A Comprehensive Handbook on Tree Spices

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Foreword

The global spice trade has long been a fascinating narrative of discovery, culture, and commerce. From the ancient maritime routes that connected the East and the West to today's diversified spice industries, these aromatic treasures have shaped economies and enriched cuisines around the world. Among the vast array of spices, tree spices derived from perennial woody plants occupy a distinct and enduring place. Their production represents not only a rich botanical heritage but also a vital component of sustainable agriculture, traditional medicine, and rural livelihood.

It gives me immense pleasure to introduce ***A Comprehensive Handbook on Tree Spices***, a timely and comprehensive work that addresses an important yet often underrepresented segment of the spice sector. In an era where agricultural diversification and eco-friendly farming systems are increasingly emphasized, this handbook stands out as a valuable guide that combines scientific rigor with practical insight into the production technology of tree spices.

The authors has meticulously compiled detailed information on major tree spices such as cinnamon, nutmeg, clove, *kokum*, Malabar tamarind, allspice, curry leaf, and tamarind. Each chapter describes the details on varieties, propagation, and cultivation techniques to harvest and post-harvest management, processing, and value-addition, and quality standards in the simplest language. Such an approach ensures that readers, whether they are students, researchers, farmers, or entrepreneurs, gain a complete perspective on the subject. This handbook, will undoubtedly serve as a trustworthy companion and ready reference for a wide range of readers. It would bridges the gap between academic research and field application, encouraging both scientific curiosity and practical innovations by all stakeholders.

I congratulate the editors and other fellow researchers on this remarkable contribution to the field of tree spice cultivation. I am confident that this publication ***A Comprehensive Handbook on Tree Spices*** will become a useful standard reference book for farmers, nursery men, students, agricultural extension service professionals, policy planners etc. and will inspire future research and enterprise in the realm of spice cultivation and utilization.

01/12/2025

(Sanjay Kumar Singh)

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Preface

Spices have been an integral part of human civilization for centuries cherished not only for their ability to enhance flavor and aroma but also for their profound cultural, medicinal, and economic significance. Among these, tree spices hold a unique position, bridging the realms of forestry, agriculture, and trade. The cultivation and utilization of tree spices such as cinnamon, clove, nutmeg, allspice, kokum, Malabar tamarind, tamarind, and curry leaf represent an intersection of traditional wisdom and modern science, providing immense potential for sustainable livelihood and biodiversity conservation.

The present book, "A Comprehensive Handbook on Tree Spices" has been designed as a comprehensive reference for students, researchers, agriculturists, spice growers, and entrepreneurs who seek a deeper understanding of these valuable resources. It aims to consolidate scattered knowledge and present it in a structured, practical, and accessible manner.

This handbook begins by briefly introducing the tree species, providing readers with a foundation for understanding their ecological and economic importance, and subsequently delves into the cultivation practices, covering aspects such as propagation, planting techniques, nutrient management, pest and disease control, and post-harvest handling. Each crop is discussed in detail, highlighting the practical aspects of climate, soil requirements, yield potential, and processing methods.

Recognizing the modern challenges and opportunities in spice cultivation, the book also addresses sustainable production systems, organic farming practices, agroforestry integration, and value addition. Special attention has been given to quality standards, grading, export potential, and processing technologies, making this handbook not only a scientific guide but also a practical tool for commercial growers and processors.

The preparation of this handbook has involved consultation with subject experts, field practitioners, and research literature from across the world. Efforts have been made to ensure accuracy, clarity, and relevance for both academic and practical audiences. Illustrations, tables, and flow charts have been included to enrich understanding and facilitate easy reference.

It is hoped that *A Comprehensive Handbook on Tree Spices* will serve as a valuable resource for anyone interested in the science, cultivation, and commerce of these remarkable plants. May it inspire renewed appreciation for the trees that flavor our food, sustain our economies, and enrich our ecosystems.

Editors

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Chapter - 1

TREE SPICES: AREA, PRODUCTION, AND TRADE

The tree spices form a distinctive and economically significant segment of the spice sector, contributing substantially to both domestic consumption and international trade. Unlike herbaceous spices, tree spices are derived from perennial woody plants that provide a steady yield over many years. The most important tree spices include nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum* sp.), tamarind (*Tamarindus indica*), curry leaf (*Murraya koenigii*), kokum (*Garcinia indica*), and allspice (*Pimenta dioica*). Together, these crops not only add diversity to the spice economy but also serve as critical livelihood and export commodities across tropical regions.

Global Scenario

Globally, tree spices occupy a combined area of around 1.5 million hectares, producing nearly one million tonnes annually. Among the tree spices, four commodities are commercially cultivated at the global level on a significant scale. They are nutmeg, clove, cinnamon, and, to a limited extent, tamarind.Clove and cinnamon account for the largest share of both area and output, followed by nutmeg and tamarind (Table 1). According to the compiled estimates, clove covers approximately 7,02,000 ha with an output of 1,86,706 tonnes, primarily from Indonesia, Madagascar, and the Island nation of Comoros. Cinnamon is cultivated on about 3,55,000 ha with 2,38,403 tonnes of production, led by Vietnam, Indonesia, China, and Sri Lanka. Nutmeg, grown mainly in Indonesia, India, and Laos, covers ~308,000 ha, yielding 75,216 tonnes, while tamarind—important both as a spice and condiment—accounts for about 110,000 ha and 407,000 tonnes globally.

Table 1. Global production scenario of major tree spices

Crop	Area (ha)	Production (t)	Major producing countries
Nutmeg	3,07,818	75,216	Indonesia, India, Laos
Clove	7,02,237	1,86,706	Indonesia, Madagascar, Comoros
Cinnamon	3,55,667	2,38,403	Vietnam, Indonesia, China, Sri Lanka
Tamarind	1,10,000	4,07,000	India, Thailand, Indonesia

Apart from these, tree spices commodities such as allspice, kokum,and curry leaf have created their own niche markets in food, flavour, and wellness industries. Allspice is cultivated primarily in Jamaica, Mexico, and Central America, while kokum is native to India's Western Ghats. Curry leaves are used in several cuisines, especially in India. These crops, though small in area, gain significance due to their multiple uses and applications. The estimates about the area and production from these tree spices are not collected in a systematic manner.

Tree Spice Cultivation in India

India contributes significantly to the world's tree spice production, cultivating about 73,000 hectares that yield approximately 2,39,000 tonnes of produce annually. Within India, tamarind dominates with 35,593 ha and 1,32,429 tonnes, followed by nutmeg (25,743 ha; 18,940 t), cinnamon (2,154 ha; 4,986 t), clove (1,847 ha; 1,015 t), and curry leaf (4,026 ha; 58,926 t). The minor crops kokum and allspice are still limited (<300 ha), but they represent potential crops for diversification in the humid tropics. Tree spices are grown mainly in Kerala, TamilNadu, Karnataka, and parts of the North Eastern states, often in mixed cropping systems.

Table 2. Area and production of tree spices in India (2024-25)

Crop	Area (ha)	Production (t)
Nutmeg	25,743	18,940
Clove	1,847	1,015
Cinnamon	2,154	4,986
Malabar tamarind	Not estimated	~2,500
Tamarind	35,593	1,32,429
Curry leaf*	4,026	58,926
Kokum	2,200	20,000
Allspice	< 300	< 75
Total	**73,063**	**2,38,896**

Estimates based on available literature

*A significant part of the curry leaf production is consumed at the farm household level and does not reach the markets.

Tree spices, though covering a smaller area compared to other spices, play an important role in value addition and export earnings. High-value products such as nutmeg oil, clove bud oil, and cinnamon bark oil are key raw materials for the flavour, fragrance, confectionery, and pharmaceutical industries. Tamarind contributes heavily to the domestic condiment and food processing sector, while clove and cinnamon hold a strong position in international trade. Together, tree spices contribute an estimated 4% of India's total spice export value. The export value of various tree spices commodities to the financial year, 2024-25 is appended below:

Table 3. Export value of tree spice commodities (2024-25)

Commodity	Export value (₹ crores)	Import value (₹ crores)
Nutmeg, neither crushed nor ground	160.00	49.36
Nutmeg crushed or ground	72.91	5.50
Mace, neither crushed nor ground	14.78	282.19
Mace, crushed or ground	5.25	2.19
Nutmeg oil	35.49	19.48
Nutmeg oleoresin	59.58	2.00
Cloves (whole fruit, cloves, and stems)	106.49	1952.79

Clove leaf/stem oil	10.77	160.10
Clove bud oil	4.82	7.34
Clove oleoresin	8.74	0.16
Pimenta dried fruits	6.58	10.78
Pimenta powder	15.71	-
Tamarind fresh	26.66	27.70
Tamarind dried	271.30	0.04
Flour meal and powder of tamarind	5.32	-
Tamarind kernel powder	152.12	0.33
Garcinia	1.40	16.22
Fruit rind of Malabar tamarind	0.79	-
Cambodge extract	73.25	0.21
Dried pericarp- kokum	2.65	-
Cinnamon- bark /flowers	123.94	894.07
Cinnamon leaf oil	2.09	12.92
Cinnamon bark oil	3.12	2.58
Cassia oil	0.74	3.30
Cassia powder	296.81	0.65
Cassia	23.89	795.50
Total	**1485.20**	**4245.41**

Tree spices exhibit extensive multi-sectoral linkages that go far beyond their traditional culinary roles. In the food and beverage industry, allspice, cinnamon, and clove are key ingredients in flavour formulations and spice blends, while tamarind pulp is widely used in sauces, beverages, and pickles. The essential oil and fragrance sectors rely on nutmeg and clove oils for perfumery, pharmaceuticals, and cosmetics, whereas cinnamon bark and leaf oils form essential components in several products like toothpaste, soaps, and mouthwash formulations. In the nutraceutical and wellness domain, kokum, nutmeg, and allspice are valued for their high antioxidant potential and are used in health supplements and natural food colorants. Moreover, as perennial species, tree spices support the agroforestry and carbon economy by enhancing soil conservation, sequestering carbon, and promoting sustainable land use.

However, despite their strategic importance, India's import value of tree spice commodities (₹4245 crore) far exceeds the export value (₹1485 crore), indicating a significant trade gap. High imports of commodities such as cloves, cinnamon, and mace highlight the need to strengthen domestic production systems. Enhancing the cultivation and processing of tree spices can play a critical role in achieving greater self-sufficiency in spices, reducing dependency on imports, and improving India's trade balance. Despite their limited area, they hold strategic significance for export diversification, climate-resilient farming, and rural livelihoods. With growing consumer interest in natural and functional products, tree spices are poised to expand their presence in global food, cosmetic, and wellness value chains.

Chapter - 2

CINNAMON

Scientific name: *Cinnamomum* sp.
Family: Lauraceae

Introduction

Cinnamon is one of the earliest spices used by humankind. The dried inner bark of the tree is the spice of commerce. It has a delicate fragrance and a warm, sweet, agreeable taste. It is a valuable flavouring agent in the food and beverages sector and a precious ingredient in the pharmaceuticals and cosmetics industry. Its fragrant leaves are also used as a spice in many culinary preparations.

Cinnamon originated in Sri Lanka, and in 1767 AD, the British established the first spice plantation in India at Anjarakandy in North Malabar. In India, true cinnamon is mainly cultivated in Kannur (Kerala), South Kanara (Karnataka), Nilgiris, Lower Pulneys, Courtallam, and Kanyakumari (Tamil Nadu) over an area of 2,950 ha with production of 5,050 tonnes in India (NHB Database, 2023-24). In global market, all the *Cinnamomum* species are broadly called as 'Cinnamon'. Cinnamon production is dominated by Indonesia, China, Sri Lanka, and Vietnam. Among them, Sri Lanka produces true cinnamon and the other countries produce cassia (*C. cassia*). India, Madagascar and Seychelles are the other countries producing true cinnamon. In 2024, Vietnam lead globally in area under cinnamon cultivation with 199,904 ha, China was the largest producer with a total output of 94,215.75 t, and China also recorded the highest productivity at 1,947.1 kg ha^{-1}, outperforming other major cinnamon-producing countries (FAOSTAT, 2025).

Table 1. Economically important species of Cinnamon

Common name	Botanical name	Regions of production	Characteristics
Ceylon cinnamon/ Sri Lankan cinnamon (True cinaanmon)	*C. verum* *C. zeylanicium* (syn.)	Sri Lanka/ South India	Best quality bark with delicate, mild, citrusy flavour; low coumarin content; used in teas, desserts, and medicines
Chinese cassia	*C. cassia* *C. aromaticum* (syn.)	China	Sweet flavor; bark and leaf slightly astringent; strongspicy, pungent bark; high coumarin content; used in commercial ground blends

Indonesian cassia/ Korintje cinnamon	*C. burmannii*	Java, Sumatra	Reddish brown bark; woody, mildly sweet flavour; moderate to high coumarin content, sharp and subtly sweet flavour with hints of spice and a slightly sour bite; used for baking, cinnamon rolls and blends
Saigon cassia	*C. loureirii*	Vietnam	Intense; very aromatic bark with the highest coumarin content; used in bold flavour needs (e.g., savory)
Indian Cassia (Tejpatta)	*C. tamala*	Tropical and subtropical Himalayas	Leaves are used as a spice in North India



C. verum



C. cassia



C. verum



C. cassia



C. tamala

Production technology of Cinnamon

Climate and soil

Cinnamon tolerates a wide range of climatic conditions. The crop performs well in an altitude range from 300-350 m MSL and also thrives at 1,000 m above MSL. The hot, humid climatic conditions of the warm tropics are suitable for the crop. It flourishes in places with an annual rainfall of 150-250 cm and with an average temperature of 27 °C. A soil depth of about 1 m is desirable for the crop. Cinnamon planted in shallow soils does not grow well. It does not tolerate extreme pH regimes, and a pH in the range of 5.5–6.5 ensures good growth and yield.

Varieties

The list of released varieties with their characteristics is given in Table 2.

Table 2. Characteristics of cinnamon, cassia & tejpatta varieties released from different research institutes in India

Varieties	Year of release	Breeding method	Yield	Characteristics
Varieties released by ICAR-Indian Institute of Spices Research, Kozhikode, Kerala				
IISR Navashree	1996	Seedling selection from Sri Lankan selections	Yield: 200 kg dry quills/ha Potential yield: 250 kg/ha Yield of dry bark per plant: 201.1g	High-quality line, good bark recovery with good aroma and taste, grows well in plains and higher elevations. Bark oil: 2.7% Leaf oil: 2.8% Bark oleoresin: 8.0% Bark recovery: 40.6% Cinnamaldehyde in bark oil: 73% Cinnamaldehyde in leaf oil:15% Eugenol in bark oil: 6.0% Eugenol in leaf oil: 62% Shoot regeneration capacity: 25.45/4 plants
IISR Nithyashree	1996	Seedling selection from the Indian collection	Yield: 200 kg dry quills/ha Potential yield: 250 kg/ha Yield of dry bark per plant: 194.6 g	Good regeneration capacity, bark and leaf oleoresin contents are high, good bark recovery with good aroma and taste Bark oil: 2.7% Leaf oil: 3% Bark Oleoresin: 10% Cinnamaldehyde in bark oil: 58% Cinnamaldehyde in leaf oil: 14% Eugenol in bark oil: 5.0% Eugenol in leaf oil: 78% Shootregeneration capacity: 18.90/4 plants





IISR Navashree





IISR Nithyashree

Varieties released by the TNAU-Horticultural Research Station, Yercaud, Tamil Nadu				
YCD-1	1995	Clonal selection from OP seedlings progenies of the Sri Lankan type	360 kg dry bark/ha	Good bark recovery, adapted to a wide range of soil and rainfed conditions. Bark oil:2.8% Leaf oil: 3.0% Bark recovery: 35.3%
Varieties released by TNAU-Horticultural Research Station, Pechiparai, Tamil Nadu				
PPI (C)-1	2003	Selection from OP seedlings progeny introduced from Sri Lanka	973 kg fresh bark/ha	High oil recovery from the bark (2.9%) and leaf oil recovery of 3.3%, bark recovery 34.22%. Suitable for cultivation in high rainfall zones and hill regions of Tamil Nadu at an altitude range of 100-500 m MSL





YCD-1

Varieties released by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra				
Konkan Tej	1993	Seedling selection from progenies of Sri Lankan accessions	378 g fresh bark per plant	Brown colour bark, bark oil: 3.2%, cinnamaldehyde: 70.23 %, dry bark: 250 g, dry leaves: 1.94 kg, cinnamaldehyde in bark oil: 70.23%, eugenol in bark oil: 6.93%, bark recovery: 35.3%
Konkan Tejpatta	2008	Seedling selection from progenies of Sri Lankan accessions	1.60 kg dry leaves per plant per year	Good in taste, bark oil: 2.8%, eugenol: 80.30%
Konkan Cassia	2018	Seedling selection from progenies of Sri Lankan accessions	100 g bark per plant	First variety of cassia in India, good in bark yield, low level of coumarin content (19.9 mg/kg), and bark oil 2.40 %





Konkan Tej





Konkan Tejpatta




Konkan Cassia

Varieties released by Aromatic and Medicinal Plants Research Station, KAU, Odakkali, Kerala				
Sugandhini (ODC-130)	2001	Single tree selection from waynad local collection. Sri Lankan type	1.2 kg fresh bark/tree/year	Recommended for cultivation for leaf oil production, bark oil: 0.94 %,leaf oil 1.6 %, bark recovery 51 %
Varieties released by CSIR-Regional Research Laboratory, Bhubaneswar, Odisha				
RRL (B) C-6	2003	Selection from germplasm collection –OP seedling progenies	250 kg dry bark/ha	High quality, sweet and pungent bark, leaf oil 0.8 %, spreading, and branching nature
Variety released by ICAR- Central Coastal Agricultural Research Institute, Goa				
Goa Dalchini-1	2024	Chance seedling selection(GT-C-3) from true cinnamon progeny	275 – 325g / plant	The bark colour is light brown, bark recovery : 39.8%, bark oil: 2.66%, leaf oil: 3.1% (higher content of cinnamalde-hyde), recommended for the state of Goa




Goa Dalchini-1

Sri Lankan varieties

Sri Gemunu: It has a distinctive sweet and pungent flavour, and the typical aroma characteristics of Ceylon cinnamon. It produces an average bark yield of 1200-1300 $kgha^{-1}$

and has high bark oil content (3.25–3.6%), leaf oil (3.6–3.9%), and cinnamaldehyde content (80–83%) of bark oil.

Sri Wijaya: It produces a high bark yield of 1600–1800 $kgha^{-1}year^{-1}$ with a higher content of eugenol (88–92%) in leaf oil.

Propagation

Cinnamon is propagated through seeds and vegetative propagation methods like stem cuttings and air layering. Large commercial plantations are established by high-quality cinnamon seedlings. High-yielding varieties are generally propagated by layering and cutting.

Seed propagation

Season: Under West coast conditions of India, cinnamon flowers in January, and the fruits ripen during June-August. Only about 20–22% of cinnamon flowers produce the drupaceous fruits, which mature within 4–5 months. July-August is the best time for sowing in Kerala.

Selection of mother plant: Seeds should be collected from mother plants with desirable characteristics such as healthy growth, erectness of stems, high yield and quality, peelability, and freedom from pests and diseases. A mature, well-developed cinnamon tree produces about 250–500 seeds per year.

Collection of seeds: The fruit pericarp becomes blackish purple when ripe. It is ideal to collect the seeds directly from the mother trees, as there is a chance of mixing up the fallen seeds with wild species due to the perching of birds. The birds relish the pericarp of ripe drupes; hence, the use of bird netting is necessary for collecting adequate seed material for establishing large-scale plantations. As all the fruits in a bunch do not ripen at the same time, care should be taken to harvest only the ripe fruits. To produce planting material for one hectare, 30–35 kg of seeds is required.



Cinnamon fruits



Cinnamon seeds



Cinnamon nursery

Seed extraction: For seed extraction, ripe fruits should be kept in a heap for about 1–2 days under shade to soften the pericarp. The pulp is then removed, and the seeds are extracted by washing thoroughly under running water.

Seed storage: It is advisable to sow seeds immediately after washing to achieve a high germination rate. Seeds, being desiccation sensitive, cannot be stored long without loss of viability. Cinnamon seeds generally lose 40–60% of viability within 4 weeks and are completely lost by 6–8 weeks. Reports say that they can be stored in dried sawdust or air-dried river sand; seed viability exceeding 90% could be maintained up to 6 weeks.

Nursery preparations and sowing: The nursery should have adequate sunlight with provision for shading during the early stages of the seedlings. It is better to keep the nurseries ready before the fruit harvesting season. Seeds could be planted in rows in raised seed beds in 12 cm ×3 cm spacing. Seeds germinate within 2–3 weeks, and when seedlings reach a height of 10 cm, they should be transferred to polythene bags (20 cm × 12.5 cm) filled with a potting mixture containing equal parts of topsoil, river sand, coir dust, and dried cow dung. Seedlings germinated in beds can be transplanted to polythene bags in the 2-3 leaf stage. Seeds (8-10 nos.) can be directly sown in polythene bags (20 cm × 12.5 cm) filled with the potting mixture.

