ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research

Vol. 17, Issue, 01, pp.31603-31625, January, 2025
DOI: https://doi.org/10.24941/ijcr.48297.01.2025

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

REVEIW ARTICLE

ORIGIN, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY, BREEDING AND CULTIVATION OF CLOVE

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ARTICLE INFO

Article History:
Received 20th October, 2024
Received in revised form
17th November, 2024
Accepted 24th December, 2024
Published online 31st January, 2025

Key Words:
Clove, Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding

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ABSTRACT

Clove belongs to the family *Myrtaceae,* genus *Syzygium* and species *Syzygium aromaticum* . Indian name in differet languages are in Hindi : Laung, Bengali : Lawang, Gujarati : Lavang, Kannada : Lavanga, Malayalam : Grambu, Marathi : Luvang, Oriya : Labang, Punjabi : Laung, Sanskrit : Lavanga, Tamil : Kirambu, Lavangam, Telugu : Lavangalu, Urdu : Laung, Kashmiri—Raung. Foreign name in different languages are in English**:** Clove**,** Arabic : Kabsh ,Qarunfil, Chinese : Ding xiang French : Clou de girofle, Indonesian : Cengkeh, German : Nelke. The word *clove*, first used in English in the 15th century, derives via Middle English *clow of gilofer*, Anglo-French *clowes de gilofre* and Old French *clou de girofle*, from the Latin word *clavus* "nail". The related English word *gillyflower*, originally meaning "clove", derives via said Old French *girofle* and Latin *caryophyllon*, from the Greek *karyophyllon* "clove", literally "nut leaf". Cloves are the dried, unopened, nail-shaped flower buds of the evergreen tree *Syzygium aromaticum*. The name "clove" derives from the Latin word for nail, *clavus* (because of its shape). Clove is one of the most valuable spices that has been used for centuries as food preservative and for many medicinal purposes. Clove is native of Indonesia but nowadays is cultured in several parts of the world including Brazil in the state of Bahia. This plant represents one of the richest sources of phenolic compounds such as eugenol, eugenol acetate and gallic acid and posses great potential for pharmaceutical, cosmetic, food and agricultural applications. Spices as clove, oregano, mint, thyme and cinnamon, have been employed for centuries as food preservatives and as medicinal plants mainly due to its antioxidant and antimicrobial activities. Nowadays, many reports confirm the antibacterial, antifungal, antiviral and anticarcinogenic properties of spice plants. Clove in particular has attracted the attention due to the potent antioxidant and antimicrobial activities standing out among the other spices. *Syzygium aromaticum* (**S.** *aromaticum*) (synonym: *Eugenia cariophylata*) commonly known as clove, is an median size tree (8-12 m) from the Mirtaceae family native from the Maluku islands in east Indonesia. For centuries the trade of clove and the search of this valuable spice stimulated the economic development of this Asiatic region. The clove tree is frequently cultivated in coastal areas at maximum altitudes of 200 m above the sea level. The production of flower buds, which is the commercialized part of this tree, starts after 4 years of plantation. Flower buds are collected in the maturation phase before flowering. The collection could be done manually or chemically-mediated using a natural phytohormone which liberates ethylene in the vegetal tissue, producing precocious maturation. Nowadays, the larger producer countries of clove are Indonesia, India, Malaysia, Sri Lanka, Madagascar and Tanzania specially the Zanzibar island. In Brazil, clove is cultured in the northeast region, in the state of Bahia in the regions of Valença, Ituberá, Taperoá, Camamu and Nilo Peçanha, where approximately 8 000 hectares are cultivated, producing near 2 500 tons per year.

Citation: K.R.M. Swamy. 2025. "Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding and Cultivation of Clove*". International Journal of Current Research*, 17, (01), 31603-31625.

INTRODUCTION

Clove belongs to the family *Myrtaceae,* genus *Syzygium* and species *Syzygium aromaticum* (Khan, 2022; Indianspices, 2024; NEW, 2024). Indian name in differet languages are in Hindi : Laung, Bengali : Lawang, Gujarati : Lavang, Kannada : Lavanga, Malayalam : Grambu, Marathi : Luvang, Oriya : Labang, Punjabi : Laung, Sanskrit : Lavanga, Tamil : Kirambu, Lavangam, Telugu : Lavangalu, Urdu : Laung, Kashmiri—Raung (Indianspices, 2024; Nikita, 2024). Common names are Clovos, Caryophyllus, Lavang, Laung, Grambu, Grampus, Krambu (Yadav *et al*., 2021). Foreign name in different languages are in English: Clavo**,** Arabic : Kabsh ,Qarunfil, Chinese : Ding xiang French : Clou de girofle, Indonesian : Cengkeh, German : Nelke,

Nepalese Lwaang; **Spanish** Clavo, Clavo de olor; **Korean** Jeonghyang; **Turkish** Carenfil; **Greek** Garifalo;; **(**Khan, 2022; (Indianspices, 2024).

The word "Clove" is derived from the French and English words "Clou" and "Clout," both of which mean "nail," due to the resemblance of the Clove tree's flower bud to a broad-headed nail. When 1.5 to 2 cm long, cloves are harvested. They are made up of four unopened petals that form a small ball in the centre, a long calyx that ends in four spreading sepals, and a long calyx that extends to the ground (Reddappa *et al*., 2022). The botanical genus name *Syzygium* derives from Greek *syn* together, with and *zygon* yoke (from *zeugnynai* join). The name refers to the petals, which are merged (joined) into a cap-like structure. Being fused, they cannot open at the onset of flowering but seperate from the plant and fall to the ground; the showy part of the flower is made entirely of the anthers. Another group of names for clove are found in India, *e. g.*, Pashto and Urdu *lung* Kashmiri *rong* , Hindi and Punjabi *laung* , Gujarati *laving* , Bengali *labango* and Telugu *lavangalu* . These names have no discernible etymlogy in the Indo–Aryan (or Dravdic) languages and are in all likelihood loans; they might be distantly related to the group of *karyophyllon* and *kanplu* (Gernot, 2024). The word *clove*, first used in English in the 15th century, derives via Middle English *clow of gilofer*, Anglo-French *clowes de gilofre* and Old French *clou de girofle*, from the Latin word *clavus* "nail". The related English word *gillyflower*, originally meaning "clove", derives via said Old French *girofle* and Latin *caryophyllon*, from the Greek *karyophyllon* "clove", literally "nut leaf" (Wikiwand, 2024; Wikipedia, 2024a). Cloves are the dried, unopened, nail-shaped flower buds of the evergreen tree *Syzygium aromaticum*. The name “clove” derives from the Latin word for nail, *clavus* (because of its shape). Clove goes by many names in different languages such as *ding xiang* (Mandarin Chinese), *laung* (Hindi), *clavo* (Spanish), *clou de girofle* (French), *chiodo di garofano* (Italian), *qurnafl* (Arabic), and *nelke* (German) (MCSI, 2024).

Clove is one of the most valuable spices that has been used for centuries as food preservative and for many medicinal purposes (Cortés-Rojas *et al*., 2014). Clove is native of Indonesia but nowadays is cultured in several parts of the world including Brazil in the state of Bahia (Cortés-Rojas *et al*., 2014). This plant represents one of the richest sources of phenolic compounds such as eugenol, eugenol acetate and gallic acid and posses great potential for pharmaceutical, cosmetic, food and agricultural applications (Cortés-Rojas *et al*., 2014). Spices as clove, oregano, mint, thyme and cinnamon, have been employed for centuries as food preservatives and as medicinal plants mainly due to its antioxidant and antimicrobial activities. Nowadays, many reports confirm the antibacterial, antifungal, antiviral and anticarcinogenic properties of spice plants. Clove in particular has attracted the attention due to the potent antioxidant and antimicrobial activities standing out among the other spices (Cortés-Rojas *et al*., 2014). *Syzygium aromaticum* (*S. aromaticum*) (synonym: *Eugenia cariophylata*) commonly known as clove, is an median size tree (8-12 m) from the Mirtaceae family native from the Maluku islands in east Indonesia. For centuries the trade of clove and the search of this valuable spice stimulated the economic development of this Asiatic region (Cortés-Rojas *et al*., 2014). The clove tree is frequently cultivated in coastal areas at maximum altitudes of 200 m above the sea level. The production of flower buds, which is the commercialized part of this tree, starts after 4 years of plantation (Cortés-Rojas *et al*., 2014). Flower buds are collected in the maturation phase before flowering. The collection could be done manually or chemically-mediated using a natural phytohormone which liberates ethylene in the vegetal tissue, producing precocious maturation (Cortés-Rojas *et al.,* 2014). Nowadays, the larger producer countries of clove are Indonesia, India, Malaysia, Sri Lanka, Madagascar and Tanzania specially the Zanzibar island (Cortés-Rojas *et al*., 2014). In Brazil, clove is cultured in the northeast region, in the state of Bahia in the regions of Valença, Ituberá, Taperoá, Camamu and Nilo Peçanha, where approximately 8 000 hectares are cultivated, producing near 2 500 tons per year (Cortés-Rojas *et al.,* 2014).

