal Sharma, a progressive farmer from Nalda village in Lahaul-Spiti, who has been actively engaged in the conservation and cultivation of rare medicinal herbs. He also leads Nanda Industry, a local enterprise focused on the commercial processing of medicinal plants, aiming to support livelihood generation and biodiversity conservation in high-altitude regions. In addition, the Tridev Aushdhiya Society, based in Ruhal, Shimla, plays a pivotal role in organizing farmer groups on sustainable wild harvesting and cultivation practices.

7. Sustainability and future trends

To satisfy the future needs of growing populations for specific valuable biodiversity, immediate action is needed to address threats to biodiversity brought on by development, changes in land use, and overexploitation. Medicinal plants were especially identified as a crucial group that deserves further research because many of them have already been farmed and many more are probably going to be in the future. The balance between in situ and ex situ conservation strategies, as well as the involvement of locals in cultivation and conservation, should be a special area of emphasis. It is hoped that local medicinal plant biodiversity can be sustainably conserved by increasing residents' understanding of the importance of indigenous medicinal plant biodiversity and by implementing suitable conservation and use measures.

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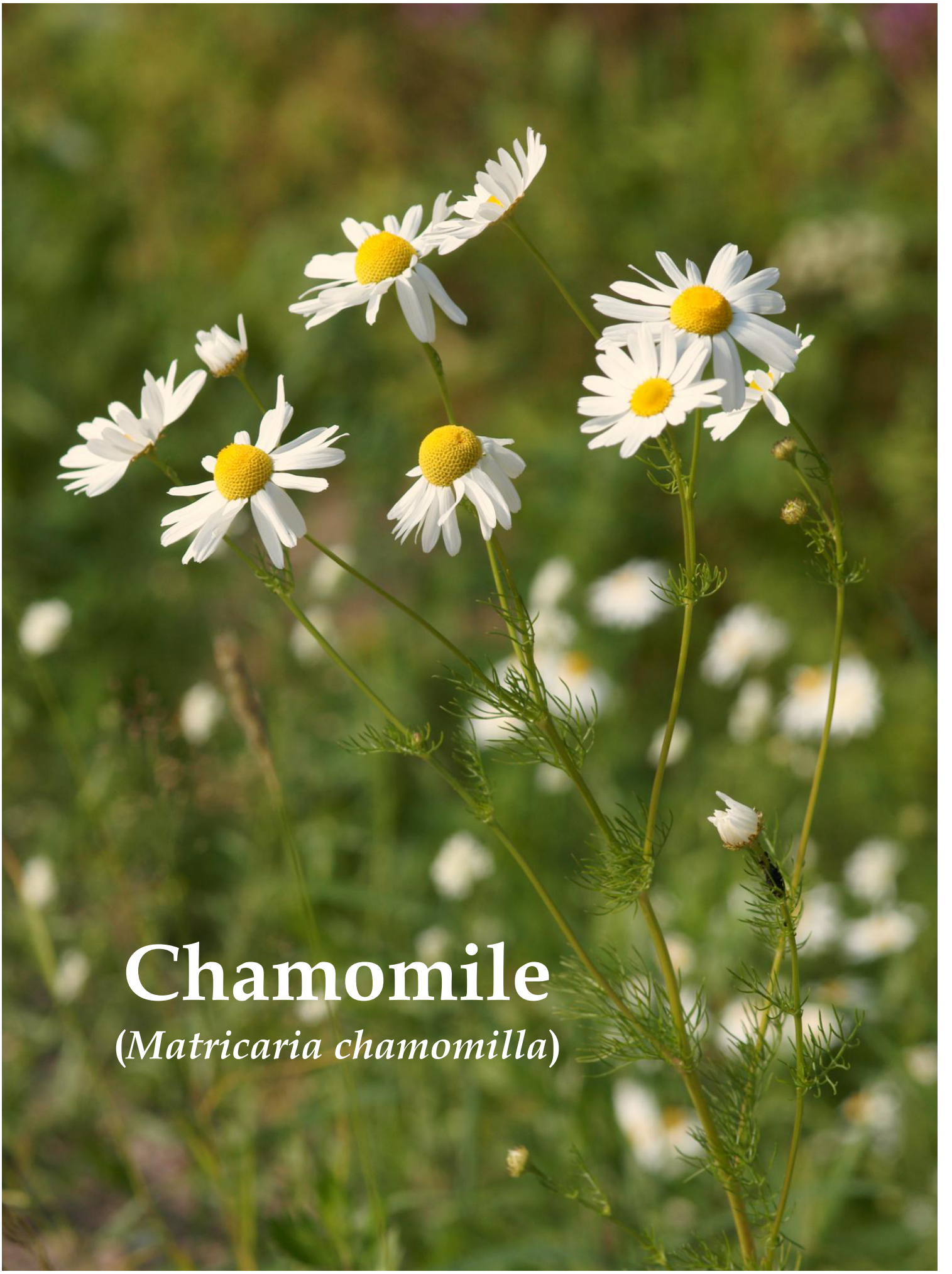

Chamomile

(*Matricaria chamomilla*)

Chamomile (*Matricaria chamomilla*)

Dr. Satbeer Singh and Hari Sharan
Agrotechnology Division

Chamomile (*Matricaria chamomilla* or *Chamomilla recutita*) is a well-known medicinal plant with a long history of use in traditional and modern herbal medicine. Its dried flowers contain numerous bioactive compounds including flavonoids (like apigenin), terpenoids (like chamazulene), and essential oils, which contribute to its therapeutic properties.

1. Health benefits of chamomile

The essential oil of chamomile contains more than 40 different natural compounds. The most important ones are chamazulene, (E)-β-farnesene, α-bisabolol oxide A, and bisabolol oxide B (Ghareeb et al., 2022). Chamazulene and α-bisabolol, have special health benefits. They can reduce inflammation, fight harmful bacteria, and relax muscle spasms. They are often used in making medicines for stomach problems (Petronilho et al., 2012). Chamomile extract also helps to calm the nervous system and reduce sudden attacks or seizures (Yuan et al., 2021). In addition, the leaf extract of chamomile is used in aromatherapy to improve mood and reduce stress (Parveen et al., 2021).

Helps in Digestion

Chamomile helps to keep the stomach and intestines healthy. It reduces gas, bloating, and stomach cramps. Drinking chamomile tea after meals can prevent indigestion and ease stomach pain. It also protects the stomach lining from acid and inflammation, which may help in preventing ulcers.

Reduces inflammation

Chamomile has natural compounds like chamazulene and bisabolol, which reduce swelling and redness in the body. These anti-inflammatory properties make it useful in conditions like arthritis, sore muscles, or skin problems. It works by blocking certain chemicals in the body that cause inflammation.

Improves sleep and reduces anxiety

Chamomile has a mild calming effect on the brain. A compound called apigenin binds to brain receptors and helps to relax the mind. This makes chamomile helpful for people who have trouble sleeping or who feel anxious or stressed. Drinking chamomile tea before bed is a common natural remedy for better sleep.

Acts as an antioxidant

Chamomile is rich in natural antioxidants. These are substances that protect the body from damage caused by harmful molecules called free radicals. Antioxidants help prevent diseases like heart problems, cancer, and early aging. Regular use of chamomile may keep your cells healthy and strong.

Boosts immunity

Chamomile can help the immune system fight infections. It has antibacterial and antiviral properties that make it effective against colds, flu, and other common illnesses. Drinking chamomile tea regularly may help reduce how often you get sick.

Eases menstrual pain

Chamomile has natural pain-relieving and muscle-relaxing effects. It can help reduce cramps and discomfort during menstruation. It also helps to relax the uterus and reduce stress, which makes periods less painful and easier to manage.

Good for Skin

When applied to the skin, chamomile helps to heal wounds, burns, and rashes. It reduces redness, swelling, and itching. Chamomile creams and oils are used to treat conditions like eczema, acne, and dry skin. It also keeps the skin soft and healthy.

2. Economic impact and market demand

Chamomile is the fifth most sold herb in the world and is widely used in food, cosmetics, and medicines. It is sold in two main forms: as dried flower heads (capitula) or as an essential oil called "blue oil", which is a popular name in the international market. This oil is highly valuable and sells for about Rs. 40,000 per kilogram (Singh et al., 2011). In 2023, the global market value of chamomile flower oil was USD 4.35 billion, which increased to USD 4.55 billion in 2024. It is expected to grow further at a rate of 4.92% per year, reaching around USD 6.09 billion by 2030 (Global Forecast 2025–2030).

3. Raw material availability and conservation status

Chamomile, a valuable medicinal and aromatic herb, is widely cultivated for its dried flower heads, which serve as the primary raw material for herbal tea and essential oil production (Salamon, 2006). Globally, countries such as Germany, Egypt, Hungary, Argentina, and Bulgaria are the major producers of chamomile raw material (Bhowmik et al., 2011; Joshi, 2013). The flower heads are harvested during peak bloom, and oil is extracted from the dried material through steam distillation. The availability of chamomile raw material is highly dependent on proper cultivation practices, climate conditions, and post-harvest handling techniques (Singh et al., 2011). Although chamomile is both cultivated and found in the wild in some temperate regions, excessive collection from natural populations, particularly in Eastern Europe and parts of West Asia, has raised concerns about its long-term sustainability (Lange, 2002). Wild populations are threatened by overharvesting, habitat degradation, and land-use changes. While chamomile is not classified as endangered on a global scale, conservation efforts including ex situ cultivation, preservation of wild genetic resources, and application of good agricultural and collection practices (GACP) are recommended to ensure a stable supply and to protect its natural diversity (WHO, 2003).

4. Agrotechnology

In the last two decades, rising international demand for chamomile oil has encouraged farmers to grow German chamomile instead of traditional crops. However, this annual plant needs special care, especially during harvesting, as all flower heads do not mature at once and multiple pickings are needed, increasing labour. To get better flower and oil yield, the crop requires good agronomic practices such as using high-yielding varieties, proper plant spacing, balanced fertilizers, good irrigation, pest control, and correct harvesting methods.

Cultivation technique

Soil and climate requirements

Chamomile prefers well-drained, sandy to loamy soil rich in organic matter. It grows best in soils with pH between 6.0 and 8.0. The crop thrives under full sunlight with day temperatures of 15–20°C during vegetative growth and can tolerate night temperatures as low as −10°C. Germination is best at 10-20°C. Long daylight hours and high sunshine increase essential oil content and chamazulene levels (Salamon, 2006; Joshi, 2013).

Field preparation

The field should be ploughed 2-3 times to get fine tilth and a levelled surface. All weeds and residues from the previous crop should be removed. Pre-sowing irrigation is necessary if the soil lacks moisture. Well-rotted farmyard manure (FYM), poultry manure, or vermicompost (10-15 t/ha) should be incorporated before the last ploughing to improve soil fertility and texture (Singh et al., 2011).

Propagation and Planting

Chamomile is propagated either by direct seed sowing or transplanting nursery-raised seedlings. In direct sowing seeds are sown at a shallow depth (0.5-1 cm) in rows spaced 20-25 cm apart. During transplanting, seeds are first sown in raised nursery beds. After 25-30 days, healthy seedlings are transplanted to the main field at 20-30 cm spacing. Transplanting gives better crop stand and early flowering (Bhowmik et al., 2011).

Nutrient management

In addition to organic manure, a balanced dose of NPK (40:40:20 kg/ha) may be applied. Half of the nitrogen and the full dose of phosphorus and potassium can be applied at sowing, and the rest of the nitrogen is applied after 30-40 days.

Flower harvesting

Chamomile flowers are harvested by hand when the flowers are in full bloom. Because not all flowers mature at once, multiple pickings (up to 6-8) are needed every 4-7 days. Timely harvesting is important for good flower quality and oil content. Flowers are sun-dried or shade-dried and then stored in dry conditions to avoid loss of aroma.

Oil extraction

Dried flowers are processed through steam distillation to obtain essential oil, which contains active compounds like bisabolol and chamazulene. Oil yield is about 0.3%-1.0% of the dry flower weight.

5. Cultivar developed at CSIR-IHBT

CSIR-IHBT, Palampur, has made significant advances in the genetic improvement and varietal development of chamomile to meet the increasing demand for high-quality essential oil and to enhance cultivation prospects in the western Himalayan region. Through systematic breeding, characterization, and multi-location evaluation, one superior cultivar has been developed and is available for commercial cultivation.

'Him Kanti' (CSIR-IHBT-MC19005)

The variety 'Him Kanti' of German chamomile has been developed by CSIR-IHBT, Palampur through half-sib progeny selection approach. The variety was selected for higher capitulum yield and essential oil content. This selection "CSIR-IHBT-MC19005" has recorded significantly higher capitulum yield (2.55 kg/plot) and essential oil content (3.49 g/kg) than the overall mean (1.95 kg/ha and 2.53 g/plot, respectively) in Himachal Pradesh.

The identified selection 'Him Kanti' (CSIR-IHBT-MC19005) has an advantage of 31% and 39% over population mean for capitulum and essential oil yield, respectively. The genotype CSIR-IHBT-MC19005 has a larger capitulum disc diameter of 13.75 mm, capitulum diameter of 25.33 mm and a plant height of 89.03 cm. It requires about 128 days for flowering in low- to mid-hill conditions of western Himalaya. It has stable performance for capitulum yield and essential oil content over different locations in low- to mid-hill conditions of Himachal Pradesh.



6. Stakeholders and purpose of collaboration

The cultivation and promotion of chamomile involve farmers, researchers, government agencies, industries, and exporters. Farmers grow chamomile for its income potential, as it is used in herbal tea, medicine, oil, and cosmetics. Researchers and agricultural institutes improve its yield, and quality. CSIR-IHBT, Palampur, supports farmers by providing planting material, training, and processing technology under the CSIR Aroma Mission. In Himachal Pradesh, chamomile cultivation has increased through such support. Industries and research institutes work together to improve cultivation, processing, and marketing. Government schemes and training programs also help farmers. Industries use chamomile for value-added products and ensure regular raw material supply. Exporters meet international demand. The collaboration aims to increase yield, improve quality, raise farmer income, and promote sustainable chamomile farming and trade.

7. Sustainability and future trends

Chamomile shows strong potential for sustainable agriculture due to its ability to grow in dry conditions with minimal inputs, making it suitable for organic and eco-friendly farming systems (NMPB Report, 2021). Its increasing use in herbal medicine, cosmetics, and essential oil industries enhances its market value and long-term economic viability (Singh et al., 2011). Current research focuses on developing high-yielding, stress-tolerant varieties and improving essential oil quality using modern breeding and molecular markers (CSIR-IHBT Annual Report, 2022; Sharan et al., 2024). These efforts support sustainable production, environmental conservation, and better income for small and marginal farmers, aligning with future trends in medicinal plant cultivation (Ghosh et al., 2018).

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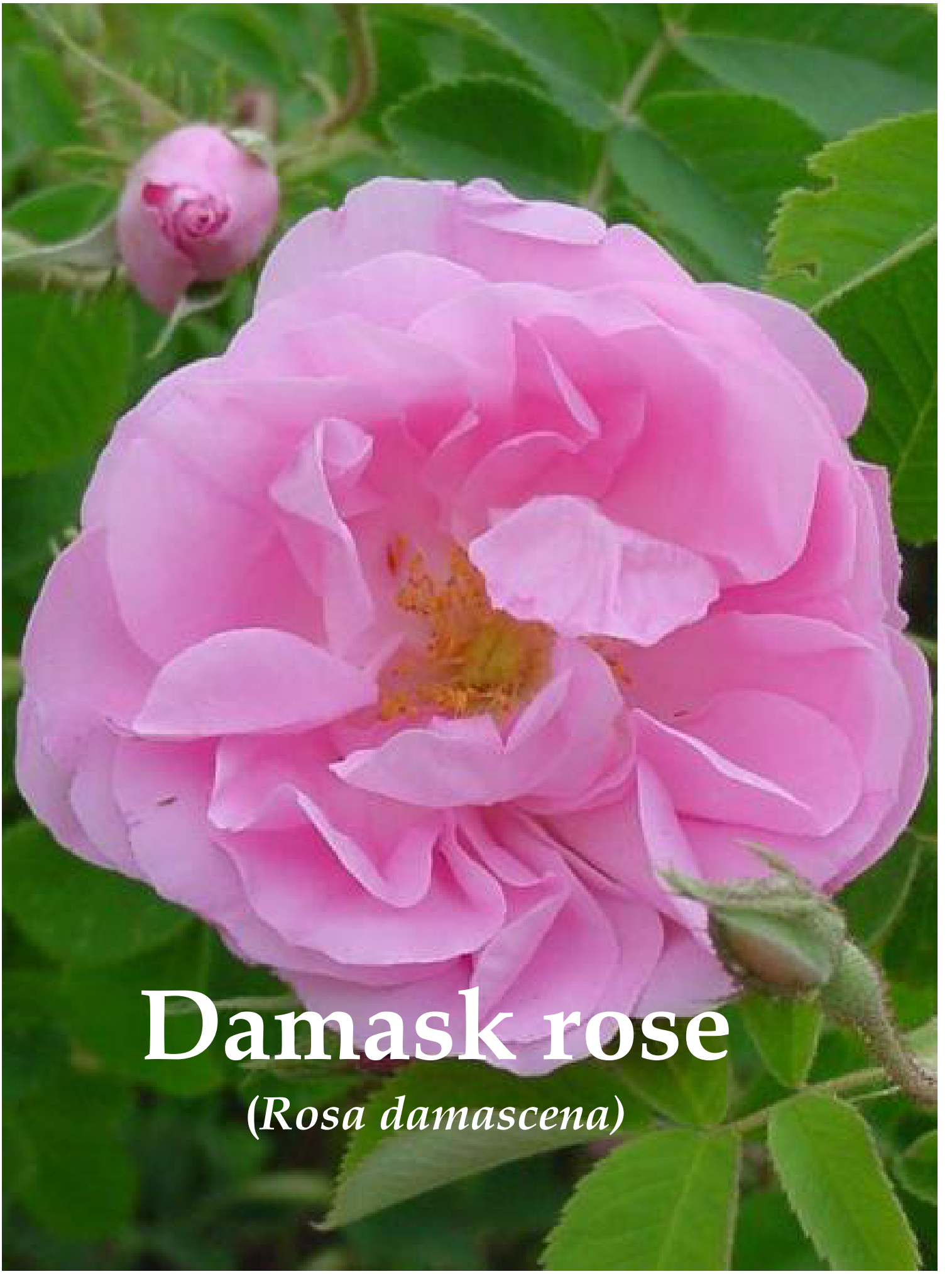
Damask rose
(Rosa damascena)

Damask rose (*Rosa damascena)*

Dr. Sanatsujat Singh and Romika Thakur
Agrotechnology Division

1. Health benefits and applications in medicine

Damask rose (*Rosa damascena*) is valued for its wide range of medicinal and cosmetic applications, stemming from its rich composition of antioxidants, anti-inflammatory compounds, and other bioactive substances. In traditional medicine, it has been used to treat a variety of ailments, including chest and abdominal pain, indigestion, cough, depression, and nervous stress (Hongratanaworakit et al., 2009). More recently, it has been explored for its potential in skincare, as an antimicrobial agent, and for its cardiovascular and neurological benefits (Yassa et al., 2009). It has been famous as cardio tonic for strengthening the heart (Shahriari et al., 2006). The essential oil is used for treatment of different ailments. Rose water traditionally was used as antiseptic agent for eye washing and mouth disinfecting (Gocheva et al., 2008) and as antispasmodic agent for alleviating the abdominal pains, and bronchial and chest congestions (Moein et al., 2010). The decoctions of dried rose water was used as diuretic and was recommended as anti-tumor, anti-carcinogenic and a relief for fever (Kumar et al., 2006). Rose oil can help in treatment of depression, nervousness, tension, allergies, headaches, and migraine (Shieber et al., 2005' Leenen et al., 2000)

2. Economic impact and market demand

The damask rose has a significant economic impact, primarily due to its use in the production of rose oil and rose water, which are highly valued in fragrance and cosmetics industries. The market for damask rose products is growing, with the global damask rose water market size valued at USD 109.10 million in 2024, and projected to grow at a CAGR of 7.4% from 2025 to 2032. It oil has a global market value of approximately USD 278.7 million in 2018 and is anticipated to increase at a CAGR of 6.8% between 2019 and 2025 (Grand View Research, 2019). The essential oils are renowned for their exquisite perfumery applications and usage in pharmaceutical formulations (Kovats, 1987). The most expensive essential oil in the world market is rose oil owing to low oil content and lack synthetic substances (Baydar and Baydar, 2007). Annually, the world production of rose oil and rose concrete is 15-20 tons (Baydar, 2006). The major producers and suppliers of the rose oil in the world market are Bulgaria and Turkey, their share being 80-90% of the world production (Gunes, 2005). The rest of the world production supply comes from France, Italy, Lebanon, Iran, Russia, India, China, Morocco, and Mexico (Gunes, 2005).

3. Raw material availability and conservation status

The Damask rose is cultivated to obtain rose oil, which is the main raw material of perfume industry. The most important rose oil producers in world are Bulgaria and Turkey. Both "Turkish Oil Rose" and "Bulgarian Oil Rose" are distilled from fresh rose oil flowers (Hussen et al., 2023). The conservation of Damask roses is crucial due to their historical and cultural significance, particularly in the perfume and culinary industries. It includes ex-situ and in-situ preservation, traditional cultivation practices, managing water resources carefully, controlling pests and diseases, and exploring cryopreservation techniques for long-term storage (Halmagyi et al., 2022; Kumar and Singh et al, 2013).

4. Agrotechnology

Damask roses thrive in well-drained, loamy soil with adequate organic matter, and are suited to subtropical and mild temperate regions. Propagation is typically done through stem cuttings or water-shoots, with transplanting of rooted cuttings in the monsoon season being ideal for establishment in the field. Harvesting involves picking the flowers when they are at their peak fragrance, typically early in the morning.

Cultivation Techniques:

Soil preparation and climate needs

Damask roses prefer well-drained, friable loamy soil rich in organic matter. They are suitable for subtropical and mild temperate regions, including the northern plains and mid-hills up to 1200m altitude. Himroz variety is suitable for higher altitudes (1200-2500m).

Propagation

Propagation is primarily through stem cuttings, water-shoots, or seeds.

Planting

Rooted cuttings are transplanted during the monsoon season.



Irrigation

Irrigation is necessary during dry periods.

Fertilizer

A balanced fertilizer application (N:120-150, P:60-90, K:40-50 kg/ha/yr) is recommended.

Intercultural operations

Provide drainage channels, hoeing and weeding are important. Pruning is done after two years of transplanting.

Harvesting

Flowers are typically harvested in the morning when they are at their peak fragrance. Harvesting should be done before the petals start to drop.

5. Cultivars developed at CSIR-IHBT

IHBT has developed two varieties of Damask rose designated as 'Jwala' for sub-tropical and 'Himroz' for temperate agro climatic zones. These varieties give consistent flower yield and oil quality in different locations.

'Jwala'

This variety is suitable for cultivation in sub-tropical northern plains, mid-hills and mild temperate regions up to 1200 m altitude. The plants are short, compact, bushy and have low tendency to produce non-bearing shoots. Under sub-tropical conditions it flowers in March-April (main flush) and then in September (second flush). It is less effected by management lapses. It has short thick pedicellate flowers borne in clusters in compact bunches. Weight of single flower varies from 2.2 to 5.0 grams, and number of petals vary from 25 to 55. It flowers for 28-30 days in a year during March-April. Flowering time can be manipulated up to some extent by pruning and other agronomic practices. It is tolerant to hail storm, rains and high velocity winds. Oil content varies from 0.030-0.06%.

'Himroz'

This is suitable for cultivation in mild temperate to cold temperate regions (1200-2500m). Plants are tall, having asymmetric and non-terminal shoot growth with long and thin pedicellate flowers borne single or in loose bunch clusters. Weight of single flower varies from 1.8 to 4.0 gram and number of petals vary from 25 to 45. It is winter tolerant and grows in temperate areas without any visual sign of winter injury. Flowering period is of 22-25 days which falls during early summer. Flowering time depends on ambient temperature of the location. Loose bunch flowers facilitate easy plucking. It produces consistent flowering shoots in temperate regions and unproductive shoots (up to 65%) if grown under tropical and sub-tropical conditions. Oil content varies from 0.030% to 0.060% and flower yield varies from 40 to 45 quintal per hectare

'Him Basant'

The variety 'Him Basant' (CSIR-IHBT-RD-04) of *Rosa damascena* has been developed by CSIR-IHBT, Palampur through half-sib selection approach. The variety has high flower yield (4.1 tonnes/ha) and essential oil content of 0.0309% and was selected from clonal breeding lines developed from germplasm collections through half-sib family selection. The variety was evaluated over four years and found to be vigorous in growth with good adaptability.