Nursery management: During the first 2 months of the nursery period, temporary shade must be provided to protect seedlings from sunburn. Watering should be done as and when required. Management of pests, diseases, and weeds is important to produce high-quality planting material. Seedlings will be ready for field establishment within 6 months.

Cuttings

Establishment of mother plant blocks: It is important to manage mother plants through proper training and pruning to facilitate the production of more erect shoots. A separate plot of mother plants is advisable for the propagation of high-yielding varieties.

Selection of cuttings: Cinnamon is a hard-to-root woody perennial tree. Semi-hardwood cuttings of 10 cm length with two mature leaves are ideal for rooting. Only upright shoots should be collected for cutting, so that the resulting trees will have an erect architecture. Selection of single nodal semi-hardwood cuttings with active buds is better for large-scale propagation of cinnamon. Removal of one-third of the leaf blade enhances the success rate of rooting. Cuttings should be immediately kept in water under shade to prevent desiccation.



Rooted cutting of cinnamon

Planting of the cuttings: Cuttings can be planted for rooting either in polythene bags filled with sand or a mixture of sand and coir dust (1:1) or in sand beds raised in a shaded place. Dipping the base of the cuttings in 2000 ppm IBA or IAA will enhance the rooting percentage.

Nursery management: Providing a humid atmosphere till the root formation is essential for obtaining a higher rooting percentage. For this, the cuttings can be kept inside mist chambers or temporary humidity chambers/tunnels made up of transparent polythene sheets. The cuttings root within 45-60 days, and the well-rooted cuttings can be transplanted to polythene bags filled with potting mixture and maintained in a shaded place for hardening.

Air layering

The most favourable season for air layering in cinnamon is July, followed by June and August in general. In Dapoli, 95% success was reported in September, and in the Andaman Islands first week of July was reported as the most suitable time for air layering in cinnamon. Air layering of cinnamon is done on semi-hardwood shoots. A ring of bark with a 0.5 cm width is removed from the shoot, and the ringed portion is covered with moist coir dust or sand or soil, and wrapped with a polythene sheet of 20 cm length. Rooting takes place in 40-60 days. Application of rooting hormone (IBA 2000 ppm or IAA 2000 ppm) can enhance rooting percentage. Well-rooted shoots are separated from the mother plant and carefully bagged in polythene bags filled with potting mixture and kept in a shaded place or nursery by watering twice a day.



Ringing of the bark



Covering the ringed portion with media



Covering with polythene



Rooted cuttings ready for bagging

Air layering in cinnamon

Field planting and after care

Planting season is fixed as June-July to take advantage of the monsoon for the establishment of seedlings. Pit size and spacing for cinnamon vary based on the soil situations. Pits are filled with compost and topsoil before planting. In each pit, 3-4 seedlings or rooted cuttings, or air layers can be planted. In some cases, the seeds are directly dibbled in the pits that are filled with compost and soil. Providing partial shade in the initial years is advantageous for the healthy, rapid growth of plants. Spacing and pit size recommendations at various locations are given below.

Kerala and Maharashtra: 3 m × 3 m spacing and a pit size of 50 cm^3

Andaman and Nicobar: 2 m × 2 m and a pit size of 45 cm^3

Sri Lanka: Flat lands/plains -120 cm × 90 cm (six plants per 30 cm^3 pit or 1.08 m^2 per planting point): 9000–9250 plants/ ha

Slops/ contours: 120 cm × 60 cm spacing and a pit size of 30 cm^3

High yield was estimated with 120 cm × 45 cm (three plants per pit or 0.54 m^2 per planting point)

Intercropping

Dapoli

DBSKKV, Dapoli recommends cultivating cinnamon, nutmeg, black pepper, banana, and pineapple as an intercrop in the coconut-based multistoried cropping system in Konkan agro-climatic conditions for higher yield and returns.

Andaman & Nicobar Islands

One row of cinnamon between four arecanut plants, planted in 2.7 m × 2.7 m

Sri Lanka

Coconut-Cinnamon system: 120 cm × 60 cm in three rows with coconut rows spaced 8.5 m apart

Rubber-Cinnamon system: Inter-row spacing of 14.4, 15.6, and 16.8 m

High-density planting: Research at ICAR- CPCRI, Kasargod, revealed that a high-density pentagonal planting method with a spacing of 0.6 m × 1.2 m with 7290 plant population ha^{-1} in coconut plantations of Kerala

Planting direction: East–West direction is preferred to intercept more light, reduce mutual shading, and facilitate intercropping with suitable short-term crops during the early stages of establishment.

Gap filling: The first gap filling could be done 3 months after planting with normal seedlings in polybags. In later stages, 18-month-old seedlings with a height of about 45 cm raised in large polybags (30 cm × 25 cm) should be used.

Irrigation: Cinnamon is commercially cultivated as a rainfed crop. An annual rainfall of 200-250 cm is ideal. In the initial 2-3 years, watering is given during the summer months twice a week. The quantity of water depends upon the soil moisture level and the growth of plants. However, 8-10 litres of water can be given during the summer months in the initial years. Irrigation can also be provided through drip or sprinklers.

Weed management: Weed management during the early stages of establishment is important for the growth and yield of cinnamon. It is recommended to keep a circle with a radius of about 45 cm from the plant free from competitive weeds to prevent suppression of crop growth. Two weeding in a year, during June-July and October-November, and one digging of soil around the bushes during August-September are recommended.

Manuring: Cinnamon plants are manured during May -June and September- October. Mulching with green leaves (25 kg) during summer and application of FYM (25 kg) during May-June is also recommended. Location-specific manuring and fertilizer recommendations for cinnamon are given below.



A young cinnamon plantation

Table 3. Location specific manuring and fertilizer recommendations for Cinnamon

Location	First year	Second year	Third year onwards
India	20: 20: 25 g of NPK or 20: 18:25 g NPK along with 20 kg of compost	200: 180: 200 g NPK and 50 kg of compost per year	200: 180: 200 g NPK and 50 kg of compost per year
Sri Lanka	300 kg ha^{-1} FYM 3 months after planting in two splits	600 kg ha^{-1} FYM+ 210: 60: 135 kg of NPK ha^{-1} $year^{-1}$ in two splits	900 kg ha^{-1} in two splits

Training and Pruning

The cinnamon tree may attain a height of 10-15 m, but it is generally coppiced or cut back periodically to ensure the availability of long and straight harvestable shoots. When the plants are 2 years old, they are coppiced during June-July to a height of about 12 cm from the ground. The stump is then covered by earthing up. This operation encourages the development of side shoots from the stump. This is repeated for every side shoot developing from the main stem during the succeeding season, so that the plant will assume the shape of a low bush of about 2 m height, and shoots suitable for peeling would develop in a period of about 4 years.



Training of cinnamon bushes through repeated coppicing

Plant Protection

Diseases

Leaf spot and dieback

Leaf spot and dieback diseases are caused by *Colletotrichum gloeosporioides*. Small, deep brown specks appear on the leaf lamina, which later coalesce to form irregular patches. In some cases, the affected portions are shed, leaving shot holes on the leaves. Later, the entire lamina is affected, and the infection spreads to the stem, causing dieback. Pruning the affected branches and spraying Bordeaux mixture1% are recommended to control the disease.



Shot holes in the leaf

Seedling blight

Seedling blight caused by *Diplodia* sp.occurs on seedlings in the nursery. The fungus causes light brown patches that girdle the stem, resulting in mortality. The disease can be controlled by spraying Bordeaux mixture 1%.

Grey blight

Grey blight is caused by *Pestalotia palmarum* and is characterized by small browns spots, which later turn grey with a brown border. The disease can be controlled by spraying Bordeaux mixture 1%.



Brown spots on the leaf

Insect pests

Cinnamon butterfly

The cinnamon butterfly *(Chilasa clytia)* is the most serious pest, especially in younger plantations and nurseries, and is generally seen during the post-monsoon period. The larvae feed on tender and slightly mature leaves. In severe cases of infestation, the entire plant is defoliated, and only the midribs of leaves with portions of veins are left behind. The adults are large butterflies and occur in two forms. One has blackish brown wings with white spots on the outer margins; the other has black wings with bluish white markings. Fully grown larvae are pale yellow with dark stripes on the sides and measure about 2.5 cm in length. The pest can be controlled by spraying systemic insecticide on tender and partly mature leaves.



Larvae of the cinnamon butterfly



Adult cinnamon butterfly

Leaf miner

Infestation by the leaf miner(*Conopomorpha civica*) is more common during the monsoon period, and generally, nursery seedlings are seriously affected. The adult is a minute, silvery grey moth. The larvae are pale grey initially and become pink later, measuring about 10 mm in length.

They feed on the tissues between the upper and lower epidermis of tender leaves, resulting in linear mines that end in 'blister' patches. The infested leaves become crinkled, and the mined areas dry up, leaving large holes in the leaves. Spraying any systemic insecticides during the emergence of new flushes is effective in preventing pest infestation. Many other leaf-feeding caterpillars and beetles also occur sporadically on cinnamon, feeding on tender flushes. Application of any systemic insecticides would keep them under check.



Damage to the cinnamon leaf

Harvesting and post-harvest practices

The first harvest of cinnamon can be done in the fourth or fifth year of planting. The shoots are harvested from September to November, under Kerala conditions. Coppicing is done in alternate years, and shoots having 1.5-2.0 cm thickness (usually thicker than the thumb of the hand) and uniform brown colour are ideal for bark extraction. The season for harvesting cinnamon bark is from February to May in Dapoli. DBSKKV, Dapoli recommends retaining 5 sprouts after coppicing in the regular harvesting season (October to May) to get maximum yield of cinnamon bark and leaves, and to harvest cinnamon bark from 5 to 6 cm thick branches for obtaining a higher yield.

A 'test cut' or test peeling can be made on the stem with a sharp knife to judge its suitability for peeling. If the bark separates readily, coppicing can be commenced immediately. The shoots are cut close to the ground when they are about 2 years old. Such shoots are bundled after removing the leaves and terminal shoots.



Ready to harvest cinnamon bark



Bark not ready for harvest

The cut stems are collected, tied, bundled, and carried to the peeling shed. The cut stems are subjected to scraping, rubbing, and peeling operations. After scraping the outer skin, the stems are rubbed with a piece of the wooden/ copper/ brass rod of 15 mm diameter, 203 mm length, and 1.1 kg weight. Rubbing is the most laborious step in cinnamon processing, which loosens the bark to detach from the core of the stem. During the rubbing process, bark sap oozes, indicating proper rubbing. However, extreme rubbing can damage the bark. ICAR-CIARI, Sri Vijaya Puram (Port Blair) has developed a user-friendly cinnamon bark rubbing tool, 'CinnRub', that reduces the time of rubbing.



Cinnamon harvest



Tools used in cinnamon harvest

The peeling of the bark is done carefully using a specially made knife. Branches and leaves are removed from harvested sticks before peeling. Two longitudinal slits are given on opposite sides of the stem, and by working the knife under, the bark is lifted. The halves of the bark obtained are then combined by keeping the edge of one inside the other. The tube-like barks thus obtained in lengths of 6 to 8 inches (15-20 cm) are placed one inside the other to form a tube of 36 inches (90 cm), called quills.

These peels are piled up within enclosures of sticks and wrapped up in mats and kept overnight in that condition. A little softening of the bark does occur, with the result that the peels become more pliable for the subsequent piping operation. These are then dried on a mat in the sun for about three days and thereafter in the shade for another three days. Barks, which cannot be taken out like tubes, are called 'quillings'; the scraped pieces are called 'featherings', and 'Chips' are the scraped off greenish brown mature thick hand-picked pieces of the bark, which are of inferior quality cinnamon. About 70-100 kg of quills and 30 kg of quillings and featherings are obtained from an acre of cinnamon after four years.

Besides quill extraction, the cinnamon leaves could be used for distillation to obtain aromatic oil. The yield of cinnamon leaf oil was 1.8-2.6 per cent in fresh leaves and 3.75 per cent in dried leaves. Recovery of oil from leaves dried for 2-3 days in the shade is recommended to avoid loss of oil.



Harvested fresh cinnamon leaves



Dried cinnamon bark

Bark drying

Drying is an essential step in cinnamon processing, as the fresh bark peels off when dried. The inner side of the barks remain moist and causes fungal growth that destroys the bark. To prevent the bark from peeling off, the bark prepared on a stick that has been stripped of bark but dried in the sun should be placed in 2-3 layers. Usually, the bark from 3-4 branches will fit on one stick. To prevent the bark from slipping off the stick, tie it very loosely with a rope and dry it in the shade in a place where there is plenty of light. The next day, remove the rope and move the bark up the other side in layers so that the upper layer goes down and the lower layer comes up. Tie it again with twine and dry it in the shade for 2 days. On the fourth day, remove the bark from the stick and dry it in the shade for another 3-4 days. By drying the bark in this way, the bark does not fade and dries well from the inside out. The drying time depends on the season and the place of drying. After ensuring that the bark is completely dry, it should be packed in a polythene bag and sealed.

Yield

Under Sri Lankan conditions, peak yield is generally achieved by 8–10 years, which will continue for about 40 years in seedling propagated stands, after which it tends to decline. Good management practices can improve the yielding till 50 years. The average bark yield of cinnamon in Sri Lanka is around 500 kg ha^{-1}, whereas yields exceeding 1000 kg ha^{-1} can be obtained under good management.

Standard quality specifications

Ceylon cinnamon grades

Quills are graded based on the diameter of the quill and the level of foxing. There are four main grades and accompanying subgrades. The main grades are Alba, Continental (C grade), Mexican (M Grade), and Hamburg (H Grade) (TSP 2010).

Table 4. Ceylon grades of cinnamon

Classification	Description	Measurements
Quills	Alba Continental Mexican Hamburg'	Less than 6 mm in diameter Less than 16 mm in diameter Less than 19 mm in diameter Less than 32 mm in diameter
Quillings	Pieces of bark less than 106 mm long	-
Featherinsg	Inner bark of twigs and twisted shoots	-
Chips	Trimmings of quills, outer and inner bark that can't be separated	-

Indian National Standards

National standards for cinnamon cover aspects like moisture, ash, and volatile content, and are free from contaminants, which focus on ensuring quality, safety, and proper labeling of both whole and powdered cinnamon. The Indian Standards were adopted by the Bureau of Indian Standards after the draft finalized by the Spices and Condiments Sectional Committee had been approved by the Food and Agriculture Division Council.

Table 5. Grade designation of cinnamon bark and its requirements

Grade Designation	Length	Diameter	Colour	Texture
Quills fine	Up to 1 m	Not more than 10 mm	Pale Brownish Yellow	Brittle and smooth
Quills average	Up to 1 m	Not more than 20 mm	Slightly reddish	Brittle and smooth
Quillings	Large pieces of quills less than 1 m	Not more than 30 mm	Pale brown to reddish	Brittle and smooth
Chips	10 to 30 mm	-	Pale brown to reddish	Brittle

Source: Bureau of Indian Standards (1992)

Cinnamon bark: It shall have a characteristic odour and flavour and shall be free from foreign flavour and mustiness. It shall be free from mould, living and dead insects, insect fragments, and rodent contamination. The product shall be free from added colouring matter, foreign vegetable matter, and other harmful substances. The following standards are to be considered for cinnamon.

Table 6. Standards for cinnamon bark

Extraneous matter	Not more than 1.0% by weight
Moisture	Not more than 12.0% by weight
Total ash on dry basis	Not more than 7.0% by weight
Ash is insoluble in dilute HCl on a dry basis	Not more than 2.0% by weight
Volatile oil content on a dry basis	Not less than 0.7% by volume/ weight Not
Insect-damaged matter	more than 1.0% by weight
Coumarin content (on dry basis)	Not more than 0.3% by weight

Source: Bureau of Indian Standards (1992)

Cinnamon powder: The powder shall be yellowish to reddish brown in colour with characteristic odour and flavour, and shall be free from off-flavour and mustiness. It shall be free from mould, living and dead insects, insect fragments, and rodent contamination. The product shall be free from added colouring matter, foreign vegetable matter, and other harmful substances.

Table 7. Standards for cinnamon powder

Moisture	Not more than 12.0% by weight Not
Total ash on dry basis	more than 7.0% by weight
Ash is insoluble in dilute HCl on a dry basis.	Not more than 2.0% by weight
Volatile oil content on a dry basis	Not more than 0.5% by weight
Coumarin content (on dry basis)	Not less than 0.3% by volume/weight

Source: Bureau of Indian Standards (1992)

Cassia : The product shall have a characteristic odour and flavour and shall be free from off-flavour and mustiness. It shall be free from mould, living and dead insects, insect fragments, and rodent contamination. The product shall be free from added colouring matter, foreign vegetable matter, and other harmful substances.

Table 8. Standards for cassia bark

Extraneous matter	Not more than 1.0% by weight
Moisture	Not more than 12.0% by weight Not
Total ash on dry basis	more than 5.0% by weight
Ash is insoluble in dilute HCl on a dry basis	Not more than 1.0% by weight
Volatile oil content on a dry basis	Not less than 2.0% by volume/weight

Source: Bureau of Indian Standards (1992)

Cassia powder: The powder shall have a characteristic odour and flavour and shall be free from off-flavour and mustiness. It shall be free from mould, living and dead insects, insect fragments, and rodent contamination. The powder shall be free from added colouring matter, foreign vegetable matter, and other harmful substances.

Table 9. Standards for cassia powder

Moisture	Not more than 12% by weight
Total ash on dry basis	Not more than 5.0% by weight
Ash is insoluble in dilute HCl on a dry basis	Not more than 1.0% by weight
Volatile oil content on a dry basis	Not more than 1.5% by weight

Source: Bureau of Indian Standards (1992)

International Standards

The International Standard applies to whole or ground (powdered) cinnamon produced using the bark of *Cinnamomum verum/ Cinnamomum zeylanicum* (*Ceylon cinnamon*). These standards specify the safety, quality, and labelling requirements for cinnamon intended for human consumption.

Table 10. Chemical requirements of Ceylon cinnamon

Characteristics	Requirements	Method of tests
Moisture content, % (m/m). max	12.0	ISO 939
Total ash, % (m/m) on dry basis, max	5.0	ISO 928
Acid insoluble ash, % (m/m) on dry basis, max	1.0	ISO 930
Volatile oils (ml/100g) on dry basis- whole cinnamon	1.0 (Tentative)	-
Ground (Powdered) cinnamon	0.7 (Tentative)	ISO 6571

Source: International Organisation for Standardization (2014)

Table 11. Classification of cinnamon quills, type Sri Lanka (Ceylon)

Commercial designation of the grades and qualities	Diameter of quills max. (mm)	Number of whole quills (1050 mm) per kg min.	Extent of foxing (% max)	Minimum length of quills in a bale (mm)	Pieces of tubes and broken pieces of the same quality per bale % max. (m/m)
Alba	6	45	Nil	200	1
Continental					
C5 Special	6	35	10	200	1
C5	10	31			
C4	13	24			
C3	16	22	15		
C2	19	20	20		
C1		18	25		
Mexican	16				
M5 Special		22	50	200	1
M5		22	60		
M4		18	50		
Hamburg					
H1	23	11	25	150	3
H2	25	9	40		
H3	38	7	65		

Source: International Organisation for Standardization (2014)

Chapter - 3
NUTMEG

Scientific name: *Myristica fragrans* (Houtt.)
Family: Myristicaceae

Introduction

Nutmeg is a dioecious, evergreen tropical tree grown for its nuts and mace (aril). It is native to Moluccas Islands of Indonesia, but well adapted to the warm-humid agroclimatic conditions of India. In India, it is cultivated in 17,760 ha with a total production of 12,088 tonnes. It is mostly grown in Kerala, Karnataka, Andaman and Nicobar, Tamil Nadu, parts of Maharashtra, Goa, and Assam. Pollachi in Tamil Nadu, Angamaly, and Kalady in Kerala are well-known belts of nutmeg in India.Over 50% of the world's export of nutmeg and mace is from Indonesia. Grenada is the second-largest exporter of nutmeg and mace in the world.

Nutmeg is a slow grower compared to other perennial crops. Trees are tall; branches are spreading with dark gray bark; leaves are shiny and oblong to ovate in shape. Flowers are fragrant, creamy yellow in colour, waxy, and fleshy. Nutmeg fruit consists of a fleshy pericarp, scarlet red mace, and a nut. Myristicin and elemicin are the two major active ingredients in nutmeg that impart a unique flavor and therapeutic value to this crop. The mace oil is similar to nutmeg oil in odour, flavour, and composition. The major principle in Indian nutmeg oil and mace oil is myristicin. The rind of nutmeg contains about 14% pectin. This spice is widely used as a stimulant, carminative, astringent, aphrodisiac, and hallucinogen, and is used in tonics, electuaries, and also in several medicines prescribed for stomach disorders. Nutmeg has potent antibacterial and anti-cancer properties. Mace is used for flavouring cigarettes and chewing gums. The fleshy pericarp of the fruit is used for making pickles, jelly, and candy.