Cloves are native to the eastern Indonesian islands referred to as the Moluccas including Ternate, Tidor, Motir, Makian and Batjan. In an extraordinary archaelogical discovery in Syria (ancient Mesopotamia), the remains of cloves were found in a domestic kitchen site, dating back to around 1700BC (Hemphil, 2018). One can scarcely imagine the journey those cloves made from the Moluccas by sea and land and the number of hands they would have passed through on their way to their final destination (Hemphil, 2018). Cloves are believed to have been introduced to China during the Han dynasty (206 BC–AD 220) (Hemphil, 2018). They were probably the first form of breath freshener, as it was recorded that courtiers held cloves in their mouths to sweeten the breath when addressing the emperor (Hemphil, 2018). Cloves were a caravan import known to the Romans and were brought into Alexandria in the second century AD. By the fourth century AD this spice was well known around the Mediterranean and by the eighth century throughout Europe (Hemphil, 2018). The Arabs, who traded cloves from centres in India and Ceylon, kept the origins of their precious cargo a closely guarded secret (Hemphil, 2018). Cloves were found to have a natural antiseptic effect, and the pungent oil gave quick relief from toothache. By the 13th century, people were making pomanders (apples or oranges studded with cloves) to carry on them to ward off the plague (Hemphil, 2018). Columbus sailed west in search of these spice islands but instead found the West Indies. Five years later, Vasco da Gama sailed around the Cape of Good Hope to India on the same search, and obtained cloves in Calicut (Calcutta), a trading centre that had probably brought the cloves from the East Indies (Hemphil, 2018). The Portuguese monopoly in the Moluccas was broken by the Dutch, who expelled them in 1605 and ruthlessly maintained control for another 200 years, using cruel and gruesome measures. Part of the Dutch strategy to maintain high prices for cloves was to restrict by law the cultivation of cloves to the island of Amboina, uprooting and burning trees growing on other islands (Hemphil, 2018). The death penalty was imposed on anyone cultivating or selling the spice anywhere except Amboina (Hemphil, 2018). With varying degrees of success, clove plantations were established on Réunion, Martinique, Haiti and in the Seychelles (Hemphil, 2018).

Syzygium aromaticum (L.) , known as clove, is an Indonesian native plant especially from the Maluku islands (Hariyadi *et al*., 2020). As part of the center of clove origin in the Maluku Islands, Indonesia, Ambon Island has many typical clove germplasm including aromatic cloves varieties (Hariyadi *et al.,* 2020). *S. aromaticum* var. *Tuni* is typically from Maluku which is widely cultivated compare to *S. aromaticum* var. *Zanzibar*. The two types of clove varieties were morphologically different but still in the

aromatic clove Group (Hariyadi *et al.,* 2020). To date, dried clove buds are the main portion of the plant to be utilized, but the extraction of essential oils from these two varieties from Ambon island is still limited (Hariyadi *et al*., 2020). Clove oil is produced by plants via secondary metabolic pathways, can be extracted from buds (bud oil), flower stalks (stem oil), and leaves (leaf oil) through hydrodistillation, steam distillation or dry distillation (Hariyadi *et al*., 2020). Maluku Province as the center of origin of clove plants has a high diversity of clove germplasm. The cloves of Tuni and Zanzibar varieties are part of the clove germplasm in Maluku and are widely cultivated by farmers (Hariyadi *et al*., 2020). Both clove varieties are classified as cultivated cloves from the aromatic group (Hariyadi *et al.,* 2020). *S. aromaticum* from Bangladesh found that bud oil was composed of eugenol (60–90%), eugenyl acetate, caryophyllene, and other minor components, and leaf oil contained eugenol (82–88%), small amounts of eugenyl acetate, and other minor components, while stem oil was composed of eugenol (90–95%) and several other minor components (Hariyadi *et al*., 2020). Previous research also reported that clove buds contained 21.3% essential oil with eugenol content of around 78–95%, flower stalks contained 6% essential oil with eugenol content 89–95%, while leaves contained 2–3% essential oil with eugenol content about 80–85% (Hariyadi *et al*., 2020).

Cloves were native to only five tiny, volcanic islands in the East Indian Archipelago: Ternate, Matir, Tidore, Makian, and Bacan, all belonging to the Maluku Islands or the Moluccas. The nutmeg tree was native to sheltered valleys on the hot, tropical Banda Islands in the Maluku region of Indonesia (Hancock, 2021). In antiquity, they became popular in the medicines of India and China, and they were a major component of European cuisine in the medieval period. European countries fought mightily for control of the spice trade (Hancock, 2021). The name clove refers to the dried, unopened buds of the evergreen tree, *Syzygium caryophyllata* in the myrtle family (Hancock, 2021). The nutmegs are the dark reddish-brown seeds within the fruits of *Myristica fragrans*, of the *Myristicaceae* family. These seeds are surrounded by a deep red, fleshy net-like membrane, or aril, which is the mace (Hancock, 2021). The first mention of clove is in the Chinese literature of the Han period, around the 3rd century BCE. The spice called *hi-sho-hiang* ("bird's tongue") was first used as a breath freshener; officers of the court were required to place cloves in their mouth before discussions with their sovereign (Hancock, 2021). Cloves were used much more widely in medicines than food preparation. They were considered an internal warming herb, which helped dispel cold and warm the body. They were used as tonics and stimulants and were prescribed as a digestive aid and antiseptic. Cloves were used to treat a wide range of ailments including intestinal distress, impotence, diarrhea, vomiting, and cholera. They were made into a poultice to treat cracked nipples, scorpion stings, toothaches, and pretty much any abscess that caused pain (Hancock, 2021). Cloves became popular in traditional Ayurvedic medicine & were used to treat a wide range of problems (Hancock, 2021). Cloves also played an important role in ancient Indian society, although they arrived there several centuries later than in China. Cloves became popular in traditional Ayurvedic medicine and were used to treat a wide range of problems including colds, asthma, indigestion, vomiting, toothache, laryngitis, low blood pressure, and impotence (Hancock, 2021). In the ancient Sanskrit text, *Charaka Saṃhita* (1st century CE), it is stated that "one who wants clean, fresh, fragrant breath must keep nutmegs and cloves in the mouth" (Hancock, 2021). The Roman writer Pliny the Elder (23-79 CE) was the first to describe cloves in the West in his *Natural History* (70 CE) where he recorded that "there is also in India a grain resembling that of pepper but larger and more fragile, called *caryophyllom*, which is reported to grow on the Indian lotus tree; it is imported here for the sake of its aroma" (Hancock, 2021). Roman emperor Constantine the Great (r. 306-337 CE) is said to have presented Saint Silvester, the bishop of Rome (314-335 CE), with gold and silver vessels filled with incense and spices, including 68 kg of cloves. The Greek physician Paul of Aegina wrote in the 5th century CE: "It is of the nature of a flower of some tree, woody, black, almost as thick as a finger; reputed aromatic, sour, bitterish, hot and dry in the third degree; excellent in relishes and other prescriptions" (Hancock, 2021).

Clove are the aromatic flower buds of a tree in the family Myrtaceae, Syzygium aromaticum (Yadav *et al*., 2021). They are native to the Maluku islands (or Moluccas) in Indonesia, and are commonly used as a spice (Yadav *et al.,* 2021). Clove are available throughout the year owing to different harvest seasons in different countries (Yadav *et al.,* 2021). Clove is use in antioxidants, help protect against cancer, it can also kill bacteria, helpful in liver health, regulate blood sugar, and help in many more health problems (Yadav *et al.,* 2021). The clove tree is an evergreen that grows up to 8- 12 meters tall, with large leaves and crimson flower grouped in terminal clusters (Yadav *et al*., 2021). Clove have the essential oil extract named Eugenol comprises 72- 90%. Clove is a Volatile Oil (Yadav *et al*., 2021). Zanzibar and Pemba are now the world's largest producers of clove (Yadav *et al*., 2021). Clove is mainly used in Ayurvedics. It is usually known as "lavang" (Yadav *et al.,* 2021). Clove is mainly used for preparation of food. Clove oil is used for antimicrobial, antiviral, anti-inflammatory, anti-diabeties and antioxidant properties (Yadav *et al*., 2021). Eugenol, the most important composition of Clove oil, has been accepted as food preservatives by China, US European Union, and other countries and regions (Yadav *et al*., 2021). Clove was originated from Indonesia. The name comes from the Latin word clavus. The name comes from the French "clou" meaning nail (Yadav *et al.,* 2021). Clove tree is monoecious, flowers are hermaphrodite and self- pollinating (Yadav *et al*., 2021). The tree matures between 8-10 years after planting. Clove generally are dried flower buds from the clove tree. Clove were important in the earliest spice trade and are believed to be indigenous to the Moluccas, or Spice Islands, of Indonesia (Yadav *et al.,* 2021). Cloves are one of the world's most important, popular, and useful plants (Yadav *et al.,* 2021). Clove is one of the most ancient and valuable spices of the orient, with its origin as old as the first century, before Christ (Yadav *et al*., 2021). The ancient Chinese Han dynasty lasting from 207 B.C. to 220 A.D. gives us our first clue to the use of fragrant clove (Yadav *et al.,* 2021). The use clove as a spice reached Europe around the 4th century A.D., when commercial trading really started with the Arabs, who in turn acquired these dried and fragrant buds from the cultures to the East in Asia (Yadav *et al.,* 2021). For over 2,000 years, both Indian and Chinese traditional medicine made extensive use of clove flowers and clove oil (Yadav *et al.,* 2021). Clove introduced in India around 1800AD by the East India company in it's 'spice garden' in Courtallam, Tamil Nadu (Yadav *et al*., 2021). Cloves are believed to be native to the Molucca Islands of Indonesia. Although Indonesia is the largest producer of Cloves, Zanzibar and Madagascar are the major exporters, where Clove trees cover thousands of acres of the islands. Historically, Clove originating from Madagascar have been considered superior (Yadav *et al*., 2021).

Cloves was the main plantation commodities originally from Indonesia , which used as an ingredient for cigarette and trade (Cahyaningrum *et al.,* 2021). Cloves has known as a fragrant spice consist of 80% eugenol and 5% eugenic (Cahyaningrum *et al*., 2021). The economic rate in Southeast Asia in the 14th century increased because the Portuguese and Spanish bought cloves directly from the Maluku Islands (Cahyaningrum *et al.,* 2021). Because of a high economic value of the clove, the farmers continue to maintain them generation to generation (Cahyaningrum *et al.,* 2021). High demand to the commodities was depend on the plant conditions and the flowering season. In general, the clove plantation in North Maluku was not cultivated optimally because fertilization and sanitation are not done properly (Cahyaningrum *et al.,* 2021). The information of cloves diversity and types in North Maluku was limited. The diversity of clove could be done by observing the morphological characteristics on the field (Cahyaningrum *et al*., 2021). The cloves in Talaga Jaya village consist of several varieties such as Afo, Zanzibar, Sikotok, and local varieties which known as superior local clove. This local varieties were similar to the other three, but if a detailed observation was carried out, it will show the morphological difference between the four types of plants (Cahyaningrum *et al*., 2021). The differences can be seen from the shape of the tree, flower, fruit, flower color, leaf shape, and color of leaf (Cahyaningrum *et al.,* 2021).