Flower of Him Basant

6. Chemical composition and Oil quality

Ratio of citronellol/geraniol, presence of trans-trans farnesol and cyclic monoterpene ethers cis- and trans-rose oxides, play major part in the odour and performance of rose fragrance. The stereoptanes give fixative property to rose oil. The alcohols (citronellol, geraniol and phenyl ethyl alcohol) impart main body character to rose oil. Oil of JWALA is relatively rich in citronellol than that of HIMROZ, though the ratio of citronellol/geraniol remain within the prescribed limits of 1 to 2. Oil of JWALA has lower stereoptanes than HIMROZ. However, there is no major difference in overall quality of rose oil of both the varieties, when grown under recommended conditions.

7. Sustainability and future trends

Damask rose cultivation can benefit significantly from practices like organic farming, eco-friendly techniques, and emerging technologies like phytofarming (phytofactory/hydroponics/aeroponics) and smart farming to ensure both high yields and minimal environmental impact.

Water conservation: Implementing efficient irrigation system like drip irrigation can minimize water usage and optimize water delivery to the plants.

Integrated pest management (IPM): Utilizing natural predators and pest-resistant varieties can reduce the need for chemical pesticides.

The Damask rose is experiencing growing demand in various markets, with a projected 7.4% CAGR for the rose water market from 2025 to 2032. This growth is fueled by its use in perfumery, cosmetics, and traditional medicine, as well as increasing consumer preference for natural and organic products.

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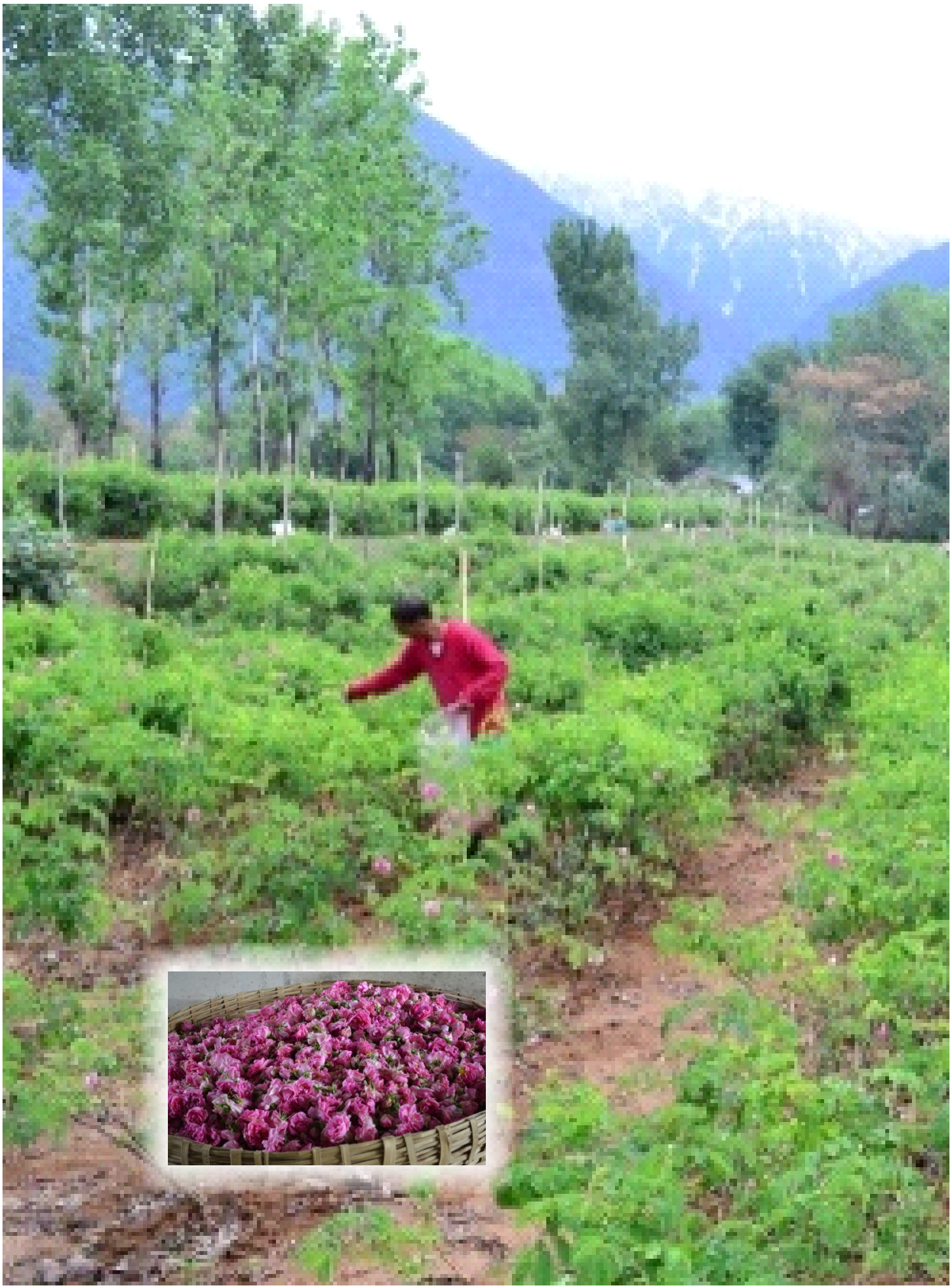
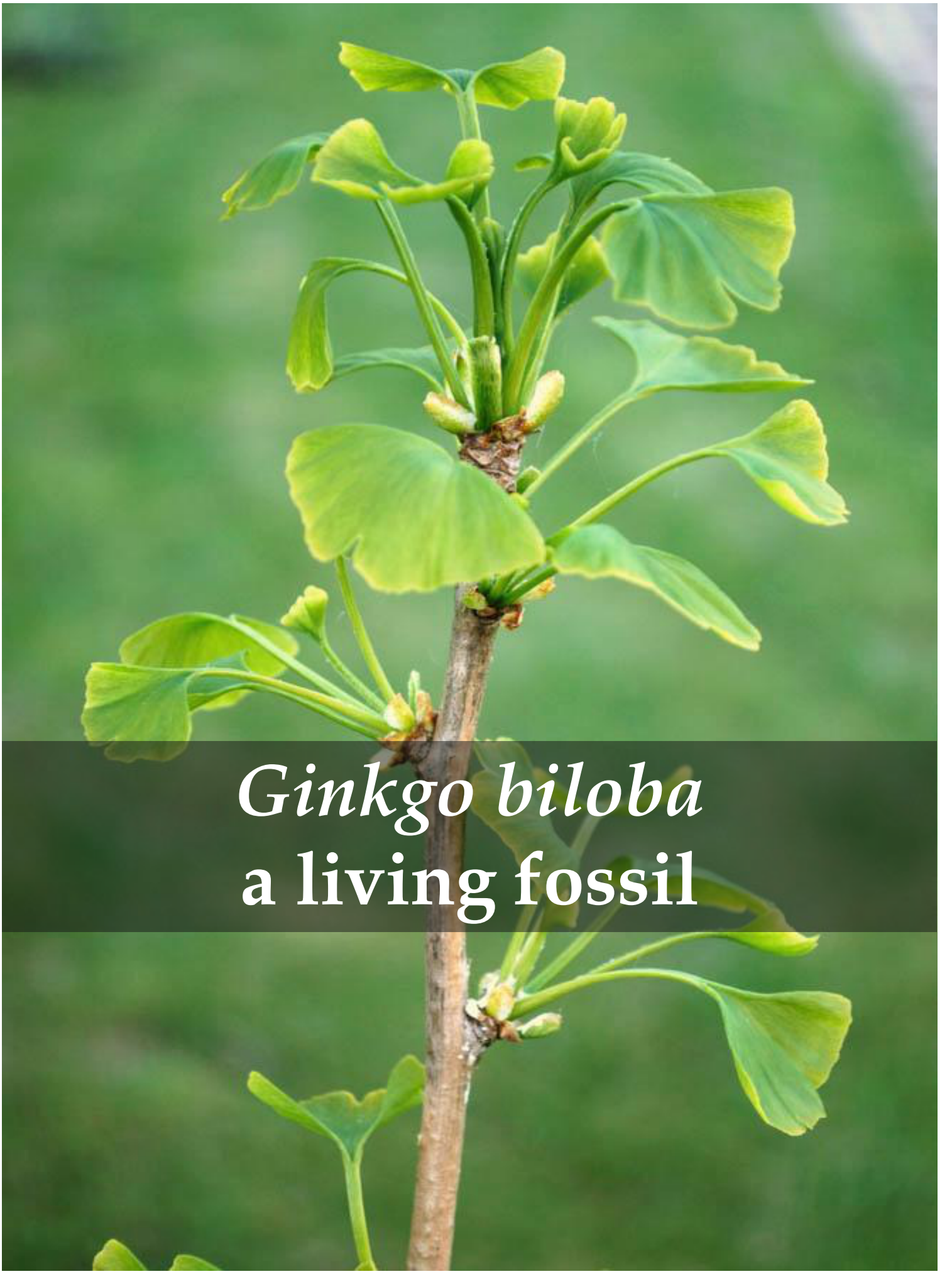




Ginkgo biloba
a living fossil

***Ginkgo biloba* - a living fossil**

Dr. Probir Kumar Pal and Ramjee Lal Meena
Agrotechnology Division

1. Health benefits and applications in medicine

Ginkgo biloba L. has been a valuable plant for mankind for more than 5000 years and is considered a "living fossil" of the Jurassic period. *G. biloba* has been mentioned in the Chinese Materia Medica about 5000 years ago by Deng. The Ginkgo tree has been of interest to mankind for more than 2000 years, making it one of the oldest known medicinal plants. It is used for treating allergies, alzheimer's disease, headaches, asthma, tinnitus, impotence, circulatory disorders, eye disorders, diabetes, multiple sclerosis, and brain trauma. The extract of *G. biloba* leaves has been used in the cardio protective mechanism, myocardial ischemia and reperfusion injury, it is efficient in environmental pollution tolerance to SO_2, and accumulation of sulphur. In China, Korea, France, Germany, and the United States, Ginkgo is a tree of great beauty, with a long lifespan, highly resistant to insects, bacterial, viral infections, and air pollution. Extract of leaves of *G. biloba* is among the top 10 commercial products in the world. Pharmacological properties of its leaves include radical scavenging, improved blood flow, vasoprotection, and anti-platelet activating factor activity. Ginkgo extract is also known for its anti-ischemic, antioxidant, and anticonvulsant properties. Moreover, the increasing research evidences support that the bioactive components of Ginkgo extract have significant therapeutic effects on age-related physical and mental deterioration and on cerebral vascular insufficiency, e.g., Alzheimer's and cardiovascular disease.

Its main constituents are: bilobalide (BB), ginkgolide A (GA), ginkgolide B (GB), ginkgolide C (GC), and ginkgolide (GJ).

2. Economic impact and market demand

The total expenditure involved in this crop, including nursery raising, plantation, and all over management of the crop after 7-8 years, is about Rs. 2,41,444. As per our calculation, in a five-year period, the expenditure on each plant was Rs. 200. The cost of its dry leaf is Rs. 300-400/kg. The dry weight of these leaves is 1.536 t/ha, which costs around Rs. 4,60,800. The net benefit is therefore, Rs. 2,19,356. The recurring expenditures for the plantations after 7-8 years will be Rs. 8000-10000 ha. However, the average yield and benefit ratio will increase every year. In 1st and 2nd years, the income may be low, but after 1st year onwards, all expenditure will be reduced and higher income will be obtained. The global ginkgo biloba extract market is on a steady upward trajectory, projected to grow from USD 1.79 billion in 2025 to approximately USD 2.68 billion by 2035, registering a CAGR of 4.1% over the forecast period.

3. Raw material availability and conservation status

CSIR-IHBT developed a protocol for the generation of quality planting material through vegetative propagation and established a plantation at CSIR-IHBT. About 3,956 planting materials of *G. biloba* have been distributed in the last five years. An agreement has been signed between CSIR-IHBT and the Research Institute in Indian Systems of Medicine (RIISM), Ministry of Ayush, Joginder Nagar, for plantation in Bharmour & Pangi Blocks of Aspirational District Chamba of Himachal Pradesh.

4. Agrotechnology:

Climate and soil requirements for cultivation

G. biloba prefers temperatures ranging from 10°C to a maximum of 25°C, relative humidity of 60-85%, rainfall of 1800-3200 mm, and it likes bright sunshine. It is observed to grow well at altitudes of 500-3600 meters asml. During the growing season, drought, hailstorm, excessive rainfall, etc., affect the quality of leaves. *G. biloba* prefers clayey loam soil rich in organic matter and generally grows in acidic to neutral soil with a soil pH value ranging from 5.11 to 8.05. The electrical conductivity of soil should be between 0.07 M mhos/cm to 1.965 M mhos/cm. Organic matter content should vary from 0.974 to 15.02 %. The available nitrogen, available phosphorus, and available potassium in soil must be between 191.29 to 686.78 kg/ha, 12.30 to 846.89 ppm, and 45.89 to 456.10 ppm, respectively.

Cultivation

G. biloba is a perennial plant, which is raised with a plant-to-plant spacing of 3 to 6 m. It prefers full sunlight and well-drained soil with a mean soil temperature of 15° to 27 °C. A study on the effect of physical treatment on germination of *G. biloba* seeds has confirmed that its seed viability decreases with time. Use of FYM at the rate of 45 t/ha resulted in excellent production of fresh leaf weight.

Propagation through seeds

Seeds are stored in an incubator at 5°C for three months (Fig. 1). After every 15 day's interval, the seeds are dipped in ordinary water for five to six minutes; the seeds are washed and cleaned with a clean towel and all the water droplets are removed from the outer layer of the seed coat. The seeds are again kept in an incubator at 5°C. This process is applied after every 15 days of interval. Before sowing, in a polyhouse under controlled conditions, temperature 25°C ± 2°C and humidity of 70% are maintained.



Fig. 1 Seeds of G. biloba



Fig. 2 Seedlings of G. biloba



Fig. 3 Nursery of G. biloba

The old soil from beds is removed up to a depth of 8 inches. A two-inch layer of fine sand is spread on the deep surface of the beds. In the middle layer 1:1:1 ratio (soil:FYM:sand) is thoroughly mixed and spread as a 4-inch layer above the fine sand layer. Again, at the top, a 2-inch fine sand layer is also spread out. The seeds are sown at 2-inch depth in the sand layer. The treatment of hormones IAA, IBA, NAA, and salicylic acid, 250 mg/1, 500 mg/1, and 1000 mg/1, respectively, is taken, and the seeds are dipped for 3 hours. One set is sown in a polyhouse and 2nd in an open bed covered with 50% agro-net providing partial shade, as it was observed that the agro-net shade no germination was recorded. Irrigation is done as and when it is required. The same culture media can be used in both treatments. In controlled conditions (polyhouse), the seed germination was observed at 85.74 %.

Propagation through stem cuttings

It is done using semi-hard cuttings (3-4 years old) of pencil thickness. The best results were observed in the cuttings taken from three-year-old side branches from mother plants. The stem cuttings should be 12-15 cm in length and 6-9 mm in diameter with 5-6 nodes. The stem cutting should be treated with some selected growth hormones using different concentrations. The cuttings have to be planted in the month of December in a polyhouse under controlled conditions. The sprouting is observed in April, just after returning the normal climatic conditions after winter. The sprouted cuttings are placed in the polyhouse for three years under controlled conditions (temperature 25°C ± 2°C and humidity 70%). After 4 years, these plants are shifted into polythin sleeves (Fig. 6) and put for hardening under partial shade using a 50% green agro-net. CSIR-IHBT has raised more than 30,000 saplings by following the above techniques and also has a six-acre area of plantations of this species in CSIR-IHBT research farms.



Fig. 4 G. biloba propagation by seed



Fig. 5 G. biloba by stem cutting



Fig 6. G. biloba planting material





***G. biloba* nursery plantation view after second year in polyhouse**



G. biloba transfer to the field



***G. biloba* plantation in the field**

Harvesting and yield

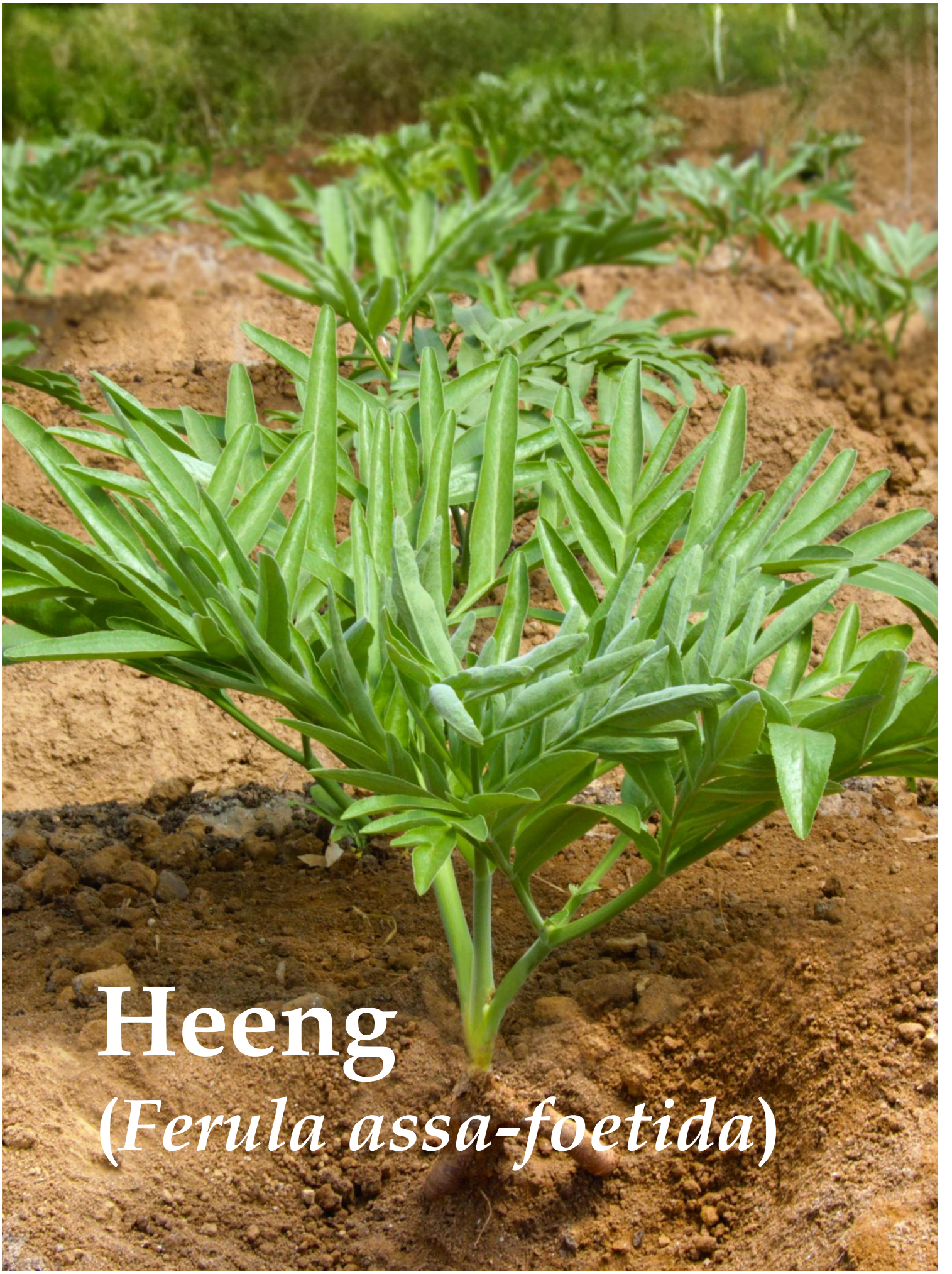
The plant is ready to harvest from the end of October month till the mid of November. The leaves are plucked manually from the plant, and these are dried under partial shade/shade conditions for a week. The yield from its fresh leaves is 3.338 t/ha after four years of plantation.

Planting materials can be obtained from CSIR-IHBT presently at Rs. 200/plant.



Ginkgo plantation at CSIR-IHBT, Palampur, HP




Heeng
(Ferula assa-foetida)

Heeng (*Ferula assa-foetida*)

Dr. Satbeer Singh, Dr. Ramesh Chauhan and Dr. Sanatsujat Singh
Agrotechnology Division

Ferula assa-foetida (heeng) is one of the prominent spices and medicinal plants which is a native of Iran and Afghanistan. Raw asafoetida (heeng) is extracted from the fleshy roots of *F. assa-foetida* as an oleo-gum resin. India is the primary consumer as well as the secondary supplier/re-exporter of heeng. However, cultivation of this herb is hindered by several challenges such as low germination, seed dormancy, plant survival, extended plant dormancy, specific agro-climatic conditions and poor oleo-gum resin extraction methods. Besides, this plant has a high potential to diversify sources of farmers' income and improve their livelihood, especially living in the Himalayan periphery.

1. Health benefits and applications in medicine

Due to its antispasmodic and anti-inflammatory characteristics, asafoetida, also known as heeng, has been used as a medication for centuries to treat stomach ailments like gas, bloating, intestinal worms, and flatulence. Further, due to its anti-inflammatory, anti-viral, and antibacterial properties, asafoetida may also aid in treating respiratory problems including asthma, bronchitis, dry cough, and others. Additionally, it aids in phlegm release and chest congestion relief. Asafoetida is also known as a natural blood thinner that has the potential to reduce blood pressure. It is loaded with coumarin, a substance that helps to increase blood flow and prevents the development of clots. Besides this, menstrual cramps and soreness in the lower abdomen and back may be lessened by asafoetida. It also increases progesterone release, encouraging smooth blood flow and lessening discomfort. The herb is considered useful in the treatment of several problems concerning women, such as sterility, unwanted abortion, pre-mature labor, post-delivery period, unusually painful, difficult and excessive menstruation and leucorrhoea.

2. Economic impact and market demand

India is one of the largest heeng consumers globally, yet it does not cultivate the crop domestically. Consequently, imports mainly from Afghanistan, Iran, and Uzbekistan meet the entire national demand. About 40% of the world's consumption of *F. assa-foetida* comes from India. The Indian asafoetida market size is estimated to be INR 6000 crores. During 2024, India imported 1456.5 tonnes of asafoetida valued at Rs. 1240.56 crores from Afghanistan, Iran and Uzbekistan. Asafoetida is considered a high-value commodity, and the international price for raw asafoetida ranges between Rs. 9,584 and Rs. 12,532 per kilogram.

India also processes the raw asafoetida and exports it to around 120 countries and territories. In 2020, the total export value of processed asafoetida reached Rs. 57 crores. The five major importers USA, Canada, United Arab Emirates, United Kingdom, and Singapore, together accounted for approximately 60.91% of this total, contributing Rs. 35 crores.

3. Raw material availability and conservation status

In India heeng plant is not found in wild. The entire raw material requirement has traditionally been met through **imports of oleo-gum resin** from Afghanistan, Iran, and Uzbekistan. India's dependence on imports has made it vulnerable to price fluctuations and supply disruptions.

4. Recent initiatives in domestic cultivation

CSIR-IHBT, Palampur is leading an initiative to cultivate asafoetida in India, specifically in the cold desert regions of Himachal Pradesh, and other high-altitude areas of Uttarakhand and Ladakh. This project aims to reduce the country's reliance on imported heeng by establishing domestic seed production and cultivation practices.

5. Agrotechnology

Cultivation technique

Heeng is primarily propagated through seeds. One kilogram of seeds is usually required to cultivate one hectare of land. However, if seedlings are first prepared in a nursery and then transplanted into the field, the quantity of seed needed can be reduced significantly. Cultivation of heeng is considered suitable in sloped or flat land where sunlight falls directly. Although direct sowing in the field is possible, for better germination success, it is advisable to **sow seeds in nursery beds in October/November**, just before the snowfall. Seed treatment (pre-sowing treatment) enhance germination.

Seedlings are transplanted into well-prepared pits (1.0 × 1.0 feet size) with well pulverized soil mixture having soil, FYM and sand (1:1:1 ratio) at a spacing of **1.0 × 1.5 m**. Transplanting is best done in **November/December** in midhills and for high altitude areas it is done during the month of April.



Heeng seed germination under controlled conditions



Heeng seedlings growing in nurseries

Soil preparation

The plant grows well on mixed sand and sandy loam deep soils. However, its cultivation needs well-drained soil beds. It is unbiased to a wide range of soil pH (acidic/basic/neutral) and excessive moisture in the soil can cause root rot disease resulting in plant mortality during the active vegetative phase or dormancy period. *F. assa-foetida* prefers wet conditions only during the germination stage, but it can be harmful at later stages of growth.