A full-bearing nutmeg tree

Production Technology of Nutmeg

Climate and soil

Nutmeg needs a warm and rainy tropical climate with an average temperature of 25-30°C without any dry periods. It grows up to an elevation of 1,000 m above mean sea level. A well-distributed rainfall of 150-250 cm is ideal for the growth of this crop. It is susceptible to strong winds. Sandy to sandy loam soil is most suitable, but it also grows well in clay loam soils in Indonesia, lateritic clays in Malaysia, and volcanic loams in the Moluccas. Well-drained soil rich in humus is the best. Soils with good water-holding capacity are recommended in areas with frequent dry spells. The tree performs well in poor soils when provided with high organic matter. Both waterlogged conditions and soils having inadequate moisture are not suitable for the crop.

Varieties

Table 1. Nutmeg varieties released by different institutes in India

Varieties	Year of release	Breeding method	Potential yield (kg)	Characteristics
Varieties released by ICAR-Indian Institute of Spices Research, Kozhikode, Kerala				
IISR-Keralasree	2013	Clonal selection	Nut yield:3122 kg/ha; Mace yield: 480 kg/ha,Weight of fruit: 75-100g, Weight of seed: 13-16g, Weight of aril: 4.5 to 6.0 g	Mace weight (dry): 4.5-6.0g, nut weight (dry): 13- 16g, mace oil: 7.5 %, Nut oil: 5.9 %, dark red shining mace, black bold seed, and high-yielding extremely bold nuts
IISR-Vishwasree	2001	Clonal selection	Nut yield: 3122 kg/ha Mace yield: 480 kg dry/ha	High-yielding, bushy, and compact tree, mace oil: 7.1 %, oleoresin: 13.0 % in mace and 2.5 % in nut, butter content: 30.9 %



IISR-Keralasree



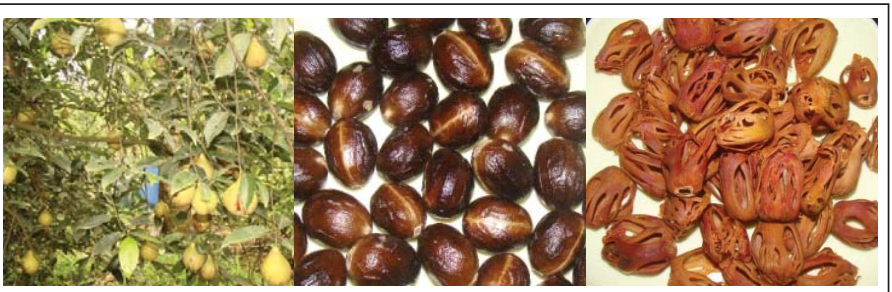
IISR-Vishwasree

Varieties released by Kerala Agricultural University, Thrissur, Kerala

Varieties	Year of release	Breeding method	Potential yield (kg)	Characteristics
KAU-Mundathanam	2018	Clonal selection	Mace yield/tree: 3.89 Nut yield/tree:19.70	Mace weight (dry): 2.49g, nut weight (dry): 12.6g, kernel oil: 6.9 %, mace oil:11.0 %
KAU-Poothara	2018	Clonal selection	Mace yield/tree: 4.53 Nut yield/tree: 22.00	Mace weight (dry): 2.06g, nut weight (dry): 10.0g, kernel oil: 4.16 %, mace oil: 7.0 %
KAU-Pullan	2018	Clonal selection	Mace yield/tree: 2.86 Nut yield/tree: 22.79	Mace weight (dry): 1.36g, nut weight (dry): 10.85g, kernel oil: 4.6%, mace oil: 12.06 %
KAU-Kochukudy	2018	Clonal selection	Mace yield/tree: 4.48 Nut yield/tree: 20.88	Mace weight (dry): 2.49g, nut weight (dry): 11.60g, kernel oil: 6.9 %, mace oil: 11.0 %
KAU-Punnathanam	2018	Clonal selection	Mace yield/tree: 4.23 Nut yield/tree: 19.39	Mace weight (dry): 3.02g, nut weight (dry): 13.85g, kernel oil: 4.5%, mace oil: 9.5%



KAU- Mundathanam



KAU- Poothara



KAU-Pullan



KAU-Kochukudy



KAU-Punnathanam

Varieties released by DBSKKV, Dapoli, Maharashtra				
Varieties	**Year of release**	**Breeding method**	**Potential yield(kg)**	**Characteristics**
Konkan Sugandha	1998	Clonal selection	500 nuts/tree/year	Monoecious, conical and compact canopy, dry nut weight: 5.25g, dry mace weight:1.00 g
Konkan Swad	2003	Clonal selection	600-700 nuts/tree/year	Female tree, dry nut weight:4.03g, dry mace weight:0.50g
Konkan Shrimanti	2005	Clonal selection	800-900 nuts/tree/year	Female tree, dry nut weight:10.00g,dry mace weight: 2.00g
Konkan Sanyukta	2018	Clonal selection	500 nuts/tree/year	Monoecious, dry nut weight: 9.20 g, dry weight: mace:1.07g



Konkan Sugandha



Konkan Swad

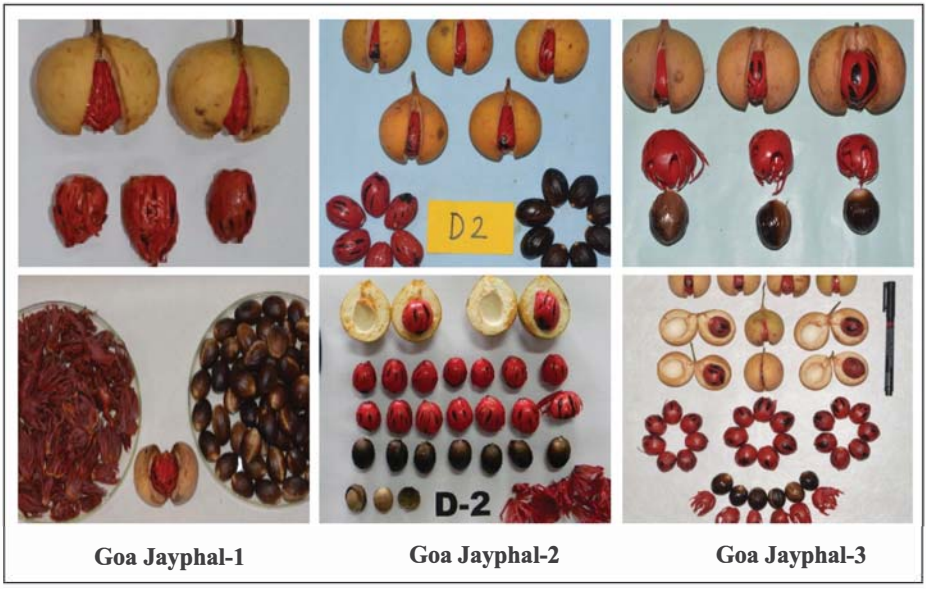


Konkan Shrimanti



Konkan Sanyukta

Varieties released by ICAR-CCARI, Goa				
Varieties	**Year of release**	**Breeding method**	**Potential yield**	**Characteristics**
Goa Jayphal-1	2024	Clonal selection	1450 fruits/tree	It is a high-yielding, female-dominated monecious variety, fresh fruit weight: 85-105g, dry seed weight: 9.88 g, dry recovery: 71.2 %, mace dry weight: 3.66 g, dry seed yield: 12-12.6 kg/ tree, dry mace yield: 4.6-4. 8 kg, mace oleoresin content: 16.59%, mace oil: 6.00%, nut oil: 9.00%, nut oleoresin: 25.77%, nut butter: 30.80%
Goa Jayphal-2	2024	Clonal selection	1882 fruits/tree	It is an open-pollinated seedling selection (NMD-2) from germplasm. It is a female-dominated monoecious tree type with a pyramidal canopy shape, fresh fruit weight: 50-55 g, seed dry weight: 6.94 g dry weight, seed dry recovery: 71.2 %, mace dry weight: 1.35 g, mace dry recovery: 35.8 %, dry seed yield: 11.5 -12.0 kg/ tree, dry mace yield: 2.3-2.5kg, mace oleoresin content: 19.94%, mace oil: 12.00%, nut oil: 10.00%, nut oleoresin: 26.80%, nut butter: 32.20%
Goa Jayphal-3	2025	Clonal selection	2270 fruits/tree	It is a cluster-bearing monecious type nutmeg with high yield and quality, dry seed yield: 13.5-14 kg/tree, dry mace yield: 2.5-3.0 kg/tree, dry seed weight: 6.28g, dry seed recovery: 69.98%, dry mace recovery: 34.8%



Goa Jayphal-1 Goa Jayphal-2 Goa Jayphal-3

PPV & FRA registered farmers' varieties

The list of PPV & FRA registered farmers' varieties of nutmeg is given in Table 2.

Table 2. List of PPV & FRA registered farmers

Variety	Registration No	Year of release	Yield	Characters	Name and address of the farmer
Kochukudy	REG/2018/79	2023	Nut yield: 20.88 kgtree^{-1} Mace yield; 4.48 kgtree-1	Canopy shape conical, spreading growth habit, round nuts, and mace	Mr. Jose Mathew, Kochi, Eranakulam,Kerala
Pullan	REG/2018/80	2023	Nut yield: 22.79 kgtree^{-1} Mace yield: 2.86 kgtree^{-1}	Canopy shape conical,kernel is aromatic with high oil content oval shaped nuts	Mr. Jose PV, Potta, Chalakudy, Kerala
Poothara	REG/2018/81	2023	Nut yield: 22.0 kgtree^{-1} Mace yield: 4.53 kgtree^{-1}	Canopy shape pyramidal, spreading growth habit, round fruits, and dark red mace	Mr. Joseph T, Poothara, Vaikom, Kerala

Mundathanam	REG/2018/82	2023	Nut yield: 19.7 kgtree^{-1} Mace yield: 3.89 kgtree^{-1}	Canopy shape is pyramidal, erect growth habit, oval fruits, round nuts, dark red mace, and dark brown nuts	Mr. Michel Joseph, Attappadi, Palakkad, Kerala
Sradhha	REG/2017/11	2024	-	-	Mr. Dilip Rajaram Mukadam, Alibag, Raigad, Maharashtra
Kajal	REG 2017/47	2024	-	-	Mr. Jayawant Harischandra Patil, Alibag,Raigad, Maharashtra
Neelkanth	REG/2017/49	2024	-	-	Mr. Prakash Bhaskar Paranje, Dapoli, Ratnagiri, Maharashtra
Thottanal Jathi	REG/2017/2304	2024	2000 fruits tree^{-1} year^{-1} 28 kg dry nuts tree $^{-1}$ year^{-1}	Strong aroma and high essential oil quality	Mr. Pushkaran TM, Adimaly, Idukky, Kerala
Nova nutmeg	REG/2023/0003	2024	30 kg tree^{-1} $^{-1}$ year	High-yielding with good flavour and aroma	Mr. Saji Mathew, Kurachund, Kozhikode, Kerala
Punnathanam Jathy	REG/2016/1719	2025	-	Extra-large, high-yielding, and pest-tolerant	Mr. VarkeyThomman, Idukki, Kerala
Namo-16	REG/2017/2330	2025	-	-	Mr. Sharad Rajaram Joshi
BPT-16	REG/2017/2329	2025	-	Bigger leaf and fruit size	Mr. Girish Krishnaji Bapat
Nutmeg Kelshi-1	REG/2017/48	2025	Dry nut: 15-25 kg tree^{1} year^{-1} Dry mace: 3-5 kg tree^{-1} year^{-1}	Medium to bold-sized fruits.Distinct fruit shape with stylar scar	Mr. Uday Shrikrushna Joshi

Kops	REG/2017/10	2025	Dry nut: 18-30kg tree^{-1} year^{-1} Dry mace: 3-5 kg tree^{-1} year^{-1}	Aromatic kernel with high oil content, thick mace, bright red colour, good recovery	Dr. Shreedhar Muralidhar Koparkar
VPP-16	REG/2017/2323	2025	-	-	Mr. Madhav Pandarinath Paranjpe
Geetarose	REG/2017/2326	2025	-	-	Mr. Raghunath Vitthal Naik
Tendoli Samarth-I	REG/2025/0660	2025	-	-	Mr. Achyut Madhusudan Tendolkar
Tendoli Samarth-II	REG/2025/0661	2025	-	-	Mr. Achyut Madhusudan Tendolkar
Cheripurath	REG/2016/1903	2025	3500 - 5000 kg tree^{-1} year^{-1}	80-100 seeds and 300-350 mace weigh one kg	Mr. Tom C. Antony, Kottayam, Kerala
Kinnattukara	REG/2025/0035	2025	-	-	Mr. K.T. Mathew Kanjirapally, Kottayam Kerala
Sharda-RD	REG/2017/2331	2025	-	-	Mr. Ravindra Narayan Damle

Table 3. Farmers' varieties recognized by the National Innovation Foundation-India (NIF)

Varieties	Yield	Characters	Name and address of the farmer
Souwriyamakkal	Dry nut 35 kg tree^{-1}, dry mace 10 kg tree^{-1}	Good quality mace, mace oil content (24.3%), non-volatile extract (33.1%), β-pinene (12.69%), and myristicin (25.95%)	Mr.VarkeyThomman, Idukki, Kerala
Edavarembil gold	200 kg of fruits year^{-1}	The variety produces high-quality bold nuts and dark red mace; nut contains higher essential oil content (13-15 %)	Mr. E V Thomas, Idukky, Kerala
Kadukamackan (Kadukanmackal)	30-40 kg /tree/year	Bolder and heavier nuts, high mace yield	Mr. Abrham Mathew Kozhikode, Kerala

Indonesian Nutmeg varieties

Fakfak

- Origin: Fakfak Regency, West Papua (released 2017)
- Traits: Obovate-lanceolate leaves, brownish-yellow oval fruits with spots, shiny dark shell, red mace; milder aroma
- Productivity: 340–2,275 nuts/tree/year; 105.6 g per fruit and 1.55 cm flesh thickness
- Essential Oil Content: ~3.27%

Nurpakuan Agribun

- Origin: Bogor Regency, West Java (released 2019)
- Traits: Oval to round fruits, light green leaves, strong mace aroma
- Productivity: Up to 8,730 seeds/tree/year; fruit weight between 51.4-63.9 g; flesh thickness 1.05-2.30 cm
- Essential Oil Content: ~12.18 per cent

Patani

- Origin: Central Halmahera, North Maluku (released 2020)
- Traits: Slightly elongated, smooth dark green leaves; ivory-yellow oval fruits; blood-red mace
- Productivity: 3,000-5,000 seeds per harvest; 7.3 g per fruit; 1.0-1.7 cm flesh; dry mace yield -3.6 kg/tree
- Essential Oil Content: 8.5%

Siau (Siaw)

- Origin: Sitaro (Siau) Islands, North Sulawesi
- Notable for being organically cultivated with no synthetic fertilizers, benefiting from volcanic ash soil and varied rainfall patterns.
- Holds a Protected Geographical Indication (GI) in Indonesia known as "Pala Siau"

Banda

- Native to the Banda Islands, Maluku,historically known as the "Spice Islands"
- High essential oil content and famed for its bold, rich flavour, widely viewed as one of the finest globally

Ambon Forest Nutmeg (*Myristica fatua*)

- Distinct from *M. fragrans,* this endemic species isn't used much in cooking
- Much lower essential oil levels, e.g., seed oil 0.63% vs. 1% in Banda nutmeg; mace and flesh oil contents are also markedly less

Papuan or Macassar *(Myristica argentea)*

- Found in primary rainforests of Eastern Indonesia (Fakfak, Kaimana, Aru Islands)
- Sometimes called Fakfak or Tomandin nutmeg; used locally but much less common commercially

Propagation

Nutmeg is propagated by both sexual as well as asexual propagation methods. It is dioecious in nature and hence vegetative methods of propagation are beneficial. Seedlings are mostly used for rootstocks for budding and grafting.

Mother plant selection: Seeds are collected from regular bearing and high-yielding trees, having at least 30 g fresh fruit weight, 1 g dry mace weight, 10 g dry nut weight. A higher germination percentage is observed in nuts collected from female trees growing nearer to male trees.

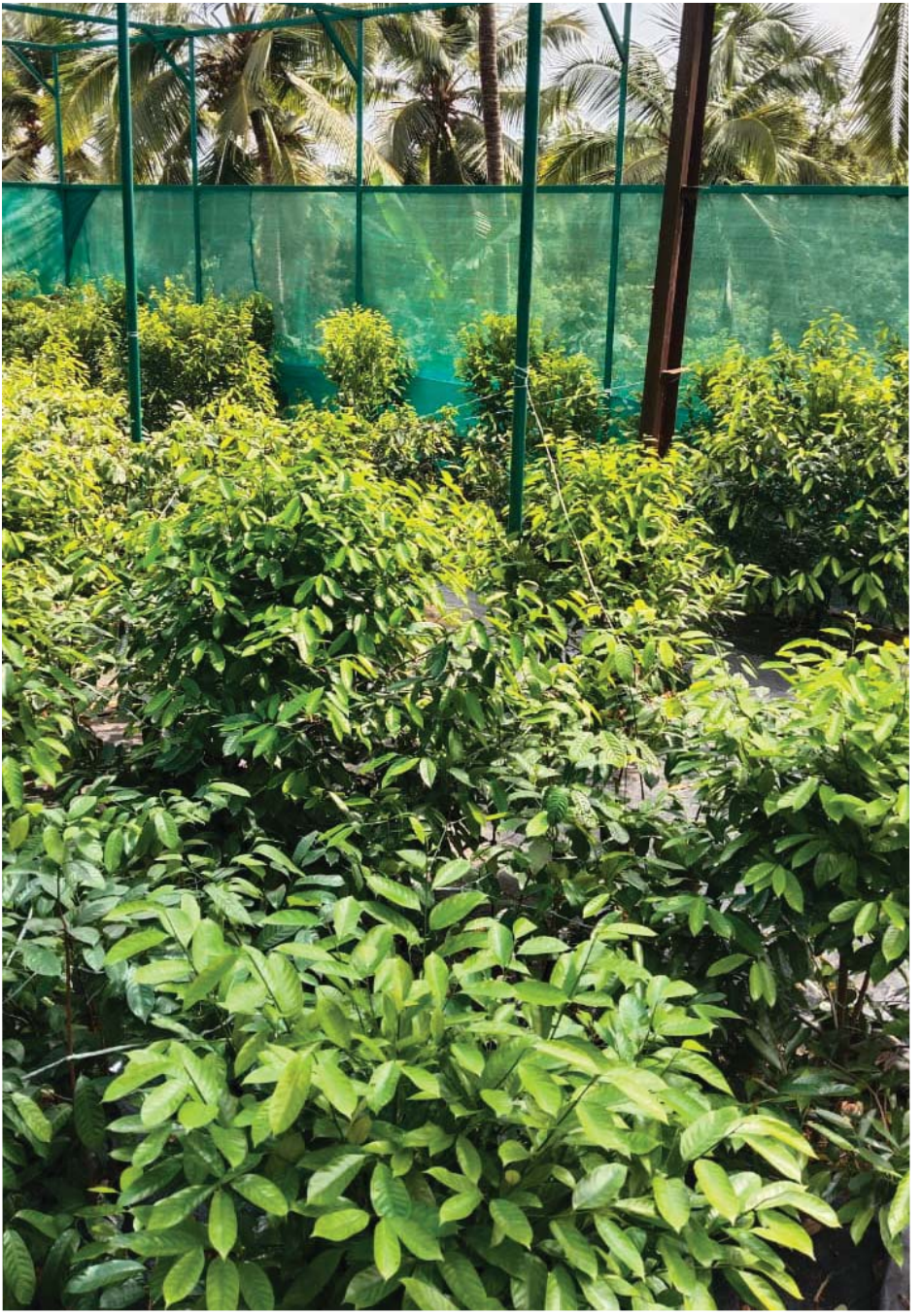
Selection of seeds: Naturally split, healthy fruits are harvested during June – August, and the seeds are collected immediately.

Seed storage: Nutmeg seeds are recalcitrant and lose viability rapidly; hence, sown immediately after harvest. However, storing the seeds in polythene bags, sphagnum moss, moist sand, or plastic bags is useful to extend the viability of nutmeg seeds.

Sowing and nursery management: The extracted seeds are sown immediately in sand beds of convenient length, 1 to 1.5 m width, and 15 cm height. Seeds can also be sown in baskets, polythene bags filled with potting mixture. Germination will commence from the 30th day onwards and last up to 90 days after sowing. The peak germination period is between 50 and 80 days. About 20 days old, sprouts are transplanted to polythene bags containing a mixture of soil, sand, and cow dung (3:3:1). The delay in transplanting causes damage to the root system.