Laung, also known as clove or Kalinga in Indonesia, is a spice that comes from the flower buds of an evergreen tree called *Syzygium aromaticum* (Origin, 2022). Native to Asian countries like Indonesia, India, Pakistan, and even some areas of East Africa, clove is a spice that offers many health benefits. For Centuries, clove has been used as a flavoring agent and as medicine (Origin, 2022). Clove/ Laung is a popular spice in India used in different ways. They have a sweet, spicy flavor and are mostly used in desserts (Origin, 2022). Cloves have a very intense flavor that goes well with many different dishes and dairy products! When you breathe in the fragrance of cloves, you can feel the intensity (Origin, 2022).

Clove is a widely traded spice for the dried aromatic fully grown unopened flower buds and is one of the most expensive spices in the world (Reddappa *et al*., 2022). Clove is native to the Moluccas Islands of Indonesia and was introduced to India in the 18th century (Reddappa *et al.,* 2022). The variability of clove in India is limited and its autogamous nature also limits the extent of variability (Reddappa *et al.,* 2022). From the few studies, there is sufficient diversity of clove in India both for qualitative as well as quantitative characters. Those can be used for further breeding studies (Reddappa *et al*., 2022). High yielding clove trees producing large-sized flower buds with a dwarf bushy nature can be utilized in breeding programmes. Exploring and preserving the clove germplasm is one method for creating commercial clove varieties (Reddappa *et al*., 2022). The genus Syzygium contains more than 500 species, but *Syzygium aromaticum* (L.) Merr. & Perry is the only commercialized aromatic spice. The important species of *Syzygium* that occur in the Indian subcontinent are *S. aromaticum, S. cumini, S. fruticosum, S. jambos* and *S.zeylanicum*. But the cultivated Syzygium aromaticum is not very close to any of these species (Reddappa *et al*., 2022). Clove has been employed for centuries as a food preservative and as a medicinal plant because of its antioxidant and antimicrobial activities (Reddappa *et al.,* 2022). Clove buds, a common source of raw materials for the cigarette industry, and spices are the main products. Other products include oil and oleoresin, which can be extracted from flowers or leaves. Eugenol is the primary constituent of clove oil. Eugenol compounds have antibacterial, antifungal, antiseptic, antioxidant, and antivirus properties (Reddappa *et al.,* 2022). Clove is one of the oldest and most valuable spices, grown primarily in Indonesia, Zanzibar, Madagascar, Pemba, and Sri Lanka. The major clove-growing regions in India are Kanyakumari, the Nilgiris of Tamil Nadu, Calicut, Kottayam, Quilon and Trivandrum districts of Kerala and South Kanara of Karnataka (Reddappa *et al*., 2022). Because clove was introduced to India infrequently, the genetic base of the clove is narrow. Furthermore, clove is self-pollinated, resulting in a lack of variation (Reddappa *et al.,* 2022). There are no true varieties of clove in India; only local types are under cultivation (Reddappa *et al.,* 2022). Information as well as assessment of genetic variability in the existing germplasm of a crop is a prerequisite for varietal development. The agro-morphological characterization of genotypes is essential for providing information for plant breeding programmes (Reddappa *et al.,* 2022). There is a little knowledge of the types and diversity of cloves in India. Observing the morphological characteristics of clove in the field can be used to determine its diversity (Reddappa *et al.,* 2022).

Clove, tropical evergreen tree of size 8-12 m belongs to the family Myrtaceae which is native to Moluccas islands or often called spice island of east Indonesia and its small reddish brown flower buds used as a spice (Binisundar *et al*., 2023). Cloves are available throughout the year owing to different harvest seasons across various countries (Binisundar *et al.,* 2023). A wide range of bioactive compounds, including some potent antioxidants and antimicrobials, are present in cloves (Binisundar *et al.*, 2023). The clove tree is frequently cultivated in coastal areas at maximum altitudes of 200 m above the sea level (Binisundar *et al*., 2023). The trees are evergreen with large leaves and crimson flowers grouped in terminal clusters (Binisundar *et al.,* 2023). The major component of clove taste is imparted by the chemical eugenol (Binisundar *et al.,* 2023). The larger producer countries of clove are Indonesia, India, Malaysia, Sri Lanka, Madagascar and Tanzania (Binisundar *et al.,* 2023). Chemical and pharmacological basis of clove the dried flower bud of *Syzygium aromaticum* dominated by eugenol, fixed oil dominated by oleic and linoleic acids; terpenoids dominated by oleonolic and masilinic acids, flavonoids and phenolic acids, as well as highly water-soluble tannins with a great deal of structural diversity (Binisundar *et al*., 2023). The essential oil of clove has anaesthetic and antimicrobial qualities, and is used to prevent halitosis and ameliorate dental pain. Eugenol, chemically known as 4 - ally - 2 - methoxyphenol, is the principal active component of clove oil well invested for its pharmacological effects with respect to the anti-arthritic (Binisundar *et al*., 2023). Clove and its compounds in noncytotoxic concentration exhibited immunomodulatory and anti-inflammatory actions on cytokine production by murine macrophages (Binisundar *et al*., 2023). Clove is one of the most ancient and valuable spices of the orient and holds a unique position in the international spice trade. Native to Moluccas, the so called 'Spice Islands' in the East Indian Archipelago, this spice was first introduced in India around 1800 A.D. by the East India Company (Nikita, 2024). The company's spice garden in Courtallam in Tamil Nadu was then established to cultivate clove and nutmeg as the principal spice crops (Nikita, 2024). Induced by the success of the cultivation in Courtallam, cultivation of clove was extended during the period after 1850 A.D. to Nilgiris (Burliar) in Tamil Nadu, Southern regions of Travancore and also to

Cochin State on the slope of Western Ghats (Nikita, 2024). The Important clove growing regions in India now are Nilgiris, Tenkasi hills, and Kanyakumari districts of Tamil Nadu and Kottayam and Quilon districts of Kerala (Nikita, 2024). Although clove has been under cultivation in India for over about 170 years, its development has been very slow owing probably to its long pre-bearing period and lack of knowledge regarding the method and economics of its cultivation (Nikita, 2024). Clove is the dried unopened flower bud of *Syzygium aromaticum*, a medium statured, cone- shaped ever-green tree belonging to the Family—*Myrtaceae* (Nikita, 2024). Clove tree attains a height of 10 to 12 metres. The stem is usually forked near its base with two or three main branches. Smaller branches are slender, rather brittle and covered with grey bark. The leaves appearing in pairs, are lanceolate, acute at both ends and are of dark shining green colour. The aromatic nature of the leaves is due to numerous oil glands found on their under-surfaces. The flower buds are greenish when fresh and are borne on ends, which are picked green and dried in the sun till they become dark brown, form the 'clove' of commerce (Nikita, 2024). The buds have slightly cylindrical base and are surmounted by the plump ball like unopened corolla which is surmounted by the four toothed calyx (Nikita, 2024). If the bud is left unpicked, the flower develops after fertilization into a fleshy, purple and one- seeded oval fruit as 'Mother of clove'. The fruit is about 2.5 cm. long and 1.25 cm. in width. The seed is oblong, rather soft in texture and grooved on one side. The leaves, unripe fruit and broken clove, including the stalk are all aromatic and yield an essential oil (Nikita, 2024).

Clove is indigenous to the Molluccas Island of Eastern Indonesia. Later, it was introduced to Mauritius and later on established in the islands of Zanzibar and Pemba (Ecourse, 2024). The important clove-producing countries in the world are Tanzania (Zanzibar), Pemba, Madagascar and Indonesia. Tanzania accounts for roughly 75% of the world output (Ecourse, 2024). Clove is also grown in Malaysia, Sri Lanka, Haiti and India. France, USA, India and West Germany are the major importers of clove (Ecourse, 2024). The world's annual production of clove is 40,000-50,000 tonnes, out of which nearly 15,000 tonnes are used for the production of `Kretek' cigarettes (Ecourse, 2024). In India, clove was introduced in 1800 AD by the East India company and is now cultivated in Tamil Nadu, Kerala and Karnataka (Ecourse, 2024). The production of clove in India has not kept pace with its increasing demand and most of the clove requirement in India is met through import from Tanzania, Singapore, Malagasy and Indonesia. There is scope for extending the cultivation of this spice along the Western Ghats (Ecourse, 2024). The first references to cloves are found in Asian literature from the Chinese Han period under the name "chicken-tongue spice" (MCSI, 2024). From the 8th century on, cloves became one of the major spices in European commerce. In the Moluccas Islands (now part of Indonesia), where cloves were first discovered, parents planted a clove tree when a child was born (MCSI, 2024). When the clove forests were first discovered, all were enchanted with the fragrance and beauty of this tropical evergreen tree which "must always see the sea" in order to thrive (MCSI, 2024). Cloves were extremely costly and played an important part in world history. Wars were fought to secure exclusive rights to the profitable clove business (MCSI, 2024). For many years, the Moluccas Islands were part of the Dutch East Indies and the Dutch government sought to control their monopoly by destroying every clove tree that grew anywhere else. However, by the early 1800's, the French established a smuggling operation to transport clove tree seedlings to the islands of Zanzibar and Pemba (MCSI, 2024).