Climate needs

Agro-climatically, the cultivation of *F. assa-foetida* is suitable at an altitude of 2000-4000m amsl and from 15 to 70 percent steep slopes with an average annual precipitation ranging from 25 to 35 cm. It is a crop of the cold desert regions and needs abundant direct sunlight for its growth. Therefore, cold desert hilly areas with sun-facing side is most suitable for its successful cultivation.



Heeng plantation in Lahaul & Spiti

6. Cultivars developed at CSIR-IHBT

Currently, the genetic potential of heeng has not been fully harnessed through breeding practices worldwide and remains still underutilized. CSIR-IHBT introduced heeng (six accessions) for the first time in the country through ICAR-NBPGR, New Delhi and the germplasm was again enriched further with sixty accessions from Iran and Afghanistan, respectively. These diverse germplasm lines are being characterized at several targeted locations in cold desert regions in India by the institute. Since, the plant enters the reproductive phase and produces oligo-gum resin in the fifth year of its growth; hence, classical breeding approaches and selection can only be employed once in a five-year period, making its varietal improvement a very long drawn process. Plant harvested for oleo-gum resin cannot produce seeds for the next generation, making the direct selection for resin quality and yield impossible. Hence, a homomorphic selection approach that can offer selection tools in a crop where seed yield and economic yield are mutually exclusive have been developed at CSIR-IHBT and is being followed. Also, new genetic variations need to be created for adaptation under different agro-climatic conditions. Techniques such as hybridization, induced mutagenesis and somaclonal variations are being undertaken for its genetic improvement.

7. Stakeholders and purpose of collaboration

The successful cultivation and commercialization of *F. assa-foetida* in India involves a multi-stakeholder approach. Key stakeholders are farmers, NGOs and Farmer Producer Organizations (FPOs), Industrial Partners (Herbal/Pharma/Aroma Industries), Research and Development Institutions (e.g., CSIR-IHBT, ICAR, NBPGR), Government Agencies & Departments (e.g., Agriculture/Horticulture Boards).

8. Sustainability and future trends

Organic farming and eco-friendly practices

Heeng is naturally suited for organic cultivation due to its low input requirements. Organic farming avoids chemical fertilizers and pesticides, ensuring safer and more environmentally responsible production. Use of compost, vermicompost, biofertilizers, and natural pest repellents can support soil health and biodiversity.

Emerging innovations in agriculture

New farming technologies are gaining attention for enhancing productivity, sustainability, and resource efficiency:

Phytofarming/Phytofactory: Controlled cultivation of heeng for consistent resin yield in protected environments such as greenhouses, potentially enabling year-round production.

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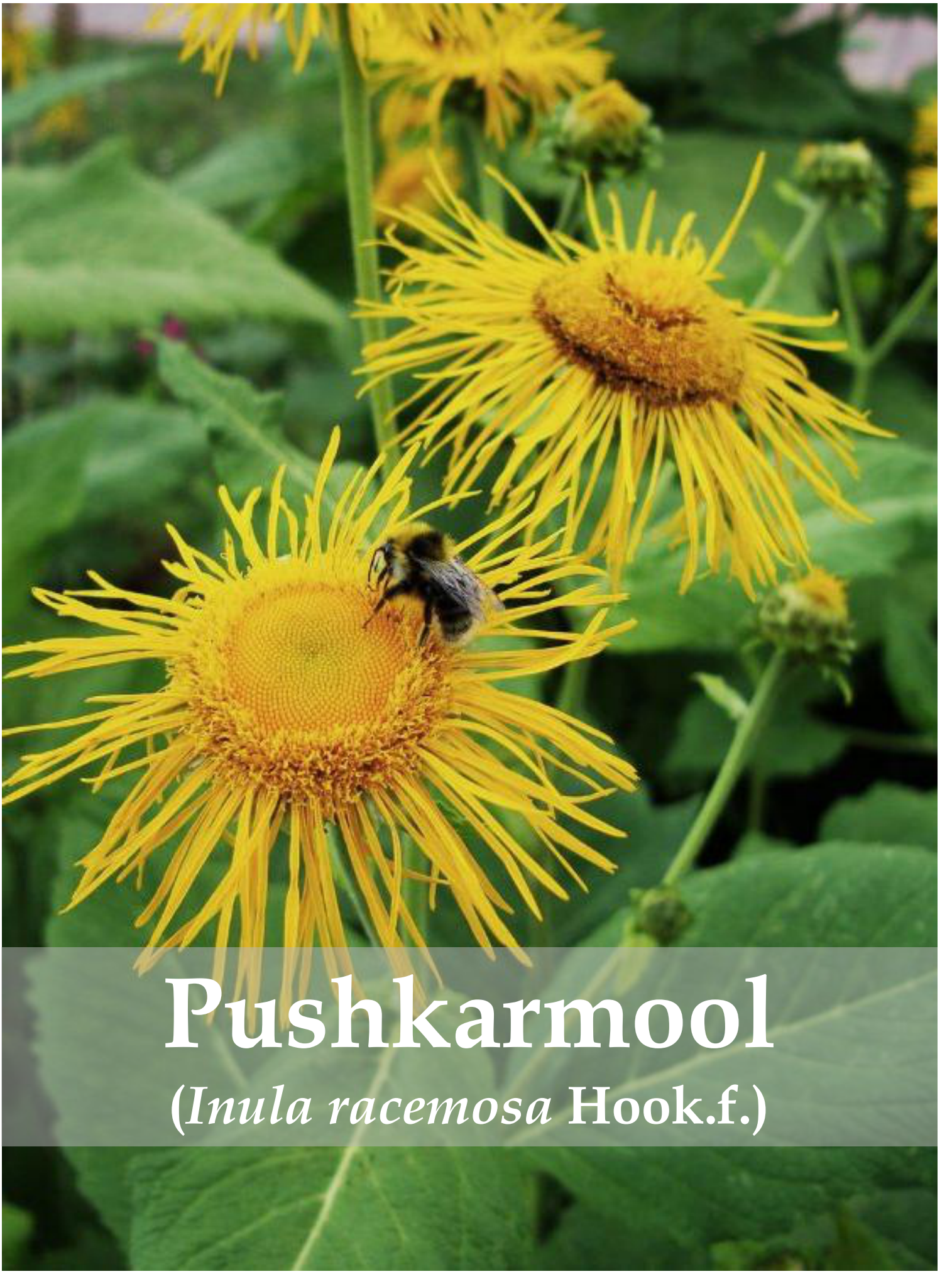


Pushkarmool

(*Inula racemosa* Hook.f.)

Pushkarmool (*Inula racemosa* Hook.f.)

Dr. Ramesh Chauhan, Mohit and Tamanna Bhalla
Agrotechnology Division

1. Health benefits and applications in medicine

Inula racemosa Hook.f. (Pushkarmool or Mannu) is a perennial herb found in temperate regions at higher altitudes reaching up to 4200 m amsl, commonly growing in open meadows and forest margins. It can grow up to 1.5 meters in height, with multiple stems emerging from an aromatic rootstock and elliptic-lanceolate leaves with a densely hairy underside. Its roots and rhizomes have been extensively used in traditional medicine systems such as Ayurveda, Tibetan, Chinese, and Nepalese medicine. The plant is traditionally employed for treating a wide range of health conditions including respiratory ailments (cough, breathlessness, asthma), gastrointestinal issues (dyspepsia, abdominal pain, indigestion), cardiovascular disorders (angina, palpitations), reproductive issues (menstrual irregularities, miscarriage prevention), infectious diseases (bacillary dysentery, acute enteritis), metabolic disorders (diabetes), inflammatory conditions, joint and muscular pain, and even certain cancers. It is also used as a general tonic and rejuvenator to enhance vitality and immune function.

Phytochemically, *I. racemosa* is rich in essential oils containing sesquiterpene esters and lactones, including compounds like dihydro-iso-alantolactone, allolantolactone, and β-elemene. These bioactive constituents contribute to its pharmacological effects such as hypoglycemic, cardioprotective, immunomodulatory, antimutagenic, and antiapoptotic activities. Its therapeutic potential has led to its increasing utilization in the pharmaceutical industry for drug synthesis and the development of novel compounds (Rathore et al. 2022, Thakur et al. 2024)

2. Economic impact and market demand

I. racemosa holds substantial economic and medicinal importance, with growing demand in both domestic and international herbal markets. The increasing global interest in plant-based therapeutics and traditional medicine systems has significantly boosted its market value, particularly in countries such as India, China, and Nepal, as well as in parts of Europe and North America where it is imported as a raw material for pharmaceutical, nutraceutical, and herbal industries. The global *Inula* extract market was valued at approximately USD 238.47 million in 2023 and is projected to reach USD 342.12 million by 2029, reflecting a CAGR of 6.20% (Stat Market Research, 2024). In India, particularly in the Lahaul valley of Himachal Pradesh, *I. racemosa* has been successfully domesticated, with commercial cultivation yielding about 6 tonnes/ha dried roots per hectare. The market price ranges from ₹175–200 per kg and the current estimated annual trade demand for *I. racemosa* is around 200-500 metric tonnes (Goraya and Ved 2017, Divya et al. 2022 and Vishvamitera et al. 2025).

3. Raw material availability and conservation status

In India, the availability of *I. racemosa* as a raw material remains a significant concern due to its overreliance on wild harvesting and limited cultivation. Despite its high medicinal value and commercial demand, over 90% of the raw material is still sourced from wild populations through destructive methods.

Historically, *I. racemosa* was categorized as Critically Endangered (CE) and was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), as well as among the 427 endangered plant species of the Red Data Book. Although it is not currently recognized as such on the IUCN Red List, likely due to increased cultivation efforts, the species remains vulnerable due to habitat loss and overexploitation by the pharmaceutical industry. Over the past few years, renewed commercial interest driven by market demand has encouraged local communities to reinitiate its cultivation. Despite this revival, the species continues to face threats from habitat degradation and unsustainable harvesting, emphasizing the urgent need for both *in situ* and *ex situ* conservation strategies to ensure its long-term survival and availability for commercial use (Rana et al. 2022).

4. Agrotechnology

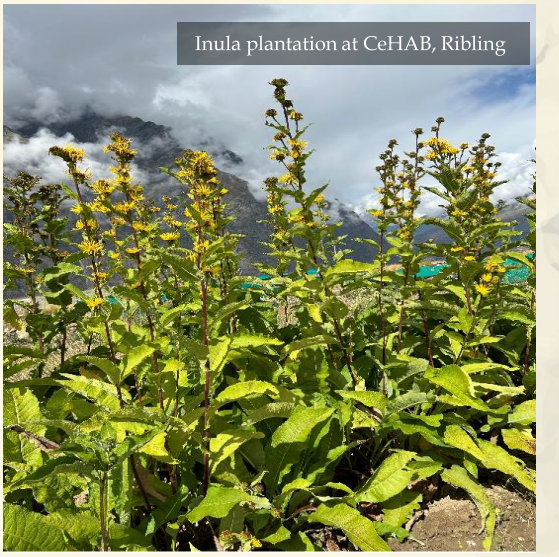
Propagation

Propagation of *I. racemosa* is commonly achieved through both seed sowing and root cuttings. Seeds are typically collected in September and require pre-sowing treatments such as chilling and GA_3 application. About 1 kg seed is required for 1 ha of land and consequently raises about 40,000 seedlings. Seed sowing is done in greenhouse nurseries or polyhouse conditions during November to December, where germination begins around March. About two months after sowing, seedlings are then transplanted to the field. Root cuttings, prepared from fresh roots with developing apical buds, are also be used for propagation, especially since seed survival can be low. Root propagation is usually initiated between October and November and is favored for its reliability and faster plant establishment.


Inula plants during flowering


Root Biomass of Inula plant


Inula plants during flowering


Inula plantation at CeHAB, Ribling

Climate

I. racemosa thrives best in alpine and dry temperate climates at altitudes ranging from 1500 to 4200 meters (amsl) in the Himalayan region. The species favors open, sunny locations that promote optimal growth. The ideal temperature range for its successful cultivation is between 15 and 25°C.

Soil preparation

I. racemosa grows best in sandy, porous soils, particularly black sandy loam with well-decomposed farmyard manure (6–8 tons/acre) for optimal yield. Successful cultivation requires thorough land preparation, including deep tilling (15 cm), removal of debris and stones, breaking compacted soil, and leveling the field to ensure proper drainage. Porous soils promote faster root growth and better establishment.

Planting density and nutritional requirement

In transplantation method, transplanting of two months old seedling in the main field can be done at an optimum recommended spacing of 30×45 cm or sometimes can be increased to 50×50 cm. Inorganic fertilizers like nitrogen, phosphorus, and potassium are applied at the rate of 120, 75, and 40 kg/ha, respectively, per season. The full dose of nitrogen is given in two equal split doses, first as basal dose, and the second dose is given as top dressing after 2 months of transplanting, while, full dose of phosphorus and potassium are applied at the time of planting.

Harvesting

The roots of *I. racemosa* are typically harvested in October, after two to three years of growth. Prior to harvesting, the field is irrigated to soften the soil, making digging and uprooting easier. In September, the aerial parts of the plant are removed, and the crop is left in the field for about a month. Harvesting is then carried out using a pickaxe to extract the roots, which are subsequently cut into small pieces. These root segments are stored in underground pits and retrieved as needed, either for replanting in March/April or once the snow has melted to initiate the next crop cycle (Thakur et al. 2024).

5. Cultivars developed at CSIR-IHBT

Genetic improvement and varietal development efforts in *Inula racemosa* is taken up at CSIR-IHBT. A total of ten selections (for higher root biomass) were made through a single plant selection approach from the base population (IR-B) and are being maintained at the Centre for High Altitude Biology (CeHAB) farm in Ribling, Himachal Pradesh. Selections were subsequently maintained in isolation at CeHAB as separate plots and sib-mating was allowed within the progenies (half-sib progenies). The multi-location experiments to assess performance for morphological traits among the genotypes were laid out at diverse locations in Himachal Pradesh. Selection strategies based on multi-environment evaluations and contributing traits have been developed for this plant. The selection CSIR-IHBT-IR-09 is a stable genotype for higher root biomass and essential oil content across the environments in Himachal Pradesh. In addition, this selection is unique for the presence of highest alantolactone and isoalantolactone (marker compounds) in the essential oil across all the tested locations.

6. Processes and products formulated

The essential oil extraction of *I. racemosa* of roots is done through hydrodistillation process. The essential oil yield obtained varies from 55-85 kg/ha and essential oil content extracted in the range of 1.14% to 1.19% (Vishvamitera et al. 2025). Also, method for the enrichment of Alantolactone (ALT) and Isoalantolactone (IALT) has been developed at CSIR-IHBT with forty percent purity (40% hexane: ethyl acetate by column chromatography) from the roots of *Inula racemosa.*

7. Stakeholders and purpose of collaboration

Multiple stakeholders such as local farmers, pharmaceutical companies collaborate to promote the sustainable cultivation and conservation of *I. racemosa*. This collaboration aims to establish a sustainable value chain by integrating scientific research, improved cultivation practices, and market linkages. Farmers can be supported through training, technical guidance, and access to quality planting material, while industry partners ensure market assurance and quality compliance.

8. Sustainability and future trends

The sustainability of *I. racemosa* cultivation and utilization is gaining attention due to its ecological vulnerability and high commercial demand. Traditionally overharvested from the wild, the species has faced significant population declines, prompting its listing as critically endangered in some conservation assessments. However, the shift toward cultivated sources has opened a path for sustainable production. Adoption of good agricultural practices (GAPs), promotion of organic farming, and community-based conservation models are emerging as effective strategies to reduce pressure on wild populations and ensure long-term availability.

Looking ahead, the future of *I. racemosa* lies in integrating science-led cultivation protocols, value addition through processing, and traceable supply chains for the herbal and pharmaceutical industries. Research into *in vitro* propagation techniques, high-yielding varieties, and climate-resilient practices is expected to play a key role in scaling up sustainable cultivation. Additionally, rising demand for herbal and plant-based medicines globally is likely to drive investments in contract farming, public-private partnerships, and policy support. With the right combination of conservation, cultivation, and commercialization strategies, *I. racemosa* holds strong potential for sustainable livelihoods and biodiversity preservation.

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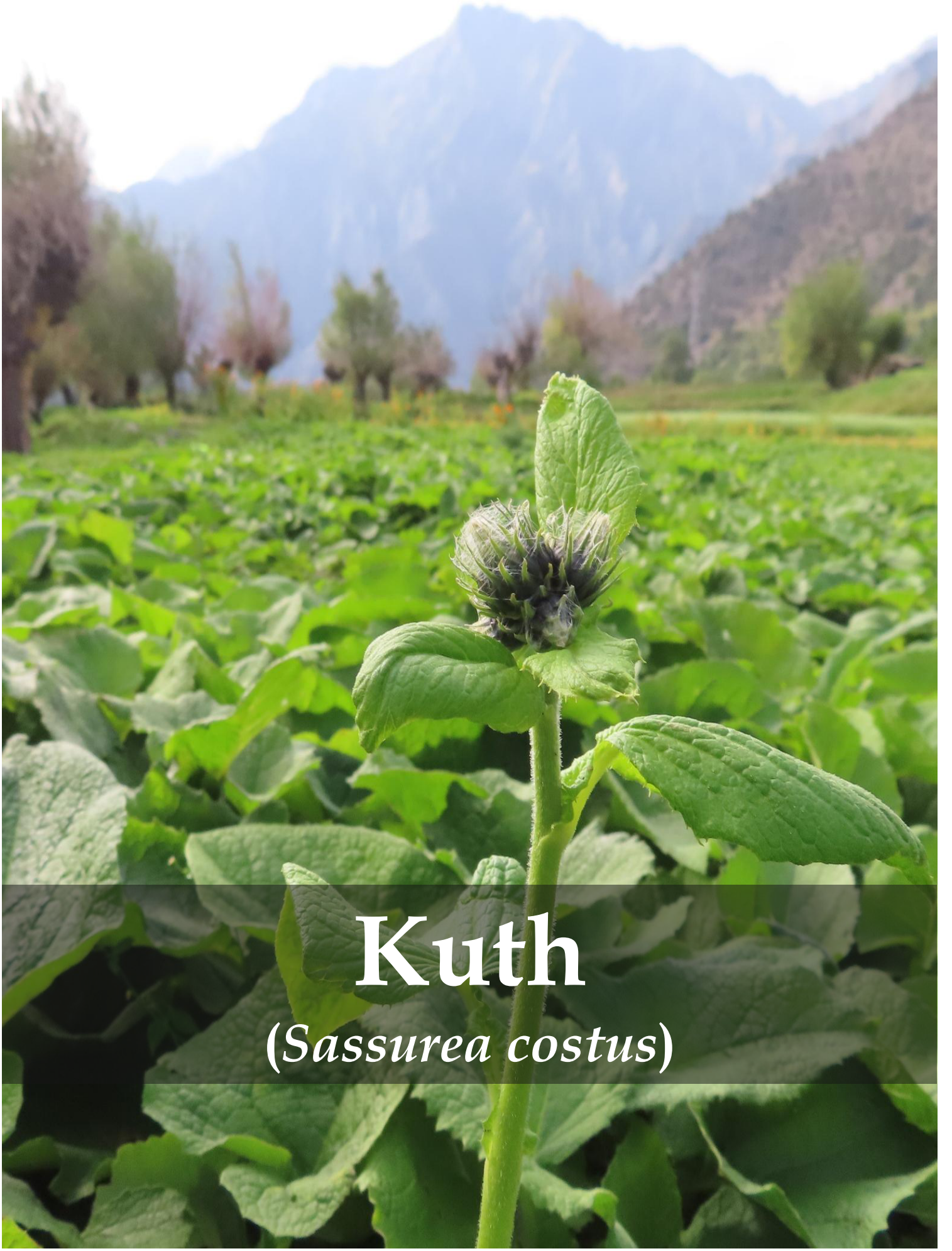

Kuth

(*Sassurea costus*)

Kuth (*Sassurea costus*)

Dr. Ramesh Chauhan and Mohit
Agrotechnology Division

Saussurea costus, also known as Kuth, Kostus, Kut root, or Kstha, is an endangered medicinal plant endemic to the northwestern Himalayas and its surrounding regions. In the wild, it is found in areas such as Pithoragarh, the Bhilangana and Bhagirathi valleys of Uttarakhand, as well as Kinnaur, Lahaul and Spiti in Himachal Pradesh, and various parts of Jammu and Kashmir. Due to continuous and unregulated extraction from its natural habitat, the population of this species has drastically declined, pushing it to the brink of extinction. As a result, *Saussurea costus* has been officially listed as an endangered species in the Red Data Book of Indian Plants, emphasizing the urgent need for conservation efforts.

1. Health benefits and applications in medicine

In India, it is cultivated in the Himalayas as a medicinal plant and also for its use in perfumery and for preserving furs. It is used singly or as an ingredient in the drug formulations prescribed for the treatment of cough, bronchitis, colic, dental trouble, diarrhoea and dysentery, liver dysfunction, pulmonary disorders, fever, flatulence, hair wash, headache, hysteria, chest complaints, nervous disorders, irregular menstrual problems, promoting urination and rheumatism. The roots have an acrid, strong and sweet aromatic odour and bitter taste with neutral potency. The root of this plant is credited with anodyne, anti-arthritis, aphrodisiac, astringent, stimulant, digestive, diaphoretic, deodorant, antiseptic, diuretic, emmenagogue, expectorant, febrifuge, spasmodic, vermifuge and tonic properties. The roots contain an alkaloid, 'saussurine', which is medicinal. It is used in skin diseases, asthma, high blood pressure and stomach ailment. Also used as carminative, prophylactic and sedative. Dry roots constitute the drug 'Saussurea'. In Kashmir the roots are used to protect woolen fabrics. Kuth is also distilled for its essential oil. Dry roots (Kuth, Costus) are strongly scented and yield an aromatic oil used in making insecticides. The pharmacological investigations of costus oil of *S. costus* revealed its anti-carcinogenic potential for breast cancer, in addition to its effectiveness against several microbial infections due to the presence of sesquiterpenoids, flavonoids, monoterpenes, lignan glycosides, steroids, triterpenes, etc. Its different formulations are also used in Ayurvedic medicines for the treatment of several problems like quartan malaria, typhoid fever, leprosy, toothache, persistent hiccups, gout, stomach ache, etc. Various traditional Tibetan preparations that are employed for the treatment of chronic inflammation of the chest and lungs contain *S. costus* as one of the important components.

Major Therapeutics Potential of *S. costus*

Anti-inflammatory properties

Research has shown that certain natural compounds found in *Saussurea costus*, especially sesquiterpenes, have strong anti-inflammatory effects. According to Damre et al. (2003), these compounds help reduce inflammation by preventing certain harmful cell activities and controlling the levels of inflammatory markers like NOX and TNF-alpha in immune cells. Another compound, costunolide, reduce the production of a key inflammatory protein called interleukin-1beta.

Anti-tumor properties

Cancer is one of the top causes of death globally, and *Saussurea costus* has shown promising results in lab studies (*in vitro*) for its anti-cancer potential. The key compounds responsible for these effects are costunolide, cynaropicrin, and dehydrocostus lactone.

Antibacterial properties

S. costus has been shown to exhibit antibacterial action against a wide range of resistant pathogens using various aqueous extracts, including petroleum ether, ethanolic, and methanolic extracts. The effectiveness of an ethanolic extract against 5 clinical strains of *Helicobacter pylori* was reported by Yang (1997).

Cardiovascular properties

Upadhyay et al. (1996) reported that an extract of *S. costus* lowers blood pressure, cholesterol, and triglycerides levels in the blood. Blood fibrin content is strengthened by aqueous decoction of root oil of costus and has been linked to a hypoglycemic effect.

2. Economic impact and market demand

The trade reported is for the roots, live plants, derivatives, extracts, oil and formulations. Kullu is the biggest centre of trade. The raw drug (roots) collected from wild plants comes mainly from Jammu & Kashmir while the cultivated sources come from Lahaul Valley of Himachal Pradesh. Jammu & Kashmir State's Forest Development Corporation located at Baramulla handles the commercial supply of the raw drug collected from Jammu & Kashmir. Small quantities of the raw drug are also produced from Uttarakhand. Lahul Kuth Growers Co-operative Marketing Society based at Manali markets this raw drug produced by cultivation in Himachal Pradesh. This raw drug is also available with the drug dealers located at Chamba, Kullu and Manali in Himachal Pradesh; Rishikesh and Ramnagar in Uttarakhand. Crude drug markets located at Amritsar, Delhi and Mumbai undertake commercial supplies on specific demand. Presently, roots of this plant are mostly exported to Hong Kong, France and Singapore. It is also exported to China, Thailand, Vietnam, Japan, Sri Lanka, Siberia and Netherlands. France is the largest importer of costus root. China was the largest exporter of costus, it has exported 1024 tons from 1983 to 2009, and India as the second-largest exporter shipped out 266 tons in the same period.