A nutmeg nursery



Mother plant block

Vegetative propagation

Vegetative propagation in nutmeg can be done by means of grafting, budding, and air layering. Since nutmeg has a dimorphic branching pattern with orthotropic and plagiotropic branches, the selection of scion and the propagation method have a significant influence on tree architecture. The budded plants or grafts raised from orthotropic shoots show vigorous, erect growth and canopy development similar to the seedling-raised trees, whereas the scions extracted from the plagiotropic lateral shoots turn into a bushy graft. Orthotropic grafts/ buds have the advantage of faster growth and yield owing to the increased canopy size. On the other hand, the plagiotropic grafts can be used for high-density planting with closer spacing, and they resist wind damage to a certain extent. Varieties with comparatively erect branches and a vigorous growth pattern are preferred for producing plagiotropic grafts.



Upright shoots of nutmeg

Epicotyl grafting

July to December is found to be the most favourable period for epicotyl grafting in nutmeg (DBSKKV, Dapoli). In this, 20-day-old young seedlings are used as rootstocks. Selected rootstock should have at least 3 cm height from the base to the first leaf and 0.5cm or more stem girth at the first leaf stage. The stock and scion should approximately have the same diameter. The rootstock is cut at a height of 6-10 cm above the seed, and a vertical slit of 3 cm is made at the centre of the rootstock with a sharp grafting knife or blade. The base of the scion is tapered by cutting either side using a sharp knife to fit into the vertical slit made in the scion. The tapered base of the scion is inserted into the slit of the rootstock and tied with polythene strips. On completion of grafting, it is planted in polythene bags of 25 cm × 15 cm size containing potting mixture, and the scion is covered with a polythene bag. During grafting, precautions should be taken to prevent wilting of scions and to complete the grafting as soon as possible. Grafted plants are kept in a cool, shaded place protected from direct sunlight. After 30-45 days, the covered bags can be opened, and the grafts showing sprouting of scions may be transplanted into polythene bags, containing a mixture of soil, sand, and cow dung (3:3:1), and kept in shade for development. The polythene strip of the grafted portion has to be removed after 3 months.



Myristica fragrans



Myristica beddomei



Myristica malabarica



Myristica andamanica

Softwood grafting

May to July is the ideal time for softwood grafting in nutmeg. Usually, 6 to 8 month-old nutmeg seedlings are used for softwood grafting. For obtaining maximum survival and vigorous growth of nutmeg grafts, the use of *Myristica malabarica* as a rootstock for softwood grafting during November to August is recommended by DBSKKV, Dapoli. The rootstock should be healthy and vigorous with a 25–30 cm length. A sharp cut of 6 to 7 cm is given on the top of the rootstock, and the leaves are removed before grafting. In the scion, a single mature leaf is allowed. The base of the scion is shaped as a wedge by cutting around 4 cm off both sides. Then it can be inserted into the vertical cut of the rootstock. Wrap the graft union with a 1.5 cm wide strip of 200-gauge polythene and tie it securely. Next, cover the entire graft area, down to the base of the rootstock, with a thin plastic bag (6 x 4 inches or 5 x 7 inches). Secure this covering loosely with plastic twine just below the graft point. Place the grafted plant in a shady area and water it carefully, avoiding direct moisture on the graft.

Keep the plastic cover on for about 30 days, or until new growth appears. Once the graft shows signs of sprouting, remove the plastic cover. Afterward, water the grafted plant using efficient methods such as a micro sprinkler system. Regularly inspect the graft area and remove the growth that may appear below the graft joint. The grafts can be planted in the field after 12 years.



Grafting in Nutmeg



A young orthotropic graft



A grown-up orthotropic graft



A young plagiotropic graft



A grown-up plagiotropic graft

Budding



Bending

Budding is the most preferred method of propagation employed in commercial nurseries as it gives the maximum number of orthotropic planting material from a mother tree in a stipulated period. However, success in budding nutmeg is an operation that needs a lot of skill and experience. Seedlings after attaining the age of one to two and a half years are generally used as rootstock for budding. Apart from *Myristica fragrans*, the wild species *M. malabarica* and *M. beddomii* are also used as root stock for budding. It is ideal to use cultivated nutmeg as rootstock since it gives maximum growth and yield. Actively growing healthy rootstocks have to be used for budding to ensure easily detachable bark. The bud wood selected for the extraction of bark should also possess easily detachable buds. The vigorous shoots that emerge as a result of de-topping the main trunk of the mother tree carry such healthy buds. To ensure the availability of a sufficient quantity of buds, a bud wood nursery can be established by planting the budded plants of the desired variety at a closer spacing. These plants can be maintained at the desired height by repeated pruning of the main stem and extraction of bud wood. Beheading of the main stem enables the production of more orthotropic shoots for the extraction of buds. Budding in the earlier hours of the day ensures maximum success.



Budding in nutmeg

Patch budding is commonly practiced in nutmeg. A patch of skin having 3-4cm length and 1-1.5 cm width, depending on the girth of rootstock, is detached at a convenient height using a sharp budding knife. A healthy bud detached from the bud wood with a patch of skin is placed in this portion, leaving space on all four sides, and tied carefully with a polythene strip. Green or brown buds can be used, depending on the size of the rootstocks. Care should be taken to avoid touching the inner surface of the bud patch and to place the bud upward while doing budding. The polythene strip is removed after a month, and the success can be determined from the greenness of the bud by gently scratching on the budded patch without injuring the bud. Successful plants can be de-topped above 10 cm from the bud union to induce sprouting of the bud.



Patch budding

Methods of bending and tying of the rootstock above the budded portion or keeping the budded plants in a slanting position facing the bud upward are also practiced for inducing buds. All sprouts other than from the budded patch have to be removed periodically. June to November is the ideal time for budding in South Indian plains, and the success rate in the hot summer months is generally low. The skill and fastness of the budding person have a high influence on the percentage of success, and a well-experienced person can do up to 200 buddings in a day. Budding success varies from 20-90% depending on season, skill of the person, and selection of root stock and scion. Budded plants after producing two whorls of branches can be planted in the field. *In situ* budding on the established seedlings in the field is also practiced in nutmeg by some farmers. Apart from these methods, nutmegs can be propagated through approach grafting and air layering, which do not require much expertise. However, these methods are used to a limited extent because of the operational difficulty and time consumption.



Air layering



Approach grafting

Land preparation, planting, and aftercare

Planting in the main field is done at the beginning of the rainy season. Pits of 0.75 m x 0.75 m x 0.75 m size are dug at a spacing of 9 m x 9 m and filled with organic manure and soil about 15 days earlier to planting. For planting plagiotropic grafts, a spacing of 5 m x 5 m has to be adopted. A male graft has to be planted for every 20 female grafts in the field, especially when the nutmeg plantations are established in non-traditional areas. Grafts of monoecious types are well suited for this purpose as they serve as a pollinator. The plants should be shaded to protect them from sun scorch during the early stages. Permanent shade trees are to be planted when the site is on hilly slopes and when nutmeg is grown as a monocrop. Irrigation is essential during the summer months. In Grenada, seedlings are planted 9 m apart, and are also planted in a triangular system with three seedlings at 60 cm apart. Once the graft shows signs of sprouting, remove the plastic cover. Afterward, water the grafted plant using efficient methods such as a micro sprinkler system. Regularly inspect the graft area and remove the growth that may appear below the graft joint. The grafts can be planted in the field after 12 months.

High-density planting

ICAR-IISR, Kozhikode recommends a high-density planting with plagiotropic grafts at 2 m × 2 m spacing in the field or in pots. These plants are termed 'bush nutmegs'. The yield of bush nutmeg in the field varied between 100 and 150/tree/year. It can be grown in backyards, verandas, and terraces, and is suitable for intercropping or high-density planting. Scion collection is also easy in these plants. Approximately 100 scions can be collected from a well-grown single bush per year.

Intercropping

Nutmeg can best be grown as an intercrop in coconut gardens that are more than 15 years old, where shade conditions are ideal. Coconut gardens along river beds and adjoining areas are best suited for nutmeg cultivation. While planting in the kitchen garden, nutmeg is planted at least 4-5 m away from other tall plants.



Nutmeg intercropped with coconut and arecanut

Training and pruning

The grafted plants tend to grow slowly in the initial years. Therefore, training is necessary to encourage the development of branches in all directions, helping to build a strong and balanced framework for the tree. Sprouts that appear below the graft union need to be removed regularly.

Top-working

The surplus male trees in the plantation, after maintaining sufficient trees for pollination, can be converted to productive females by top-working. For this, the male trees are de-topped at a convenient height, and budding or grafting is done on the emerging sprouts on the trunk.

Manuring and fertilizer application

Manures are applied in shallow trenches or pits dug around the plants. KAU, Thrissur, Kerala recommends 20 g N (40 g urea), 18 g P_2O_5 (110 g superphosphate) and 50 g K_2O (80 g muriate of potash) during the initial year and progressively increasing the dose to 500 g N (1090 g urea), 250 g P_2O_5 (1560 g superphosphate) and 1000 g K_2O (1670 g muriate of potash) per year in subsequent years for a fully-grown tree of 15 years or more. FYM is to be applied @ 25 kg for 7-8-year-old trees and 50 kg for grown-up trees of 15 years. Application of coir pith compost 1 kg plant^{-1} during May, soil application of recommended nutrients (80:72:200 g plant^{-1}) during June and September, foliar spray of micronutrients (0.5%), and spraying of BA (10 ppm) during June and September was found effective in improving early fruiting (within four years) in young nutmeg plants by ICAR-IISR, Kozhikode.

For soil acidity amelioration: If the soil pH is < 6.0, apply 1 kg dolomite lime + 1 kg gypsum along the drip line/ canopy periphery during May-June at the onset of monsoon, every year. For the soil pH > 6.0, this may be applied during alternate years. Apply nitrogen, phosphorus and potassium fertilizers at the rates recommended based on soil test values: 800 g Urea, 500 g Factamfos and 1.50 kg Muriate of Potash in two equal splits (rates based on Nutrient Index of Ernakulam District). Enrich 100 kg of FYM: neem cake mixture (mixed in 9: 1 proportion) with *Trichoderma harzianum* @ 1-2 kg formulation per 100 kg and apply @ 20-25 kg of enriched mixture per tree during the onset of monsoon. Apply foliar spray of IISR nutmeg micronutrient mixture - @ 5 g/ L water at flowering and flower development stages at monthly intervals (2-3 sprays). Cut and remove the dried or infected branches (due to thread blight infection) and spray Bordeaux mixture (1%) on leaves at the onset of monsoon (May-June).

Plant protection

Diseases

Thread blight

Two types of blights are noticed in nutmeg. The first is white thread blight, where in fine white hyphae aggregate to form threads that traverse along the stem underneath the leaves in a fan-shaped or irregular manner, causing blight of the affected portions. The dried-up leaves with mycelium form a major source of inoculum for the spread of the disease. The disease is caused by *Marasmius pulcherima.*

The second type, the horse hair blight, fine black silky threads of the fungus form an irregular, loose network on the stems and leaves. These strands cause blight of leaves and stems. However, these threads hold up the detached, dried leaves on the tree, giving the appearance of a bird's nest when viewed from a distance. The disease is caused by *Marasmiuse quicrinus*.



Thread-like fungal growth under the leaves





Affected leaves showing the appearance of a bird's nest

Leaf fall and fruit rot

Phytophthora citromeadii and *P. citrocaptalis* cause leaf fall and fruit rot in nutmeg. Immature fruit split, fruit rot, and fruit drop are serious problems in the majority of nutmeg gardens in Kerala. Immature fruit splitting and shedding are noticed in some trees without any apparent infection. In the case of fruit rotting, the infection starts from the pedicel as dark lesions and gradually spreads to the fruit, causing brown discolouration of the rind, resulting in rotting. In advanced stages, the mace also rots, emitting a foul smell. However, the reasons for fruit rot could be both pathological and physiological. Bordeaux mixture (1%) may be sprayed to prevent the incidence of the disease.



Rotten leaves



Leaf and nut fall



Rotten fruit

Shot hole

The disease is caused by *Colletotrichum gloeosporioides*. Necrotic spots develop on the lamina, which is encircled by a chlorotic halo. In advanced stages, the necrotic spots become brittle and fall off, resulting in shot holes. A prophylactic spray with Bordeaux mixture (1%) is effective against the disease.



Shot hole damage on nutmeg plants

Die-back and decline

This fungal disease is caused by *Lasiodiplodia theobromae*. The symptoms include general decline of the tree's health, water-soaking symptoms on branches and tree trunks, die-back of twigs/branches, formation of necrotic lesions on bark beneath water-soaked lesions, and necrosis (death of tissues) of the vascular system. The symptoms are more pronounced on trees experiencing various abiotic stresses like drought, flooding, overexposure to sunlight, and even nutrient deficiency.

Regular monitoring is highly imperative to accurately diagnose the disease at an early stage based on the external symptoms manifested on the trees, such as general decline, die-back of twigs/branches, water soaking on the bark, and occasional gummosis, i.e., exudation of gum.

Prune the affected plant parts along with some healthy portions and destroy. Chisel out the water-soaked portions on the trunk along with healthy portions and smear the cut end surface with any wound dressing, fungicide like Bordeaux paste. Care should be taken that the implements used for pruning/chiseling the infected plant parts are not used immediately for undertaking pruning operations in healthy trees, as the pathogen may be transmitted through the contaminated tools.

Generally, the disease was severe on the trees that were experiencing/experienced abiotic stresses like waterlogging and drought. Moreover, the disease incidence was also found to be higher in poorly managed plots. Hence, adopt recommended crop management practices, including provisions for adequate irrigation to the trees, especially during the summer season and strictly adhere to recommended nutrient management and crop protection.



Infected nutmeg branch and tree

Insect pests

Black scale

The black scale (*Saissetia nigra*) infests tender stems and leaves, especially in the nursery and sometimes young plants in the field. The scales are clustered together and are black, oval, and dome-shaped. They feed on plant sap, and severe infestations cause the shoot to wilt and dry.



Black scale-affected twig

White scale

The white scale (*Pseudaula caspiscockerelli*) is greyish white, flat, and shaped like a fish scale and occurs clustered together on the lower surface of leaves, especially in nursery seedlings. The pest infestation results in yellow streaks and spots on affected leaves, and in severe infestations, the leaves wilt and dry.

Shield scale

The shield scale (*Protopulvinaria mangiferae*) is creamy brown and oval and occurs on tender leaves and stems, especially in nursery seedlings. The pest infestation results in wilting of leaves and shoots. The scale insects mentioned above and other species that may also occur sporadically on nutmeg can be controlled by spraying dimethoate (0.05%).

Mealy bugs

Both nymphs and adults remain between the nutmeg graft joint and suck the cell sap and weakening the plant. It causes the mortality of the graft. This pest is observed generally in the nursery in December, February, and June. Application of Imidacloprid (2ml/ltr) in the bags is recommended for control of the pest.

Harvesting and processing

Both male and female trees typically reach their peak flowering period between July and October. After flowering, the fruits take about 6 to 9 months to ripen. Trees grown from seeds start bearing fruit 5 to 8 years after planting, whereas those propagated vegetatively begin fruiting earlier (3-4 years). When mature, the fruits naturally split open on the tree, revealing the bright crimson-red aril surrounding the nutmeg seed. They are usually harvested by hand-picking or with long poles and attached hooks. A healthy, mature nutmeg tree in full production typically produces 1,500 to 3,000 fruits annually between the 15th and 30th years of growth.

The harvested fruits are transported to a processing place. The first thing to do is separate the mace (aril) from the rest of the seed. The fruits are opened by hand, and the scarlet aril (mace) surrounding the nut is removed by cutting with a small pointed knife the attachment of the mace to the base of the nut (nutmeg). Care needs to be taken to avoid damage to the nut. An alternative method of shelling the nuts is to tip them onto a sloping cement floor from a height of three to four metres. Another option is to soak the nuts in water for four to twelve hours and then squeeze between the thumb and forefinger until the nut pops out. The nut is dried in the sun, while the mace is dried in the shade. In artificial drying methods, if adequate precautions are not taken, mace hardening occurs. Mechanical drying at 50°C is found to be better than conventional methods. Drying of mace and its storage is a delicate processes. Mace is dried to 5% moisture level for which takes about 16 hours under open sun, 24-28 hours under shade, and 5-6 hours in mechanical drying. A mild blanching followed by sulphiting helps in colour retention and quality of mace. Blanching of nutmeg seeds with mace in hot water containing 100 ppm of chlorine or 1000 ppm of alum is recommended to avoid mold growth on mace.

ICAR- IISR, Kozhikode, has developed a protocol for uniform ripening of fruits. Fully ripen physiologically mature but unsplit fruits (6 to 8 months after flowering) have to be dipped in 500 ppm Ethrel for 10 minutes and then dried and stored in shade. Within 18 to 20 hours, 90–100% of the treated fruits will split open uniformly.

Grades of nutmeg

Whole nutmegs are grouped under three broad quality classifications:

Sound: Nutmegs which are mainly used for grinding and to a lesser extent for oleoresin extraction. High quality or sound whole nutmegs are traded in grades which refer to their size in numbers of nutmegs per pound: 80s, 110s and 130s (110 to 287 nuts per kg), or 'ABCD' which is an assortment of various sizes.

Substandard: Nutmegs which are used for grinding, oleoresin extraction and essential oil distillation. Substandard nutmegs are traded as 'sound, shrivelled' which in general have a higher volatile oil content than mature sound nutmegs and are used for grinding, oleoresin extraction and oil distillation; and 'BWP' (broken, wormy and punky) which are mainly used for grinding as volatile oil content generally does not exceed 8%.

Distilling: Nutmegs of poor quality are used for essential oil distillation. Distilling grades of nutmegs are: 'BIA' or 'ETEZ' with a volatile oil content of 8% to 10%; and 'BSL' or 'AZWI' which has less shell material and a volatile oil content of 12% to 13%.

Nutmeg products

Nutmeg mace

Mace is the thin, lacy material covering the kernel and represents only a small fraction of the weight of the kernel. For each 100 kg of nutmeg, there is only 3-3.5 kg of mace. The quality of mace depends on the amount of volatile oil. Mace is available in the market as whole, broken, or ground types. The separated mace is flattened by hand and dried on mats in the sun. This takes between two and four hours. Grenadian mace is cured by storage in the dark for four months. This produces a brittle, pale yellow mace that attracts a premium price and is graded according to size; the bigger the mace, the better the premium. After grading, the mace can be classified and bagged. Commercial mace consists of flattened lobed pieces, 2.5 cm long and about 1mm thick. It has a similar taste and aroma to nutmeg, but is more delicate. There are four different types of nutmeg:

1. Banda mace – considered to be the finest. It has a bright orange colour and a fine aroma
2. Java Estate mace – this mace is golden yellow, interspersed with bright red streaks
3. Siauw mace – this mace has a lighter colour than Banda mace and less volatile oil
4. Papua mace – contains very little volatile oil (the oil that it contains has a pungent aroma). It is not suitable for distillation.

Nutmeg seeds

Green nutmegs are sorted to remove any broken, discoloured, rotten, waterlogged, or mouldy seeds. The nutmegs are spread out to dry in the sun in their shells. They are turned each day to prevent fermentation. The nutmegs are sufficiently dry when they rattle inside the shell. The

drying time depends on the external temperature, humidity, and air flow across the nutmegs, but generally takes about one week. Sometimes artificial dryers are used to speed up the process. To produce shelled nutmegs, the dried seeds are cracked by tapping the end of the nuts with a small wooden mallet. If the nuts are tapped on the side, there is a possibility that the kernel may be bruised. Cracking the shell is often done by a centrifugal-type machine. The nuts are forced against the inside of the drum, which causes the shell to crack. After cracking the shells, the nuts are sorted. Whole kernels are separated from the broken pieces of kernels.

Packaging and storage

Sorted kernels are bagged and labelled appropriately. They are usually packed into Hessian sacks or gunny bags. Nutmegs are usually sold whole, either with or without the shell. Ground nutmeg is also available, but this is generally of inferior quality and can easily be adulterated. The taste and aroma of ground nutmeg deteriorate very rapidly. Dried whole nutmegs have a long shelf life if they are stored in a dry place away from sunlight and insect infestation.

Adulterants

Two nutmeg species are found as adulterants of true nutmeg or mace: *M. argentea* (Macassar Nutmeg, Papua Nutmeg) from New Guinea and *M. malabarica* (Bombay Nutmeg, Wild Nutmeg) from South India. The latter lacks fragrance, while the former has a very pungent aroma. Both adulterants can be identified by the shape of their seeds: true Banda nutmegs are shaped like an egg, while the two other species have seeds that are more corn-shaped than egg-shaped.