As early as 200 BCE, envoys from Java to the Han-dynasty court of China brought cloves that were customarily held in the mouth to perfume the breath during audiences with the emperor (EEB, 2024). During the late Middle Ages, cloves were used in Europe to preserve, flavour, and garnish food (EEB, 2024). Clove cultivation was almost entirely confined to Indonesia, and in the early 17th century the Dutch eradicated cloves on all islands except Amboina and Ternate in order to create scarcity and sustain high prices (EEB, 2024). In the latter half of the 18th century the French smuggled cloves from the East Indies to Indian Ocean islands and the New World, breaking the Dutch monopoly (EEB, 2024). In the early 21st century, Indonesia was the world's largest producer of cloves, followed by Madagascar, Tanzania, and Sri Lanka (EEB, 2024).

Modern cuisine is flavored with a rich medley of spices from the farthest corners of the globe. We take for granted the fact that we can buy jars of spices, even scarce and exotic ones, for a few dollars each and use them in our everyday cooking (Lewis, 2024). Because spices occupy a small space in the supermarket and in our kitchen cabinets, we often overlook their importance in shaping the modern world. It is hard to comprehend the centuries of exploration, conquest, slavery and war that brought these products to our shelves, and it is impossible to estimate the number of lives and fortunes that were risked and lost along the way (Lewis, 2024). Spices were among the first commercial products to be traded over long distances. Used to flavor food and preserve meat, spices such as black pepper, cinnamon, ginger and cardamom were carried from the tropics to emerging civilizations in Asia, the Middle East and Europe (Lewis, 2024). The story of cloves is especially colorful, involving a complex, secret system of trade that lasted for thousands of years. Cloves are the dried flower buds of *Syzygium aromaticum*, a tropical tree in the myrtle family (Lewis, 2024). The flower buds contain high concentrations of eugenol, an aromatic chemical compound that is also found in cinnamon, nutmeg and basil (Lewis, 2024). The tree is native to a row of volcanic islands, the Spice Islands or Moluccas, in what is now Indonesia's North Maluku Province Province. Prior to the 17th century, clove trees could not be found anywhere else (Lewis, 2024). There is archaeological evidence that cloves made their way from the Spice Islands to world markets in ancient times. Like many other spices, they appear to have reached India by 1700 BC and southern Europe by the first century AD (Lewis, 2024). We can find additional clues about the history of cloves by studying their integration into the cultures and traditions of Asia. Cloves are a particularly important component of Indian cuisine, appearing in a wide variety of spicy dishes and in spiced teas. This suggests an ancient and strong connection between the Spice Islands and many parts of India (Lewis, 2024). Cloves also have widespread traditional use in China and Japan, where they are used to make incense and perfume (Lewis, 2024). Merchants kept the location of the Spice Islands a closely guarded secret for thousands of years. Ancient writings from Asia, the Middle East, and Europe mention possible locations of the islands, but few of them are even remotely accurate. This secrecy was maintained as cloves became increasingly common in markets worldwide (Lewis, 2024). With an aura of mystery surrounding their origin, fanciful myths about cloves began to emerge. One theory, persisting for centuries, suggested that cloves could only be grown and harvested by genies using magical techniques (Lewis, 2024). By the first century AD, traders had learned to sail

westward across the Indian Ocean on the steady monsoon winds, carrying cloves and other spices from Southeast Asia to North Africa. From there, overland routes brought spices to the Mediterranean Sea, where they could be distributed far and wide to markets throughout the Roman Empire (Lewis, 2024). When Rome lost control of North Africa in the seventh century, a new trading route was established through the Middle East to what is now Turkey. Trade along that route flourished for 800 years, until it was interrupted by the rise of the Ottoman Turks (Lewis, 2024). Without an overland connection to the Indian Ocean, Europe lost its supply of precious Asian spices. As the nations of Middle-Ages Europe became desperate to reestablish the spice trade, they launched expeditions to chart new maritime routes, beginning the Age of Discovery (Lewis, 2024). Resolving the mysterious origin of cloves became a top priority for those expeditions. It took more than a century of exploration, multiple around-the-world voyages and an extraordinary investment of wealth to pinpoint the location of the Spice Islands (Lewis, 2024). Portuguese explorers arrived first, in the mid-15th century, followed soon by the Spanish, English and Dutch. The first detailed maps of the world's continents were produced during those early voyages, as were the first records of the plants and animals of distant lands (Lewis, 2024). As the world's powerful nations began to expand and colonize territories overseas, the Spice Islands were the prize they coveted most. Through a series of bloody conflicts, the Dutch seized and controlled the Spice Islands for 350 years (Lewis, 2024). In their quest to monopolize the supply of cloves forever, the Dutch established plantations to the south on the well-fortified island of Ambon. Once those plantations were able to adequately supply global markets, Dutch soldiers began burning all clove trees in their native range of North Maluku. That action was strongly resisted by the local people, who had traditionally planted clove trees to commemorate the birth of each child (Lewis, 2024). Even under the tight grip of the Dutch, clove seeds were eventually smuggled out to other tropical regions in the 18th century. The trees were propagated in French and English colonies, and cloves quickly became widely available and less expensive (Lewis, 2024). As the Dutch monopoly was finally broken, cloves were reestablished as an important part of the North Maluku economy and culture. Today, the intensely fragrant flower buds can be found drying in the sun along roadsides throughout the islands. North Maluku is now peaceful, and little evidence of its bloody history remains (Lewis, 2024). The majority of the world's cloves now come from elsewhere, primarily Zanzibar, Madagascar and Sri Lanka. The bulk of the world supply is used to make clove cigarettes, which are especially popular in Asia (Lewis, 2024). Cloves remain a favorite culinary spice throughout the world, used in a variety of baked goods, meat dishes and soups. They stand as one of the best examples of a local crop that skyrocketed onto the world stage and forever transformed the global economy (Lewis, 2024).

Cloves, an ancient spice native to the Maluku Islands of Indonesia, historically known as the Spice Islands, were one of the key spices in the historic Spice Trade (Hortiforum, 2024). Cloves are the dried flower buds, particularly the unopened ones, which are highly valued. Clove trees belong to the well-known Syzygium genus, making them related to the Jambolan Plum, Wax Jambu, Lipote, Malay Apple, and the common ornamental Lilly Pilly species (Hortiforum, 2024). The species name of cloves, *Aromaticum*, aptly reflects their unique flavour and aroma, which combine elements of sweetness and bitterness (Hortiforum, 2024). Cloves are widely used across the globe in both sweet and savoury dishes. They are commonly added as a spice in curries and biryanis or traditionally used to stud and flavour baked hams (Hortiforum, 2024). They thrive in deep, fertile, well-draining loam soil, as they cannot tolerate waterlogging but prefer consistently moist conditions. An acidic or slightly acidic soil with a pH between 4.5 and 6.5 is ideal. Young Clove plants benefit from partial shade but mature into full sun. Cloves require plentiful rainfall although flowering is prompted by a short dry season. Though slow-growing, Clove trees are long-lived and begin full production after 20 years (Hortiforum, 2024). Clove trees mature into beautiful specimens, growing up to 15 meters tall with a wide, pyramidal canopy. In some cases, they can even reach heights of 20 meters. The leathery, glossy leaves are aromatic when crushed. Clove trees produce terminal panicles with dense clusters of colorful flower buds. If the buds are not harvested and are allowed to flower, the flowers become quite ornamental, with a profusion of white stamens contrasting against the dark red to crimson base (Hortiforum, 2024).

Cloves are native to the Molucca Islands, now a part of Indonesia (Spiceadvice, 2024). Cloves have been used for thousands of years (Spiceadvice, 2024). One of the earliest references to them says that the Chinese, in order to approach the emperor, had to have a few Cloves in their mouths to sweeten the breath (Spiceadvice, 2024). Cloves were once very costly and played an important part in world history. Wars were fought in Europe and with native islanders to secure rights to the profitable Clove business (Spiceadvice, 2024). Natives in the Molucca Islands planted a Clove tree for each child born. They believed that the fate of the tree was linked to the fate of that child (Spiceadvice, 2024). In 1816, the Dutch set a fire to destroy Clove trees and raise prices. The natives revolted in a bloody battle which changed the climate and politics of the area forever (Spiceadvice, 2024). Ground Cloves add spicy depth to ginger bread, cookies, apple sauce, muffins, cakes, and other sweets (Spiceadvice, 2024). It's a secret ingredient in barbecue and cocktail sauces. Blend Ground Cloves with maple syrup and drizzle over cooked sweet potatoes and winter squash. Add a few Whole Cloves to bean and split pea soups (remove before serving) (Spiceadvice, 2024). Eugenol (clove oil) will collect and cake in the container when Cloves are stored in a warm place. If you choose to grind your own Cloves, do not use a grinder that has plastic parts. Clove oil can cloud some plastics (Spiceadvice, 2024).

In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding and Cultivation of Clove are discussed.

ORIGIN AND DISTRIBUTION

Clove from the French word clou meaning nail, is a dried flowers bud that sprouts off its evergreen tree, making it sparkle in a dash of red and white. Which also happens to be the colour of the Indonesian flag, making it apt as the tree is native to the Indonesian province of Maluku. They are also pink sometimes, but that would ruin that smooth transition. But yes, they are also pink, though they start their life off in as green buds, before turning yellow then red (also pink). The tree has a special place in its

homeland; every child born is marked by the planting of the tree. Its life directly tied to the life of the human whose birth it marked. This spice has a rich journey in human history; usage has dated all the way back to Syria in 1782 B.C. From references in The Arabian Nights tales, to the Chinese famously chewing them before an audience with the emperor to avoid bad breath. Cloves as well as our previously discussed nutmeg were the most valuable of the 16th century. Its value pushed a drive to control them creating war, famously known as the spice war. It was fought between the Portuguese and The Dutch East, and West India Company. The dried brown bud was worth more in its weight than gold at the time (Utama, 2016). A spice with origin dating back to the first century before Christ, clove is one of the most valuable and ancient of the spices (Reddappa *et al.,* 2022). Originating in the Maluku Islands, commonly known as the Moluccas, they are a well-known spice, adding flavor, scent, and charm to culinary creations and even making their way into consumer items such as toothpaste, soaps, and cosmetics (Thomas, 2023).