Estimated consumption by the domestic herbal manufacturing units has been assessed at a range between 100 and 200 MT (dry wt.). Kuth exported to Europe, primarily France and The Netherlands is used for oil production. Export to France started in 1964-65 and Japan in 1965-66 with steadily increasing trends. Export price varies among different countries. Export price to Thailand was highest, Rs. 9.77/kg during 1970-74 and to that of Singapore was Rs. 6.44/kg. The current market price of roots of this plant ranges from Rs. 80 to 100/per kg. Essential oil of the roots of this plant varies from Rs. 10,000 to 12,000 per kg.

3. Raw material availability and conservation status

Wild-collected roots mainly come from **Jammu & Kashmir**, while **cultivated sources** are located in the **Lahaul Valley of Himachal Pradesh**. *Saussurea costus* is internationally recognized as a **critically endangered species,** primarily due to uncontrolled exploitation and rising demand in the global market. Over the years, the plant has disappeared from several natural habitats as a result of unsustainable harvesting practices. In response to this alarming decline, cultivation efforts have been increasingly promoted in recent decades to support its conservation. A significant initiative in this direction is the **CSIR Phytopharmaceutical Mission project**, launched by the **Council of Scientific and Industrial Research (CSIR).** Under this mission, the **IHBT, Palampur, Himachal Pradesh,** has undertaken large-scale captive cultivation and has developed **superior planting material**. The aim is to restore its wild populations and eventually **to bring** *S. costus* **from "critically endangered" to "non-endangered"** category through strategic conservation and propagation efforts.

4. Agrotechnology

Cultivation technique

Temperate and sub-alpine regions have better agro-climatic conditions for its cultivation. Before the winter falls, typical seed propagation is carried out in October and November.

Soil preparation

S. costus can be grown in both alluvial and sandy soil, but loamy soils with a well drainage system are best for its cultivation. Sloppy and stony soils are not fit for its cultivation. Crop grown in deep rich porous soils resulted in long and thick roots. *S. costus* is a root crop, hence soil should be plowed two to three times to obtain ideal conditions for root growth. Stubbles of previous crops and weeds should be removed from the field. Farmyard manure (FYM) should be well mixed and incorporated into the soil to make it crumbly. Apply planking after each tillage operation to break the heavy clod and to make the soil friable.

Climate

S. costus peculiarly occurred in geographically constrained parts of the western Himalayas (Jammu and Kashmir, Uttarakhand, and Himachal Pradesh) at an elevation of 3000-3800 m amsl. **Propagation and harvesting methods**

The main obstacle for *S. costus* cultivation is its lengthy cultivation cycle and profitable roots being harvested after 2-3 years. *S. costus* can be propagated through seed, seedling, and root cutting; however, seed sowing is more economical. *S. costus* is generally grown through seed sowing and sowing is done before the onset of winter, i.e. October/November to fulfill its chilling requirement. However, the farmers in the Garhwal region (Uttarakhand) start sowing during April-May. For broadcasting, around 34.02 kg of seed is needed for 1 hectare. Seed can be sown through hand dibbler or in rows 25-30 cm apart and 2-3 cm deep using seed at 30 kg/ha. This crop can be grown by raising seedlings in nursery for 1 year and further can save time and space (Personal communication). For nursery, 6.5-7.7 kg of seed per hectare is sufficient. Seedlings can be transplanted in the month of April-May after the melting of snow from the field. The collar zone of the root (2-3 cm in length) can also be used for replanting *S. costus*. The plants become dormant in winter and start sprouting in April-May.



Plantation of Kuth in Lahaul & Spiti

Typically, well-grown, mature root tubers develop in 2-3 years and are harvested in the month of October. The output, nevertheless, comes from crops that are 3 years old. In order to make the topsoil layer soft and loose for simple digging, the field is typically watered before harvesting. Pickets are used to excavate the roots. By screening through a locally built coarse-sieve, the soil and undesirable scales are eliminated. The soil and roots that are free of scales are then fully dried. Finally, they are kept in a dry location, after being tightly sealed in a gunny or plastic bag.

5. Processes and products formulated

Extraction and Purification of Bioactive Compounds

IHBT has developed technologies for extracting and purifying costunolide and dehydrocostus lactone from Kuth, which are key bioactive compounds with potential medicinal properties.

6. Stakeholders and purpose of collaboration

The conservation and commercial cultivation of *Saussurea costus* involve multiple stakeholders working in coordination under government and institutional initiatives. The primary aim is to ensure sustainable utilization**,** species conservation**,** and economic development through scientific intervention and market integration. Key stakeholders are Farmers/Local Communities, NGOs and Farmer Producer Organizations (FPOs), Industrial Partners/Herbal Drug Manufacturers and Government Agencies (e.g., NMPB, State Forest Departments.

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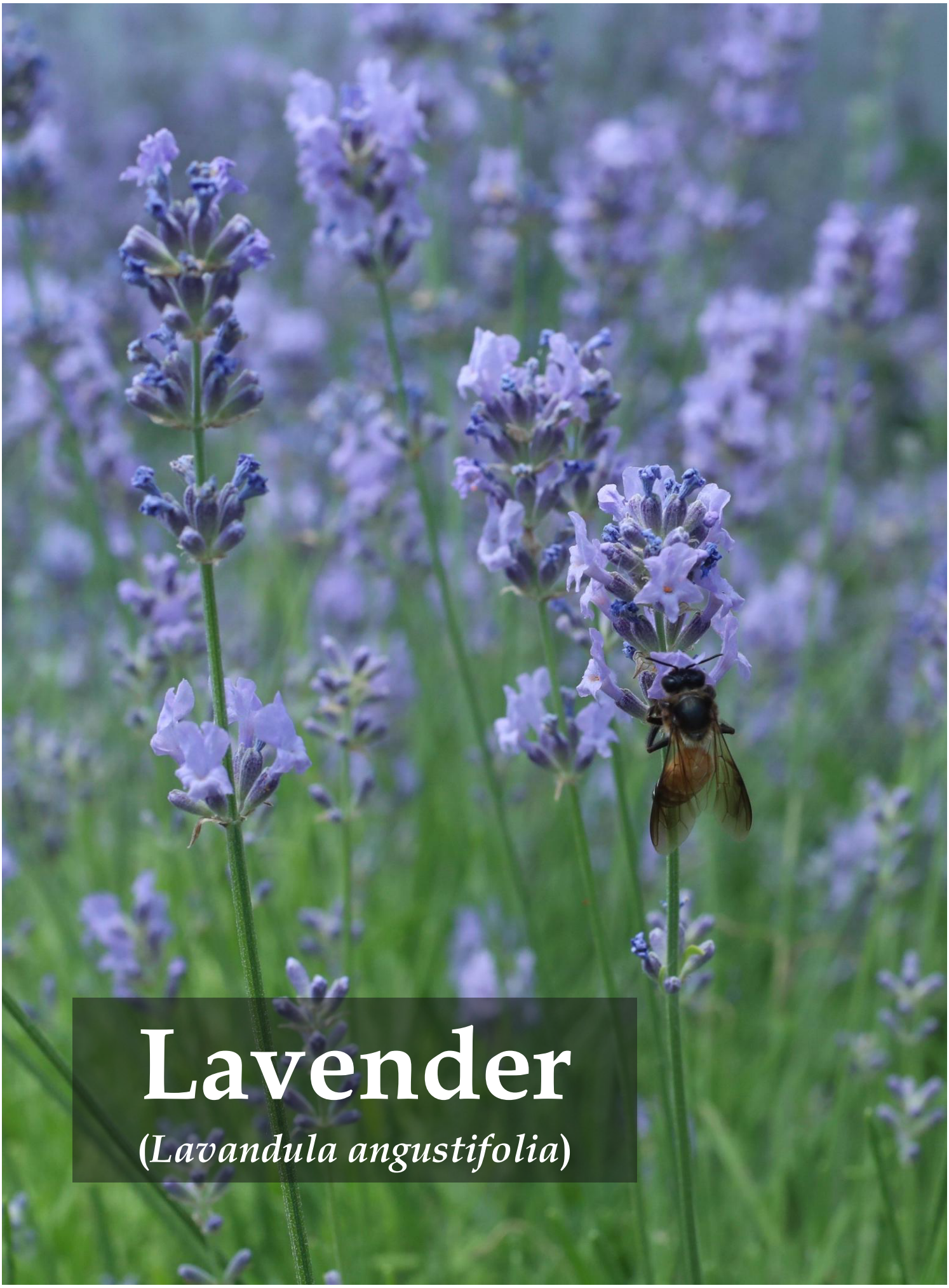

Lavender

(*Lavandula angustifolia*)

Lavender (*Lavandula angustifolia*)

Dr. Satbeer Singh and Pratibha Pandey
Agrotechnology Division

1. Health benefits and applications in medicine

Lavandula angustifolia, commonly known as English lavender is a perennial, aromatic shrub belonging to the family Lamiaceae. It is native to mediterranean region and leading lavender producers are Bulgaria and France, followed by other countries such as Russia, Ukraine, Moldova, Romania, Hungary, Poland, Italy, Spain, Turkey, Morocco, United Kingdom, United States, Australia, South Africa. Lavender plantations, both inside and outside Europe, have increased in number recently. In India, it is particularly cultivated in Jammu & Kashmir, Himachal Pradesh, and Uttarakhand under Aroma Mission. Its essential oil is mainly extracted from flowers which has many therapeutic properties and health benefits like anti-inflammatory (arthritis, muscle soreness), antimicrobial (bacterial, fungal skin infections), neuroprotective (Alzheimer's, cognitive decline), anxiolytic (Generalized Anxiety Disorder), antioxidant (oxidative stress-related disorders), wound healing effect (Cuts, burns, abrasions), analgesic (headaches, migraines, joint pain) etc. and calms the nervous system due to which it is used in aromatherapy.

2. Economic impact and market demand

Due to high quality essential oil of lavender, its oil is mostly used in perfumery and cosmetic industries, as flavoring agent in food and beverage industries. the worldwide production of true lavender (*Lavandula angustifolia* Mill.) essential oil is estimated at 300-500 tons per year. Global lavender oil market is expected to reach USD 864.7 million with a CAGR of 10.3% between 2020-2025.

3. Raw material availability and conservation status

Lavender is a non-native cultivated species which is maintained in germplasm banks by CSIR-IIIM, Jammu, CIMAP, Lucknow, CSIR-IHBT, Palampur, and other agriculture universities. It is not naturally found in the wild in India hence not listed in any threatened categories but its preservation is usually done by germplasm banks, through CSIR missions. Climate and loss of genetic diversity due to clonal propagation majorly affect its conservation status.

4. Agrotechnology

Propagation

Lavender plants can be propagated by seed, cuttings, plant division, layering or tissue culture but is mainly propagated from cuttings. Cuttings should be made from strong and healthy plants. Cuttings are taken in autumn or in spring (September, October, March or April) from 3-5 years old plants. Generally rooting hormones are preferred to encourage growth of roots. Application of indole butyric acid (IBA) on basal stem cuttings showed a higher percentage of rooting and a greater number of roots.

Climate

Lavender prefers a climate with warm summer and cool winter regions. It requires a relatively high temperature for germination and for entering into the vegetation stage (around 10°-15°C. Water requirements are moderate, and the plants are resistant to occasional drought, but persistent long periods of dryness can wilt the plants. Among the environmental factors, the microclimate, such as temperature and precipitation distribution along with some geographical particularities, can contribute to differences among chemotypes in aromatic plants (Crișan et al., 2023).

Soil preparation

Lavender can adapt to light, sandy, or sandy loam or gravelly soils with low fertility. They grow well in full sun with well-drained soil and require soil pH between 6 and 8. The best part of lavender is that it can be cultivated even on poor and eroded soils. Too wet and poorly drained soil causes reduction in plant growth, diseases or even kills the plant. Lavender does not need fertilizers to grow and it even thrives on nutrient-deficient soil. Application of excess nitrogen reduces the oil value of the plant making it unhealthy and increasing growth of weeds (Salehi et al., 2018).

Harvesting

The lavender harvesting starts in the second year of the crop at flowering, which takes place in June-July and continues yearly for 12-15 years in conditions of high productivity. The period and duration of flowering varies with geographical region. The harvested plant part for essential oil production is flowering tops/inflorescence. Fresh lavender flowers contain about 0.7%-1.4% volatile oil. When the plant material is dried, some volatile oil is lost. One ton of fresh inflorescence results, on average, in about 10 kg of volatile oil.

5. Cultivars developed at CSIR-IHBT

CSIR-IHBT, Palampur, has made significant advances in the genetic improvement and varietal development of lavender to meet the increasing demand for high-quality essential oil and to enhance cultivation prospects in the western Himalayan region.

'Him Aarohi (CSIR-IHBT-MC19005)

The variety 'Him Aarohi' of Lavender has been developed by CSIR-IHBT, Palampur through hybridization and clonal selection approach. The CSIR-IHBT-LOH15141 is a F_1 clone developed by hybridization between 'SeK-1' and 'No9'. The variety was selected for higher spike yield and essential oil content. This F_1 clone "CSIR-IHBT-LOH15141" has significantly higher spike yield (3.03 kg/plot) and essential oil content (12.59 g/kg) than the check (2.63 kg/plot and 11.37 g/kg) and population mean (2.60 kg/plot and 11.38 g/kg) in Himachal Pradesh.

6. Stakeholders and purpose of collaboration

Stakeholders include farmers, Ministry of Science and Technology under Aroma Mission, NABARD, and research and development institutes like CSIR-IHBT, CSIR-CIMAP, CSIR-IIIM for its large-scale production that can aid in farmers income and investigation of other benefits that can be extracted from this plant.

7. Sustainability and future trends

Among hundreds of essential oil-bearing plants, *L. angustifolia* remains one of the most valuable. Its increasing market demand is driven by consumer behavior because of its use being associated with a healthy lifestyle. Breeding efforts making use of novel findings that could aim at creating cultivars with more complex volatile profiles.

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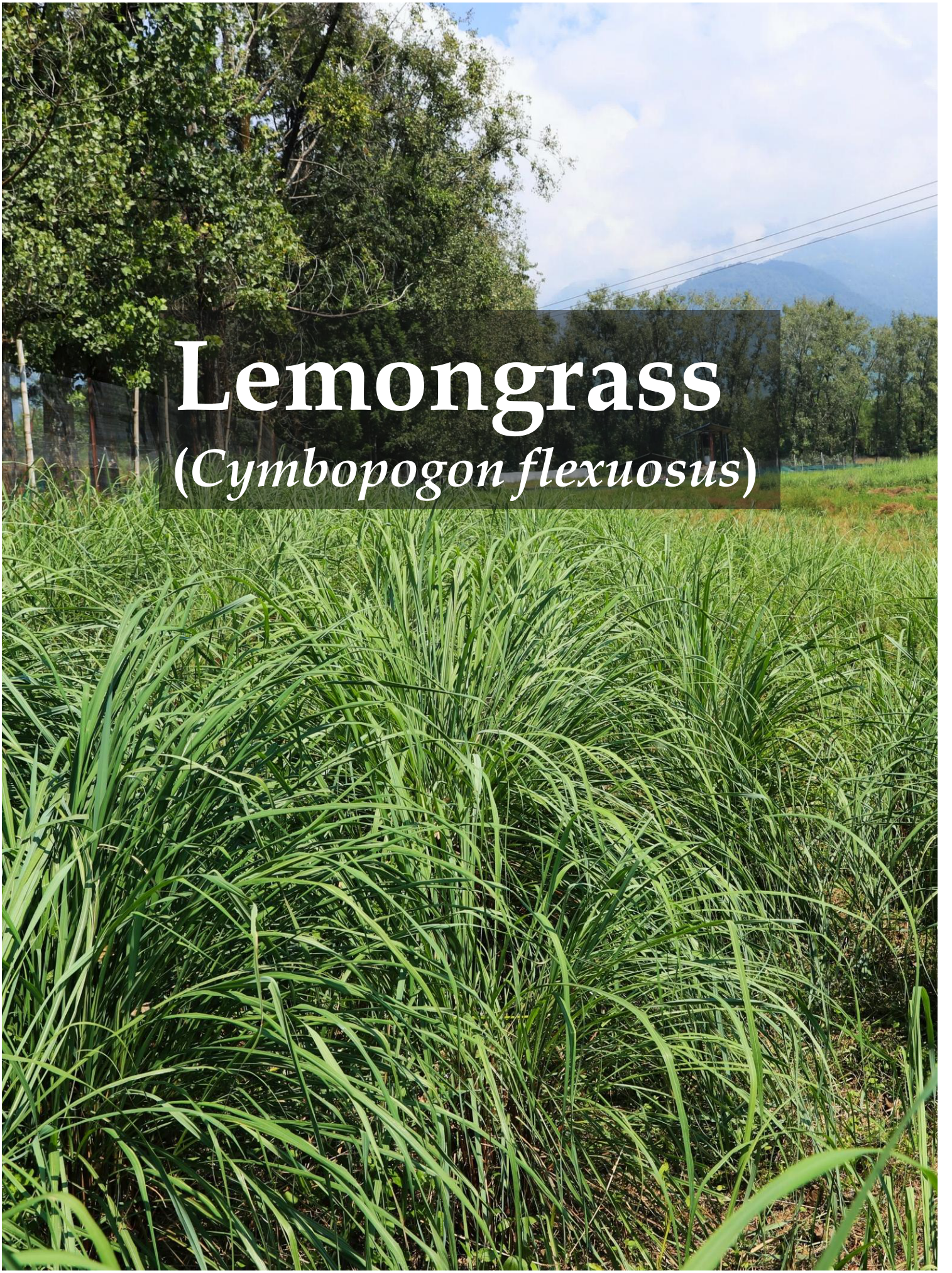
Lemongrass
(*Cymbopogon flexuosus*)

Lemongrass (*Cymbopogon flexuosus*)

Dr. Satbeer Singh, Dr. Ramesh Chauhan and Rajni
Agrotechnology Division

Lemongrass, botanically known as (*Cymbopogon flexuosus*), is a fragrant tropical grass widely cherished for its citrusy aroma and remarkable health-promoting properties. Beyond its refreshing flavor, this grass holds immense value in medicine, industry, and sustainable agriculture. With growing global interest in natural products and eco-friendly farming practices, lemongrass has emerged as a promising crop offering health benefits, economic opportunities, and environmental advantages.

1. Health benefits and applications in medicine

For generations, lemongrass has held a special place in traditional healing systems, particularly in Asia, Africa, and South America. The herb is rich in essential oils, predominantly citral, which gives it both its characteristic lemony fragrance and medicinal qualities. Modern research has validated several of its traditional uses, making lemongrass an important resource in herbal medicine. Lemongrass is commonly used to alleviate digestive disorders, reduce fever, relieve muscle pain, and combat respiratory infections. Its antimicrobial and anti-inflammatory properties make it effective against certain bacteria and fungi, while its antioxidant compounds help neutralize harmful free radicals in the body.

In recent years, lemongrass oil and extracts have gained popularity in aromatherapy, owing to their calming and stress-relieving effects. Some studies also suggest potential applications in managing cholesterol levels, supporting healthy skin, and even exhibiting anticancer properties, although further clinical research is ongoing in these areas. The growing demand for herbal products, especially those offering immunity-boosting and wellness benefits, has propelled lemongrass into mainstream medicine, cosmetics, and nutraceutical markets.

2. Economic impact and market demand

The economic importance of lemongrass has grown significantly due to its versatile applications in multiple industries. Its essential oil is a highly sought-after ingredient in perfumery, cosmetics, soaps, detergents, and herbal medicines. Globally, the lemongrass essential oil market has witnessed consistent expansion, driven by the rising demand for natural fragrances and eco-friendly personal care products.

India is one of the major producers of lemongrass, alongside countries such as Thailand, Indonesia, Guatemala, and Brazil. In India, lemongrass cultivation is an important source of livelihood, especially in rural and hilly areas where the crop adapts well. The income generated from essential oil extraction, value-added products, and herbal teas has helped improve the economic condition of many farming communities.

The international market also shows promising trends, with increasing demand for organic and sustainably sourced lemongrass oil. As health-conscious consumers shift toward plant-based remedies and clean-label products, lemongrass stands out as a lucrative crop for small and large-scale producers alike.

3. Raw material availability and conservation status

Lemongrass is abundantly available across tropical and subtropical regions. It thrives well in diverse agro-climatic conditions, particularly in regions with warm temperatures and moderate rainfall. In India, states such as Uttar Pradesh, Karnataka, Assam, and parts of Himachal Pradesh have emerged as major lemongrass cultivation zones. Although lemongrass is not classified as a threatened species, responsible cultivation practices are essential to prevent over-exploitation of wild populations and maintain soil health. Promoting scientific cultivation and preserving genetic diversity through improved varieties are key to ensuring sustainable raw material availability for the future.

4. Agrotechnology

Soil preparation and climate requirements

Lemongrass grows best in well-drained sandy loamy soils, although it can tolerate a wide range of soil types. The ideal soil pH ranges from 5.5 to 7.5. Proper land preparation involves ploughing the field thoroughly to loosen the soil and remove weeds, followed by application of organic matter to enrich soil fertility. The crop prefers warm, humid climates with temperatures between 20°C and 30°C. Annual rainfall of around 1000 to 2500 mm is considered ideal. Lemongrass requires ample sunlight, and shady or waterlogged areas are not suitable for its cultivation.

Propagation and planting

Propagation is primarily done through root divisions, also called slips, which ensure uniform and vigorous plant growth. Well-developed clumps are divided into smaller units containing roots and shoots, which are then transplanted into prepared fields. The recommended spacing for planting is about 45 to 60 cm between rows and 30 to 45 cm between plants, depending on local conditions and cultivation methods. Planting is ideally done at the onset of the monsoon or with adequate irrigation in dry regions.

Crop management and harvesting

Regular weeding, soil aeration, and irrigation during dry spells are essential for optimal growth. Organic manures and biofertilizers are increasingly promoted to minimize chemical inputs and enhance soil health. The first harvest is usually done 4-5 months after planting, when the grass reaches a height of about 1 to 1.5 meters. Subsequent harvests can be done every 3 to 4 months. The grass is cut close to the ground to encourage regrowth, making it a sustainable, multi-cut crop. Post-harvest, the leaves and stalks are subjected to steam distillation to extract the valuable essential oil, which is the primary marketable product.



5. Processes and products formulated

Lemongrass essential oil extracted through standardized processes from steam distillation with high purity and consistent quality. In addition to essential oil, there are wide range of value-added products, including:

Herbal teas and infusions enriched with lemongrass.

Natural cosmetics and skincare products containing lemongrass oil.

Ayurvedic formulations and wellness products leveraging its medicinal properties.

Insect repellents and eco-friendly cleaning products using lemongrass extracts.

These innovations not only create new market opportunities but also enhance the commercial viability of lemongrass farming for rural communities.

6. Stakeholders and collaborative initiatives

The success of lemongrass cultivation and commercialization depends on active collaboration among multiple stakeholders. Farmers, Farmer Producer Organizations (FPOs), Self-Help Groups (SHGs), Non-Governmental Organizations (NGOs), and industrial partners play vital roles in the value chain. CSIR-IHBT and other research institutes have established Training of Trainers (ToT) programs to disseminate cultivation techniques, processing knowledge, and quality standards to farmers and entrepreneurs. MoUs and technology transfer agreements with industrial partners facilitate scaling up of essential oil extraction units and product development. Such collaborations aim to generate employment, enhance farmers' incomes, promote women-led enterprises, and ensure sustainable utilization of bioresources.

7. Sustainability and future trends

Organic farming and eco-friendly practices

With increasing global awareness about environmental health, organic farming of lemongrass is gaining popularity. Organic cultivation uses natural resources including Farm Yard Manure (FYM) as fertilizer and avoids the use of chemical fertilizers and pesticides, leading to healthier soils, reduced environmental pollution, and premium market prices for organic lemongrass oil. Intercropping with legumes and incorporating organic manures improve soil structure and fertility while reducing production costs.

Emerging Innovations in agriculture

The future of lemongrass cultivation is closely linked to innovations in smart agriculture. Technologies such as hydroponics and aeroponics are being explored for growing lemongrass in controlled environments, especially in urban and resource-scarce settings. Phyto-farming or phyto-factories, where plants are grown under controlled conditions to maximize bioactive compound production that offer exciting prospects for producing high-quality lemongrass essential oil throughout the year. The integration of precision farming, sensor-based irrigation, and remote monitoring can further enhance productivity, optimize resource use, and reduce the ecological footprint of lemongrass farming.