Drying of nutmeg seeds



Drying of nutmeg mace

Quality control and grading of nutmeg

The dried seeds are sorted using the flotation method. Lighter kernels (which are generally unsound) float to the surface of a tank and can be removed. The sound kernels are sorted based on their quality and size. Good quality whole kernels are separated from the

quality and broken kernels. For export, the bagged nutmeg is fumigated with methyl bromide. Grading Nutmegs are graded according to their size. Sizing can be carried out using different mesh sizes sieves. Larger nutmegs (weighing about 8 g) are considered superior and are traded at a higher price. In Grenada, it is usual to specify the size of nutmegs according to the number of dried nutmegs per British pound. The best nuts are referred to as '55' nuts (8.2 g) to '65' nuts (7.0 g). The smallest grades traded are '160' nuts, which weigh only 2.8 g. Smaller nutmegs and nutmeg fragments are included in the BWP grade (broken, wormy, and punky), which is the lowest quality.

National Standards

Nutmeg whole and ground has National and International Standards that denote the quality and safety as defined by the Codex Alimentarius Commission. These standards address aspects like moisture, ash, volatile oil content, and freedom from contaminants.

Nutmeg: The dried seed (kernel) of *Myristica fragrans*. It shall be of greyish brown colour, but it may be white if it has been subjected to liming. It shall have a characteristic aromatic flavour free from foreign odour and mustiness. It shall be free from mold, living and dead insects, insect fragments, and rodent contamination. The product shall be free from added

Table 4. Quality standards for nutmeg

Extraneous matter	Absent
Mace in nutmeg	Not more than 3.0% by weight
Moisture	Not more than 10.0% by weight
Total ash on dry basis	Not more than 3.0% by weight
Water-insoluble ash on a dry basis	Not less than 1.5% by weight Not
Ash-insoluble in dilute HCl on a dry basis.	more than 0.5% by weight Not
Volatile oil content on a dry basis	less than 6.5 % volume/weight

Source: Bureau of Indian Standards (1993)

Table 5. Quality standards for nutmeg powder

Moisture	Not more than 8.0% by weight
Total ash on dry basis	Not more than 3.0% by weight
Water-insoluble ash on dry basis	Not more than 1.5% by weight
Ash-insoluble in dilute HCl on a dry basis.	Not more than 0.5% by weight
Volatile oil content on a dry basis	Not less than 6.0% by volume/weight
Crude fibre	Not more than 10% by weight
Non-volatile ether extract on dry basis	Not less than 25% by weight

Source: Bureau of Indian Standards (1993)

Mace: Mace whole means the dried coat or aril of the seed of *Myristica fragrans*. It shall not contain the aril of any other variety of *Myristica malabarica* or Fatua (Bombay mace) and *Myristica argentea* (Wild mace). It shall have a characteristic aromatic flavour free from foreign odour and mustiness. It shall be free from mold, living and dead insects, insect fragments, and rodent contamination. The product shall be free from added colouring matter.

Table 6. Quality standards for mace

Extraneous matter	Not more than 0.5% by weight
Moisture	Not more than 10.0% by weight
Total ash on dry basis	Not more than 4.0% by weight
Ash-insoluble in dilute HCl on dry basis.	Not more than 0.5% by weight
Volatile oil content on dry basis	Not less than 7.5% volume/weight
Insect-damaged matter	Not more than 1.0 % by weight
Nutmeg in mace	Not more than 1.0% by weight

Mace powder: It means the powder obtained by grinding the dried coat or aril of the seed of *Myristica fragrans*.It shall have a characteristic aromatic flavour free from foreign odour and mustiness. It shall be free from mould, living and dead insects, insect fragments, and rodent contamination. The powder shall be free from added colouring matter.

Table 7. Quality standards for mace powder

Moisture	Not more than 10.0% by weight
Total ash on dry basis	Not more than 3.0% by weight Not
Ash-insoluble in dilute HCl on dry basis.	more than 0.5% by weight
Volatile oil content on dry basis	Not more than 5.0% volume/weight
Crude fibre	Not less than 10% by weight
Non-volatile ether extract	Not less than 20% and not more than 30.0 % by weight

Source: Bureau of Indian Standards (1993)

International Standards

International Standard specifies requirements for nutmeg, whole or broken, and for mace, whole or in pieces, obtained from the nutmeg tree (*Myristica fragrans*). for wholesale commercial purposes. As nutmeg and mace are obtained from the same plant, it was considered preferable to give the specifications for these two spices in one International Standard. It does not apply to Papua-type nutmeg and mace (*Myristica argentea*).

Table 8. Categories of nutmeg

Whole sound nutmeg	Whole, sound, and well-formed nutmegs are classified as a function of size
Sound shrivels	Shrivelled, but sound, nutmegs which have not been attacked by insects
BWP (South East Asia) or Defectives (West Indies)	Broken nutmegs or whole nutmegs that have been attacked by insects (but with no living insects and practically free from dead insects). They may have been limited

Source: International Standard ISO 6577:2002(E), 2002

Whole nutmegs are sold either as an "assorted" mixture (ABCD), without sorting by size, or by the number of nutmegs to the (English) pound after sizing. For example, "Whole sound nutmegs 80" would indicate nutmegs of category 1, of a size corresponding to 80 to the pound. The most commonly used size ranges in commerce are 60 to 65, 80 to 85, 100 to 110, 110 to 120, 120 to 130, and 130 to 150.

Table 9. Categories of Siauw-type and Banda-type mace

Commercial designation	Description
Whole	Whole mace containing not more than 5% of about quarter-size broken pieces
Broken mace I	Mace containing at least 75% of pieces larger than about quarter size
Broken mace II	Pieces smaller than quarter size
Sifting I	Small broken pieces
Sifting II	Very small broken pieces

Source: International Organisation for Standardization (2002)

Table 10. Categories of Grenada type mace

Commercial designation	Description
Whole No. 1	Whole mace, pale yellow in colour, containing not more than 5 % of broken pieces.
Broken No. 2	Pieces ranging from yellow to dark red in colour, but overall yellow, of at least quarter-size, with a proportion of smaller pieces and dust(less than 5%).
Mace pickings	Dust and discoloured pieces of mace, ranging from yellow to black and containing damaged “country" mace

Source: International Organisation for Standardization (2002)

Export standards of nutmeg

To export spices and spice products, exporting countries have to comply with the specifications laid down by regulatory agencies in the importing countries. Specifications for whole and ground nutmeg and mace are indicated in the Tables.

Table 11. ESA quality minima for nutmeg

Product (whole form)	ASH%	AIA%	H_2O	V/O%
Nutmeg3	3(ISO)	0.5(ISO)	12(ESA)	6.5 (ESA)
The following methods are used for quality evaluation:				
Moisture		: ISO 939		
Total ash		: ISO 928		
Acid-insoluble ash		: ISO 930		
Volatile oil		: ISO 6571		

Source: Tainter and Grenis, 1993

For whole-scale commercial purposes, ISO 6577 specifications are followed for nutmeg and mace.

Table 12. Whole nutmeg chemical and physical specification

Specification	Suggested limits	
	Broken	Whole
ASTA cleanliness specifications		
Whole dead insects, by count	4	4
Mammalian excreta (mg/lb)	5	0
Other excreta (mg/lb)	1.0	0.0
Mold, % by weight	1	2
Insect-defiled/infested, % by weight	1	2
Extraneous, % by weight FDA DALs	0.50	0.00
Insect-infested and/or mouldy pieces by count	Av. of 10%	
Volatile oil (%min.)	7.0	
Moisture (% max.)	8.0	
Ash (% max)	3.0	
Acid-insoluble ash (%max.)	0.5	
Average bulk index (mg/100g)	N/A	

Source: Tainter and Grenis, 1993

Table 13. Whole mace chemical and physical specification

Specification	Suggested limits
ASTA cleanliness specifications	
Whole dead insects, by count	4
Mammalian excreta (mg/lb)	3
Other excreta (mg/lb)	1.0
Mold, % by weight	2.00
Insect-defiled/infested, % by weight	1.00
Extraneous, % by weight FDA DALs	0.50
Insect-infested and/or mouldy pieces by weight	Av. of 3%
Mammalian excreta	Av. of 3 mg per lb
Foreign matter through a 20-mesh sieve	Av. of 1.5%
Volatile oil (% min.)	15.0
Moisture (% max.)	8.0
Ash (% max.)	5.0
Acid-insoluble ash (% max.)	0.5
Average bulk index (mg/100g)	N/A

Source: Tainter and Grenis, 1993

Table 14. Ground Nutmeg: chemical and physical specification

Specification	Suggested limits
FDA DALs (6 subsamples)	
Insect fragments/ 10 gm	Av. of 100 or more
Rodent hairs/10 gm	Av. of 1 or more
Volatile oil (% min.)	6.0
Moisture (% max.)	8.0
Total ash (% max)	3.0
Acid-insoluble ash (% max.)	0.5
Military specifications (EE-S-63IJ, 1981	
Volatile oil (ml/100g, min.)	7.5
Moisture (% max.)	8.0
Total ash (% max)	3.0
Acid-insoluble ash (% max.)	0.5
Non-volatile ether extract (%min.)	25.0
Granulation (%min. through USS #20)	95
Bulk index2 (ml/100g)	180

Source: Tainter and Grenis, 1993

Table 15. Ground mace: chemical and physical specification

Specification	Suggested limits
FDA DALs (6 subsamples)	None
Volatile oil (% min.)	14.0
Moisture (% max.)	8.0
Total ash (% max)	5.0
Acid-insoluble ash (% max.)	0.5
Military specifications (EE-S-63IJ, 1981)	
Volatile oil (ml/100g, min.)	12.0
Moisture (% max.)	6.0
Total ash (% max)	3.5
Acid-insoluble ash (% max.)	0.5
Non-volatile ether extract (%max.)	20.0-35.0
Granulation (%min. through USS #20)	95
Bulk index2 (ml/100g)	205

Source: Tainter and Grenis, 1993

Value-addition

The pericarp or rind of the nutmeg fruit, comprising 80% of the fruit, generally goes to waste.The kernel constitutes 16-17% and mace constitutes2-2.5% by weight of the fruit. The volatile oil content of nutmeg and mace is15% and 20% respectively.Oil is extracted from nutmeg, and mace is not differentiated in trade. *Myristicin and elemicin* are hallucinogenic principles present in nutmeg and mace oil. The characteristic scarlet colour of mace has been identified as lycopene. The pericarp of nutmeg is used for the preparation of value-added products, viz.,preserves, pickles, candy, and sweet chutney.

Preparation details of the major value added products of nutmeg are given in the flow charts below.

Nutmeg Value added products

Nutmeg Rind Candy (Confectionery)

Fresh Nutmeg Fruits
↓
Removal of Rind
↓
Washing & Trimming
↓
Blanching (Steam / Hot water, ~10 min)
↓
Slicing
↓
Soaking in Sugar Syrup (40°Brix)
↓

Gradual Syrup Concentration (Daily boiling → 70°Brix)
↓
Draining Excess Syrup
↓
Drying (60°C, 6–8 h)
↓
Cooling
↓
Packaging (Moisture-proof)

FSSAI standards: TSS ≥ 70°Brix, free from fermentation, FSSAI-permitted preservatives only. Optional permitted preservatives -potassium metabisulphite (≤150 ppm) or sorbates (≤500 ppm).

Nutmeg Rind Jam (Fruit Spread)

Nutmeg Rind
↓
Washing & Blanching
↓
Pulping
↓
Addition of Sugar + Citric Acid
↓
Cooking
↓
TSS Adjustment (~68°Brix)
↓
End-point Testing (Sheet / Drop test)
↓
Hot Filling (Sterilized Bottles)
↓
Sealing & Cooling

FSSAI Standards: Minimum 68°Brix, no microbial spoilage.

Nutmeg Rind Syrup

Nutmeg Rind
↓
Cleaning & Blanching
↓
Pulp Extraction
↓
Addition of Sugar Syrup
↓
Heating & Clarification
↓
TSS Standardization (60–65°Brix)
↓

Filtration
↓
Bottling & Sealing

Nutmeg Rind Wine (Fermented Beverage)

Nutmeg Rind
↓
Crushing & Juice Extraction
↓
Addition of Sugar & Yeast
↓
Fermentation
↓
Clarification
↓
Maturation
↓
Bottling

Nutmeg machineries

Nutmeg desheller

This machine was developed by Mr. Sachidanandan VR from Kochi, Kerala The machine has a hopper, a striking drum, a rotating disk with 'S-shaped' baffles, a motor, an output chute, an outer casing, and a stand. It has a 0.5 hp motor, RPM – 1425, and works with 90 % efficiency. Overall dimension of the machine is 570 mm X 570mm X 850 mm, and the capacity is 150 kg/h. A patent has been filed (4027/CHE/2011), and the technology was recognized by NIF-India.



Nutmeg desheller machine

Chapter - 4
CLOVE

Scientific name: *Syzygium aromaticum* (L.) Merr. & Perry

Family: Myrtaceae

Introduction

Clove is a medium-sized evergreen tree cultivated for its aromatic flower buds. It was first introduced in India around 1800 AD by the East India Company in their 'spice garden' in Courtallam (Kuttalom), Tamil Nadu. Major clove growing regions in India are Kanyakumari (Keeriparai, Mahendragiri, Pechiparai), Nilgiris (Kallar, Burliar), Dindigul, Madurai, Salem (Shevroys), and Namakkal (Kolli hills) of Tamil Nadu, Limited patches of clove plantings are also available in Kozhikode, Kottayam, Kollam, and Trivandrum districts of Kerala, and South Kanara regions of Karnataka.

Clove has been traded globally since ancient times. The English name derives from the Spanish *clavo* or Latin *clavus,* meaning 'nail', a term given owing to the shape of the dried clove bud that is available in the market. Indonesia is a major producer of cloves, accounting for approximately 60% of global production. The UAE, Japan, the UK, Singapore, Kuwait, Saudi Arabia, Vietnam, the USA, India, West Germany, and France are major importing countries. The area and production of cloves in India are estimated at 2,380 ha. Clove is a globally popular spice prized for its flavor and medicinal benefits. Both whole and ground cloves are widely used in the food processing industry. Additionally, clove oil is utilized in perfumery, pharmaceuticals, and flavoring, while clove oleoresin serves as an important ingredient in food processing.



Clove trees

Varieties

Clove plantations in India are reported to have originated from a few seedlings from Mauritius, and hence, much variability is not seen in the population, mainly due to self-pollination in its crop. In Indian gardens, some trees produce cloves larger than the usual size of cloves, and they are called 'king cloves'. A few selections made by the Horticulture Research Station, Pechiparai, Kanyakumari, of Tamil Nadu Agricultural University are given below.

SA-3 (PP CL-1): A high-yielding clove selection proposed to be released as a state variety.

KC-1: Bold flower bud variant than the standard 'king clove'

KC-2: It is a small flower bud type called 'mini clove or dwarf clove'

Lc-1: It is a dwarf clove type identified from Kanyakumari.

Clove types from Southeast Asian countries

The types of cloves in Indonesia, their characteristics, and uses are described in the table below.

Table 1. Comparison of different clove varieties from Southeast Asian countries

Variety	Origin/region of cultivation	Notable traits	Common uses
Zanzibar	Zanzibar, East Africa, was introduced to Indonesia during Dutch colonial times, Sulawesi, Sumatra	Large buds, high oil, prolific yield	Kretek* blends, essential oils, and exports
Lal Pari	North Sumatra (highlands)	Premium grade, intense aroma, distinctive reddish-brown colour, high eugenol, handpicked and meticulously processed	Culinary, kretek, perfumery
AB6 (Ambon 6 / Banda Ab6)	Ambon/ Banda Islands, Maluku	Rich aroma, uniform buds, dark color	Oil production, cosmetics, pharma industries
Siputih	Java, Maluku	Smaller buds, strong aroma	Cooking, kretek
Sikotok	Java, Sulawesi	Medium buds, balanced oil content	General use (culinary/industria)l
Zambon	Hybrid type (Zanzibar + Ambon)	High productivity, oil content,brown -black colour	Multi-purpose, especially kretek
Tuni	Released by Indonesia's Ministry of Agriculture (2013)	High eugenol content, highly valued	Aroma industries
Afo / Raja	Maluku Islands (endemic)	Unique wild type clove	Specialty cultivation/ research
Java, Makassar, Pioneer, Spanish, Bali	Various regions	Diverse traits (sizes, aroma, oil levels)	Cooking, kretek, oil, medicinal, trade

*a type of Indonesian cigarette made from a mixture of tobacco, cloves, and other flavorings.

Production Technology of Clove

Climate and soil

Clove requires a humid climate and grows 1500 m above MSL. A rainfall of 1500-2000 mm and a mean temperature of 20-30 °C are required for the production of this crop. Deep red loam, black soil, and deep gravelly subsoil are suitable, but waterlogged conditions are undesirable. Clove grows well in rich loamy soils of the humid tropics and can be grown successfully in the red soils of the midlands of Kerala as well as in the hilly terrain of Western Ghats at higher elevations in Tamil Nadu and Karnataka. A cooler climate with well-distributed rainfall is ideal for flowering.

Propagation

Clove trees are propagated exclusively through seeds. The fruit (called 'mother of clove') keeps viability only for a short period and hence needs to be sown immediately after harvest. Before sowing, the outer fleshy pericarp is removed because it contains sugars and gets fermented, causing injury to the embryo. For sowing, only well-developed seeds of uniform size that show early signs of germination, indicated by a visible pink radicle, are selected. Delayed sowing reduces seed viability, as the seeds tend to lose their ability to germinate if stored for too long.



Mother Cloves



Ready to transplant clove seedlings

Nursery practices

Seed beds of 15–20 cm height, 1-meter width, and a convenient length need to be prepared before the harvest season. These beds should consist of a loose mixture of soil and sand, topped with a 5–8 cm thick layer of sand. Seeds may also be sown directly into sand beds, spaced 2–3 cm apart and planted at a depth of around 2 cm. However, it's important to protect the beds from heavy rain to prevent nutrient leaching. Additionally, the beds should be shielded from direct sunlight. When only a small number of seeds are available, they can be sown directly into polybags filled with a mix of soil, sand, and cow dung, and kept in a cool, shaded area. Germination usually begins within 10 to 15 days and can continue for up to 40 days. The vigour of the seedlings was found to be closely associated with larger-sized seeds and the orientation of sowing. Therefore, seeds need to be placed horizontally in the seedbed.

The germinated seedlings are transplanted in polythene bags (25 cm x 15 cm) containing a mixture of soil, sand, and well-decomposed cow dung (3:3:1). Sometimes, seedlings are again transplanted after 1 year to large polythene bags containing the same soil mixture. Transplanting time can be reduced to 1 year by planting clove seedlings in a mixture consisting of soil and vermicompost in a 1:1 proportion. The nurseries are usually shaded and irrigated daily. The seedlings are ready for transplanting in the field when they are 18-24 months old.

Planting

Clove can be cultivated either as an individual crop or intercropped with coconut, arecanut, or coffee. Before the monsoon season, the chosen site for planting is cleared, and pits of 75 cm^3 are dug at 7-meter intervals. Ideal locations for clove cultivation include eastern and north-eastern hill slopes, well-drained valleys, and areas near riverbanks. When grown as an intercrop, the planting distance should be modified according to the spacing of the main crop.



Ready to plant clove seedlings

The pits are partially filled with compost, green leaves, or cattle manure, and then covered with topsoil. Seedlings are transplanted to the main field at the start of the rainy season, typically in June–July, while in low-lying areas, planting is done later, around September–October, towards the end of the monsoon. Clove thrives in partially shaded environments and grows well in higher elevations with evenly distributed rainfall.

Intercropping

Clove can be intercropped with black pepper, arecanut, tea, coconut, sweet oranges, coffee, banana, pineapple, and tapioca, since the spacing adopted is 6 m, which is entirely open in the field during the early stages. The shade cast by these plants will provide enough protection to clove from the hot sun. In order to give a cool, humid microclimate, intercropping with banana is ideal.



Branching pattern in clove tree

Training and pruning

Training and pruning are not required in clove plantations. Occasional thinning of branches helps in preventing overcrowding of branches in full-grown trees. Diseased and dead shoots are systematically removed without injuring trees.

Manuring

Each bearing tree needs to be given about 50 kg of cattle manure or compost annually, along with 2 to 5 kg of bone meal or fish meal at the beginning of the rainy season in trenches dug around the trees. The application of inorganic fertilizers @ 20 g N (40 g urea), 18 g P_2O_5, (110 g superphosphate), and 50 g K_2O (80 g muriate of potash) in the initial stage is recommended. The dosage is progressively increased to 300 g N (600 g urea), 250 g P_2O_5 (1,560 g superphosphate), and 750 g K_2O (1,250 g of muriate of potash) per year for a grown-up tree of 15 years or more. Fertilizers should be applied in two equal split doses, once during May–June and again in September–October. They are placed in shallow trenches dug around the tree, typically 1 to 1.5 meters away from the base. Additionally, mulching with fallen leaves and applying river silt around the trees can further enhance growth.