Cloves have a rich history dating back thousands of years. Originating from the Maluku Islands in Indonesia, they became a significant part of global trade. In ancient times, cloves were highly valued in Indian and Chinese medicines. They were used to treat various ailments, benefiting from their antimicrobial properties. European explorers discovered cloves and fought fiercely to control their trade. During the medieval period, cloves were a favourite in European cuisine, especially for flavouring meats and pastries (Epicure. 2024). They are native to the Maluku Islands in Indonesia, and are commonly used as a spice. Cloves are commercially harvested primarily in Indonesia, India, Madagascar, Zanzibar, Pakistan, Sri Lanka and the largest producer, Pemba Island, just off the coast of Tanzania (Pubchem, 2024). The native range of this species is Maluku. It is a shrub or tree and grows primarily in the wet tropical biome (POWO, 2024). The clove tree is endemic to the North Moluccas (Indonesia) and was of old cultivated on the islands of Ternate, Tidore, Bacan and the West coast of Halmahera. The Dutch extended cultivation to several other islands in the Moluccas, particularly Ambon, but only after the end of the Dutch monopoly (18.th century), clove trees were introduced to other countries (Gernot,2024). The plant is indigenous to North Molucca Islands of Indonesia. It is also grown in Zanzibar, Madagascar, Malaysia, Sri Lanka and India. The tree prefers well drained rich soil with sufficient soil moisture throughout the year. High atmospheric temperature (25 to 35 degree C) with heavy sun light, good and well-distributed rainfall (above 150 cm) and high humidity (above 70%) are preferred (Indianspices, 2024). Cloves are believed to be native to the Maluku Islands (Moluccas), an archipelago in Indonesia historically known as the "Spice Islands." The name "clove" derives from French *clou*, a nail, as the buds vaguely resemble small irregular nails in shape (NEW, 2024).

The Clove originates from the Moluccas, a province of Indonesia formed by the islands of the southern half of the Moluccan archipelago. It was known very early in China, it is mentioned in ancient books by stipulating that courtiers must have some in their mouths when they addressed the emperor, in order not to disturb him with their breath! From the 2nd century A.D. onwards, fragrant buds reached Alexandria by caravan. The clove was introduced in France around 1225. It was quite popular in the country but very expensive. The origin of this spice, which was deliberately kept secret by the colonizers of the Moluccas region, was unknown and was therefore avoided as a precaution. Today, the clove is a spice widely used in France. If it is still used for its medicinal virtues, it is mainly found in the culinary arts, its characteristic taste perfuming ideally all types of dishes (Pages, 2024). Some of the Molucca Islands are the origin of clove *(*Unitproj, 2024*).*

TAXONOMY

The family Myrtaceae has at least 3000 species distributed in 130-150 genera, including such well-known representatives as myrtle, guava, feijoa, allspice, and eucalyptus. All species are woody, with essential oils, and have flower parts in multiples of four or five. Clove belongs to the family *Myrtaceae,* genus *Syzygium* and species *Syzygium aromaticum* (Khan, 2022; Indianspices, 2024; NEW, 2024).

Synonyms (**MCSI, 2024; Wikipedia, 2024**).
Caryophyllus aromaticus L.
Eugenia aromatica (L.) Baill.
Eugenia caryophyllata Thunb.
Eugenia caryophyllus (Spreng.) Bullock & S.G.Harrison
Jambosa caryophyllus (Thunb.) Nied.

Synonyms (Pubchem, 2024)
Caryophyllus aromaticus L., 1753
Caryophyllus aromaticus
Eugenia aromatica (L.) Baill., 1876
Eugenia aromatica
Eugenia caryophyllata
Eugenia caryophyllata Thunb., 1788
Syzygium aromaticum (L.) Merr. & L.M.Perry, 1939
Syzygium aromaticum

Synonyms (POWO, 2024)

Caryophyllus aromaticus L. in Sp. Pl.: 515 (1753)
Eugenia aromatica (L.) Baill. in Hist. Pl. 6: 311 (1876), nom. illeg.
Eugenia caryophyllus (Spreng.) Bullock & S.G.Harrison in Kew Bull. 13: 52 (1958)

Myrtus caryophyllus Spreng. in Syst. Veg., ed. 16. 2: 485 (1825)
Caryophyllus hortensis Noronha in Verh. Batav. Genootsch. Kunsten 5(4): 11 (1790), nom. nud.
Caryophyllus silvestris Teijsm. ex Hassk. in Abh. Naturf. Ges. Halle 9: 167 (1866)
Eugenia caryophyllata Thunb. in Caryoph. Arom.: 1 (1788)
Jambosa caryophyllus (Thunb.) Nied. in H.G.A.Engler & K.A.E.Prantl, Nat. Pflanzenfam. 3(7): 85 (1893)