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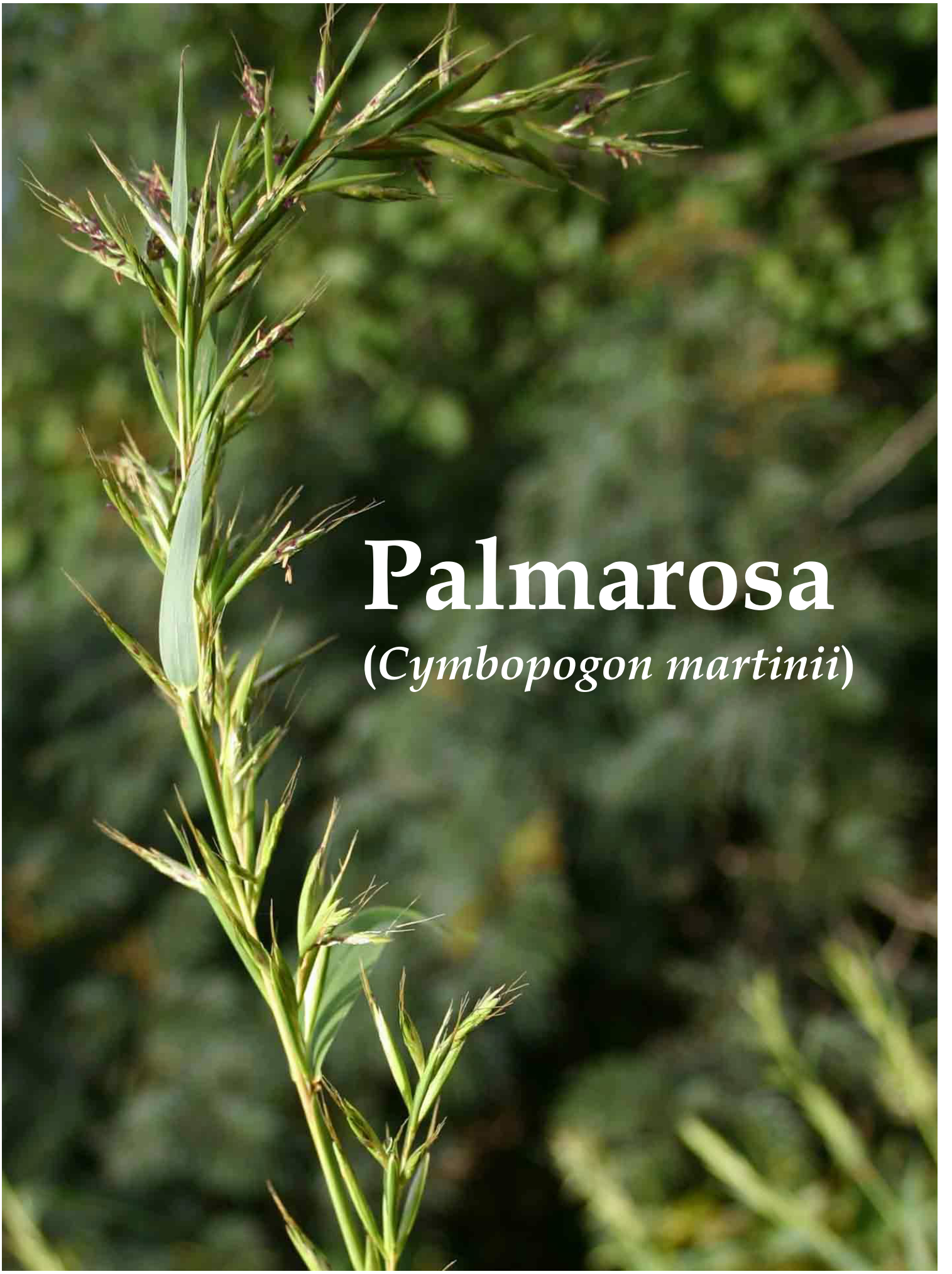
Palmarosa
(Cymbopogon martinii)

Palmarosa (*Cymbopogon martinii*)

Dr. Satbeer Singh, Dr. Ramesh Chauhan and Monalisa
Agrotechnology Division

1. Health benefits and applications in medicine

The genus *Cymbopogon* belongs to the family Poaceae (Gramineae) under the tribe *Andropogoneae* and is commonly known as aromatic grasses. Taxonomically, the odoriferous species of this genus is comprised of approximately 180 species out of which more than 50 species have been reported from India (Adhikari et al., 2022). In the Indian context, two botanical varieties have been distinguished: *var. motia*, characterized by high-quality oil with 75-95% geraniol, and *var. sofia*, which exhibits a reduced geraniol content of less than 70%. Among these varieties, palmarosa (*Cymbopogon martinii* [Roxb.] Wats. var. *motia* Burk.), a member of Rusae series, is cultivated extensively in India as a modern cash crop due to its abundant essential oil content (Smitha and Manivel, 2021). Palmarosa essential oil has versatile uses with proven antimicrobial, antifungal, and antioxidant properties. Research highlights its efficacy against staph infections and foodborne pathogens, often surpassing conventional treatments (Kumar et al., 2021). In skincare, it hydrates, balances oil production, reduces wrinkles, and treats acne while promoting cell regeneration and wound healing. Beyond dermatology, palmarosa aids digestion, supports gut health, and may help lower cholesterol and protect the liver. Emerging studies suggest neuroprotective benefits, potentially aiding in Alzheimer's prevention and mental well-being, though further human trials are needed. Its calming aroma is also used in aromatherapy to relieve anxiety and fatigue. With its broad therapeutic potential, palmarosa is increasingly integrated into medical, cosmetic, and wellness products for its protective and restorative effects.

2. Economic impact and market demand

Global production of palmarosa essential oil is estimated at 60-70 metric tons annually, with India serving as the primary producer, followed by Brazil, Guatemala, and Indonesia (Latha et al., 2017). Ranked among the world's top ten essential oils, palmarosa oil is widely utilized in perfumery, cosmetics, flavoring, and aromatherapy industries (Bhasker et al., 2015). Over the past two decades (2002-2022), cumulative exports have reached 6,61,290 kg, generating an estimated commercial value of USD 15 billion (Rana et al., 2025). Variations in chemotypic features across geographic distributions may result from conventional breeding practices, introduction of multiple phenotypes, sporadic mutations, and anthropogenic interventions.

3. Raw material availability and conservation status

Palmarosa is widely cultivated across several Indian states, including Uttar Pradesh, Madhya Pradesh, Rajasthan, Karnataka, Maharashtra, and Tamil Nadu, indicating robust raw material availability in these regions. The plant is adaptable to a range of soil types, including degraded, marginal, and salt-affected soils, and can thrive under tropical conditions with annual rainfall around 150 cm and soil pH up to 9.5 (Kumar et al., 2024). Cultivation is typically done via seeds or slips, with the first harvest available 3-4 months after planting and subsequent harvests every 3-4 months for up to five years before replanting is needed. Annual herbage yields range from 20-30 tons per hectare, with oil yields increasing from 20 kg/ha in the first year to 70 kg/ha in the third and fourth years. Palmarosa is also grown in nurseries to optimize germination and yield, and is often intercropped with other crops to suppress weeds and improve land use efficiency.

Palmarosa is described as a drought-hardy, resilient grass that is both cultivated and found wild in certain wetlands of India and Nepal. Its adaptability to marginal soils and regular cultivation cycles support its continued availability as a raw material, and there are no reports of overexploitation or significant decline in natural populations. As a result, palmarosa is not considered at risk, and its conservation status remains stable due to widespread cultivation and agronomic practices that support sustainable production (Kumar et al., 2024).

4. Agrotechnology

Propagation

Palmarosa (*Cymbopogon martinii*) is commercially propagated through vegetative slips (rooted divisions) for uniformity and faster establishment, though seeds can also be used for large-scale planting. For vegetative propagation, mature clumps are divided into slips with shoots and roots, then transplanted directly into fields or nursery beds at the onset of rains. Seed propagation involves sowing in nurseries and transplanting seedlings after 40-50 days, though this may result in genetic variability. Both methods require well-drained soil, organic amendments, and adequate moisture during early growth. Once established, palmarosa becomes a hardy, multi-cut crop, yielding high-quality essential oil for several years with proper management.

Climate requirement

Palmarosa thrives in a warm, humid tropical climate with ample sunshine throughout the year. The ideal temperature range for its cultivation is between 15°C to 35°C, and it grows best at elevations up to 300 meters. Annual rainfall of 90-150 cm is optimal, and the crop is highly susceptible to frost, which can kill the plants and reduce oil content. Therefore, frost-prone areas are unsuitable for palmarosa cultivation.

Soil Preparation

A well-drained sandy loam or clay loam soil with a pH of 7.5–8.5 is considered ideal for palmarosa. The crop can tolerate a range of soils, including those that are slightly alkaline (up to pH 9), but growth and oil yield decrease if pH exceeds 8.5. Proper drainage is crucial since palmarosa does not withstand waterlogging. Land should be plowed thoroughly and leveled, and organic manure (such as farmyard manure at 10 t/ha) is recommended as a basal dose during soil preparation.

Planting Density

Palmarosa is typically propagated by seeds or slips. For optimal growth, seedlings or slips are transplanted at a spacing of 60 x 60 cm or 60 x 45 cm, depending on the method used. This translates to about 28,000 slips per hectare. Seeds are sown in nursery beds and transplanted after 3–4 weeks, while slips are planted directly during the June–July season.

Nutritional Requirement

A balanced fertilization regime is essential for healthy palmarosa growth and oil yield. The recommended basal dose is 10 tons/ha of farmyard manure along with NPK at 20:50:40 kg/ha. Additionally, nitrogen should be top-dressed at 15 kg/ha in three splits-at 3, 6, and 9 months after planting. Regular weeding and earthing up after each harvest, followed by top dressing, help maintain soil fertility and plant vigor.

Harvesting

The first harvest is ready 3-4 months after planting, with subsequent harvests at 3-4 month intervals. Harvesting involves cutting the upper third of the stem along with the leaves, ideally when the plant just begins to bloom, as this stage yields the highest oil content. The plantation can be maintained for up to 8-10 years, but oil yield declines after the fifth year. Annual herbage yields range from 20-30 tons per hectare, with oil yields increasing from 20 kg/ha in the first year to about 70 kg/ha by the third year.

5. Stakeholders and purpose of collaboration

The sustainable cultivation and commercialization of palmarosa involve a multi-stakeholder framework comprising farmers and Farmer Producer Organizations (FPOs) as direct beneficiaries, gaining access to improved varieties, quality planting material, and technical support while being organized into clusters for collective market leverage. Non-Governmental Organizations (NGOs), such as the Society for Technology and Development, Mandi, facilitate technology dissemination and capacity building through collaborations with research institutions. Industrial partners contribute via Memoranda of Understanding (MoUs) and Transfer of Technology (ToT) agreements, enabling product commercialization, processing infrastructure, and assured market linkages. As the nodal research body, CSIR-IHBT drives innovation through improved cultivars, standardized agro-processing protocols, and mission-based initiatives like the Aroma and Floriculture Missions. Government agencies and policymakers further bolster this ecosystem by shaping supportive policies, funding mechanisms, and scaling strategies through summits and mission programs, ensuring an integrated, sustainable value chain.

6. Sustainability and future trends

Palmarosa is increasingly cultivated using organic and eco-friendly practices, which reduce reliance on synthetic chemicals and enhance soil health. Organic farming of palmarosa not only minimizes environmental impact but also produces high-quality essential oil, as seen with producers who emphasize fair trade and sustainability throughout the value chain. Integrating palmarosa into crop rotations and combining it with other tree species helps conserve soil, water, and biodiversity, while its ability to thrive in poor soils with minimal inputs makes it a model for sustainable agriculture. Recycling and reusing waste from oil extraction and implementing fair trade practices further contribute to the crop's long-term viability and positive socio-economic impact.

Smart farming practices-such as precision irrigation, soil health monitoring, and data-driven crop management are likely to be integrated to further enhance sustainability, reduce resource use, and maintain consistent quality in essential oil production. These trends position palmarosa as a forward-looking, climate-resilient, and environment friendly crop for the essential oil and wellness industries.



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Clary Sage
(Salvia sclarea)

Clary Sage (*Salvia sclarea*)

Dr. Ramesh Chauhan, Diksha Dhiman and Gaytri Hetta
Agrotechnology Division

1. Health benefits and applications in medicine

Salvia sclarea L. is a popular herb in the Middle East and Southern Europe. In recent decades, its uses have expanded from cosmetics to pharmaceutics, including food packaging, perfumery, and aromatherapy. *S. sclarea* exhibits a strong pharmacological activity, primarily related to the composition of its essential oil: terpenoid compounds (i.e., monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, diterpenes, and oxygenated sesquiterpenes), contained in the volatile fraction of the plant material, are associated with anti-inflammatory, antioxidant, antibacterial, and anticancer properties (Tuttolomondo et al. 2020). The floral parts of *S. sclarea* are traditionally used for treating gastrointestinal ailments, while extracts from leaves and branches are known for their sedative properties and are employed in managing colds and diarrhoea (Özdemir & Alpınar, 2015).

The essential oil, extracted from the aerial parts of *S. sclarea*, is used in the treatment of various conditions including stress, anxiety, depression, insomnia, and arthritis. It exhibits a wide range of biological activities such as antibacterial, antifungal, antiviral, antitumor, anxiolytic, sedative, and neuroprotective effects (Cui et al., 2015). Beyond the aerial parts, the roots also display several pharmacological properties including antimicrobial, antileishmanial, sedative, and tranquilizing effects. Additionally, the essential oil of *S. sclarea* has been reported to possess anti-aging and anti-dandruff properties (Georgiev & Stoyanova, 2006).

2. Economic impact and market demand

S. sclarea essential oil, particularly rich in linalyl acetate and linalool, is a high-value commodity and serves as a natural substitute for synthetic compounds in fragrances and flavouring agents. The rising consumer preference for natural and plant-based products has significantly boosted the global demand for *S. sclarea* essential oil. Currently, the *S. sclarea* oil market is valued at USD 708 million for 2023 and is expected to grow up to USD 1184 million with a CAGR of 4.2% up to 2033. Thus, large-scale commercial cultivation is required to fulfil its increasing demand (Kumar et al.2024).

3. Raw material availability and conservation status

India, particularly in the western Himalayan region, *S. sclarea* cultivation has been actively promoted by CSIR-IHBT, Palampur for essential oil production and development of value-added herbal products. These efforts have significantly enhanced the local availability of raw material, thereby supporting small-scale distilleries and strengthening herbal-based enterprises in the region. In India, it is primarily cultivated in temperate regions such as Himachal Pradesh and Uttarakhand, and is not considered rare or endangered at the national level. However, concerns remain due to overharvesting of wild populations, habitat degradation from urbanization and agriculture, and the impacts of climate change. As a precaution, **ex situ conservation efforts** (like botanical gardens and germplasm banks) and **agrotechnological interventions** are encouraged to preserve its genetic diversity.

4. Agrotechnology

The quantity of essential oil and its composition in *S. sclarea* differ with geographical regions/ locations, environmental factors (solar radiations, rainfall), stage of harvesting, plant part, method of extraction, and genetic differences (Chalvin et al., 2021). Cultivation practices are designed to provide optimal levels of water, nutrients, optional additives, and environmental factors including temperature, light and humidity to obtain improved yields of target products. Moreover, increased cultivation contributes to decreases in the harvest volume of medicinal plants, benefits the recovery of their wild resources, and decreases their prices to a more reasonable range (Sharifi-Rad et al.2018).

Habitat

***S. sclarea* is a temperature -sensitive species that thrives best in temperate climates and is typically found at elevations above 2000 meters above mean sea level. However, it has also been successfully introduced as a winter crop in subtropical plains (Verma et al., 2023).**

Cultivation

The growth of *S. sclarea* is significantly influenced by climatic factors such as temperature, rainfall, light exposure, and solar radiation. In this region, nurseries are sown from mid-October to early November, with transplanting in early December. The crop spans about eight months, with flowering beginning in early May. Additionally, essential oil yield and quality are significantly improved at higher altitudes (Yaseen et al., 2014).



Propagation

S. sclarea is mainly propagated by sexual propagation (by seed). Sexual propagation is done by two methods.

Broadcasting method: Broadcasting refers to the technique of randomly distributing seeds over the surface of a seedbed. This process can be performed either manually or mechanically. Transplanting of seedlings: Transplanting consists of raising the seedlings in a nursery bed and then planting the seedlings in the main field. For raising the nursery of *S. sclarea*, the mature seed should be sown in the nursery beds in the middle of October month. The optimum temperature required for the germination of seed is 25°C. After 60 days after sowing seed, seedlings were transferred to the field at 0.45 x 0.30 m crop geometry (Dhiman et al., 2024).

Soil

S. sclarea can be cultivated in various soil types; however, it grows best in well-drained, fertile loamy soils with slightly acidic pH (5–6) and adequate sunlight exposure (Sood & Singh, 2006). Several studies have reported that moderate soil drought conditions can positively influence both biomass and essential oil yield in *S. sclarea*.

Temperature & Humidity

Plant growth is highly influenced by climatic factors such as temperature, rainfall, light exposure, and solar radiation. The optimum temperature required for the germination of seed is 25°C, while vegetative growth is favoured by cooler temperatures, seed germination and flowering require comparatively warmer conditions.

Pest and diseases

S. sclarea, a medicinal and aromatic plant, is vulnerable to several insect pests, with *Helicoverpa armigera* being the most damaging, particularly to the inflorescence (Nadda et al., 2012). Whiteflies and grasshoppers are also frequently observed as significant pests. In the absence of specific pesticide recommendations under CIBRC guidelines for *S. sclarea*, integrated pest management approaches such as the use of pheromone traps, biological control agents, and cultural practices are advised (Nadda, 2013).

Harvesting methods

The inflorescence of *S. sclarea* is harvested at the full bloom stage, as essential oil quality is closely linked to the plant's developmental stage and harvest timing. In the western Himalayan region, harvesting typically occurs in June. The full bloom stage is characterized by the opening of all florets, seed set in about 90% of them, and 60% of seeds reaching the milky white stage.

5. Cultivars developed at CSIR-IHBT

Genetic improvement and varietal development in *Salvia sclarea* is going on at CSIR-IHBT. Three diverse populations were characterized at CSIR-IHBT, Palampur. A total of fifteen selections from these heterogeneous base populations of clary sage made through half-sib progeny selection approach, being maintained in germplasm repository of aromatic crops at Agrotechnology farm, CSIR-IHBT, Palampur (H.P.), India. The multi-location experiments to assess performance for morphological traits among the genotypes were laid out at diverse locations in Himachal Pradesh. Selection strategies based on multi-environment evaluations and contributing traits have been also developed for this plant. The genotype CSIR-IHBT-SS-07 is a stable genotype for fresh inflorescence weight and essential oil content across the environments in Himachal Pradesh. Additionally, this genotype was unique in terms of the highest sclareol content at all the tested environments. Further, the climate resilient selections for the targeted locations are being evaluated at multi-locations.

6. Stakeholders and purpose of collaboration

Stakeholder identification needs to be conducted to identify stakeholders involved in MAP' trade and marketing. Field observations and interviews shall be conducted to identify stakeholders and their interests based on the first informant source. Selected stakeholders shall be considered based on experience and knowledge per the research focus. Furthermore, researchers can determine other stakeholders who provide more complete data based on data and information obtained from previous stakeholders. Stakeholders are mapped into a stakeholder analysis matrix based on the magnitude of the interests and influence of growing medicinal crops (Adil et al. 2022).

CSIR-IHBT also offers consultancy services for setting up units related to agro and processing technologies for medicinal and aromatic plants, including Salvia. They also conduct demonstrations on production technologies for farmers to promote cultivation.

The institute offers training programs for farmers and students on topics related to medicinal and aromatic plants.

MoU to undertake joint collaboration in the field of essential oil with Alaknanda Ghati Shilpi Federation (AAGAAS Federation), Pipalkoti Chamoli, Uttrakhand on 27.05.2022 by CSIR-IHBT.

7. Sustainability and future trends

The aims of organic farming of medicinal plants include producing material with better quality and high productivity, and ensuring the conservation and sustainable utilization of those plants. The defining characteristic of organic farming is the non-use of synthetic fertilizers, pesticides and herbicides, which are not allowed according to many current organic certification standards in Europe and North America. The use of organic fertilizers continuously supplies soil nutrients and improves soil stability, significantly affecting the growth of medicinal plants and the biosynthesis of essential substances. Organic farming of medicinal plants is becoming increasingly important in the long-term development and sustainability of medicinal plants.

Integrated Pest Management (IPM)

Implementing IPM strategies that combine biological control methods, resistant varieties, and cultural practices can help manage pests and diseases in *S. sclarea* without relying heavily on synthetic pesticides.

Phytoremediation

This plant is also suitable for the phytoremediation and phytostabilization of contaminated soils because it can be categorized as a hyper-accumulator for heavy metals therefore, nowadays a great emphasis has been placed on growing this economically significant plant species. Since this plant has been found to be a sufficient metal hyperaccumulator, it can be used to remove harmful metals from contaminated soil, and all of its essential oil compounds are safe to use in cosmetics.

The future prospects of *S. sclarea* research and development hold significant promise across multiple domains. One of the key areas is the optimization of agro-technological practices tailored to specific agro-climatic regions. There is a need to standardize nutrient management strategies, including macro- and micronutrient requirements, to enhance crop productivity and essential oil yield. Additionally, research should focus on refining sowing, transplanting, and harvesting techniques to ensure efficient resource use and maximum output. Post-harvest management is another critical area, where efforts are needed to develop efficient harvesting methods, along with cost-effective storage and distillation techniques that preserve oil quality. Sustainable farming of *Salvia sclarea* L. (clary sage) involves environmentally friendly practices that ensure long-term productivity while conserving natural resources. Cultivating *S. sclarea* on marginal or degraded lands contributes to land restoration, biodiversity enhancement, and pollinator conservation. Promoting organic certification, farmer training, and improved market access further supports sustainability and enhances rural livelihoods.