Irrigation

Clove trees require regular watering, but care must be taken to avoid waterlogging. During the early stages of growth, irrigation is crucial if there is no rainfall. In the summer months,

consistent watering is necessary, with about 8–10 litres of water per plant per day recommended from January to May, either through drip irrigation or the basin method, to ensure healthy development.

Aftercare

Providing shade to clove seedlings during their early years is essential. Banana plants can be cultivated to offer natural shade during the initial establishment phase, or artificial shading methods can be used until the plants are well established. Mulching around the base of the plants with dried leaves is a crucial practice in clove cultivation. Regular weeding is also an important intercultural operation to keep the field free from unwanted plants.

Plant protection

Diseases

Seedling wilt

Seedling wilt is a serious problem in the majority of nurseries. The leaves of affected seedlings lose their natural luster, droop, and ultimately die. The root system and collar region of the seedling show varying degrees of discolouration and decay. *Cylindrocladium* sp., *Fusarium* sp., and *Rhizoctonia* sp. are the commonly associated organisms with the disease. Since the infected plants promote further spread of the disease, they are to be removed, and the remaining seedlings should be treated with carbendazim 0.1% both as a spray and soil drench. Alternatively, the foliage may be sprayed with Bordeaux mixture 1% and the soil drenched with copper oxychloride 0.2%.

Die back

Drying of the shoot from the tip backwards. Caused by fungus, *Cryptosporella eugenia*, it can be controlled by spraying Mancozeb or Carbendazim.

Leaf spot and bud shedding

It is characterized by dark brown spots with a yellow halo on leaves. It is caused by *Colletotrichum gloeosporioides*. Such spots also appear on buds, resulting in their shedding. *C. crassipes* causes reddish brown spots on leaves. Dark brown lesion starts from leaf margins, which later merge to form chocolate brown necrotic areas, resulting in the drying up of branches.

Leaf rot

Leaf rot is caused by *Cylindrocladium quinqueseptatum* and is noticed in mature trees and seedlings. The infection starts as dark, diffuse patches at the leaf tip or margin, and later the whole leaf rots, resulting in severe defoliation. The foliage of affected trees should be sprayed with carbendazim 0.1%. Prophylactic sprays with Bordeaux mixture 1% also prevent the disease.

Insect pests

Stem borer

The stem-borer infests the main stems of young trees at the basal region. The larva of the pest

girdles the stem and bores downward into it. The girdled portion and borehole are covered with a mat-like frass material. The infested trees wilt and succumb to pest attack subsequently. Fully-grown larvae are creamy white with a black head and measure about 8.5 cm in length. To control the damage caused by the pest, inspect the base of clove trees regularly for symptoms of pest attack. Spray quinalphos (0.1%) around the borehole and inject the same into the borehole after removing the frass. Swab the basal region of the main stem with carbaryl paste and keep the basins free of weeds.

Scale insects

Many species of scale insects infest clove seedlings in the nursery and sometimes young plants in the field. The scale insects generally seen on clove include wax scale (*Ceroplastes floridensis*), shield scale (*Pulvinaria psidii*), masked scale (*Mycetaspis personata*), and soft scale (*Kilifia acuminata*). The scales are generally seen clustered together on tender stems and the lower surface of leaves. Scale insects feed on plant sap and cause yellow spots on leaves and wilting of shoots, and the plants present a sickly appearance.

Harvesting

Clove trees start flowering in the 6-8th year after planting under good management conditions, and the full bearing stage is reached only after 15 years. The flowering season varies from September to October in the plains to December-January at high altitudes. Flower buds are produced on young flush, and it takes about 4-6 months for the buds to become ready for harvest. The harvesting period is critical for clove buds. It should be harvested before the development of purple or crimson flowers. When the outer green leaves (the calyx) of the flower bud change from olive green to yellow pink, this is considered as best time for harvesting; also, this period is marked as prior to the petals falling. Clusters of flower buds are hand-picked from the branches.



Clove tree at harvest

Yield

Three to four kilograms of dried buds can be harvested on average from 15-20-year-old clove trees, which are reported to have alternate bearing habits. For harvesting seed, the optimum time has been identified as 78-91 days after the fruit set.



Freshly harvested clove buds

Post harvest management

Pre treatment

After harvest, the buds are removed from the stalk manually by detaching them from the stalks by holding a cluster in one hand, pressing it against the palm of the other hand. Proper precautions should be taken before separating the buds to avoid contamination. The hands of the processor and the room in which the buds are separated must be very clean to prevent contamination of the cloves. The stems and buds are separated and dried separately. The stems and stalks can also be used for oil distillation.

Drying

Buds should be processed or dried as soon as possible, as they start to ferment fast. Sun drying is the common method; however, dryers can also be used for this purpose. During the rainy season, cloves should be dried using a mechanical drier, such as a tray drier. Clove buds should be raked and turned frequently to ensure an even brown colour after drying. The colour of buds changes from pale russet to a darker brown as the clove dries. The drying process takes about four to five days. The final moisture content of the dried cloves should be 8-10%. Fully dried clove buds snap easily. The correct drying stage is reached when the stem of the buds turns pink and the rest of the bud light green in colour. Well-dried cloves will be only about one-third of the weight of the original weight. Fermented clove that is a result of incomplete drying are termed as 'Khoker cloves'.



Post harvest operations in clove

Winnowing

Winnowing is done to remove dust and other foreign matter. It is usually winnowed and dust-blown in small-scale farms. Mechanical blowers can also be used for efficient winnowing.

Packaging and storage

Well-dried clove buds are packaged in sealed polythene bags. It must be stored away from direct sunlight. The stored cloves should be inspected regularly for signs of spoilage or moisture. If they have absorbed moisture, they should be re-dried to a moisture content of 10%. The storage room should be clean, dry, cool, and free from pests. Strong-smelling foods, detergents, and paints should not be stored in the same room as they will spoil the aroma and flavour of the cloves.

Quality standards

Quality standards of clove buds and other clove products are given in the table below.

Table 2. Quality standards of whole cloves

Extraneous matter	Not more than 1.0 percent by weight
Tendrils, Mother Cloves	Not more than 2.0 percent by weight
Khokar Cloves	Not more than 2.0 percent by weight
Moisture	Not more than 12.0 percent by weight
Volatile oil content on dry basis	Not more than 17 percent by weight v/w
Headless cloves	Not less than 2.0 percent by weight
Insect-damaged cloves	Not less than 2.0 percent by weight

(Source: Bureau of Indian Standards (1993)

Table 3. Quality standards of clove powder

Moisture	Not more than 10.0 percent by weight
Total ash on dry basis	Not more than 7.0 percent by weight
Ash insoluble in dilute HCl on dry basis.	Not more than 0.5 percent by weight
Volatile oil content on dry basis	Not less than 16.0 percent volume/ weight
Crude fibre	Not more than 13.0 percent by weight

Source: Bureau of Indian Standards (1993)



Dried clove buds

International standards

The classification and ISO chemical standards of clove and powder are given in the tables

Table 4. Specifications of clove products

Oil of clove leaves	ISO 3141:1997	*Syzygium aromaticum*
Oil of clove buds	ISO 3142:1997	*S. aromaticum*
Oil of clove stems	ISO 3143:1997	*S. aromaticum*
Cloves, whole and ground (powdered)	ISO 2254:1980	*S. aromaticum*

Table 5. Classification of whole clove (ISO 2254)

Grade	Headless cloves (% Max.)	Tendril, mother of cloves (%Max.)	Khoker cloves (% Max.)	Extraneous matter (% Max.)
1 Special (hand-picked)	2	0,5	0,5	0,5
2	5	4	3	1
3	Not specified	6	5	1

Table 6. Chemical requirement of whole clove (ISO 2254)

Characteristics	Requirement	Test method
Moisture, (max. %) (mass fraction)	12	ISO 939
Volatile oil, ml/100 g on dry basis, min. grade 1 and 2	17	ISO 6571
Volatile oil, ml/100 g on dry basis, min. grade 1 and 3	15	-

Table 7. Chemical requirement for ground (powdered) clove (ISO 2254)

Characteristics	Requirement grade			Test method
	1	2	3	
Moisture (mass fraction), max.	10	10	10	ISO 939
Total ash, % (mass fraction) on dry basis, max.	7	7	7	ISO 928
Acid insoluble ash, % (mass fraction) on dry basis, max.	0.5	0.5	0.5	ISO 930
Volatile oil, % (mass fraction) on dry basis, min.	16	13	14	ISO 6571
Crude fibre, % (mass fraction), Max.	13	-	13	ISO 5498

Export standards

Export quality requirements for various clove products are country-specific. The American Spice Trade Association (ASTA) and Food and Drug Administration (FDA) recommendations for whole spice (clove) are illustrated in the table below.

Table 8. ASTA cleanliness specifications for cloves

Items	Suggested limit whole clove
Whole dead insect (mg/lb)	4.00
Mammalian excreta (mg/lb)	5.00
Other excreta (mg/lb)	8.00
Insect-defiled/infested, % by weight	1.00
Mould, % by weight	1.00
Extraneous, % by weight	1.00

Chapter - 5
KOKUM

Scientific name: *Garcinia indica* Choisy

Family: Clusiaceae

Introduction

Kokum is an underexploited fruit tree endemic to the Western Ghats and highland regions of peninsular India. It is an indigenous tree spice mainly grown in the south Konkan region of Maharashtra, Western Ghats, Coorg, Wayanad, Goa, the evergreen forests of Assam, Khasi and Jaintia hills, West Bengal, and Gujarat. In the Konkan region, kokum trees are scattered over backyards, river and stream sides, waste lands, and also in coconut and arecanut gardens. The fruits of this evergreen tree look like a small apple with highly acidic pulp surrounded by a thick rind. The seeds embedded in the pulp are rich in oil (kokum butter).

Dried kokum rind is a souring agent in culinary preparations. Fresh rind is processed into many products such as juice, jam, preserves, and concentrates. The fruits are rich in hydroxycitric acid (HCA), garcinol, and anthocyanins. HCA is a well known fat burner with obesity-reducing properties and hence has gone into innumerable weight reduction and anti-obesity formulations. Garcinol, also known as cambogiol, is a polyisoprenyl benzophenone, one of the major constituents of the extract of the rind of kokum, and this chemical is known to possess manifold biological properties. Kokum butter is solid at atmospheric temperature and widely used in the cosmetic and pharmaceutical industries. Apart from the culinary uses, the tree has several uses in traditional medicine too. The list of other species of the genus *Garcinia* is given in Table 1.



Kokum fruits



A fully grown kokum tree

Table 1. Some related species of kokum

Species	Local name	Country	Uses
Garcinia indica	Kokum	India	Culinary, medicinal
Garcinia cambogia	Malabar Tamarind	India/SE Asia	Cooking, weight loss
Garcinia atroviridis	Asamgelugur	Indonesia	Cooking (souring agent)
Garcinia parvifolia	Asamkandismerah	Malaysia	Culinary
Garcinia cowa	Cha muang	Thailand	Curries, traditional medicine
Garcinia binucao	Binukaw	Philippines	Local dishes
Garcinia quaesita	Sri Lankan kokum	Sri Lanka	Culinary, medicinal
Garcinia gardneriana	-	Brazil	Traditional medicine

Varieties

The kokum varieties released by various institutes are given in the table below.

Table 2. Kokum varieties released by various institutes

Variety	Year of release	Breeding method	Potential yield	Characteristics
Varieties developed by DBSKKV, Dapoli, Maharashtra				
Konkan Amrita	1997	Selection	Yield after 7 years- 138 kg per plant	Released first time in India, early, high-yielding, and fruits have a long shelf life. Apple shape fruit, Weight of fruit-34.45 g.
Konkan Hatis	2006	Selection	Yield after 7 years- 250 kg per plant	A high-yielding kokum variety having very bold fruits. Apple shape fruit, Weight of fruit-91.50 g.



Konkan Amrita



Konkan Hatis

Varieties developed by ICAR- CCARI, Goa				
Goa Kokum-1	2025	Selection	52.29 kg (1949 fruits) in 8th year	Bold fruit type (49.29 g), rind recovery: 30-40%, rind weight: 28.90 g, rind thickness: 3.51 mm
Goa Kokum-2	2025	Selection	14.15 kg (in 5th Year from a dwarf tree with 5.0 m^2canopy area)	Dwarf type, fruit weight: 51.51 g, rind weight: 51.11 g, rind thickness: 2.40 mm
Goa Kokum-3	2025	Selection	1.42 kg (in 4th year from a dwarf tree with5.0 m2 canopy area)	Small pointed fruits with high TSS and acidity ratio



Goa Kokum-1



Goa Kokum-2



Goa Kokum-3

Production Technology of Kokum

Climate and soil

Kokum trees grow on a wide range of soils, from marginal to deep alluvial, which are well-drained. Lateritic soils of the Konkan belt are very suitable for their cultivation. It prefers a warm and humid tropical climate and thrives well in coastal areas up to 800 m from MSL. A well-distributed rainfall of up to 200 to 250 cm encourages normal growth and yield. It performs well in lateritic and alluvial soils having depths of about 1.2 m and a pH of 6.7.

The temperature ranges from 20 ^{0}C to 35 ^{0}C, and 60 to 80 per cent humidity is ideal for this crop. In a coastal humid region of Maharashtra and Goa, it can be cultivated as a rainfed crop.

Propagation

Seed propagation

Kokum plants are usually propagated by seeds. Each fruit generally contains 4 to 8 recalcitrant seeds. Fresh bold seeds from high-yielding and regular-bearing plants are collected immediately after harvest. They are cleaned with water and then sown in polythene bags (12.5 x 20.0 cm) containing potting mixture. Two days before sowing, seeds should be soaked in water, which gives early and better germination (up to 90%). Farmers used to extract the seeds and spread them on the floor under shade. Many times, seeds are left under the tree itself, where they germinate naturally. The seeds are allowed to soak in the rain for germination. Pre-sowing

treatment of seed with wet packing or drying with coal ash is found beneficial for good germination.



Kokum seeds

Raised beds of 1 m width, 20 cm height, and of convenient length are prepared. The topsoil of the bed is mixed with farmyard manure. The seeds are placed horizontally at 1.5 to 2.5 cm in a row. The distance between two rows should be 5 cm. After germination, the seedlings are transplanted in polythene bags of 10 x 15 cm^2 size containing a potting mixture of soil and farmyard manure in the ratio of 3:1. The transplanted seedlings should be kept under shade and watered regularly. The seeds can be directly sown in polybags. Many times, two seeds are sown in a polybag. The seeds germinate between 40 and 60 days. The initial growth of the kokum seedling is very slow. One-year-old seedlings should be used for planting in the field

Vegetative propagation

The mature scion sticks of 5-6 months age can be preferred for softwood grafting.Kokum seedlings are mostly used as a rootstock. Kokum grafting by using *Garcinia gummi-gutta*, *G. cowa*, and *G. hombroniana* is successful in marshy soil. The age of root rootstock should be more than 22 weeks. The length of the scion stick, from 2.5 cm to 15 cm, did not exhibit any significant influence on the survival of the graft. The scion stick could be stored successfully in a poly bag or sphagnum moss for seven days. Whenorthotropic shoots are used for grafting, the resulting graft takes the typical architecture of a mother tree. When plagiotropic shoots are used as a scion, the resulting graft remains short and bushy. Extremely limited numbers of orthotropic shoots are available on kokum plants as compared to plagiotropic shoots. Both types of architecture have their own merits and demerits. The orthotropic plants become tall and conical-shaped, occupya large area, utilize vertical space, and produce higher yields. However, the plucking of fruits from such tall Kokum plants becomes difficult. The plagiotropic plants remain small and bushy andcan be used for high-density planting.



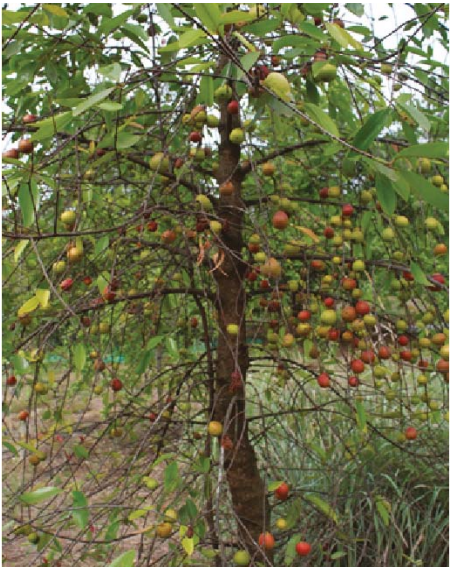
Kokum seedlings



Kokum scions for grafting



Kokum softwood grafts in the nursery



Orthotropic grafts of kokum



Plagiotropic grafts of kokum

Planting

Planting is usually done at 6 m x 5 m spacing (333 plants/ha).DBSKKV, Dapoli recommends a pit size of 60 cm^3 and a spacing of 6 m x 6 m in the square system for a sole crop. The pits should be filled with well-decomposedfarmyard manure and soil. Sevin 100 g/pit should be mixed in soil to protect the young plants from termites, and also 1 to 1.5 kg single super phosphate per pit should be mixed in soil while refilling the pits. Planting should be carried

out with the onset of the monsoon. Staking should be done at the time of planting itself.

Kokum can be planted as a monocrop or as a mixed crop in coconut and arecanut plantations, and also in a kitchen garden. While planting grafted plants, a female-to-male ratio of 9:1 is maintained. However, when seedlings are planted, the sex is not known till flowering.Hedge-row systems are also used, which provides scope for intercropping and better intercultural operations.

Intercropping

In an established coconut plantation, kokum trees can be planted at 7.5 to 8 m spacingin the centre of two coconut palms. Three hundred kokum plants can be accommodated per hectare as a mixed crop in a coconut plantation. Kokum interplanting improves the yield of coconut. In an arecanut plantation at 2.7 m x 2.7 m, kokum is planted at the alternate centre palm. When grafts are used for planting, the spacing is reduced to 5 m. While planting in the kitchen garden, kokum is planted at least 4 to 5 m away from other tall plants.

After care

The young plants should be provided with partial shade in winter and summer months, and should be irrigated at least once in a fortnight during winter and summer months, for better establishment in the field. Irrigation with 15 liters of water per week in winter and twice a week in summer is advised. Drip irrigation is beneficial compared to conventional irrigation methods.Orchards should be kept clean by removing weeds, grass, and bushes. The young plants need to be protected from stray cattle and other wild animals. When grafts are planted, periodical removal of suckers below the graft joint is essential. During the first year, it is necessary to protect the kokum plant in summer by providing shade. Mulching helps to retain soil moisture in the field.

Manures and fertilizers

Kokum should be manured regularly for healthy and vigorous growth and for higher yield.

For a one-year-old plant, 5 kg FYM or green manure and 50 g N, 25 g P_2O_5, and 25 g K_2O should be applied. This dose should be increased proportionately by 5 kg FYM, 50 g N, 25 g P_2O_5, and 25 g K_2O per tree every year. For ten-year-olds onwards, 5 kg FYM or green manure, 500 g N, 250 g P_2O_5,and 250 g K_2Oshould be given per year. The fertilizers should be applied in the month of August after heavy rains are over. A circular trench of 30 cm depth and 30-45 cm width should be dug out below the tree canopy. The manures and fertilizers should be incorporated in the trench and refilled with soil.

Intercropping

Rainfed crops like cucurbitaceous vegetables, okra, sweet potato, etc., can be successfully grown in between two rows of kokum.The kokum plant is dioecious in nature. If an orchard is established by using seedlings, only after flowering, the male and female plants can be identified. It is advisable to remove an excessive number of male plants. For ensuring adequate pollination, better fruit set, and higher yield, it is desirable to maintain 10 per cent male plants in the orchard. By the top working technique, the extra male plants can be converted into bearing female plants.

Plant protection

No serious diseases or insect pests are damaging the plant. Among insect pests, leaf miner causes damage to tender leaves. Spraying with 0.03 per cent phosphomidon or 0.03 per cent dimethoate is effective for its control.

Harvesting

Kokum seedling-raised tree commences bearing after 7 to 8 years of planting, whereas the grafted tree starts bearing after 5 to 6 years of planting. Flowering starts from October-November and continues up to February under the agro-climatic conditions of the Konkan region. Harvesting of thefruit commences from March and continues up to the first fortnight of June. The peak period of harvesting is April-May. About 40-70% of fruits are trapped in the rain and hence are lost. Post-flowering foliar spray of potassium nitrate (3 %) helps to advance harvesting by about 10 to 34 days.



A fruiting branch of kokum

At fruit maturity, the rind colour changes from green to red.All Kokum fruits on a tree may not be ready for harvesting at a time, and hence, periodical plucking is done. The number of pickings varies from tree to tree. Generally, 6 to 8 pickings are required in high-yielding plants.Fully ripe fruits are plucked by hand after climbing the tree. Farmers used to shake the branches and collect the fallen fruits, which leads to considerable loss of fruit. Approximately 35-40% fruits are lost, which include immature and broken fruits.