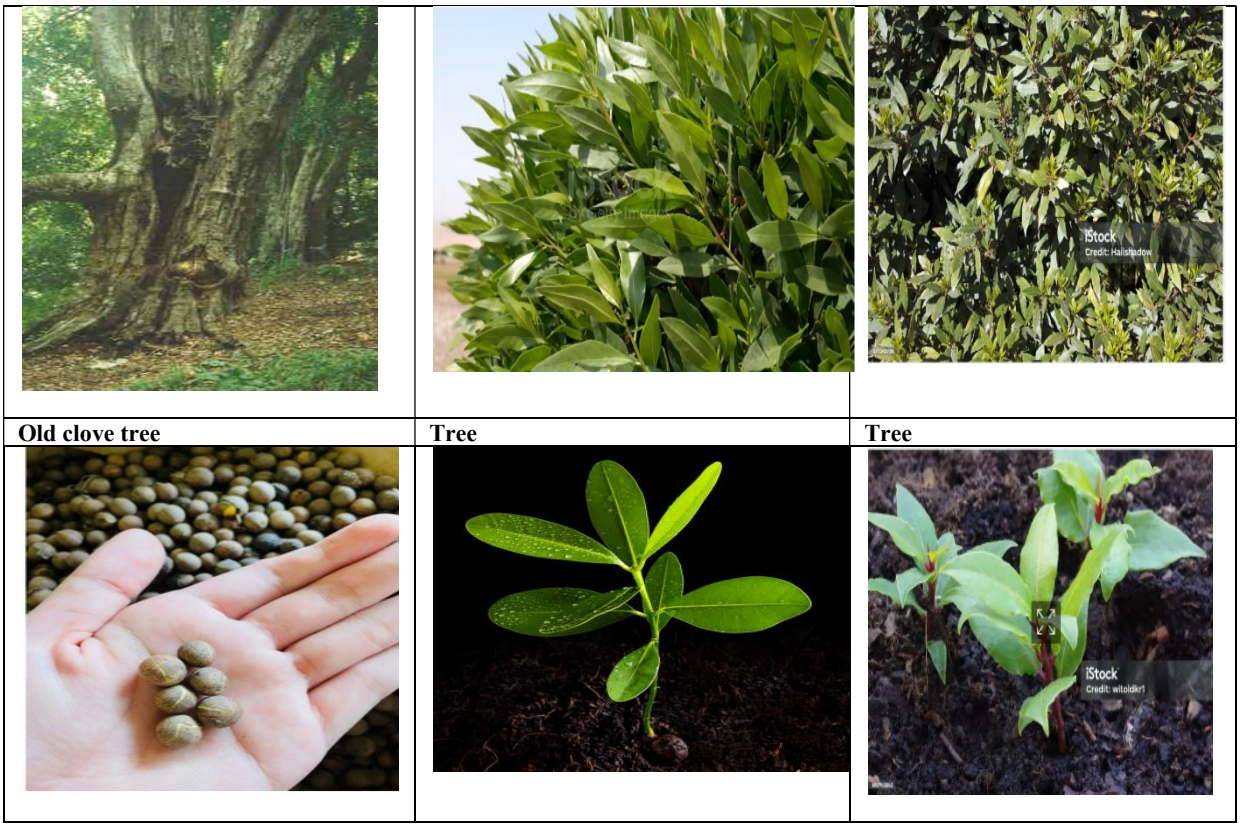
BOTANICAL DESCRIPTION

Whole cloves as we know them are the dried, unopened flower buds of an attractive, tropical evergreen tree which reaches about 10 m in height and has dense, dark-green foliage. The trunk of a clove tree is around 30 cm in diameter, and usually forks near the base into two or three main branches of very hard wood with grey, rough bark. The lower branches often die back, and when they are closely planted, these conical-shaped trees form a magical aromatic canopy. New leaves are bright-pink, and mature with a glossy, dark-green upper surface, the underneath being paler green and dull. Clove buds are borne in clusters of 10–15, and are picked when they have reached full size, though still green and just starting to turn pink – reminding one of the unopened eyes of baby marsupials. When dried, cloves are reddish brown to dark brown in colour, approximately 10–15 mm long, nail-shaped and tapered at one end. Interestingly, the name clove derives from the Latin clavus meaning 'nail'. In German nelke means 'little nails', and the Chinese ting hsiang means 'nail spice'. The 'bud' end has a friable, paler ball appearing to sit atop four engagement-ring-style clasps. The aroma of cloves is pungent, warm, aromatic, camphor-like and faintly peppery. The flavour is intensely pungent, and words like medicinal, warming, sweet, lingering and numbing come to mind. When used in moderation, cloves bring a pleasing, palate-cleansing freshness and sweet spicy flavour to food (Hemphil, 2018). The clove tree is a small to medium-sized, evergreen tree that reaches a height of 12 to 15 m and initially has a conical shape before changing to a cylindrical one. The leaves of a clove are simple, opposite, coriaceous, estipulate, hairless and fragrant and are 7-13 cm in length and 3 cm in breadth. The leaf stalk is slender, about 2-3 cm long, swollen and pink at the bottom. The leaf shape is obtuse or acuminate. Newly emerged within the flushes, they are pink in colour, while mature leaves are dark green. Forest clove trees are large, sturdy trees with less pointed canopies than other varieties of cloves. They have round and oval canopies, low branching in their main stems. The tree is an evergreen tree that starts to flower in about 7 years and continues to yield for 80 or more years. Clove leaves are opposite, obovate, oblong to elliptic, and abundantly covered with oil glands on the underside. The inflorescence of the clove tree is a terminal branching cyme with three to twenty hermaphrodite flowers that are all about 4 cm long. Each ovary measures one-quarter inch in length and is cylindrically thick, making each pale-yellow floret. A hypanthium of four fleshy ovate sepals, four tiny petals, numerous thin, white, 1 cm filaments, and a narrow central style are located above the ovary. The hypanthium is 1–1.5 cm long, 5 mm in diameter, angled, cylindrical, and slightly narrowed at the base. In the young bud, the hypanthium is green. It turns flushed pink at anthesis and deep reddish after the stamens have fallen. The ovary and sepals are the economically valuable parts sold as cloves (Reddappa *et al*., 2022). The name of clove is derived from French word 'clou' and 'clove', meaning 'nail'. Clove is pointed evergreen shrub, trunk is straight with medium sized tree that cultivate equal to 10 to 12 m in height. The color of the branches is grayish and dense. The branches are semi erect. The leaves are glabrous, have abundance of oil glands on the lower surface, simple obovate opposite and large oblong to elliptic. The flowering is start on tree in about 7 years and flowering is continues for 80 years or more **(**Khan, 2022**).** The clove length changes from 12 to 17 mm. It is bisexual, actinomorphic and epigynous. The flower bud has sub-cylindrical hypanthium narrowing at the inferior end a spherical head. Corolla has 4 petals which are imbricate, polypaptalous and several stamens. Calyx is rigid and has broad sepals among lubricate glands. Columella makes the central cylindrical region of clove hold the ring of bicollateral vascular bundles with parenchyma in the direction of edge of the cylinder. Various sphaeraphides are observed sprinkled all over the columella and to a certain amount in the center of cortical region **(**Khan, 2022**).**

The clove tree is an evergreen that grows up to 8–12 metres tall, with large leaves and crimson flowers grouped in terminal clusters. The flower buds initially have a pale hue, gradually turn green, then transition to a bright red when ready for harvest. Cloves are harvested at 1.5–2 centimetres long, and consist of a long calyx that terminates in four spreading sepals, and four unopened petals that form a small central ball. Clove *stalks* are slender stems of the inflorescence axis that show opposite decussate branching. Externally, they are brownish, rough, and irregularly wrinkled longitudinally with short fracture and dry, woody texture (Wikiwand, 2024). Cloves come from the flower buds of an evergreen tree that is native to the North Moluccas Islands in Indonesia. Clove trees grow to about 26-40 feet and flower after about 6 years. The tree becomes fully mature in 20 years and can bear fruit for more than 80 years. The flower buds gradually develop in color and are ready for collecting when they turn bright red. Cloves are handpicked before the flower opens. Harvested cloves are 0.5-0.75 inches long and consist of stems with four unopened petals which form a small ball in the center. After harvesting, clove buds are spread out in a thin layer on a mat to dry in the sun or by using an artificial dryer (MCSI, 2024). The clove tree is an ever geen that grows to about 8 to 12 metres in height. Its gland-dotted leaves are small, simple, and opposite. The trees are usually propagated from seeds that are planted in shaded areas. Flowering begins about the fifth year; a tree may annually yield up to 34 kg of dried buds. The buds are hand-picked in late summer and again in winter and are then sun-dried. Cloves vary in length from about 13 to 19 mm (0.5 to 0.75 inch) (EEB, 2024). The clove of commerce is the air-dried unopened flower bud obtained from evergreen medium sized tree. The tree grows to a height of 10-12 m. and start flowering in about 7 years. It continues to produce flower buds for 80 or more years. It is a valuable spice of the orient. Clove clusters are plucked by hand when the buds are fully developed with a pronounced pink flush and then dried over several days in the sun. Unopened flower buds, leaves and stalks yield essential oil (Indianspices, 2024). The flowers have a base number of five petals, though in several genera the petals are minute or absent. The stamens are usually very conspicuous, brightly colored and numerous. The leaves are evergreen, alternate to mostly opposite, simple, and usually with an entire (not toothed) margin. One notable character of the family is that the phloem is located on both sides of the xylem, not just outside as in most other plants. The clove tree is a conical evergreen that grows to a height ranging from ten to 20 meters, having

large oval leaves and crimson flowers in numerous groups of terminal clusters. The flower buds are at first of a pale color and gradually become green, after which they develop into a reddish brown or bright red, when they are ready for collecting. Cloves are harvested when 1.5 to 2.0 cm long, and consist of a long calyx, terminating in four spreading sepals, and four unopened petals that form a small ball in the center. The flower buds are strongly aromatic and impart a flavor that can be described as hot and pungent (NEW, 2024).

The clove tree is an evergreen which grows to a height ranging from 8-12 m, having large square leaves and sanguine flowers in numerous groups of terminal clusters. The flower buds are at first of a pale color and gradually become green, after which they develop into a bright red, when they are ready for collecting. Cloves are harvested when 1.5–2 cm long, and consist of a long calyx, terminating in four spreading sepals, and four unopened petals which form a small ball in the centre (Goodeats, 2024). The clove tree is an evergreen that grows up to 8–12 m tall, with large leaves and crimson flowers grouped in terminal clusters. The flower buds initially have a pale hue, gradually turn green, then transition to a bright red when ready for harvest. Cloves are harvested at 1.5–2 cm long, and consist of a long calyx that terminates in four spreading sepals, and four unopened petals that form a small central ball. Clove *stalks* are slender stems of the inflorescence axis that show opposite decussate branching. Externally, they are brownish, rough, and irregularly wrinkled longitudinally with short fracture and dry, woody texture (Wikipedia, 2024a). Cloves are the aromatic flower buds. The clove tree is an evergreen that grows up to 8-12 m tall, with large leaves and sanguine flowers grouped in terminal clusters. The flower buds initially have a pale hue, gradually turn green, then transition to a bright red when ready for harvest. Cloves are harvested at 1.5-2.0 cm long, and consist of a long calyx that terminates in four spreading sepals, and four unopened petals that form a small central ball (Pubchem, 2024). Clove is a monoecious (both male and female flowers on the same plant) evergreen tree in the family Myrtaceae grown for its aromatic flowers. The many branches of the tree are semi-erect with smooth oval shaped leaves. The branches end with a 3–4 flowers near the tip with one terminal flower and the others opening below it. The leaves, flowers and bark all have a distinct smell. The clove is the unopened flower buds. The tree grows 8–15 m tall and can live to be more than 100 years old (Plantvillage, 2024). The clove tree is a tall evergreen tree. It usually grows to about 8 to 12 meters in height. In certain instances, it can reach as high as 20 meters. The leaves are large, pointed, and oval-shaped. They are glossy green and leathery, measuring up to 12 cm long. Flowers are crimson and appear in terminal clusters. The flower buds have a unique colour transition. They start with a pale hue, turn green, and finally become bright red when they are ready to be harvested. Typically, the buds measure about 1.5 to 2 cm long. Its flower buds are picked at different stages for varying flavours (Epicure. 2024). The clove plant is a medium-sized tree that can reach heights of 8-12 m. It has a straight trunk with smooth grey bark. The leaves are simple, opposite, and elliptical in shape, with a glossy dark green colour. The flowers are small and numerous, with a characteristic crimson colour. These flowers are grouped into terminal clusters and have a strong, aromatic fragrance. The most valuable part of the clove plant is the unopened flower buds, which is harvested for culinary and medicinal purposes. The flowers are bisexual and have a cup has numerous stamens and a single pistil (Singh, 2024). Seedlings are spaced 3 – 4 m apart in rows with 2 m distance between rows. Clove trees take approximate 5-7 years to reach maturity and produce flowers. The flower buds are handpicked and dried to develop into cloves. The cloves are harvested when they reach the desired size and colour, usually between 6-12 months after flowering. Harvesting is done manually, as the flower buds are easily damaged, After harvesting, the cloves are cleaned, sort or with artificial heat to preserve their quality and aroma (Singh, 2024). Botanical description of clove is given in Fig. 1.



Old clove tree | **Tree** | **Tree**

Seeds	Seedling	Seedilgs
		
Leaves	**Clove tree flower buds**	**Clove buds**
		
Branch with clove flowers	**Clover flower close-up**	**Clove buds before harvesting**

Continue ….

		
Fresh cloves spread on the ground for drying.	**Cloves drying in sun**	**Dried buds of clove**
		
Clusters of unripe fruits	**Bay leaf with berries**	**Clove fruits**
		
Fruits/seeds	**Seeds**	**Dry leaves**

Fig. 1. Botanical Description

Mother cloves *(anthophylli)* are the ripe fruits of cloves that are ovoid, brown berries, unilocular and one-seeded. Blown cloves are expanded flowers from which both corollae and stamens have been detached. Exhausted cloves have most or all the oil removed by distillation. They yield no oil and are darker in color (Wikiwand, 2024).