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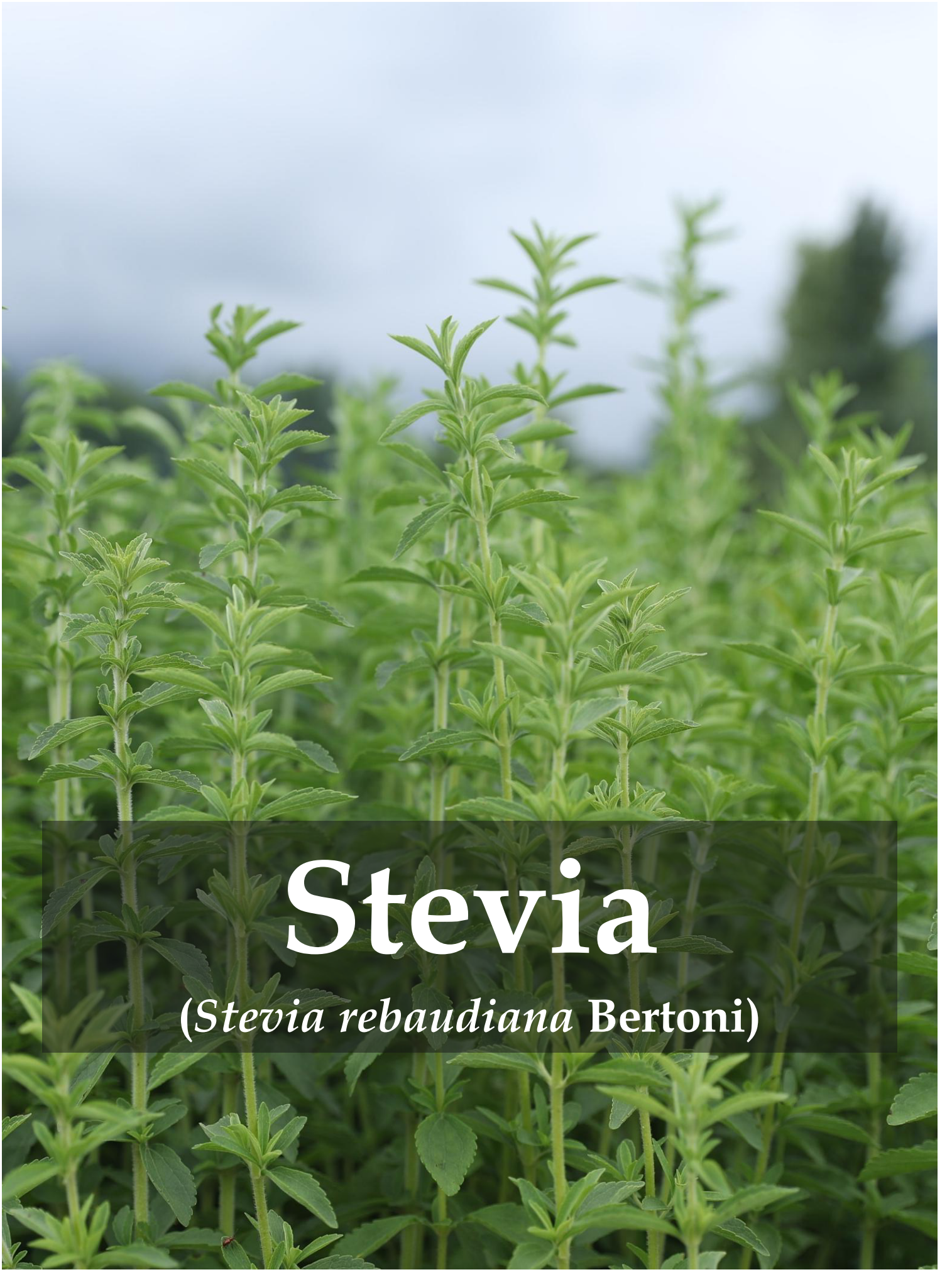


Stevia

(*Stevia rebaudiana* Bertoni)

Stevia (*Stevia rebaudiana* Bertoni)

Dr. Probir Kumar Pal
Agrotechnology Division

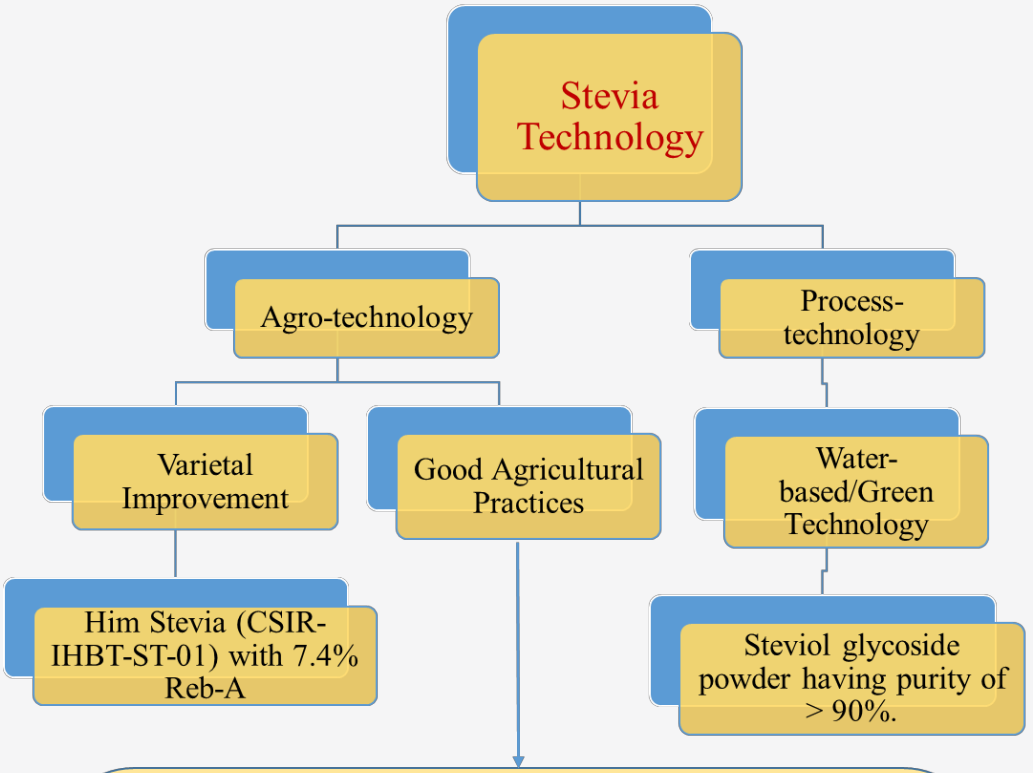
Stevia [*Stevia rebaudiana* (Bertoni) Bertoni] is one of the 154 members of the genus Stevia. It is a perennial herb of the Asteraceae family native to Paraguay. The species *S. rebaudiana*, usually recognized as a sweet leaf, sugar leaf, or simply stevia, is widely grown for its sweet leaf. The stevia leaves contain sweet-tasting diterpenoid steviol glycosides (SGs), which are used as a non-nutritive and non-caloric sweetener in a wide range of food products. Amongst the known SGs, generally, the most abundant glycosides in stevia leaf are stevioside and rebaudioside-A (Reb-A), which are about 300 times sweeter than sucrose.

1. Health benefits

The excess intake of cane sugar has adverse effects on human health and can lead to serious health complications like diabetes and obesity. As per the International Diabetes Federation (IDF) report, worldwide, 537 million people, age group of 20-79 years, are living with diabetes. This number is projected to upsurge to 643 million by 2030 and 783 million by 2045. As per the World Health Origination (WHO) report, India has an estimated 77 million people above the age of 18 years with diabetes. Generally, diabetes patients are not recommended to consume cane sugar. CSIR-IHBT took the initiative to address this aggravating health issue by introducing and developing technology for Stevia as the safest natural alternative source of low-calorie sweetener. The institute works towards developing and disseminating products and technologies for society and industries. The Indian farmers have started stevia cultivation due to the increasing demand for safe and non-calorie sweeteners for people with diabetes. Concurrently, the global demand for stevia is rapidly increasing. The Stevia Market size is estimated at USD 0.93 billion in 2025, and is expected to reach USD 1.50 billion by 2030, at a CAGR of 10.12% (https://www.mordorintelligence.com/industry-reports/stevia-market). Keeping in mind the problems pertaining to stevia cultivation, particularly the non-availability of quality planting material, lack of Reb-A rich variety, advanced agro-technology for different agro-climatic conditions, and process technology for the extraction of steviol glycosides from the leaves of stevia, the institute initiated research and development (R&D) activities on stevia in the year 2000.

2. Agro- and process-technology of stevia

In this behalf, the institutional R & D activities focused on developing improved varieties, Good Agricultural Practices (GAP) for higher biomass and SGs yields and green process technology for extracting pure SGs from leaves (Figure 1).



1. Technology for the generation of quality planting materials, including macro and micro-propagation
2. Nutrient management technology
3. Weed management technology
4. Water management technology
5. Standardization of plant population and crop geometry
6. Optimized harvesting time
7. Resource conservation technology
8. Production technology under abiotic stress (salinity and drought) conditions

Environment and soil requirement for cultivation

Stevia is a short-day plant grown under tropical and sub-tropical conditions. Long day-length is helpful for higher leaf yield. Relative humidity of 65-80% is suitable for proper growth and development. Stevia grows well in sandy loam soil with pH range of 5.0-7.5, and requires a warm and sunny weather. Soils should be well drained but with reasonable water holding capacity.

Propagation methods and planting material

Stevia can be propagated by seeds, division of suckers, vegetative cuttings and tissue culture. Propagation through seeds is easy and economically more viable. However, there are morphological and chemical variations among the individual plants of seed raised populations. Clonal propagation through cuttings and tissue culture provides uniform quality of produce, but the cost of planting material is high.

The institute has developed improved cultivar "Him Stevia" with higher proportion of rebaudioside-A (7.34%) compared with stevioside (5.78 %) and total glycoside content of 14.49% on dry weight basis. Higher proportion of rebaudioside-A is a desirable component, which provides better quality of sweetness profile. Quality planting material can be procured from the institute.



Planting material of stevia: (a) seeds, (b) suckers, (c) rooted cuttings and (d) tissue culture plantlets

Nursery raising from seeds

Direct seeds sowing practice is not recommended due to very small size of seed. Nursery raising through seeds should be done in the month of January-March. However, under protected conditions, it can be done throughout the year. Germination of seeds take place in 7-10 days. Seeds can be sown in plastic trays, pots, wooden boxes or in raised nursery beds having a good mixture of sand, soil and organic manure. The bed width should be 1.0-1.5 m with suitable length. For the first five days after sowing, daily light irrigation should be given in the nursery beds, preferably during morning and evening hours and thereafter once a day in the next five days. Two month old seedlings at 5-7 leaves stage with10-15 cm height are suitable for transplanting.



Large scale raising of nursery under poly tunnels



Stevia seedlings raised in nursery

Nursery raising from cuttings

Plants can be raised by vegetative means using stem cuttings of 10-15 cm height with 4-6 nodes. The cuttings should be taken from actively growing plants during mild weather avoiding extreme cold or hot months. Lower leaves of the cuttings are trimmed and the cuttings are planted in the bed keeping one node inside the soil. These cuttings should be raised under partial shade and high humidity for fast root development. Water should be sprinkled on daily basis till root formation occurs, which takes 10-15 days. The rooted cuttings are then transferred to sleeves filled with soil, sand and FYM mixture (1:1:1 ratio). These cutting raised plants need to be irrigated twice a week or as per the requirement.

Transplanting

Generally, 50-60 days old seedlings with about15 cm height, or rooted cuttings or tissue culture raised hardened plants are transplanted in the field during the months of March-April or June-July avoiding the periods of extreme temperatures. However, the date of transplanting should be adjusted as per the local weather conditions. Transplanting is done in raised beds or flat beds at a spacing of 45x45 cm and 45x30 cm in high and medium fertile soils, respectively. Pinching of the apical bud should be done after establishment of plants to enhance bushy growth with lateral branches.

Harvesting

Time of harvesting depends on growing season and region. Harvesting should be done manually at 10-15 cm height from the ground level. First harvest is taken at 90-110 days after transplanting. Subsequently, second harvest is taken after 50-65 days of the first harvest before the onset of flowering. In case of late transplanting, single cut is taken after 3-4 months. Since, stevia is a perennial crop, the production may be taken up to 4-5 years from the same plantation.

Economic yield

In the first year, average fresh biomass yield of 2.0-2.5 tonnes/ha is obtained out of two harvests and increased in subsequent years up to 4.0-4.5 tonnes/ha. On an average dry leaf yield of stevia is 3.0-3.5 tonnes/ha/year, which fetches market price of Rs.120 to 150/ kg, resulting in net return of about Rs.2.5-3.5 lakhs/ha/year. Maximum quantity of leaf is produced in 3rd or 4th year of planting. The average net income from stevia cultivation has been observed to be 2.0-2.5 times higher than traditional crops.

3. Cultivars developed at CSIR-IHBT

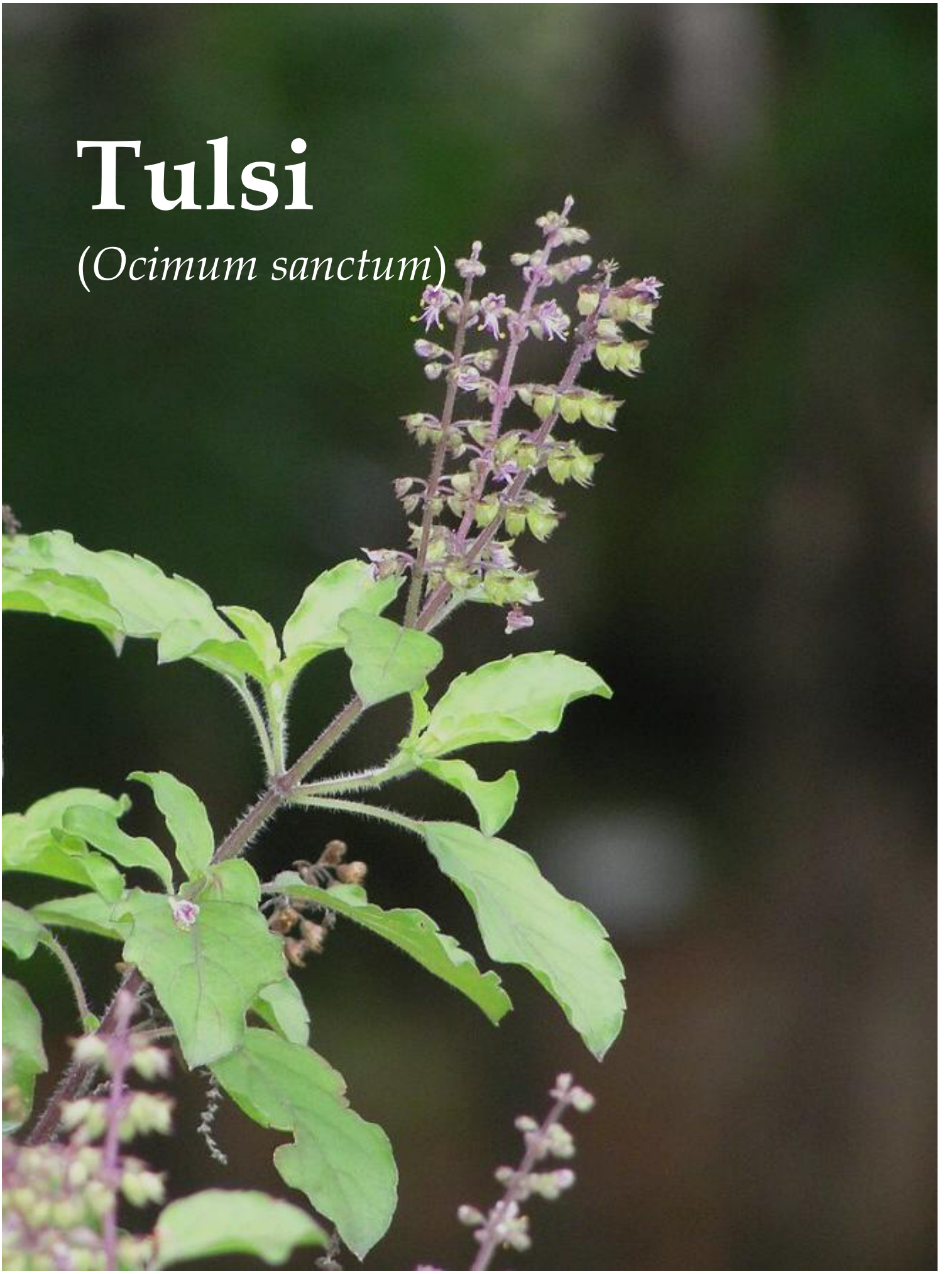
Genetic improvement and varietal development efforts in *Stevia rebaudiana* has been taken up at CSIR-IHBT. A total of three selections (for higher dry leaf biomass) were made through hybridization and mutation. Selections were subsequently maintained in isolation at CSIR-IHBT as separate plots and sib-mating was allowed within the progenies (half-sib progenies). The multi-location experiments to assess performance for morphological traits among the genotypes were laid out at diverse locations in Himachal Pradesh. Selection strategies based on multi-environment evaluations and contributing traits have been developed for this plant. The selection CSIR-IHBT-ST-1801 is a stable genotype for higher dry leaf biomass and essential oil content across the environments in Himachal Pradesh. In addition, this selection is unique for the presence of high Rebaudioside-A content (marker compound) at all the tested locations. CSIR-IHBT has developed two varieties Him Stevia and Him Stevia Utkrisht from ongoing breeding programs.

Technology transfer and societal impact

The agro-technology developed by the institute has been transferred to eight entrepreneurs/industries for commercial cultivation on a PAN India basis. Among them, three parties (M/s Agri Natural India, New Model Town, Ludhiana, Punjab; M/s DLB Herbs India Pvt. Ltd., New Delhi; and M/s Maa Danteshwari Herbal Products Pvt. Ltd, Bastar, Chhattisgarh) are cultivating at large-scale in Punjab, Haryana, Jharkhand and Chhattisgarh. Moreover, the institute has also promoted stevia cultivation directly in the states of Punjab, Haryana, Uttarakhand, HP, UP, Maharashtra, Andhra Pradesh, Assam, Jharkhand, Madhya Pradesh, Tamil Nadu and Chhattisgarh by supplying planting material, which covered ~2350 acres across India. About 2600 farmers have directly benefited from stevia cultivation. Entrepreneurs have also been supported by the institute for processing of stevia, and the liquid product of stevia is available in the market.



Stevia field visited by the Director General, CSIR



Tulsi

(*Ocimum sanctum*)

Tulsi (*Ocimum sanctum*)

Dr. Sanatsujat Singh and Mohar Singh
Agrotechnology Division

1. Health benefits and applications in medicine

The most significant herb in Ayurveda, tulsi (*Ocimum sanctum*), is a member of the Lamiaceae family, and the current review is confirming its therapeutic properties. Tulsi is one of the most significant aromatic herbs frequently employed in the pharmaceutical industry. *Ocimum sanctum* is also known as the 'Queen of Herbs' because of its numerous health benefits, which include anti-oxidative, antibacterial, anti-stress, anti-diabetic, anti-cancer, anti-epileptic, anti-Alzheimer, and insecticidal activity. Tulsi's anti-oxidant properties aid in the body's detoxification by eliminating pollutants and free radicals. Tulsi regulates the body's metabolism and aids in absorbing vital nutrients. It strengthens the digestive system because it is a digestant (Yadav et al., 2024).

As a Seasoning: Tulsi has several health benefits and is simple to produce. Because of its sweet and minty flavor, tulsi is an excellent herb for garnishing dishes, sauces, and soups. It is frequently cooked for flavor and scent and is a mainstay in Thai and Indian cuisines (Yadav et al., 2024).

As a Supplement: Dried tulsi is available as capsules, making it a practical alternative in disliking of flavour or basil aroma. Fermented choices, according to some authorities, facilitate easier digestion. The tulsi leaf and stem are excellent sources of macro and micronutrients for the body's metabolic processes (Yadav et al., 2024).

As an Essential Oil: The tulsi plant contains essential oil used in lotions, soaps, perfumes, shampoos, and conditioners. It can be diffused in house or inhaled, and it has relaxing and immune-boosting qualities. Eugenol, eucalyptol, and camphor are probably said to be present in tulsi oil (Yamani et al., 2016).

As immunity booster: Tulsi is widely known for its capacity to boost immunity and fend off various illnesses. Its anti-microbial properties alleviate cold symptoms and lower acidity by maintaining the stomach's pH equilibrium. Several phytochemicals found in tulsi have also been connected to a lower cancer risk. Sipping Water Infused with tulsi leaves is one of the best ways to benefit from this plant (Bhamra et al., 2022).

As an Eye Care Product: Because of pollution, eyes are more susceptible to dust, which can lead to many problems associated with the eyes. Tulsi relieves tension and has a calming impact on the eyes. It shields the eyes from a variety of conditions related to the eyes, such as conjunctivitis and boils (Bhamra et al., 2022).

Mouth and teeth infection: Oral infections and ulcers respond well to the leaves' therapeutic properties. Chewing a few leaves can help with several health issues. The plant is helpful for dental problems. After being ground and drying in the sun, the leaves can be used to clean teeth. It can also be used to make a paste that can be used as dental paste, together with collected oil. This is a great way to preserve dental health, avoid bad breath, and massage the gums. It also relieves pyorrhea and other dental problems (Rao et al., 2023).

Skin disorder and care: Using local tulsi leaf extract helps treat ringworm and other skin disorders. Tulsi has also been effectively used to treat leucoderma, a skin condition, and has proven highly beneficial (Chandra et al., 2016).

2. Economic impact and market demand

Tulsi is part of the growing herbal and Ayurvedic product segment. The global herbal medicine market is expected to reach **USD 430 billion by 2028,** with tulsi being a significant contributor in immunity and stress-relief categories. Major markets for tulsi are India, Europe, North America and Southeast Asia.

3. Raw material availability and conservation status

Tulsi is native to the Indian subcontinent and grows widely across tropical and subtropical Asia. It is commonly cultivated in home gardens, farms, and temple grounds due to its cultural, religious, and medicinal significance. India is the largest producer of tulsi, especially in states like Uttar Pradesh, Madhya Pradesh, West Bengal, and Maharashtra. Raw material (leaves, stems, and seeds) is readily available throughout the year. The plant grows well in a wide range of soils and requires minimal inputs, making it easy to cultivate. Harvesting is typically done two to three times a year, depending on the climate.



4. Agrotechnology

Soil Preparation

Deep plowing followed by 2-3 harrowings. Incorporate **10-15 tons/ha of FYM and soil pH** 6.0 to 7.5. Warm, tropical, or subtropical climate, optimum temperature 20°-30°C, Moderate (60-100 cm annually) rainfall and 1800 m and above altitude. Propagation is by seeds and cuttings.

Tulsi products formulated

Tulsi capsules, tulsi tablets, tulsi juices, immunity booster, decoction detoxifier etc.

5. Stakeholders and purpose of collaboration

The cultivation and commercialization of tulsi involve multiple stakeholders, each playing a critical role in strengthening the value chain through collaborative efforts. **Farmers** are the primary cultivators, whose adoption of Good Agricultural Practices (GAP) ensures quality raw material; they benefit from training, buy-back arrangements, and market assurance. **Farmer Producer Organizations (FPOs)** support these farmers by facilitating aggregation, post-harvest handling, and entering into **MoUs** with industries for contract farming and collective bargaining. **Non-Governmental Organizations (NGOs)** and **Self-Help Groups (SHGs)** play a vital role in community mobilization, especially empowering women and marginal farmers by promoting tulsi-based livelihood activities. Additionally, **government departments** (such as AYUSH, Agriculture, and Horticulture) facilitate convergence of policies, funding schemes, and certification support. Together, these collaborations aim to promote sustainable tulsi cultivation, value addition, rural income generation, and integration into national and global herbal product markets.



CSIR-IHBT providing technical support for processing to Self Help Groups growing tulsi at village Pattajatiyan, Tehsil Fatehpur, distt. Kangra, HP.