Yield

In a seedling population, 30-50 kg yield per plant is obtained, while in a well-managed plantation, up to 100 kg of fruits/plant are collected. In a mixed cropping system in a coconut plantation, 15 kg of fruit/plant can be harvested per year. The shelf-life of kokum fruits is 4 to 5 days under ambient conditions.

Storage and packing

It can be extended to 3 weeks when stored in a cool chamber at 13°C temperature and 86% RH. CFB boxes and paddy straw are good packaging materials for kokum.

Table 3. Requirements for different grades of dry kokum rind

Characteristics	Grade		Testing Method	
	1	2	Annex of This Standard	Clause Number of IS 1797: 1985
Moisture, percent by mass, Max	10	12	-	9
Kokum seed content. Percent by mass, Max	0.5	0.1	A	-
Mould-affected rind, percent by mass, Max	0.5	1.0	B	-
Acid insoluble ash percent by mass, Max	0.5	1.0	-	8

Source: Bureau of Indian Standards (1993)

Processing and utilization of kokum

A number of important processed products are prepared from the kokum fruit. The flow chart for the preparation of the major kokum products is mentioned below:



Harvested fruits

Dried green kokum rind

Select mature green, hard Kokum fruits

↓

Wash the fruit with tap water and cut it with a sharp stainless-steel knife into four equal parts

↓

Treat the slices with a 2500 ppm KMS solution for two hours

↓

Dry the treated slices in a dryer at 50-55ºC

↓

Pack the dried slices in plastic bags and store them in a cool and dry place. If placed air-tight, these slices remain in good condition for 8-10 months

Kokum syrup (Amrit kokum)

Select ripe, fresh, and firm fruit having good red colour. Discard under-ripe or over-ripe fruits

↓

Wash the fruits with water and immediately dry them with a clean cloth

↓

Cut the fruit into 4 or 8 parts manually or with the help of a kokum cutter. Separate the seeds and rind

↓

Weigh the rind and take sugar twice the weight of the rind (1:2 proportion). Apply layers of sugar and rind in food-grade plastic drums or glass jars

↓

Mix the rind and sugar thoroughly twice a day for 7 days. Af ter 7 days, all the sugar will dissolve in the juice released due to osmosis. This prepared solution is known as ‘Kokum syrup

↓

Add 720 mg sodium benzoate per litre of kokum syrup after dissolving it properly. Even without a preservative, syrup can be stored

↓

Pack the prepared syrup in clean f ood-grade plastic bottles or cans and store it in a cool and dry place

↓

Dilute the syrup to 1:5 or 1:6 with cold water before serving. Add salt and cumin powder for taste

Dried ripe kokum rind(Amsul)

Ripe kokum fruits

↓

Wash and cut into 2-4 pieces

↓

Dry on plastic and the misx seed and pulp with 20 percent salt

↓

Kokum agal extract after removing the seed

↓

Dry rind for four days under the sunlight

↓

Soak dried rind overnight in a 20 per cent salt agar solution (12-14 hours)

↓

Drain the excess solution

↓

Dry the soaked rind for two days on polythene paper in the sunlight

↓

Repeat soaking in agal and carry out subsequent drying three

↓

Amsul

Kokum agal (Brined kokum juice)

Select ripe, fresh, and red colour fruits of kokum

↓

Cut the fruits into 4 or 8 parts and weigh the rind and pulp along with the seeds

↓

To the weighed rind and pulp (with seeds), add 16 to 20 per cent salt. Keep this mixture for 3 days for the release of juice. Stir the mixture twice a day. The released salted juice is known as 'Kokum agal

↓

Pack the agal in a food-grade plastic bottle or cans and store at a cool, dry place

Kokum butter

Collect the seed left after processing of fruit and dry it completely in sunlight or cabinet dryer

↓

Pack the seeds airtight in plastic bags before us, eor remove the seed coat manually or with the help of a huller, and pack airtight

↓

Steam the seeds with the help of the steam generated by the boiler. Steam it till the seeds are soft

↓

Feed the steamed seeds to the oil expeller and extract the fat (oil)

↓

Dry the fat (oil) by cooling and pack it airtight in polythene bags

Kokum rind powder

Select ripe, fresh and firm fruits having good red col our

↓

Wash the fruits with water and immediately dry them with clean cloth .

↓

Cut the fruit into 4 or 8 parts manually or with the help of kokum cutter. Separate the seeds and rind

↓

Drying (Vacuum drying or drying rind ain cabinet dryer)

↓

Grinding (Grinding ina pulveriser)

↓

Packaging

↓

Storage

Other products

Kokum rind contains 2-3 per cent anthocyanin pigment, and it is a rich source of natural colourant for foods. Processing conditions have been standardized at CFTRI, Mysore, for commercial-scale extraction and purification of the pigment concentrate. DBSKK, Dapoli has developed instant ready-to-mix kokum sarbat mixture, kokum solkadhi mixture, and kokum rind sweet chutney.

Chapter - 6
MALABAR TAMARIND

Scientific name: *Garcinia gummi-gutta* L. N. Robson Desr (syn. *G. cambogia*)
Family: Clusiaceae

Introduction

Malabar tamarind is originated in the Malabar coast of India and is found in Nepal, Sri Lanka, China, Malaysia, and the Philippines. These trees are found mainly in the semi-evergreen to evergreen forests of Southwest India, predominantly in the Western Ghats (Maharashtra, Karnataka, Kerala, and Tamil Nadu). This tree can be grown in both plain lands and high ranges. It grows best in dry or occasionally waterlogged or flooded soils in riverbanks and valleys. It is tolerant of fluctuating water tables and drought. Malabar tamarind is the major source of this naturally occurring anti-obesity compound. There are male and bisexual types of trees. The fruit is highly acidic, with the rind being processed for the market. It has anti-obesity properties and antioxidant properties.



Malabar tamarind plot

Varieties

The varieties released by KeralaAgricultural University, Thrissur,are given below.

Table 1. Released varieties of Malabar Tamarind

Varieties	Year of release	Characteristics
Amritham	2015	Golden yellow coloured globe-shaped fruits, av. yield of 16.38 kg drying/ tree/year; mean HCA content 51.58%
Haritham	2015	A high-yielding Malabar tamarind; spreading trees; golden yellow oblate fruits; good quality fruit rind; dry rind yield of 9.91 kg/ tree/ year; HCA content 52.99%
Nithya	2018	Acidity 53.67 %; tannin 520 mg/100 g; driage 9.76 %, intensive branching with spreading canopy; 740 fruits/tree/year. Average fruit weight: 88.25 g. Suitable for loamy to laterite soil. Dry Rind – 10.11 kg/tree; HCA -16.96 %

The salient features of some of the potential accessions identified by ICAR-IIHR, Bengaluru, are given below.

IC244110: It is a promising selection with high fresh fruit weight (200g), fresh rind weight (125.5g), fresh rind thickness(13.6mm), fresh seed weight (2.4g), fresh and dry kernel weight (0.6g). It is an accession with the highestlength of protrusion (nipple) in fruit.

IC244100-2 (INGR No. 04061): It is an early bearing (6 years after transplanting), high yield in number of f ruits (1496), high fresh fruit yield (104.2 kg), single fresh fruit weight (82.6 g), high number of seeds per fruit (6), high seed weight (1.6 g), high dry rind thickness (3.5 mm) and high yielding during the last 9 years.

IC244111-1 (INGR No. 04062): It is an early bearing (7 years after transplanting), high yield in number of fruits (1470), high fresh fruit yield (99.3 kg), single fresh fruit weight (84.4 g), high number of seeds per fruit (6) and high seed weight (2.4 g), high dry rind thickness (2.5 mm) and high yielding during the last 9years.

CHES-GG-V/1: This is a promising seedling selection with higher fruit weight. The tree has upright growth, medium-sized. The fruits ripen in July. The fruit weight ranges between 75 to 85g. Fruits are dull yellow coloured, 6-7 seeds/fruit, rind yellow, pulp is white with 8 segments, and are juicy and acidic. The rind recoveryis 62 per cent. The fruit contains 13.50 Brix total soluble solids and 62 mg Vitamin C /100g pulp. The average yield is 400-700 fruits per tree.

IIHR-GG-2-09: This collection is high-yielding, a regular bearer. The tree has upright growth, medium-sized. The fruit ripens in July-August under Bangalore conditions. The fruit weight ranges between 75 to 80g. Fruits are dull yellow coloured, 6-7 seeds/fruit, rind yellow, pulp is white, 8 segments, juicy and acidic. The recovery of the rind is 56 per cent. The fruit contains 130 Brix total soluble solids. The average yield is 200-250 fruits per tree.

Two potential accessions identified by ICAR-CIARI, Sri Vijayapuram (Port Blair) are,

Dweep Agrim: Thin rind (about 5 mm), medium-sized fruits, and closely arranged shallow ridges.

Dweep Vishal: Large fruits, thick rind, and high-yielding selection.





Malabar tamarind fruits

Production Technology of Malabar Tamarind

Climate and soil

Malabar tamarind is adaptable to a wide range of climatic and soil conditions. It is a very hardy crop and can be grown in tropical and subtropical climates. Sandy loam soils are ideally suited for their cultivation. It tolerates fluctuating water tables and even prolonged inundation and hence is suitable for low-lying reclaimed soils.

Propagation

Seed propagation

Malabar tamarind can be propagated by seeds. Select the mother plants that continuously produce big fruits (mean fruit weight of 200-275 g) with high acid and low tannin content. Seeds are extracted immediately after harvest and dried under a shed for 20 days. Later, they are planted in polythene bags filled with potting mixture or raised beds during August-September. Seeds have a dormancy period of 8-9 months. Seeds with the seed coat intact remain in the soil for 8-9 months and then start sprouting during February. Removal of the seed coat will induce seed germination within 2-3 months after sowing.

Softwood grafting

Malabar tamarind is dioecious in nature; hence, softwood grafting has been standardized. One-year-old Malabar tamarind root stocks are used for grafting nine-month-old scion sticks, 6-8 cm in length. Softwood grafting done during June gave the highest success. Besides, vegetatively propagated trees come to flowering earlier (about 3 – 4 years after planting). To get a normal growth habit, orthotropic shoots should be used as scion material. If plagiotropic shoots are used, the resulting grafts will be dwarf, bushy, and drooping with reduced fruiting area. But orthotropic shoots are limited in number on mother plants.

Approach grafting

The grown-up trees with low-lying branches with 3-4 mm thickness are preferred for approach grafting. The suitable plants are brought near the mother plant and grafted to the mother plant. After 45 days, when the grafts are ready, they can be placed in the nursery for hardening.

Planting and aftercare

Planting can be done with the onset of the first monsoon showers. The plants can be raised as a pure crop or as a mixed crop in coconut and arecanut gardens. Pit size varies in different soil conditions.

Recommendation of KAU, Thrissur, Kerala

Pits of size: 0.75 m x 0.75 m x 0.75 m (Laterite soil); 0.50 m x 0.50 m x 0.50 m (Sandy and alluvial soils)

Spacing: 7 m × 7 m (seedling), 4 m × 4 m (grafts)

Slopes ≥15 %: Between rows: 5 to 5.5 m and 3.5 m between trees in a row (grafts), 8 -12 m and at 6 -8 m for trees in a row (seedlings)

ICAR- CIARI, Port Blair recommends 45 cm × 45 cm × 45 cm-sized pits, 5-6 m apart in Andaman and Nicobar.

Manuring

Application of 10 kg of FYM is recommended per seedling/graft during the first year. Gradually increase the quantity so that a well-grown tree of 15 years and above receives 50 kg of organic manure per year. Apply N: P_2O5 K_2O mixture at the rate of 20:18:50 $gplant^{-1}$ during the first year. Double the dose in the second year and gradually increase it to 500:250:1000 g $plant^{-1}year^{-1}$ at the 15th year.

Training and Pruning

Grafts will grow fast from the second year onwards. Give strong support with casuarina poles at this stage. By the fifth year, the tree will have 3 to 4 m in height. At this stage, the height of the plant may be maintained at 3.5 to 4 m and by the seventh year at 4 to 4.5 m by pruning.

Harvesting and processing

Flowering occurs in January-March, and fruits mature in July. There are reports of off-season bearers, which bear two times a year, i.e., during January-July and September-February. Mature fruits, which are orange-yellow in colour, drop off from the tree. The fruits take 130-140 days to attain full maturity. A well-managed, fully grown tree yields 400 – 450 fresh fruits or about 55-60 kg dried rind. The fruits vary in size, weighing 50 to 180 g. The fruit rind with 7-10 segments. The fruit has a yellow resinous liquid that oozes out from the fruit and later turns to a brown sticky mass. Fruits abscise on ripening and are collected from the ground, and the seeds, enclosed in a pulpy translucent aril, which is often sweet and edible, but sometimes acrid, are separated. The aril is very sour in taste. The rind is separated and dried for use. Due to the coincidence of southwest monsoon rains with the period of fruit ripening, farmers resort to smoke drying. It can also be sun-dried. In a week or two, the dry rind attains a brown colour and

develops a characteristic acrid taste. The blend of this taste with the acid components imparts an exceptional flavour to the dried rind. Separated fruit rind is first sun-dried and then either smoke-dried or oven-dried at 70-80ºC. To increase the storage life and to impart softness, mix the dried rind with common salt @ 150 g and coconut oil @ 50 ml per kg of dried rind.



Fresh Malabar tamarind fruits



Dried Malabar tamarind rinds



Malabar tamarind fruits in the drier

Chapter - 7
ALLSPICE

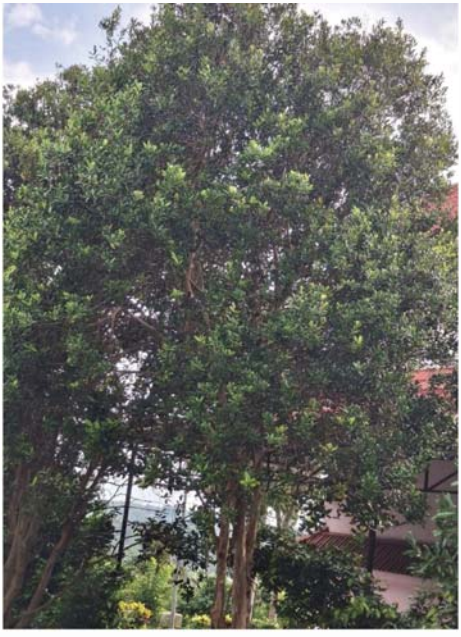
Scientific name: *Pimenta diocia* (L.) Merr.
Family: Myrtaceae

Introduction

Allspice (Jamaican pepper) is a tropical evergreen, dioecious tree spice, indigenous to the West Indies and the Central American region. Dried berries of allspice are an important spice used mainly in the Caribbean, the Americas, and European countries. The name 'allspice' was coined in 1621 in England because of the belief that this spice has a combined flavour of several spices, notably clove, pepper, cinnamon, and nutmeg.The allspice tree grows to a height of 8 to 10 meters, and the aromatic leaves are also used as spices in culinary preparations. The flowers are tiny and light in colour, and they have a strong scent. Allspice was in use in the West Indies from very ancient times as a spice and a medicinal plant. The Portuguese later introduced it to Indonesia and the Philippines. The tree is also grown in many African and Southeast Asian countries, like India and Sri Lanka. Jamaica is the largest producer and exporter of allspice. In India, it is found in the Mahendragiri hills of Nagercoil area, Ambalavayal in Kerala, and Kallar and Burliar of the Nilgiris. The major volatile compounds present in allspice are eugenol (39.9 %), myrcene (22.2%), chavicol (8.2%), and limonene (7%). The highest concentration of eugenol was recorded in fruit stalks (57%), followed by leaves (52%) and berries (39.9%).



***P. dioica* (Allspice) tree**



***P. racemosa* (Bay rum) tree**

Morphological, anatomical, biochemical, and molecular studies at ICAR-IISR, Kozhikode, have revealed that the species being maintained as all spice at IISR germplasm and also cultivated throughout the country is *P. racemosa* (Bay rum tree), not *P. dioica*. A survey was conducted to locate the allspice in India and the true allspice (*P. dioica*), and found it in an abandoned plantation in Bonacaud, Thiruvananthapuram district of Kerala. Two accessions of the same have been collected and added to the germplasm repository.



***P. dioica* (Allspice)**



***P. racemosa* (Bay rum)**

Major types of allspice

Jamaican type: This is the most famous and globally recognized allspice type. The essential oil content of Jamaican allspice is always near 4 %, while the allspice from other regions has 2-4.5 %. It belongs to a unique strain different from those found in the Caribbean and Central America.

Guatemalan type: They are known as *Pimienta Gorda* (fat pepper in Spanish). They are high-quality allspice with high essential oil content.

Mexican type: The Mexican allspice berries are larger in size and darker in color than the ordinary chocolate brown shade of other sources. The berries have less sweetness and are mellow. They usually have 2.35 per cent of the essential oils.

Honduran type: The berries are bigger than the Jamaican type and the fruits resemble Guatemalan allspice in appearance. The berries have 2.35 per cent of essential oil.

Production Technology of Allspice

Climate and soil

Allspice grows from sea level to 1000 m above altitude, but the tree flowers and fruits only at a high elevation (>800m). The performance of allspice in planes is poor. Annual rainfall of 100 to 200 cm or more, with a mean monthly temperature up to 27 °C, is the best for the growth of this tree. Laterite soils and soils with good organic matter are good for the crop. A pH of 5.5 to 6.5 is suitable for the proper growth of allspice trees.

Propagation

Seed propagation

The most typical technique of allspice propagation is seed propagation. Seeds are selected from the well-ripened fruits of highly yielding regular regular bearing mother trees. The seeds are extracted after being soaked in water overnight. The seeds are dried in the shade and sown immediately in nursery beds or plastic bags. Mulching with dried leaves, straw, paper, and moist sacks helps to speed germination in nursery beds. The beds are irrigated lightly every day. Germination occurs after 15 days.



Allspice seedlings

Vegetative propagation

It is also possible to propagate the crop by vegetative propagation methods such as bottle grafting, budding, approach grafting, air layering, and top working.

Air layering: January was the best season for air layering, which recorded 100 percent success in Konkan conditions. Air layers treated with a combination of NAA 4000 ppm + IBA 4000 ppm help in rooting.

Softwood cuttings: IBA 1000–1200 ppm treatments increase the rooting percentage in softwood cuttings.

Stooling (Mount layering): Detopping of allspice trees and treating the newly sprouted shoots with IBA 500 ppm was effective for the successful production of adventitious roots.

Approach grafting: Approach grafting with different rootstocks, namely, *S. caryophyllum*, *S. cumini,* and *P. dioica,* gives 80% success.

Top working: Male trees are also top-worked and converted to productive trees.

Planting

Six to ten months old seedlings with 25 to 30 cm can be selected for field planting. The seedlings are planted with a 6 m × 6 m spacing. Closer spacing is advised if the soil is infertile. Planting of three seedlings per 60 cm^3 pits is usually practiced. A 10:1 female: male ratio is kept in every plantation for successful cropping. The plants are stalked and thatched in the initial days. Regular irrigation and weeding have to be practiced in the field.

Intercropping

Allspice is a common intercrop in coconut and arecanut based multi cropping systems of the

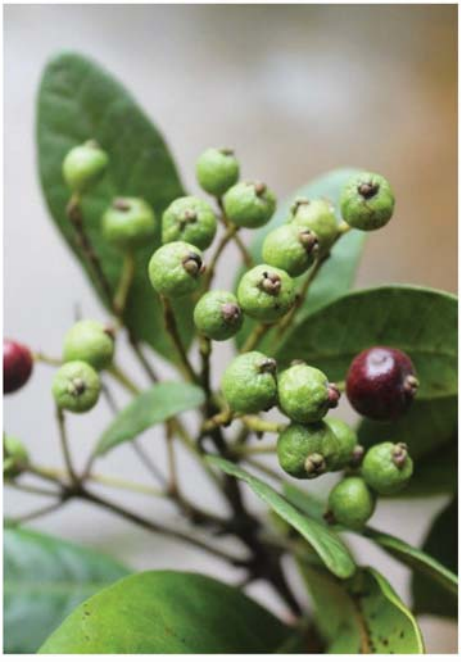
west coast Indian plains and the Western Ghat regions. It is well-suited to the coffee-based plantation systems also.

Manuring

Application of 10 kg of compost along with 20:18:50 g of N, P_2O_5, and K_2O during the first year and 20 kg of compost with 40:36:100 g of N, P_2O_5, and K_2O during the second is recommended. After 15 years, the dose is gradually increased to 50 kg of compost and 300:250:750 g of N, P_2O_5, and K_2O per tree. Fertilizers are applied in two split doses during May–June and September–October in trenches made around 1-1.5 m away from the base of the plant.