Floral Biology

wers are monoecious, borne at the terminals in small bunches. Each peduncle carries 3 or 4 stalked flowers at the end and each flower has cylindrical thick ovary clove consisting of four fleshy sepals. Above the sepals there are four whitish structures, petals, dome shaped in appearance. After fertilization stamens and styles invariably fall. The lower part of the flower, along with the calyx, develops in to a fleshy, dark one-seeded drupe. The sepals are reduced to triangular projections and this is popularly known as the mother clove (Thangaselvabai *et al.*, 2010). In clove anthesis takes place in the afternoon at 1.30 p.m. with a peak between 3.30 p.m. and 4.30 p.m. Anthers dehisce longitudinally. Anther dehiscence commences 24 hrs. before anthesis. Maximum pollen germination and tube growth were obtained in 1% sucrose + 0.01% boric acid and it was observed after 33 hrs of dusting. The stainability of pollen was 81% and stained pollen grain was larger in size and gave a higher percentage of germination. Stigma receptivity was higher on the fifth day of anthesis. The best period for pollination is between fourth and sixth day after opening. Under artificial pollination the maximum fruit set obtained was 30%, while under bagged conditions it was 28%. Self-pollination appeared to be more probable in clove. A fertilized flower takes about three months for maturity (Thangaselvabai *et al.,* 2010).

GENETICS AND CYTOLOGY

The clove plant has 22 chromosomes, making it a diploid. The aim of this study was to determine the morphological characters and essential components of clove oil extract from buds, stalks, and leaves of *Syzygium aromaticum* var. *Tuni* and *S. aromaticum* var. *Zanzibar*. The results showed that the Tuni clove varieties had a larger size of the leaves, fruit and seed morphology than the Zanzibar variety. The results of the essential component characterization are obtained information that bud oil of Tuni variety was composed of eugenol (67.9%), the stem oil contained eugenol (80.6%), the leaf oil contained eugenol (60.5%). The bud oil of Zanzibar variety was constituted of eugenol (47.4%), the stem oil contained eugenol (67.5%), the leaf oil contained eugenol (63.5%). The main components of both varieties of clove oil were eugenol, followed by caryophyllene, eugenyl acetate, and other minor components. Climate factors such as rainfall, humidity and air temperature on Ambon Island did not significantly affect the eugenol content of both varieties (Hariyadi *et al.,* 2020).

GENETIC DIVERSITY

Variability in clove has been observed in the shape of trees, bearing habits, cropping season, yield, colour, shape and dimension of clove. Tree girth and leaf area are the two important morphological traits for assessing the productivity. At IISR, Calicut, differentiated 35 elite clove trees based on their morphological and yield traits while and Identified 12 high yielding types. Variation on morphological and yield attributes was observed among the 22 clove accessions being maintained at HRS, Pechiparai (Thangaselvabai *et al.,* 2010). Quantitative characterization of bud, flower, fruit, seed and quality parameters summarized based on the descriptive statistics revealed wider range of variability in number of inflorescences per m^2 and single bud weight fresh and dry. A unique accession was identified with purple red colour young leaf with light green tinge, dark purple red hypanthium, green brown petal, dark purple red sepal and yellow green stigma. Variability among four promising genotypes of clove was also reported from Dapoli. The accessions had plants that varied in height from 5.89 to 7.15 m, girth from 35 to 40 cm, and canopy spread from 2.50 to 3.05 m. When compared to local check, SA-1 (9.31 m tall), which is one of the 24 clove accessions kept at Pechiparai, had the tallest trees at 11.78 m, followed by SA-3 at 11.63 m. The accession SA-13 recorded the highest stem girth (49.59 cm) in comparison to the local check (40.57 cm) and was noticeably superior to other accessions. The accession SA-3 recorded the highest dry bud yield (1.52 kg/tree/year), number of branches (16) leaf length (12.47 cm) and leaf breadth (7.46 cm) (Reddappa *et al.,* 2022).

The mean performance of various clove accessions, as well as a local check, was assessed in terms of tree characteristics and bud yield. The results indicate that the accessions exhibit significant variation in their tree characteristics, comprising an average height of 9.02 metres for the trees, an average stem girth of 38.76 centimetres, an average leaf length of 10.16 cm, an average leaf breadth of 6.09 cm, and an average number of branches per tree of roughly 13.28. Furthermore, an average dry bud yield of 0.99 kg per tree was shown for the accessions; values ranged from 0.66 kg to 1.67 kg per tree. On the other hand, the local check showed particular features: an average of 10 branches per tree; a dry bud yield of 0.71 kg per tree; a tree height of 12.34 metres; a stem girth of 40.99 cm; a leaf length of 11.67 cm; a leaf breadth of 4.89 cm. With regard to tree growth and bud yield, these results give a thorough understanding of the differences in performance between various accessions and the local check. The genetic divergence study produced seven unique clusters, the biggest of which, Cluster II, showed strong genetic similarity among genotypes SA-8, SA-10, SA-12, SA-7, SA-5, SA-4, SA-6, SA-9, SA-2, and SA-14 (Binisundar *et al.*, 2023).

Morphological characteristics like canopy shape, stem dimensions, leaf attributes, and inflorescence traits were examined. Additionally, GC-MS analysis identified oil chemical components. Findings revealed an average plant height of 11.72 m and trunk circumference of 115.55 cm. Canopy shape primarily exhibited a cylindrical form with 1-3 main branches. Leaves displayed green, glossy, and smooth textures upon maturity, transitioning from reddish to bright red in their young shoots, with petiole length of 2.17cm, leaf length of 10.96 cm, and leaf width of 4.39 cm and ratio 2.5. Inflorescences followed a short type, with pink to red mature flower tubes, rounded or slightly pointed corollas, and distinctive red corollas – characteristics typical of the Zanzibar type. Inflorescences were characterized by short arrangements, with an average of 12-20 flower buds per inflorescence.

There were tree-to-tree fresh flower yield fluctuations between 40 to 100 kg. Dried clove bud with water content 5.73-6.82 % contained oil 14.67 – 17.96 %. Essential oil compounds analysis indicated the presence of 15-20 chemical components, with eugenol constituting over 70%, signifying its primary compound. This population may be recommended as genetic material for breeding high-yielding cloves (Susilowati *et al*., 2024). The presented research sought to quantitatively and qualitatively analyze the morphological diversity and genetic makeup of five clove accessions using seven RAPD primers. The results of coefficient variation showed that the leaf area holds the highest value (62.7%) compared with the petiole length (18.67%). Hierarchical cluster analysis based on 11 morphological traits, including crown shape, trunk type, bark type, branching direction, leaf shape, leaf apex shape, leaf base shape, leaf margin, leaf character, leaf venation, and leaves aroma exhibited a distant relationship between the clove accessions obtained from tuni and hutan. These accessions showed a high dissimilarity between the red and the white Zanzibar. The RAPD profile showed 92 bands ranging from 800 to 2700 bp, with a polymorphism of 66.3%. Based on genetic distance analysis, red Zanzibar and hutan have the highest value (0.58%), while red Zanzibar and white Zanzibar have the lowest (0.16%). These results were consistent with phylogenetic tree reconstruction and PCoA analysis that groups hutan at a long distance from red Zanzibar and Tuni. According to morphological and molecular analysis, clove accessions tuni, red Zanzibar, and hutan were most suitable as promising parental genotypes for further improvement through plant breeding and conservation programs (Marasabessy *et al*., 2024).

BREEDING

Genetic Resources: Clove belongs to the genus *Syzygium* with about 500 species. Many species of *Syzygium* occur in the Indian subcontinent and the more important ones are *S. aromaticum, S. cumini, S. fruiticosum, S.jambos* and *S.zeylanicum*. The genetic base of the country is very narrow because the original number of introductions was few (Thangaselvabai *et al.,* 2010). Survey conducted in the major clove growing regions of TamilNadu and Kerala and a total of about 200 accessions were made. Accessions with extra bold clove buds (King clove) dwarf and busy cloves with narrow leaves are three notable collections. Two exotic collections one each from Srilanka and Zanzibar are also maintained (Thangaselvabai *et al.,* 2010).

Breeding: The present invention relates to a kind of mating system of clove grafting, it mainly makes stock with wild Right wood Shanceli, forms with pure clove twig row culture scion grafting. Get long 3-5 cm of pure cloves branch clip, cut a long 3-4.5 cm of scion bevel that is deep to medulla, cut long about 1 cm inclined-plane at the opposite side of branch lower end in the lower end of branch one side. Get wild Shanceli (*Selaginella selaginoides*) again and make stock, and cut out long 3-5 cm of tangent plane that is deep to xylem on stock, the lower end of stock tangent plane cuts out a stock otch corresponding with the scion inclined-plane. Corresponding again grafting is tightened with bandage, and gives cultivating and managing. The high growth of the graft survival rate of this method is fast, and the cloves of grafting is strong to the suitable ability of weather soil, and vitality and diseases and insect pests resistance are strong, and bud increases longer blooming period (Patents, 2008). Breeding trees for dwarf, bushy, early bearing nature with bold buds and high oil content is the main objective in the crop improvement programme. But it is not easy to achieve these aims due to lack of considerable variability in the existing population and being a perennial crop with long juvenile period. The present day clove population is originated from a few trees introduced to our country (Thangaselvabai *et al.,* 2010). Selections with distinct morphological and bud variations were made based on the survey conducted at Maramalai and Keeriparai areas of Kanyakumari District and two king clove types (KC-1, KC-2) and one dwarf clove (DC-1) collected from this region are being evaluated at HRS,Yercaud and Pechiparai, Tamil Nadu Agricultural University (Thangaselvabai *et al*., 2010).