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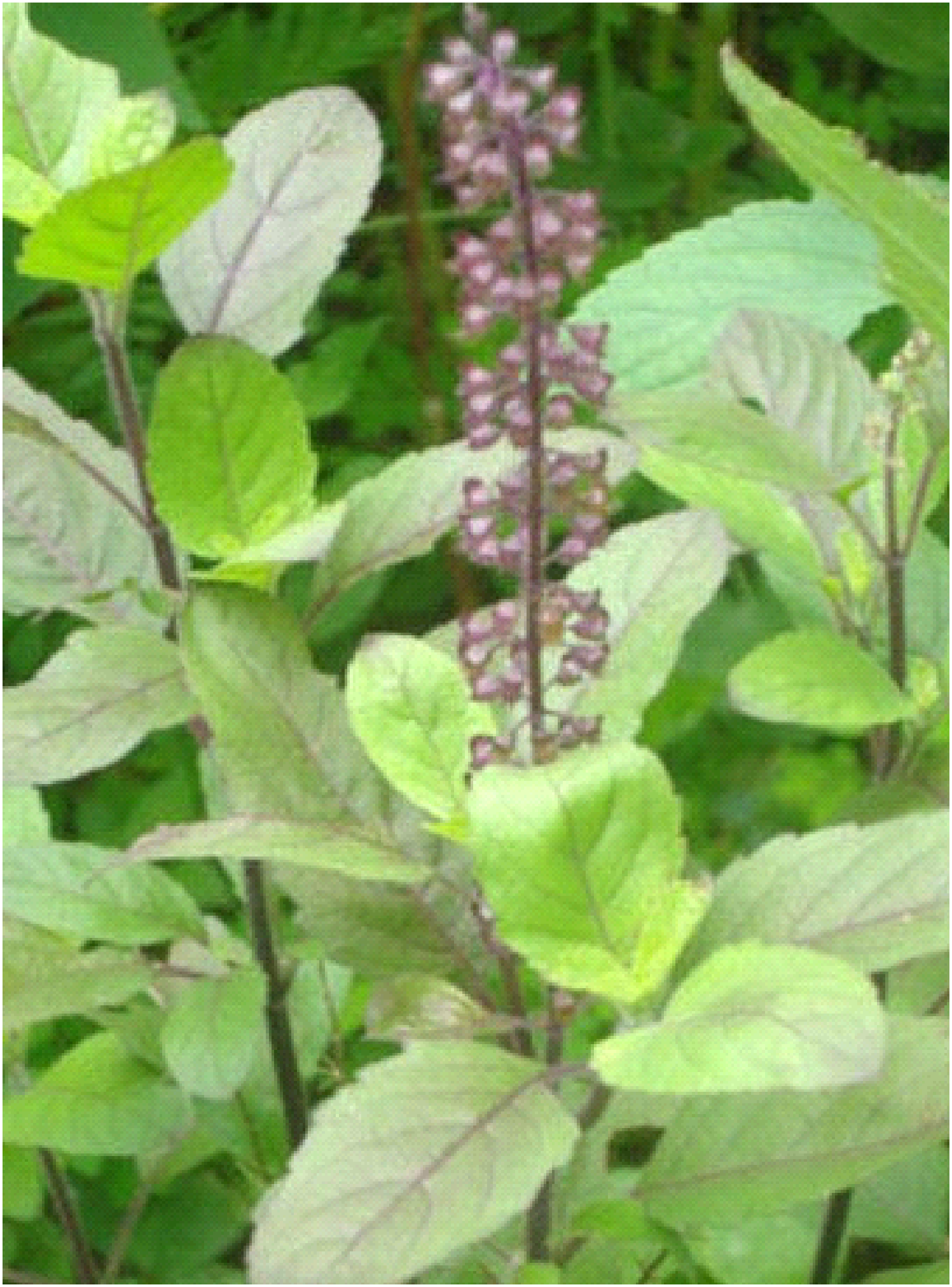
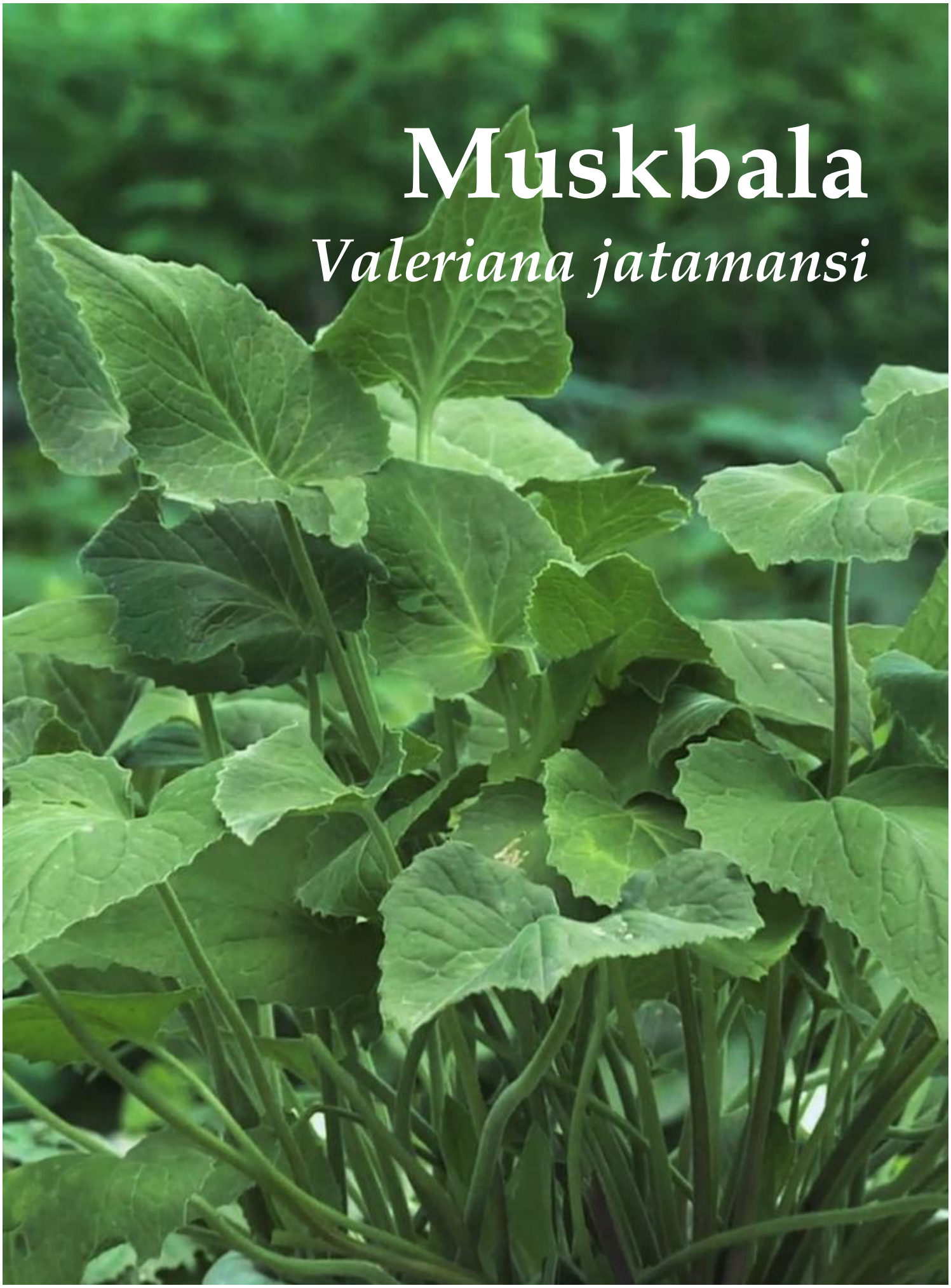




Muskbala

Valeriana jatamansi

Valeriana jatamansi
Dr. Probir Kumar Pal
Agrotechnology Division

1. Health benefits and applications in medicine

Valeriana jatamansi Jones. syn. *V. wallichi* (Family: Caprifoliaceae) is globally known and amongst the 27 listed medicinal plants under National AYUSH Mission (NAM) by National Medicinal Plants Board, New Delhi, Government of India. *V. jatamansi* has extensive antiquity of practices and cited as a medicine in the Charka Samhita, Rigveda and modern systems of medicine. It is traditionally used to treat a variety of ailments globally. It imparts antidepressant, antispasmodic and anticonvulsive properties as significant biological activities. Its roots and rhizomes are traditionally used for hysteria, nervous unrest, emotional troubles, as sedative, for sleep enhancement, in cardiac debility, ulcers, jaundice, convulsions, seminal weakness, skin diseases, leprosy, dry cough, asthma and general debility whereas its oil is used in fragrance industry and insect repelling formulations. It is highly effective against leprosy, epilepsy and hysteria, scorpion bite, cholera, anxiolytic properties and curing lewy body dementia. The herb is widely used in making perfumed powder and cardiac preparations. Apart from its pharmaceutical properties, the underground part (root/rhizome) of Indian Valerian is extensively used for perfumery purposes.

2. Economic impact and market demand

The valerian root extract market size was valued at USD 400 million in 2024 and is forecasted to grow at a CAGR of **5.0%** from 2026 to 2033, reaching USD 600 million by 2033. And the global valerian oil market size is projected to grow steadily from approximately USD 110 million in 2023 to an estimated USD 176 million by 2032, showcasing a CAGR of 5.4%. National Medicinal Plant Board (NMPB) surveyed herbal market in alliance with ICFRE, Dehradun during 2014-15 to review the situation of demand and supply of Indian herbs, and the demand of herbal raw drug was estimated about 512,000 MT whereas the trade of *V. jatamansi* was 1000-2000 tonnes annually. The estimated input cost is about Rs. 1.5 lakh per ha/2 years. The market value of dried roots and rhizomes of Indian valerian depends on quality and ranges from Rs. 300-350/kg. The current market price of valerian oil is about Rs. 45000/kg. The net profit from the cultivation of *Valeriana jatamansi* is about 1.5-2.0 lakh/ha after two years.



Valeriana jatamansi plant



Muskbala essential oil

3. Raw material availability and conservation status

CSIR-IHBT supplies farmers with certified raw planting material of the *Valeriana jatamansi* cultivar 'Him Surbhit'- selected for high essential-oil (about 0.4%), rich in patchouli alcohol and valepotriate yield, ensuring consistent quality and superior returns. CSIR-IHBT guarantees farmers receive high-quality *Valeriana jatamansi* planting material that is elite, uniform, disease-free, chemically rich (patchouli alcohol), and supported by modern agro-practices-boosting not only yield but also marketability. Cultivation of wild species and its sustainable harvesting are two important measures to conserve species germplasm. *V. jatamansi* is enlisted as a conservation concern plants under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and its foreign trade is a regulated one. In the north-eastern Himalayan region, this herb is also in the endangered medicinal plant list, and therefore, extensive breeding programs have been deployed to conserve genetic base of its population. Some of the strategies which have been adopted by the institute are:

- Develop appropriate agronomic practices for captive cultivation
- To establish repositories to conserve its germplasm
- Standardization of post-harvest drying technology
- Varietal development programme
- Promotion of captive cultivation
- Generation of quality planting materials





Quality planting material distributed to the farmers

4. Agrotechnology

Cultivation plays a crucial role in conserving endangered medicinal plant species in their natural habitats. It offers a sustainable source of raw material without disrupting wild populations (IUCN, 1993). In efforts to domesticate wild *Valeriana* strains, researchers have begun transitioning these plants from wild settings into semi-natural agroforestry systems-land-use models that integrate crop cultivation with forest trees on the same plot, as opposed to traditional monocultures. Such systems are recognized for their sustainability, diversity, integration, productivity, profitability, and promotion of human health. To commercially cultivate this herb, the development of tailored agrotechnologies is essential. However, successful introduction of wild species into cultivation requires a comprehensive understanding of their ecological requirements and adaptive characteristics.

Cultivation technique

To ensure a sustainable supply and reduce pressure on wild populations, standardized cultivation techniques have been developed. It includes land preparation, planting, irrigation, fertilization, pest control, and harvesting.

Soil preparation

Valeriana can be grown in the variety of soils ranging from heavy clay to chalk and lime stone soils. However, the herb prefers loamy soil with a pH ranging from 6.0 to 7.5 with rich in organic matter. Although, due to shallow roots of this herb, it prefers moist condition but requires good drainage as it cannot withstand water logging condition. Land designated for *Valeriana* cultivation must be well-drained and finely pulverized, achieved through three sequential ploughing operations. The first ploughing, ideally carried out in June, serves to break the soil and initiate a fine seedbed. During the second ploughing, also in June, farmyard manure (FYM) at a rate of 20 t/ha-should be evenly incorporated into the soil to enhance fertility and organic content. A final ploughing is then conducted to further fragment soil aggregates, creating a friable texture that optimizes root and rhizome development by improving root penetration, aeration, and moisture retention.

Climate needs

Indian *Valeriana* is highly adapted to diverse ecological niches across the Himalayas, flourishing at elevations ranging from approximately 1,300 to 3,300 m above mean sea level. It exhibits a clear preference for cold winters and mild summers, thriving under partial to full shade, and performs optimally within a temperature range of 15°-25 °C.

Propagation

Valeriana can be propagated via seeds or rhizomes, although vegetative propagation through rhizomes is considered superior for commercial cultivation due to more rapid plant maturation compared to seed-derived plants.

In seed propagation, fully mature seeds are harvested in March-April and used to raise planting material. Nursery beds, prepared in April-May, should consist of a well-drained mix of sand, soil, and organic manure, into which seeds are sown at a shallow depth of 0.5-1 cm. Under consistent light irrigation for the first five days, seeds typically germinate within 7-10 days, and seedlings develop to a 5-7 leaf stage in approximately three months, after which they are suitable for transplanting into the field.

For rhizome propagation, a dedicated mother nursery is established. Fresh, rooted suckers are harvested from this nursery and planted in the field with the onset of the monsoon (May-June). By using rhizome suckers, propagation yields homogenous and precocious plants, facilitating faster establishment and uniform crop stand.



Valeriana jatamansi seed



Valeriana jatamansi sucker

Transplanting

The rooted propagules are planted in the field in June-July, while seedlings are transplanted in August at higher elevations and in October at lower elevations. Seedlings should be transplanted when they attain a height of 8-10 cm and planted immediately after uprooting, so that they establish early and remain healthy. Planting in rows 30-35 cm apart and 30 cm spacing between plants in a row are recommended. Approximately 84,000 plants are required for cultivation in 1 hectare of land.

Harvesting methods

Although *Valeriana jatamansi* plants can be harvested after one year of planting, it is recommended to harvest them after two years, as they provide a higher yield of underground parts and greater essential oil content. The crop reaches physiological maturity in August, and the rhizomes and roots are typically dug up in October or November of the second year, following the yellowing of leaves, which indicates the plant's readiness for harvest. At the time of harvest, the rhizomes and roots are carefully dug up and separated from the aerial parts of the plant. The biomass yield and essential oil content in the roots are influenced by several factors, including the age of the plant and the specific geographical and environmental conditions in which it is cultivated. Under optimal agronomic practices, the average yield of dried roots in the second year is reported to be approximately 1.0-1.5 tonnes per hectare.



Valeriana Field



Valeriana Roots

5. Cultivars developed at CSIR-IHBT

Genetic improvement and varietal development efforts in *Valeriana jatamansi* have been taken up at CSIR-IHBT. A total of ten selections (for higher root biomass) were made through a single plant selection approach from the base population and are being maintained at the CSIR-IHBT, Palampur, Himachal Pradesh. The multi-location experiments to assess performance for morphological traits among the genotypes were laid out at diverse locations in Himachal Pradesh. Selection strategies based on multi-environment evaluations and contributing traits have been developed for this plant. The selection CSIR-IHBT-VJ-05 is a stable genotype for higher root biomass and essential oil content across the environments in Himachal Pradesh. In addition, this selection is unique for the presence of highest patchouli alcohol (marker compound) in the essential oil across all the tested locations.

6. Stakeholders and purpose of collaboration

In the world of agriculture, collaboration between various stakeholders plays a crucial powerful role for the development, innovation and sustainability. By working together, local farmers can share resources, knowledge and opportunities that everyone involved. Collaboration with stakeholders is important for gaining support, building trust and achieving successful outcomes. Key stakeholders are farmers, NGOs and Farmer Producer Organizations (FPOs), Industrial Partners (Herbal/Pharma/Aroma Industries), Research and Development Institutions (e.g., CSIR-IHBT, ICAR-DMAPR), Government Agencies & Departments (e.g., Agriculture/Horticulture).

Organic farming

In 2025, organic farming is no longer just a trend, it's a **global movement powered by strategy, innovation, and sustainability**. Countries are setting bold targets, launching funding schemes, and celebrating organic excellence. The core principles and practices of organic farming focus on nurturing and enhancing biological cycles within the farming system, preserving and enriching the fertility of the soil, reducing various forms of pollution, abstaining from the use of pesticides and synthetic fertilizers. Organically grown medicinal and aromatic crops have superior physical and chemical properties (quality) in comparison with traditional systems. Organic farming produces better quality and yields for medicinal and aromatic plants. Currently, the imbalanced application of chemical fertilizer leads to a decrease in quality of products, not only in terms of inferiority, but also with a residual effect that enters the food chain, and in turn, presents a threat to human and animal health. Therefore, organic farming is especially important in medicinal plants like *Valeriana jatamansi* because it ensures the purity of essential oil compounds (patchouli alcohol), retain valepotriates and safety of the herb, which is often used for its sedative, anti-anxiety, and neuroprotective properties.

Time of harvesting

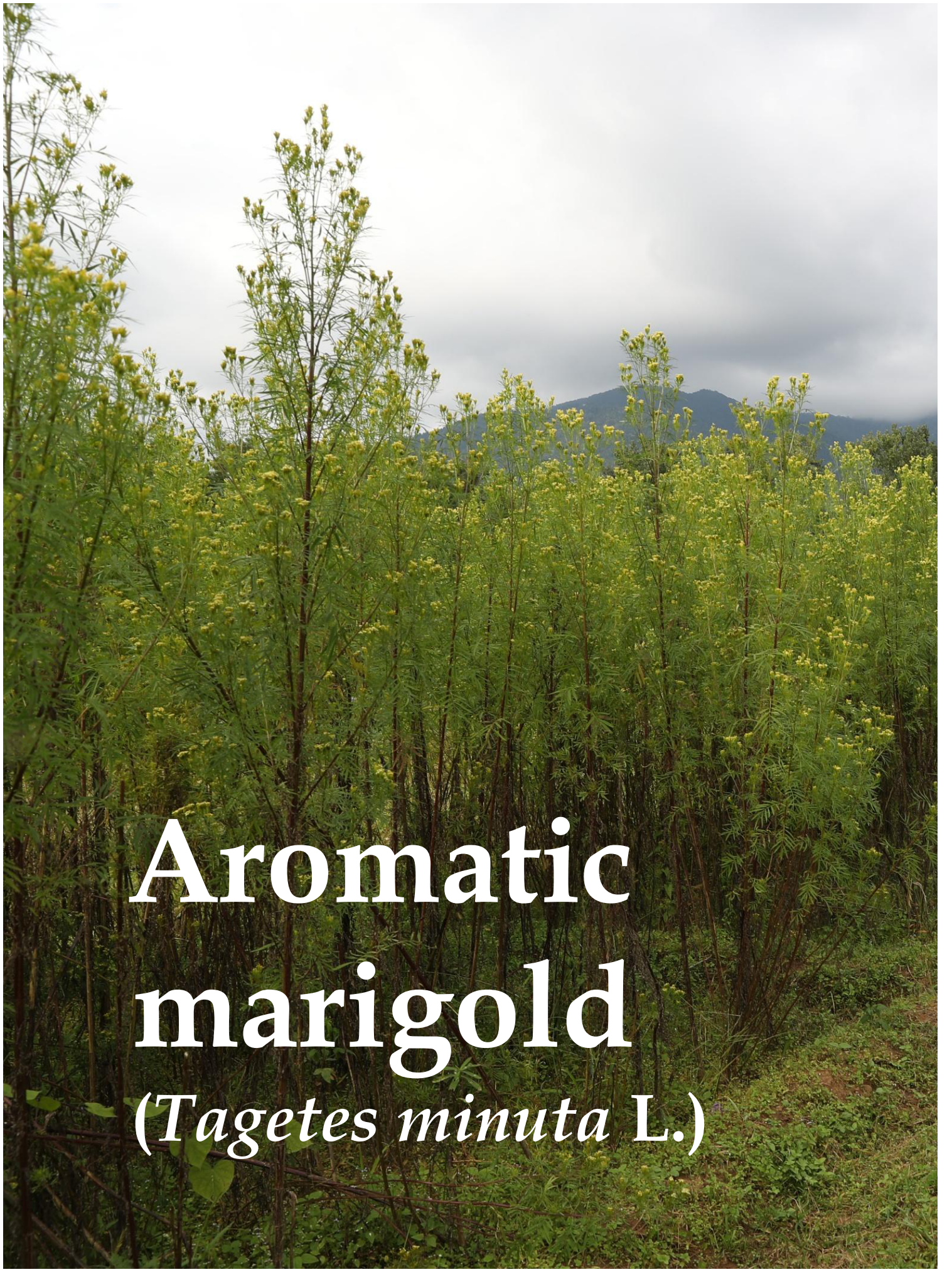
Although the plants can be harvested after one year of planting, it is recommended to harvest them after two years, since they have a higher yield of underground parts and essential oil content. Crop attains physiological maturity in August. The rhizomes and roots are dug up after two years of plantation in the month of October or November after the yellowing of leaves.

Distillation and chemical composition of oil

After digging, the rhizomes and roots are cleaned to remove adhering soil by thoroughly washing them with water. Then, it is chopped uniformly and dried under shade. To retain valepotriates as well as essential oil, the best method is drying at 40°C. The fresh root can also be distilled directly. The essential oil is extracted by steam distillation of dried rhizomes and roots. The essential oil content in root and rhizomes of Indian valerian is about 0.4%. The essential oil of Indian Valerian is characterized by the presence of three major terpenoids, i.e., maaliol, patchouli alcohol and 8-acetoxypatchouli alcohol.

Economics of cultivation

The estimated input cost is about Rs 1.5-2.0 lakh per hectare. The market value of dried roots and rhizomes of Indian valerian depends on quality and ranges from Rs. 400-450/kg. The current market price of valerian oil is about Rs. 40,000-50.000/kg. The net profit from the cultivation of *Valeriana jatamansi* is about 2.5-3.5 lakh/ha/years.



Aromatic marigold

(*Tagetes minuta* L.)

Aromatic marigold (*Tagetes minuta* L.)

Dr. Satbeer Singh, Ajeta Katoch and Dr. Sanatsujat Singh
Agrotechnology Division

1. Health benefits and applications in medicine

Aromatic marigold (*Tagetes minuta* L.) is an aromatic annual herb of the Asteraceae family, extensively grown in diverse regions, including the Himalayan belt of India. Beyond its established use in perfumery, flavouring, and aromatherapy. Aromatic marigold has gathered increasing attention for its pharmacological potential due to its chemically diverse essential oil profile. The essential oil, extracted from its aerial parts, is rich in monoterpenes such as (Z)-β-ocimene, dihydrotagetone, limonene, tagetones, and ocimenones, along with significant concentrations of thiophenes, flavonoids, and sesquiterpenes (Kumar et al., 2020; Walia et al., 2020). These bioactive compounds collectively contribute to a broad spectrum of biological activities, including antimicrobial, antifungal, nematicidal, insecticidal, antioxidant, anti-inflammatory, and allelopathic effects.

Particularly, thiophenes which are sulfur-containing heterocyclic compounds, have demonstrated promising cytotoxicity against malignant cells, mediating apoptosis through oxidative stress pathways and disruption of mitochondrial function. Experimental evidence suggests that extracts of *T. minuta* can inhibit proliferation in various tumor cell lines, highlighting their potential role in anticancer therapeutics (Babaei et al., 2021; Mahajan et al., 2020). Furthermore, the essential oil's strong antimicrobial properties have shown efficacy against a range of bacterial and fungal pathogens, supporting its use in combating resistant strains and infections. The antioxidant activity, attributed to the presence of polyphenols and carotenoids, also suggests its possible application in mitigating oxidative stress-associated disorders. Collectively, these multifaceted pharmacological activities make aromatic marigold as a promising species for novel drug development, integrative oncology, and plant-based pharmaceutical formulations.

2. Economic impact and market demand

Aromatic marigold holds significant economic and industrial value, with rising demand in both domestic and international essential oil markets. The growing global inclination towards natural flavours, fragrances, and plant-based bioactive compounds has notably enhanced its market potential, particularly in countries such as India, Germany, Taiwan, and the United States, where it is processed and imported for the flavor, fragrance, cosmetic, and pharmaceutical industries. The global essential oil market for *Tagetes* oil was estimated at approximately USD 8-15 million in recent years and is projected to grow further, driven by a CAGR of 7.0%-8.6% through 2025 (Cornelius and Wycliffe 2016; Bandana et al. 2018; Kumar et al. 2020). In India, Himachal Pradesh has emerged as a leading producer, with successful commercial cultivation established in the Himalayan and sub-Himalayan regions yielding high quality essential oil rich in Z-β-ocimene and tagetones. The market price for high-grade *Tagetes* oil varies depending on composition and quality, with substantial international trade under HS Code 3301. The current estimated annual production stands at approximately 15 tonnes, with continuous year-on-year growth reflecting its expanding role in sustainable rural livelihoods and export-oriented aromatic crop production (Singh et al. 2003; Walia et al. 2020; Babaei et al. 2021).

3. Raw material availability and conservation status

Tagetes minuta (aromatic marigold) has emerged as a commercially significant species, particularly for its essential oil used in flavor, fragrance, and pharmaceutical industries. In India, especially in regions such as Himachal Pradesh and parts of the western Himalayas, the species has transitioned from a predominantly wild or naturalized state to increasing levels of semi-domesticated and cultivated forms. Nevertheless, a portion of the raw material continues to be sourced from wild or unmanaged populations, reflecting an incomplete shift towards fully controlled cultivation systems. Unlike many other medicinal and aromatic plant species, *T. minuta* is not currently listed under any threatened category in international conservation frameworks such as the IUCN Red List or CITES appendices, primarily due to its broad ecological range, wide adaptability, and weedy growth habit. However, localized pressures including habitat fragmentation, unplanned land-use changes, and environmental stresses associated with climate variability present potential threats to its natural populations. Additionally, unregulated harvesting from natural stands, especially in remote areas, may contribute to genetic erosion and reduce population resilience over time. The growing market demand has incentivized farmers to integrate *T. minuta* into existing cropping systems, enhancing raw material availability through commercial cultivation. Despite this positive trend, there remains a need for systematic conservation efforts to preserve genetic diversity, particularly of wild genotypes that may possess valuable traits for stress tolerance and essential oil quality. In situ conservation of natural populations, coupled with ex situ germplasm preservation and structured breeding programs, will be critical to ensure the long-term sustainability of aromatic marigold as a commercial resource while safeguarding its ecological integrity.

4. Agrotechnology

Propagation

Tagetes minuta is generally propagated by seed, as it is an annual species. Both direct seeding and transplanting methods are utilized depending on available resources and field conditions. The seeds are small and light, with approximately 1000 seeds weighing one gram. For transplanting, about 1 kg of seed is sufficient for one hectare, while direct sowing typically requires around 3 kg/ha. Seeds should be sown on the soil surface or lightly covered with a fine soil layer to encourage uniform germination, which typically initiates within 10 days under favorable moisture and temperature conditions. When transplanting is practiced, seedlings are spaced at 30 cm between plants and 45 cm between rows, allowing adequate room for branching and canopy expansion.

Climate

The crop performs best in the mid-hill regions of the western Himalayas, particularly at elevations between 1000 and 2500 m. Its cultivation is typically synchronized with the monsoon, beginning in June and extending until November. Moderate daytime temperatures paired with cooler nights, especially during flowering, significantly favor essential oil production and quality. However, excessive moisture from heavy rains can lead to waterlogging, which adversely affects plant health and productivity. Therefore, effective drainage management is critical in high rainfall zones.

Soil preparation

Optimal growth occurs in well-drained, light to medium-textured soils with sufficient organic matter and a pH range of 5.5 to 7.5. Prior to planting, fields should be well-prepared through deep ploughing to produce a fine tilth, ensuring weed-free conditions for successful seedling establishment. Incorporating 10 to 15 tons per hectare of well-decomposed farmyard manure during land preparation enhances soil fertility, improves physical properties, and increases water retention capacity.