Regulation of flowering and fruit set

Generally, allspice does not flower and set seed in all agro-climatic situations. However, the tree responds well to the flower induction treatments. The tree basins can be drenched with Cultar (Paclobutrazol) at low concentrations to improve flowering and seed set. Application of 1 g ai paclobutrazol during August induces maximum flowering in Kerala. Drenching the tree basin with 1 g ai of paclobutrazol, followed by spraying with IAA 25 ppm + BAP 5 ppm, helps in attaining large-sized berries.



Allspice berries

Plant protection

Diseases

Leaf rot

Leaf rot caused by *Cylindrocladium quinquiseptatum* results in heavy defoliation. The necrosis starts from the margins of the leaf lamina and extends inwards, leading to leaf rot. Occasionally, necrotic spots appear on the leaf lamina, and the central portion drops off, leaving a shot hole. Leaf rot is often combined with dark brown leaf spots caused by *Pestalotiopsis* sp. The fruiting bodies of the fungus are generally noticed on the upper surface of the affected leaves. The combined infection leads to extensive defoliation during July-September. Spraying the foliage with Bordeaux mixture 1% is recommended to control this disease.

Insect pests

Tea mosquito bug

Tea mosquito bug (*Helopeltis antonii*) infests the young shoots and leaves, resulting in the drying of the tender shoots and formation of necrotic spots on the leaves. Spraying with

systemic insecticides will control the pest.

Scale insects

Scale insect (*Odonaspis pimentae* and *Lalveia primitiva* var. pimentae) causes foliar damage to the allspice trees.

Other insect pests of minor importance are white ants, white fly (*Aleurodicus pimentae*), red-banded thrips (*Selenothrips rubrocinctus*), bagworm caterpillars (*Oeceticus abboth*), and feeder beetle (*Prepodes* and *Pachanaeus* sp.). The trees are often affected by the termite attack, too.

Harvesting and yield

Allspice seedlings take around 5-6 years to bear under good management conditions and 12 years under poor management. Flowering time in India is from March to June. From flowering, 3-4 months are taken for fruit maturity. Fully developed greenish berries are harvested for the preparation of the commercial spice. Under good management, a well-grown tree yields 20-25 kg of dry berries per year. The dry recovery ranged from 25.5 to 32.3%.

Allspice products

Berry oil

The total yield of oil from berries varies from 3.3 to 4.5 per cent, with a eugenol content of 65-70 per cent. There is a good market for berry oil, and it is being used widely in the food industry, perfumery, and pharmacy. Oil is also used as a carminative and stimulant.

Leaf and wood oil

Oil is extracted from the leaf, and it is used as a cheap substitute for expensive berry oil. The yield of leaf oil is about 0.7 to 2.9 per cent. Wood is used for making walking sticks, umbrella handles, etc.

Pimenta leaf oil

Pimenta leaf oil, which is produced by steam distilling dried pimenta leaves, has an oil content between 1.8 and 3.8 percent. The leaf oil possesses eugenol as its primary ingredient (58–62%), along with myrcene (14–17%) and 1,8–cineole (6.6–8.4%), however, it has a weaker aroma and flavour than berry oil. Additionally, the leaves contain tannin that can be utilized for tanning.

Chapter - 8
CURRY LEAF

Scientific name: *Murraya koenigii* Spreng
Family: Rutaceae

Introduction

Curry leaf plays an important role as a condiment in the culinary preparation of South Indian dishes. Curry leaf plant is originated in India and its adjoining regions such as Sri Lanka, Bangladesh, and Nepal. This plant is considered an essential component of homestead gardens and has recently gained importance as a commercial crop. It is cultivated on a field scale in Coimbatore, Erode, Madurai, Salem, and Trichy districts of Tamil Nadu and in Dharward, Belgaum, and Uttara Kannada of Karnataka State.Monoterpenoids, sesquiterpenoids, and their oxygenated derivatives provide the unique properties of curry leaves. They are rich in antioxidants and have anti-inflammatory, anti-cancerous, and anti- diabetic properties. They are used in Ayurvedic and Unani medicines. The leaves have a well-accepted role in the traditional hair care products.



Curry leaf plant

Curry leaves are broadly classified into three morphotypes.

1. Gamthi (GM): Slow-growing genotypes with dark brown, small, and thick leaves having serrated edges are Brown/Gamthi (GM). It is the most fragrant type of curry leaf.
2. Regular (RE): These genotypes grow very fast, sometimes turn into small to medium-sized trees, and produce exstipulate, bipinnately compound dark leaves with long reticulate venation are referred to as the regular type (RE). this type is available throughout India.
3. Dwarf (DF): These are moderately growing genotypes with spreading branches to form a bushy habit, and their leaves are light green, exstipulate, bipinnately compound with long reticulate venation, and have a unique aroma.

Another classification of curry leaf is the 'broad-leaved type' and 'small leaves type'. Small-leaved types are more fragrant types and are used in the oil extraction industry. Broad-leaved types are used as vegetable or leaf spice.

Curry leaves have several chemotypes based on the chemical composition of the leaves. The chemotypes of Western Ghats were dominated by monoterpenes such as sabinene (6.90-40.59%), β-phellandrene (1.39-45.89%), and α-pinene (1.93-63.66%). In the Northern part of India, the chemotypes have a higher concentration of β-pinene, α-pinene, β-caryophyllene, and β-phellandrene.

Varieties

There is a famous local variety 'Senkampu' with shiny, leathery leaves and good fragrance. This variety is a preferred variety of farmers in Tamil Nadu. University of Agricultural Science, Dharwad has recently released two cultivars,*viz*., DWD-1 and DWD-2, which have an oil content of 5.22 and 4.09% respectively. Both varieties have a strong aroma. DWA-1 (Suvasini) is a clonal selection from root suckers, and the plant has dark green, highly aromatic, shining leaves. It is sensitive to low temperatures in winter, and hence, bud burst is poor during winter. The leaves have an oil content of 5.22%.



Green and red types of curry leaves

Production Technology of Curry leaf

Climate and soil

It does not require a specific climate and can come up in a dry climate too. The ideal climate is 26 to 37 °C. In places where the minimum temperature goes below 13ºC, the growth of the shoot will be slightly affected. Its growth was observed at an altitude of 1500-2000 m above MSL. Though it can be cultivated in most soil types, it comes up well in light-textured red soils.



Curry leaf seeds

Propagation

Curry leaves are propagated by seeds and cuttings. The well-ripened curry leaf seeds are collected from the healthy and high-yielding mother plants and sown in polybags or raised beds. The pulp should be removed before sowing the seeds. The seeds

Field preparation and planting

The main field should be ploughed repeatedly. Normally, a spacing of 90 to 120 cm is followed on either side. KAU, Thrissur recommends 4 m × 4 m spacing to accommodate 625 plants per hectare. High-density planting (0.75 m on either side) is also followed. One month before planting, pits of 30 × 30 × 30 cm dimensions are dug out and are filled with topsoil mixed with well-decomposed farmyard manure at the time of planting. Healthy seedlings are planted in the centre of the pits. Then, long furrows are formed connecting all the pits to facilitate easy irrigation.The seedlings are irrigated once in five to seven days for up to three years and once in 15 days afterwards.Under commercial scale, drip irrigation is being practiced in certain parts of the Coimbatore district. This being a perennial crop, the field should be kept free of weeds. Normally, curry leaf plants are not fertilized with inorganic sources by the farmers. However, for better growth and yield, each plant may be fertilized with 20 kg of farmyard manure besides 150:25:50 g of NPK per year. Poultry manure at 12 t/ha and a foliar spray of panchagavya (3%) increase leaf yield.Application of 10 kg FYM and 60:80:40 NPK is recommended for Kerala conditions.

Aftercare

Curry leaf plants should be maintained at a height not exceeding 1.20 meters. To promote branching, they should be pruned to about 15 cm above ground level when they are around six months old. This encourages the growth of new shoots, allowing for 2–3 harvests before another pruning is needed at the same height. By following this cycle, it's possible to achieve 3–4 harvests annually. With proper care, the plants can remain productive for 15 to 20 years. A well-maintained plantation can yield between 8 to 10 tonnes of leaves each year. However, pests like mealy bugs, aphids, and leaf rollers commonly affect curry leaf plants. Since the leaves are directly used in cooking, pest control should involve safe methods, such as using neem-based products or other non-toxic chemicals.

Plant protection

Aphids attack the plant when the plants are in the vegetative stage, and spraying of dimethoate at the rate of 2 ml/L of water is recommended. Leaves from such sprayed plants should not be harvested for 10 days, lest residual toxicity of the pesticide. Citrus butterfly causes serious damage to the crop. Manual destruction of the larvae and spray of Malathion 1 ml/ litre is recommended to manage this insect. Psyllid bugs and scales can be controlled by spraying Dimethoate @ 1 ml/lit. Leaf spots can be managed by spraying carbendazim at the rate of one gram per litre.

Harvesting

In curry leaf farming, the first harvest typically occurs at the end of the first year, with subsequent yields increasing as the plants mature. The expected yield from one hectare varies with the age of the plantation. In the first year, the yield is around 400 kg/ha, while in the second and third years, it ranges from 2000 to 2200 kg/ha. By the fourth year, the yield increases to 2500 kg/ha, and from the fifth year onwards, it ranges from 3500 to 5000 kg/ha.

It's important to note that the plantation can be maintained for 20 to 25 years, depending on the management practices followed. Harvesting techniques involve carefully plucking the mature leaves without damaging the plant. Proper timing and gentle handling during harvesting are crucial to ensuring the sustained growth and productivity of the curry leaf plants.

Post-harvest management

Post-harvest processing of curry leaves is essential to maintain their flavor and quality. Freshly harvested leaves can be used immediately in various culinary applications, such as flavoring fish and beef stews, adding depth to chutneys and pickles, and featuring in yogurt drinks. However, if not used immediately, there are several methods for preserving the leaves. One approach is freezing the leaves for later use, while another involves drying the leaves and crushing them for use.

When drying the leaves, it's important to store them in a glass jar away from light and use them within a couple of months to retain their flavor. Additionally, the leaves can be used in various recipes, such as relishes, and as a seasoning in Indian dishes. By employing these post-harvest processing techniques, the flavor and aroma of curry leaves can be preserved, ensuring their availability for culinary use over an extended period.

Value addition

Value added products such as dried curry leaf, curry leaf powder, curry leaf oil, curry leaf extract, infused vinegars and oils and spice blends, and seasonings are prepared from curry leaves.

Chapter - 9
TAMARIND

Scientific name: *Tamarindus indica* L.
Family: Fabaceae

Introduction

Tamarind is an important souring agent, grown in semi-arid tropical conditions suited for dry land horticulture. It originated in East Africa and reached India through Ethiopian traders. The tree has a strong trunk and pinnately compound leaves with 10-20 pairs of small leaflets. The flowers are small, scented, and attractive with yellow and red colours. Pods are flattened and vary considerably in size and shape. When ripe, the fruits are stiff and brittle. The ripe fruit (pod) is widely used as a souring agent in curries. The fruit contains sweet-acidic pulp (55%), seed (33%), and fibre (12%).Tamarind has various medicinal and industrial uses. Its pulp is used for digestive and therapeutic purposes, treating fevers, sore throats, and imbalances of vata, pitta, and kapha. Tamarind kernel powder (TKP) is valuable in the textile and leather industries and as a pectin substitute in food. The seeds provide carbohydrates for paper and jute products and yield oil used in paints and varnishes. Tamarind wood is used for tools and agricultural equipment, while other parts of the plant also have medicinal uses. Additionally, the plant serves as an effective windbreak. This tree is cultivated in tropical regions of Africa, Asia, and South America. India recorded a total area of 39,000 hectares and a production of 152,000 metric tons in 2023–2024(NHB, 2023). The major growing regions are Dharmpuri, Kamrajar, and Kanyakumari in Tamil Nadu; Chintamani and Srinivaspur regions of Karnataka; Sholapur, Osmanabad, Satara, Sangli, Ahmednagar, Nasik, and Aurangabad districts in Maharashtra; and Bastar in Chhattisgarh.It is also found in Kerala, Odisha and Madhya Pradesh, and Andhra Pradesh. Based on pulp quality, tamarinds are classified as brown type, red type, and sweet type. The biochemical characteristics of these types are given in Table 1.

Table 1: Biochemical constituents of different types of tamarind

Parameters	Brown type (acidic pulp)	Red pulp type	Sweet pulp type
TSS (%)	78-86	82-85	81-83
Titratable acidity (%)	8.74 -16.91	10.26-17.10	6.84 - 7.51
TSS: acid ratio	5.02 -9.50	4.91-2.28	11.05-11.84

Source: Karale (2001)



Varieties

The existing cultivated types of tamarind are all of seedling origin, being highly heterozygous; there are a few recognized varieties based on the pulp colour of the fruit. The local varieties can be classified as 'brown sour types' and 'reddish sweet types'. The popular types among the local types are Bangalore Tamarind, Tumkur Tamarind, Hosur Tamarind, Krishnagiri Tamarind, Natham Tamarind, Nagarkoil Tamarind, Villupuram Tamarind, Ranchi Tamarind, etc.

Table 2. Improved tamarind varieties

Name of variety	Year of release	Institute	Characteristics
Prathistan	1985	Fruit Research Station, Aurangabad, Marathwada Agricultural University, Parbhani	This is an improved sweet pulped high-yielding variety of tamarind released from Marathwada Agricultural University, Parbhani.
PKM-1	1992	Tamil Nadu Agricultural University, Coimbatore	A clonal selection from the gene bank, it is an early variety yielding 263 kg pods per tree with pulp content of 39 per cent.
Ajintha	2006	Fruit Research Station, Aurangabad- Marathwada Agricultural University, Parbhani	Sweet tamarind. Regular bearer. Acidity-5.09 %
Goma Prateek	2013	ICAR, CHES, Godhra, Gujarat	It is an early variety with a spreading growth habit, a

			regular bearer, and suitable for processing.
Shiwai	2018	Fruit Research Station, Aurangabad- Marathwada Agricultural University, Parbhani	Regular bearer, TSS- 41.6 %, Acidity- 31.2 %
Urigam		Tamil Nadu Agricultural University, Coimbatore	Red tamarind with 20 tonnes of fruit/year yield. The average length of the fruit is 30 cm, and the width is 6.25 cm.
No. 263	1987	Fruit Research Station, Aurangabad- Marathwada Agricultural University, Parbhani	It is a regular bearing type, The yield is 6-10 quintal fruits/ tree. The fruitshave pinkish and light-yellow pulp, and 1 8-19%acidity. Fruits are large. On average, 45 fruits weigh 1 kg
Yogeshwari	1997	Taluk Seed Farm, Ambajogai (Beed) in Maharashtra	The fruits are large and have red and sour-sweet red pulp with 6-7% acidity
DTS 1	1997	College of Horticulture, Arabhavi- University of Agricultural Sciences, Dharwad	The pods are straight, having a semi-curve shape, 23.6 cm length, 3 cm width, 19.5 g weight, 51% pulp, and 13.6% acidity. It is a late variety and takes 310 days from fruit set to maturity.
DTS 2	1997	College of Horticulture, Arabhavi- University of Agricultural Sciences, Dharwad	The pods are straight, having a semi-curved shape, 17.6 cm length, 2.6 cm width, 18 g weight, 53% pulp, and 12.2% acidity. It is an early variety, and the pods mature in 280 days after fruit set
PKM-2 (Red Tamarind)	2024	Tamil Nadu Agricultural University, Coimbatore	Red-colored pulp, 217 kg per tree per year (21.78 t/ha)yield, pods are bold, lengthy, fleshy, and medium length (47-55 cm)



Prathistan



Ajintha



Shiwai



Goma Prateek

Production Technology of Tamarind

Climate and Soil

Tamarind can thrive in tropical and subtropical climates except in places experiencing frost. It thrives in sodic and saline soils, ravines, and degraded land, but silty and clay soils are not suitable. It cannot withstand water logging and is susceptible to ants and termites. The ideal pH range for this tree is 5.5 to 6.8. It requires 500-1500 mm of rainfall annually, but can withstand heavy rain situations too. A wide temperature range from -3°C to 47 °C can be thrived by this tree. The heavy branches and deep root system make it a hurricane-resistant tree. It has grown up to 2000 m above MSL.

Propagation

Seed propagation

Tamarind is generally propagated through seeds. Seeds are extracted from the fully mature, brown, brittle pods after shade drying. The seeds can be stored for up to six months in gunny bags. Seeds can be raised in polythene bags or in beds. Seeds are sown during March- April. Germination usually takes two weeks, but can be improved by water soaking (24-48 hrs), mechanical, or acid scarification (50 % acid for 1 hr) of the seeds. A well-established tree can yield up to 80 kg of seeds per tree. For a hectare of plantation, around 20 kg of seeds are required. One-year-old seedlings will be ready for the main field planting.

Vegetative propagation

Vegetative propagation of tamarind can be done by root and stem cuttings, air layering, grafting, or budding. Improved varieties are usually propagated by these methods, even though the success rate is low. October is the best time for stem cuttings. Approach grafting is more successful than normal grafting. Wood grating in 8-month-old seedlings during March- April is successful. Vegetative propagation through whip cum the inarching method gives more than 90 percent success. Patch budding on 9-month-old saplings also gives more than 90 percent success. Air layering with 4000 ppm IBA improved the success percentage in Tamarind. For shield budding, about 25-30 cm tall seedlings having stems of pencil thickness can be budded using etiolated, well-mature brownish buds from the current season's growth in 3cm long size shields.

Planting

Tamarind seedlings may be planted from June to November in South India, and a spacing of 10 × 10 m may be adopted to accommodate 100 plants per ha. A triangular or square system of planting with 8-15 m plants is another good option for this crop. For a commercial plantation, 10 m × 5 m is also ideal. A pit size of 1m ×1m ×1m may be dug for planting and is refilled with topsoil and farmyard manure for good establishment of the saplings. Grafts can be planted in a 6m × 6m spacing.

Aftercare

Regular watering should be given till the plants establish well in the field. As it is a dry land crop, it is not manured generally. But it responds well to organic manure. In the case of grafts or buddings, the rootstock sprouts should be periodically removed. Intercrops may be raised in the alley spacing up to 4 or 5 years. Application of 25 kg FYM, 200:150:250 g NPK per year in two split doses is recommended for tamarind. The trees have to be pruned regularly to maintain their size and shape. Pruning enhances the production of fruiting branches, too. Peak flowering season is May-June. Only 3-5 % of flowers set fruit, and the rest fall off. It is a cross-pollinated crop; hence, the lack of pollinators or poor crop nutrition may be the reason for flower drop. The tree is an alternate bearer that can be managed by pruning or growth regulator application.



Tamarind fruits

Harvesting and Yield

The seedlings take 8 to 10 years to fruit, and the grafts take 4 to 5 years to fruit. It is not uncommon for trees that are more than 100 years old to yield normally. The pulp colour varies from greenish brown to dark brown when ripe. At maturity, the pericarp shell becomes brittle, and the pulp detaches from the outer pericarp, and a rattling sound when shaken. Fruits are harvested from December to April. Traditionally, the crop is harvested manually by climbing strong branches. Nowadays, mechanical and hydraulic tree shakers are available to harvest these types of trees. Though the graft starts yielding from the fourth or fifth years, a good yield of 250 kg per tree is obtained from the ninth year in the PKM-1 variety.

Plant Protection

Shothole borers, toy beetles, caterpillars, bagworms, mealy bugs, and scale insects attack tamarind. Among them, mealy bugs and scales often cause serious concern, especially in the nursery, and can be controlled by spraying dimethoate 30 EC (2 ml/L).Powdery mildewinfects the leaves and can be controlled by spraying 0.1% Karathane. At the nursery stage, management of seedling blight caused by *Macrophominaphaseolina* and *Rhizoctoniasolani* is important.

Processing

The harvested fruits are dried, dehulled, and deseeded. Fruits are sundried mostly and dehulled using wood. TNAU, Coimbatore, has invented a tamarind dehuller with a 1 00kg/ hr dehulling rate and 94% dehulling capacity. A dehuller with 500 kg capacity was developed by the PHT centre of GKVK, Bengaluru.The seeds are removed by hand beating or piercing. Mechanically, the seeds can be removed by the hammer-type tamarind deseederdeveloped by TNAU, Coimbatore. The dried pulp is stored in bundles or cakes, sometimes mixed with rock salt and stored with 20 % moisture in polythene barrels, bags, or tins. Tamarind seeds are roasted in a horizontal cyclone furnace at 220 °C and decorticated mechanically and sorted based on their external layer (Testa) and internal tone (creamy white).

Value added products

Several value-added products can be prepared from Tamarind. The sweet pulp is mixed with sugar and crushed to make candies and toffees. R.T.S., syrup and concentrates, and sweet beverages are made by mixing the pulp with sugar and water. Pulp powder, pickles, jam, and fruit leather are also made from tamarind pulp.

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