Planting density and nutritional requirement

A spacing of 30 cm between plants and 45 cm between rows is ideal for achieving a desirable balance between vegetative and reproductive growth, thereby maximizing leaf and flower biomass, which directly influences essential oil yield. Nutrient management is critical for optimizing biomass and oil production. Typically, a balanced fertilizer application of nitrogen, phosphorus, and potassium at 100:60:40 kg/ha is recommended, with adjustments based on soil nutrient analysis. Supplementation with micronutrients such as zinc and boron can further improve growth and oil quality. Integrating organic manures and biofertilizers enhances soil health and long-term sustainability.

Crop Management

During the early stages of growth, *T. minuta* grows slowly and is highly susceptible to competition from weeds. Manual weeding and shallow hoeing during the first two months are essential to minimize competition and support robust crop establishment. Removal of apical shoots (nipping), typically performed around August, is a key cultural practice to suppress excessive vertical growth, promote lateral branching, and increase the proportion of leaf and flower biomass relative to stems. This practice not only enhances essential oil yield but also reduces the risk of lodging as the plants mature.

Harvesting, distillation and storage

The essential oil in *Tagetes minuta* accumulates primarily in the leaves and flowers, while stems contain minimal oil content. Consequently, harvesting is performed approximately 60 cm above ground level, leaving behind the lower, largely defoliated stem sections. Harvesting is carried out at full seed maturity, generally from October to November, when essential oil content and composition are optimal.

Post-harvest, the biomass should be distilled promptly, ideally within two to three days to minimize losses of volatile constituents. Steam distillation is the preferred method for oil extraction. Throughout processing and storage, exposure to direct sunlight, moisture, or high temperatures must be avoided to prevent degradation of oil quality. The freshly extracted oil, which ranges from pale yellow to dark yellow in colour, should be promptly dehydrated to eliminate residual moisture. For long-term storage, oil should be kept in airtight, filled containers made of stainless steel, amber-coloured glass, or aluminium, and stored in cool, dark conditions to preserve its chemical integrity and prevent oxidative deterioration.

Inflorescence of aromatic marigold





5. Cultivars developed at CSIR-IHBT (Genotypes available)

CSIR-IHBT, Palampur, has made significant advances in the genetic improvement and varietal development of *Tagetes minuta* to meet the increasing demand for high-quality essential oil and to enhance cultivation prospects in the western Himalayan region. Through systematic breeding, characterization, and multi-location evaluation, two superior cultivars have been developed and are available for commercial cultivation.

'Him Gold'

'Him Gold' is an improved variety developed through a rigorous recurrent selection approach using germplasm collected from Kangra, Mandi, and Kullu districts of Himachal Pradesh. Over six years of selection, a highly uniform population with approximately 95% genetic homogeneity was established. The variety exhibits synchronized seed germination (within 10-15 days), uniform flowering (initiating in mid-September), and consistent seed maturity (by mid-October) when sown in June under mid-hill conditions.

'Him Gold' is particularly well-suited to both temperate and sub-tropical climates and thrives in slightly acidic soils (pH 5.5–7.0) with a well-distributed rainfall of about 150 cm. The variety demonstrates high adaptability, making it suitable as a diversification crop in regions affected by animal depredation, and can also be grown as an intercrop with maize during the kharif season.

The essential oil from 'Him Gold' contains high levels of commercially important acyclic monoterpene ketones and hydrocarbons, making it valuable for use in perfumery, flavor, and pharmaceutical industries. With the adoption of the institute's optimized production technology, farmers can achieve net returns of INR 1.5-2.0 lakh per hectare.

'Him Swarnima' (CSIR-IHBT-TM-09)

'Him Swarnima' (CSIR-IHBT-TM-09) has been developed through a half-sib progeny selection approach from advanced breeding lines derived from CSIR-IHBT's germplasm core collections. The variety has undergone extensive multi-location evaluations across diverse agro-ecological zones in Himachal Pradesh.

This cultivar is characterized by its vigorous growth habit, high adaptability, and superior biomass productivity. It consistently produces fresh biomass yields ranging from 18.0 to 23.0 tonnes per hectare, coupled with an essential oil content of 0.30% to 0.34%. The variety's robust performance across locations highlights its potential for wide-scale cultivation under variable environmental conditions, particularly in the mid-hills and lower elevations of the western Himalayan region.



Field view of aromatic plantation

6. Processes and products formulated

1. Steam distillation

The primary method for extracting essential oil from *Tagetes minuta* is steam distillation, using freshly harvested aerial parts, particularly leaves and flowers. As the stem does not contain essential oil, harvesting is done approximately 2 feet above ground level to maximize oil-bearing biomass. The harvested material should be distilled within 2-3 days to preserve oil quality and minimize deterioration.

Yield

Essential oil content typically ranges from 0.30% to 0.34%, depending on the variety and cultivation conditions.

7. Agro- and Processing Technology

Aromatic marigold (*Tagetes minuta*) is gaining considerable attention among farmers due to the rising demand for its essential oil, which is widely used in perfumes, hair care products, and as a flavouring agent in various food and beverage items. Recognizing its commercial potential, CSIR-IHBT, Palampur, has developed an improved selection named 'Him Gold'. This variety is known for its superior oil quality and consistent yield performance.

Under optimal cultivation conditions, 'Him Gold' produces an herb yield of approximately 120 quintals per hectare, with an essential oil recovery of about 0.3%. To promote its cultivation, CSIR-IHBT supplies high-quality seeds of 'Him Gold' to farmers. In addition, the institute offers comprehensive support through essential oil extraction technology and conducts regular trainings on cultivation practices and processing techniques to ensure efficient production and post-harvest management.

CSIR-IHBT Support

CSIR-IHBT provides complete technology packages for essential oil extraction and offers training on both agro-technology and processing methods. Seeds of the high-yielding 'Him Gold' variety are made available to farmers to support commercial cultivation

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Aromatic marigold biomass is ready for distillation

8. Stakeholders and purpose of collaboration

Identification of stakeholders involved in *Tagetes minuta* cultivation and trade is crucial for strengthening its value chain. Field observations and interviews help in recognizing stakeholders based on their expertise and role in cultivation, processing, and marketing. These stakeholders can be further categorized by their level of interest and influence. CSIR-IHBT, Palampur, plays a central role by offering consultancy for agro-processing units, conducting training programs, and providing technological support under the CSIR Aroma Mission. Through MOUs with farmers, the institute supplies quality planting material, leading to the expansion of cultivation, particularly in Himachal Pradesh, where Chamba district has become a major production hub. Collaboration among farmers, industry partners, and research institutions integrates improved cultivation practices, processing technologies, and market assurance to promote sustainable production.

9. Sustainability and future trends in the cultivation of aromatic marigold

The cultivation of aromatic marigold, a valuable aromatic plant producing essential oil rich in industrially significant compounds such as dihydrotagetone, (Z)-β-ocimene, and tagetones, offers significant potential for sustainable agriculture. With increasing consumer demand for natural and eco-friendly products, sustainable cultivation practices, innovative breeding approaches, and modern technological interventions are becoming central to ensuring long-term productivity and environmental conservation.

Organic farming and eco-friendly practices

The organic cultivation of aromatic marigold aims to achieve high-quality essential oil production while preserving soil fertility and ecological balance. Organic farming prohibits the use of synthetic agrochemicals, relying instead on organic manures and composts that enhance soil microbial activity and nutrient availability. The continuous supply of organic nutrients fosters plant growth and the biosynthesis of secondary metabolites, which directly influence essential oil composition and yield (Kumar et al., 2022). Furthermore, aromatic marigold's natural bioactive properties, including its insecticidal, antifungal, and nematicidal activities (Kumar et al., 2020), contribute to its self-defense against pests and diseases, making it highly suitable for organic farming systems with minimal pesticide interventions.

Integrated Pest Management (IPM)

Aromatic marigold can benefit significantly from Integrated Pest Management (IPM), which combines biological control agents, resistant varieties, cultural practices, and minimal chemical inputs. Its own essential oil contributes to deterring pests due to its biocidal compounds (Walia et al., 2020; Babaei et al., 2021). Additionally, practices like optimal plant spacing, weed management, and crop rotation can further enhance plant health and reduce the incidence of pests and diseases.

Water conservation and abiotic stress management

Water availability is a major limiting factor for aromatic marigold cultivation, especially in semi-arid and rainfed regions. Adoption of water-saving techniques such as drip irrigation, mulching, and rainwater harvesting is crucial. Under drought stress, aromatic marigold shows adaptive responses such as reduced leaf area, increased root biomass, accumulation of osmolytes like proline, polyamines, and glycine betaine, and enhanced activity of antioxidant enzymes like catalase (CAT), ascorbate peroxidase (APX), and guaiacol peroxidase (GPX) to maintain cellular homeostasis (Babaei et al., 2021; Cicevan et al., 2016). In controlled studies, somaclonal variation and *in vitro* selection using mannitol have been effectively utilized to identify drought-tolerant clones (Mohamed et al., 2000). These approaches present practical tools for developing drought-resilient lines suitable for resource-limited environments.

Future trends and emerging innovations

Genetic engineering and genomic-assisted breeding

Genomic technologies offer promising avenues for the rapid improvement of aromatic marigold. The identification of quantitative trait loci (QTLs), single nucleotide polymorphisms (SNPs), and gene expression studies can facilitate the development of stress-tolerant, high-yielding varieties (Langridge et al., 2006; Crossa et al., 2017). Marker-assisted selection can help integrate complex traits such as drought tolerance, salinity resistance, and heavy metal phytoremediation capacity into elite cultivars. Transcription factors such as WRKY, MYB, bZIP, bHLH, NAC, and AP2/ERF families play crucial roles in regulating stress responses and secondary metabolite biosynthesis in aromatic marigold under abiotic stress (Meraj et al., 2020; Mahajan et al., 2020).

Tissue culture, micropropagation, and synthetic seeds

In vitro propagation methods offer rapid multiplication of elite genotypes with desirable traits. Encapsulation of somatic embryos for synthetic seed production presents a viable strategy for conservation, transportation, and mass multiplication of superior lines, particularly when natural seed availability is low (Mohamed et al., 2000).

Phytofarming and phytoremediation applications

Aromatic marigold exhibits significant phytoremediation potential, particularly for heavy metals like lead (Pb) and nickel (Ni), accumulating these elements predominantly in its roots and shoots without translocating them to the essential oil fraction (Sosa et al., 2016; Chand et al., 2015). Co-cropping systems with low-metal accumulator species further enhance biomass and metal accumulation (Cid et al., 2016; Xu et al., 2013). Thus, aromatic marigold cultivation on contaminated lands offers dual benefits of environmental restoration and economic return from essential oil production.

Smart farming and precision agriculture

Adoption of smart farming technologies, including soil moisture sensors, remote sensing, and AI-driven predictive analytics, can enable precise irrigation, nutrient management, and stress monitoring. These tools enhance resource use efficiency and optimize both biomass yield and essential oil quality under variable climatic conditions (Walia and Kumar, 2021b)

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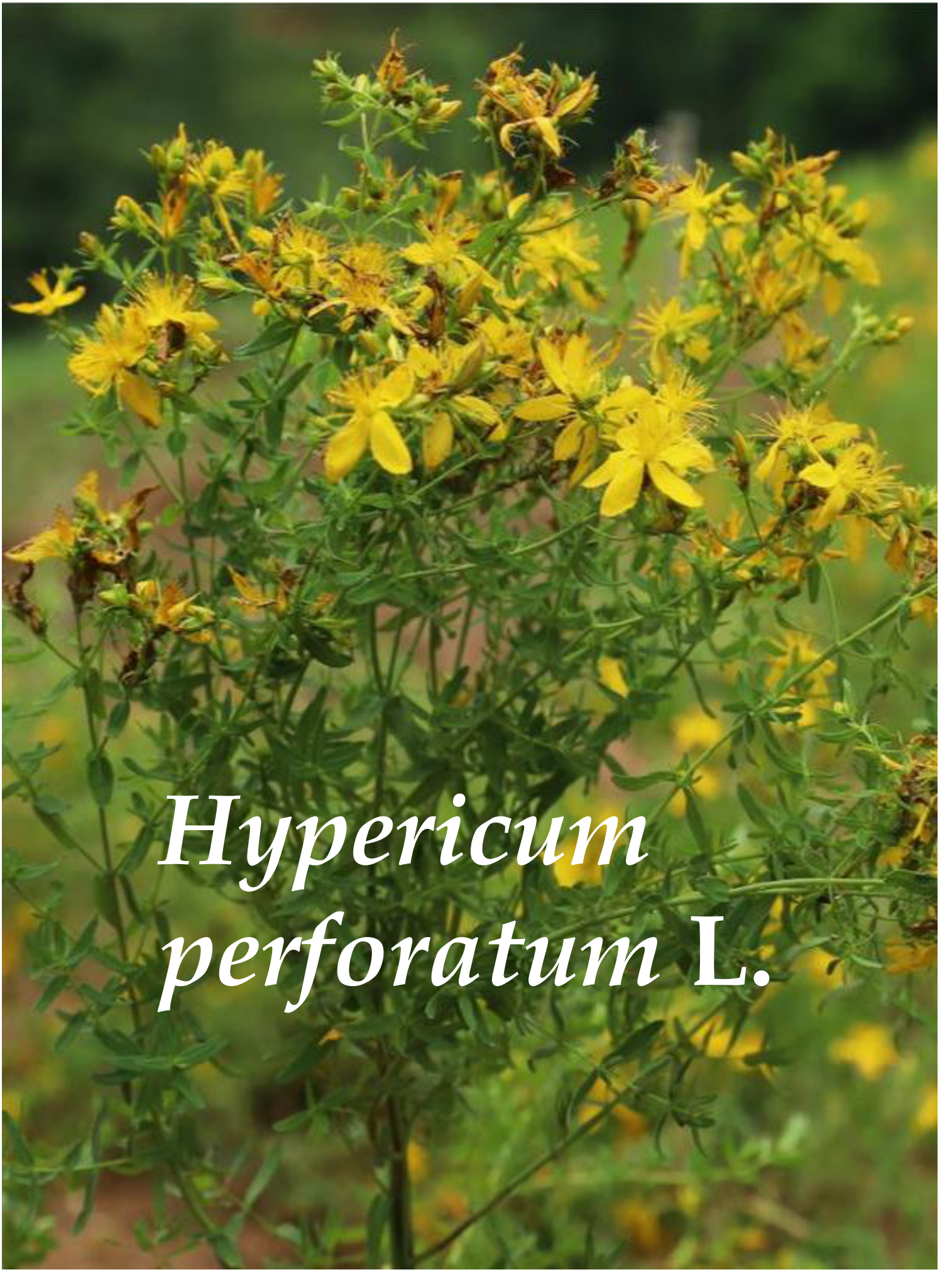

Hypericum
perforatum L.

***Hypericum perforatum* L.**

Dr. Rakesh Kumar and Dr. Yog Raj
Agrotechnology Division

1. Health benefits and applications in medicine

Hypericum perforatum L. is a perennial medicinal plant commonly known as St. John's wort (SJW) found in regions at altitudes of 1000-3000 m. According to the European Pharmacopoeia, SJW herbal preparations are made from dried flowering tops (*Hyperici herba*, 15–20 cm long) collected at the flowering stage (mid-June) (EMA, 2018; Raj et al., 2023). The efficacy of SJW herbal preparations is mainly attributed to accretion of two most important pharmacologically active specialized metabolites, namely hypericin (a naphthodianthrone-quinone) and hyperforin (a phloroglucinol-meroterpenoid) in dark glands (Rizzo et al., 2019) and in translucent glands (Wu et al., 2022), respectively. SJW formulations exhibit comparable antidepressant properties to various prescribed synthetic antidepressant drugs, such as fluoxetine, imipramine, paroxetine, or sertraline, having reduced side effects.

2. Economic impact and market demand

SJW herbal preparations sold globally, with an average annual worth exceeding USD 6 billion for treating mild to moderate depression (Nicolussi et al., 2020).

3. Raw material availability and conservation status

In India, the availability of SJW raw material is currently limited, and wild collection still accounts for a large part of the total supply. The plant has been enlisted in vulnerable category in the Indian Himalayan region (Butola and Samant, 2012).

4. Agrotechnology

Soil and climatic requirement

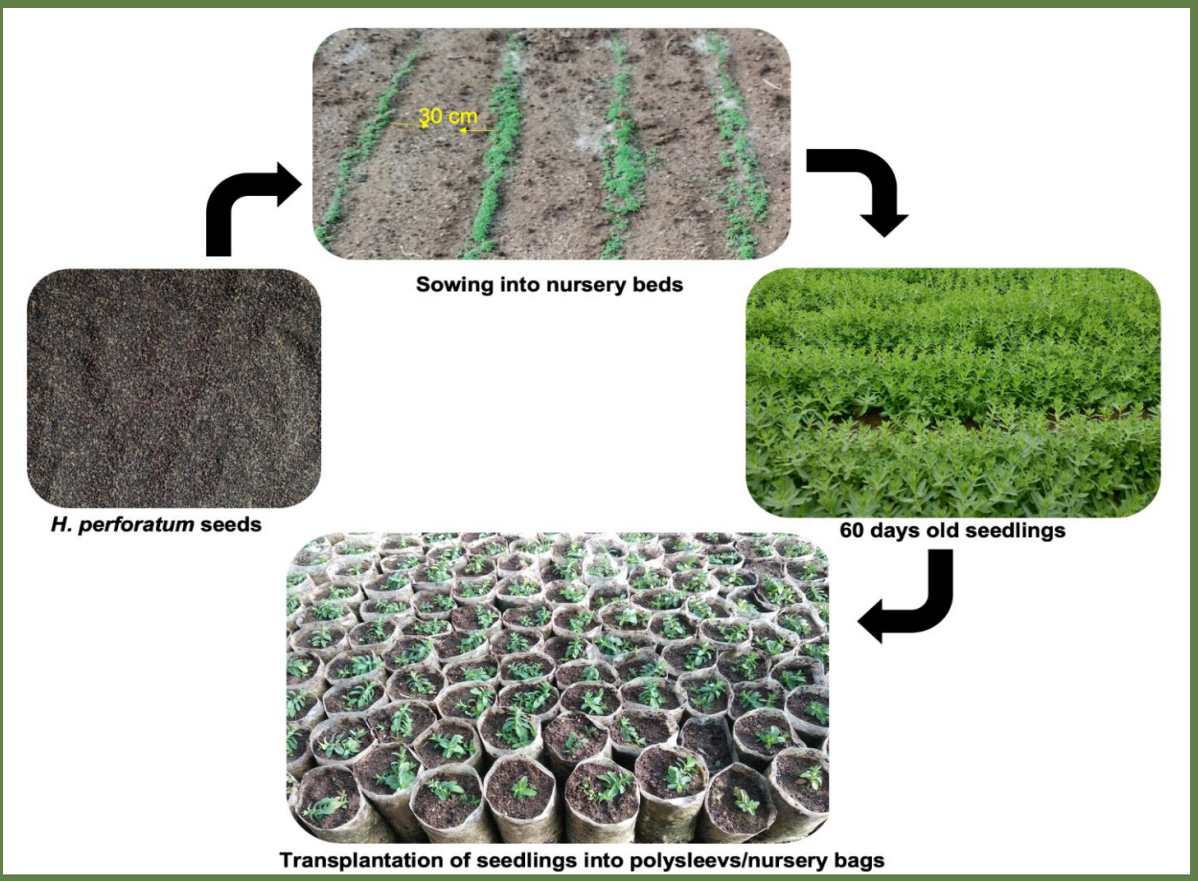
The plant is distributed throughout the world (Europe, United States, Asia, North Africa, and North America) including diverse habitats from temperate areas to high mountain regions in the tropics with altitudes up to 3000 m amsl (above mean sea level). Its natural range extends from areas with low winter temperatures to subtropical environments, although the best performance was registered in areas with at least 760 mm annual rainfall. The plant grows naturally in mesophytic areas, and proliferates well in temperate open sunny areas having well-drained, coarse-textured, slightly acidic to neutral soils (4.3–7.0) but is prone to saturated or wet soils.

Propagation

The crop can be propagated by seeds, division, or by softwood cuttings but propagation through seeds is much familiar practice. The seeds can be propagated through nurseries and direct sowing/broadcasting methods. However, direct sowing is not advisable due to its lower yield and a higher seed rate (3-4 kg/ha). Therefore, it is suggested that the plant should be propagated through seeds by raising seedlings in the nursery and then transplanting them into the main field. Approximately 500 g of seeds are required for raising seedlings for one-hectare area.

Nursery raising

The cultivation of crop is done through the raising of a nursery. The appropriate time of raising nursery is before frost in October. Raised seedbeds of 10-15 cm in height should be thoroughly prepared by the addition of well-decomposed farmyard manure (FYM) @ 1 kg/m^2 and fine sand @ 1 kg/m^2 followed by well mixing. Beds of 1 m x 4 m, having irrigation channels should be laid out and seeds (20-25 g/bed) should be mixed with fine sand (1:10) and sown in lines of 30 cm apart in line sowing, care should be taken to avoid deep sowing. Generally, seed should be sown within a depth range of 0.3-0.5 cm. Do not cover the seed but gently press into the soil. The nursery beds should irrigate immediately after sowing and regularly thereafter. It is advisable to cover the seed bed after sunset with a thin polythene sheet to avoid frost injury and to maintain the temperature at night. The cover should be removed during the day time. Usually, the seeds start germinating 7-10 days after sowing, and the germination will be complete within 30-35 days. Frequent hand weeding should be done to maintain a weed-free nursery bed. Sixty-days-old seedlings are further transplanted into polysleeves or nursey bags having a sand:soil:FYM in 1:1:1 ratio as a nursery substrate. The seedlings will be ready for transplanting in about 90-100 days after attaining a height of 10-15 cm.



Land preparation and transplanting

The land should be well prepared with 2-3 ploughings until a fine tilth of soil is obtained. Well decomposed farmyard manure @ 10 t/ha, otherwise vermicompost @ 5 t/ha has to be applied before the 2nd and 3rd ploughing. The 90-100 days old seedlings having an average height of 10-15 cm are transplanted in the main field in mid-January with a spacing of 50 cm plant to plant and 50 cm row to row. Transplanting should be preferably done in the morning or evening hours to avoid transplantation shock. Cloudy weather and fine drizzle are considered ideal for transplanting. Irrigation is required just after the planting.



Transplanting into the field

Fertilization and irrigation

A fertilizer dose of 120:60:40 kg/ha of N, P_2O_5, and K_2O, respectively is recommended for profitable yield. Irrigation depends upon the moisture in the field. Generally, irrigation is required once in a week, however, in rainy season, no irrigation is required. Irrigation should be stopped, before harvesting. Generally, the plants require more water in areas with winter rains, and less in areas with winter snow.

Weed management

Normally the seedlings become well established in the main field one month after transplanting. At this stage, first weeding should be done and subsequently the second is done one month after the first. No further weeding is required thereafter as the plants become bushy and thereby suppress the growth of weeds.



Weed free *Hypericum perforatum* plants at vegetative stage

Harvesting and post-harvest processing

The crop can be harvested at flowing time (mid-June). Flowering tops are excised and kept for drying under shaded conditions at room temperature. The dried material should be kept under dark conditions.



Ready to harvest *Hypericum perforatum* plants at flowering stage

5. Cultivars developed at CSIR-IHBT

IHBT/HP-1

6. Stakeholders and purpose of collaboration

Multiple stakeholders such as local farmers, pharmaceutical companies collaborate to promote the sustainable cultivation and conservation of SJW. The purpose of this collaboration is to establish a sustainable value chain by integrating scientific research, improved cultivation practices, and market linkages. Farmers can be supported through training, technical guidance, and access to quality planting material, while industry partners ensure market assurance and quality compliance.

7. Sustainability and future trends

The sustainability of SJW cultivation and utilization is increasingly gaining attention due to its ecological vulnerability and high commercial demand. Traditionally overharvested from the wild, the species has faced significant population declines, prompting its listing as vulnerable in Indian western Himalayan region. However, the shift toward cultivated sources have opened a path for sustainable production. Adoption of good agricultural practices (GAPs), promotion of organic farming, and community-based conservation models are emerging as effective strategies to reduce pressure on wild populations and ensure long-term availability.

Looking ahead, the future of SJW cultivation lies in integrating science-led cultivation protocols, value addition through processing, and traceable supply chains for the herbal and pharmaceutical industries. Research into *in vitro* propagation techniques, high-yielding varieties, and climate-resilient practices is expected to play a key role in scaling up sustainable cultivation. Additionally, rising demand for herbal and plant-based medicines globally is likely to drive investments in contract farming, public-private partnerships, and policy support. With the right combination of conservation, cultivation, and commercialization strategies, SJW holds strong potential for sustainable livelihoods and biodiversity preservation.

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