Mature Drupe: Look for small drupes that have turned dark purple or black Pluck them and remove the pericarp from each one – that dark, matte covering over the seed. Just pry the pericarp away with your fingers. Plant them as soon as possible after taking the coating off. You can also buy *L. nobilis* seeds from local plant nurseries and online. Mother cloves *(anthophylli)* are the ripe fruits of cloves that are ovoid, brown berries, unilocular and one-seeded. Blown cloves are expanded flowers from which both corollae and stamens have been detached. Exhausted cloves have most or all the oil removed by distillation. They yield no oil and are darker in color (Wikipedia, 2024). If the buds are not gathered, they will flower and turn into oblong, drooping fruits known as 'mother of cloves', which have no use in the spice trade. Mother cloves (anthophylli) are the ripe fruits of cloves that are ovoid, brown berries, unilocular and one-seeded. Blown cloves are expanded flowers from which both corollae and stamens have been detached. Exhausted cloves have most or all the oil removed by distillation. They yield no oil and are darker in color (Hemphil, 2018; Wikipedia, 2024a).

Dwarf tree: Two clove trees at Black Rock Estate in Kanyakumari were identified as dwarf, bushy and 2 m tall with a canopy width of 5 m. The main trunk measured only 0.6 m in height but had numerous branches. The seedling derived from these trees exhibits dwarf characteristics. For its dwarf stature, this promising accession was registered with NBPGR, New Delhi, with accession number INGR-04112. The morphological characteristics of this dwarf clove reported were 52.62 cm plant height at 8th year with a canopy of 50 cm and a bushy shape (Reddappa *et al*., 2022). Three distinct different morphological variants in clove; One king clove, two dwarf bushy clove at Black Rock Estate and three small leaved clove trees from Maramalai Estate were also reported during the surveys conducted at Tamil Nadu. The identified promising variants presented significant opportunity for crop improvement programmes to make use of diversity in *Syzygium aromaticum* (Reddappa *et al.,* 2022). Two King clove types (KC-1 and KC-2) and one dwarf clove (DC-1) based on morphological and flower bud characters, and collected variants were evaluated at the Horticulture Research Station, Yercaud (Reddappa *et al.,* 2022).

Seeds: Every year, there are two flowering seasons: November to January and July to October. Few flowers mature into fruit. The fruit known as the mother of cloves contains one or, very rarely, two seeds. Look for small drupes that have turned dark purple or black. Pluck them and remove the pericarp from each one – that dark, matter covering over the seed. Just pry the pericarp away

with your fingers. Plant them as soon as possible after taking the coating off. You can also buy *L. nobilis* seeds from local plant nurseries and online (Reddappa *et al*., 2022).

Varieties: The distinctive characteristics of local clove plants could be evaluated through morphological observations. The research was assessed during June - October 2019 in Talaga Jaya, South Wasile, East Halmahera. The study was conducted by survey method with the age of observed plants were more than 10 years old and which species consist of 10 productive trees, selected randomly. The research using local clove with comparative superior varieties of Afo. Leaf, flower, fruit, seed, and the symptom of blister blight disease were observed at 1 m^2 area on each tree. Form of the trees, stems, branches, leaves, flowers, fruits, and seeds were observed. The results showed that the characteristics morphology of local clove varieties was similar to Afo. The disease severity of blister blight in this study was mild with a 4,28% disease intensity. Morphological characteristics similar to Afo cloves and mild disease intensity of blister blight indicate that local clove varieties have the potential to be developed into new varieties (Cahyaningrum *et al*., 2021**).**

Common Varieties (Epicure. 2024)
Zanzibar Cloves: Known for their rich flavour and high oil content. Predominantly grown in Zanzibar.
Madagascar Cloves: Milder in flavour, grown mainly in Madagascar.
Moluccan Cloves: Originating from the Moluccas, these cloves have a unique aromatic profile.
Sulawesi Cloves: Grown in Sulawesi, Indonesia, and offer a distinct, spicy flavour.
Sri Lankan Cloves: Often higher in quality with a balanced flavour, cultivated in Sri Lanka.

Uses: Cloves are a staple spice of Indonesia, a walk through a local market and you'll detect its unmistakable scent trail from a vast distance, its slow warmth fill up your lungs with comfort. The little brown flower buds are sold for cooking, making burst alive with flavour. A variety of dishes can accommodate the cloves flavour strata, desserts, drinks, meats, and curry all make a perfect match for the feisty flower. Like a number of spices cloves influence extends far beyond the culinary space. The oil produced from clove has been in use in traditional medicine for centuries. It is regularly used in aromatherapy to help with digestive issues; it is applied to the stomach and gently massaged into the skin, letting the oil slowly warm your body. When people think of spice, and its exotic lingering fragrance, cloves scent defines warm sweet spice, with a deep woody base note. Exotic is an interesting word, it conjures images of faraway lands filled with ancient rites and customs, colours surround you in splashes, under blue tropical skies. The images this scent produce make it a perfect choice for setting a relaxing mood, as well as the oil, incense are also a great way to enjoy the fragrance that lies hidden in these flower buds (Utama, 2016).

In Indonesia ground cloves are mixed with tobacco to make 'kretek' cigarettes, which crackle as they burn, and give off a distinctive aroma. To encounter the smell of a 'kretek' cigarette anywhere in the world immediately transports one back to Asia. Cloves are the essential component in a clove orange, or pomander, a dramatic example of the antibacterial qualities of cloves. Because of their high pungency, cloves must always be used sparingly in cooking as too much can easily overpower a meal. Even though care is to be taken in their application, it is hard to imagine a host of traditional foods, including apple pie, ham, stewed fruit and pickles, without the addition of cloves. In Denmark they are an ingredient in the popular 'pepper cake' and are frequently added to exotic Arabian dishes. A popular mulled wine of the Middle Ages called 'hippocras' was made with ginger, cloves, and other spices. Right up to the present day, the warming spiced wines of Europe and Scandinavia are flavoured in the same way. Cloves are used in Indian and Asian curries and, as a truly international spice, can be found in the kitchens of every continent of the world (Hemphil, 2018). Cloves have been used for many times to commercial purposes. *Syzygium aromaticum* also have many pharmacological properties such as antioxidant, anti-viral, anti-diabetic and anti-inflammatory **(**Khan, 2022**).** Cloves are a staple in worldwide culinary traditions, attracting attention with their unique, powerful taste. Their slight sweetness makes them a popular complement to a variety of meals, bridging the gap between savory and sweet. Whether giving a comfortable warmth to mulled wines, a festive touch to Christmas hams, or a subtle twist to pickled fruits, cloves have the astonishing capacity to infuse dishes with a layer of unrivalled depth and complexity. Their flexibility in enhancing the essence of many cuisines has cemented their reputation as a key component, leaving an indelible impression on palates and plates worldwide (Thomas, 2023). Cooking with cloves requires a certain amount of expertise. When choosing cloves, look for ones with a plump and oily appearance, since this indicates freshness. To keep their superb taste and power, keep them in sealed containers. An intriguing alternative for a more robust perfume is to crush cloves at home shortly before use. These simple yet powerful strategies will guarantee that the essence of cloves permeates your culinary creations, raising them to a new level of olfactory deliciousness (Thomas, 2023).

Clove is a versatile spice with a wide range of uses including culinary applications, medicinal benefits, aromatic uses, insect repellent properties, and decorative purposes:

Culinary Uses: Flavouring Agent: Cloves are commonly used as a flavouring agent in both sweet and savoury dishes. They add a warm, aromatic flavour to foods and are often used in baking, particularly in the preparation of gingerbread, pumpkin pie, and other desserts. In savoury dishes, cloves are used in soaps, stews, marinades, and rice and spicy flavour. Cloves can be used whole or ground depending on the recipe. Whole cloves are often added to dishes during cooking and then removed before serving, while ground cloves are used in spice blends and rubs (Singh, 2024).

Medicinal Uses: Dental Health-Clove oil has been used traditionally for its analgesic and antiseptic properties in dental care. It is commonly used to alleviate toothaches and gum pain. Clove oil is also found in some dental products such as toothpaste and

mouthwash due to its potential benefits for oral health (Singh, 2024). Worcestershire sauce (also spelled Worcester), an Indo-British contribution to international cuisine, is markedly dominated by clove aroma. Cloves are also used to flavor many brands of tomato ketchup (catsup). Dried cloves are a key ingredient in Indian *masala chai* tea and a part of many spice blends including Chinese five spice, Indian *garam masala* and pumpkin pie spice. Cloves are an ingredient in Vietnamese pho. In Western cuisine, cloves are used to stud baked hams, as a pickling spice, and in mulled wine. Pomander balls are made by studding oranges (and other fruits) with dried cloves and can be used as a decoration or freshener (MCSI, 2024).

Clove is very aromatic and fine flavoured and imparts warming qualities. In all Indian homes, it is used as a culinary spice as the flavour blends well with both sweet and savoury dishes. Clove is used for flavouring pickle, curries, ketchup and sauces. It is highly valued in medicine as a carminative, aromatic and stimulant. Clove has stimulating properties and is one of the ingredients of betel chewing. In Jawa, clove is used in preparation of a special brand of cigarette for smoking. The essential oil which is obtained by distilling clove with water or steam, has even more uses. It is used medicinally in several ways. The chief constituent of the oil eugenol, is extracted and used as an imitation carnation in perfumes (Nikita, 2024). Cloves are used in the cuisine of Asian, African, Mediterranean, and the Near and Middle East countries, lending flavor to meats (such as baked ham), curries, and marinades, as well as fruit (such as apples, pears, and rhubarb). Cloves may be used to give aromatic and flavor qualities to hot beverages, often combined with other ingredients such as lemon and sugar. They are a common element in spice blends (as part of the Malay *rempah empat beradik* –"four sibling spices"– besides cinnamon, cardamom and star anise for example), including pumpkin pie spice and speculaas spices (Wikiwand, 2024).

Cloves are a versatile spice used in many dishes. They can be used either whole or ground to enhance both sweet and savoury recipes (Epicure. 2024):
Meat Dishes: Add cloves to marinades or rubs to bring warmth to meats like beef or pork. Stud ham with whole cloves for a festive touch and deeper flavour.

Sweet Dishes: Ground cloves add spicy sweetness to baked goods like cookies, cakes, and pies. Whole cloves can be used to infuse flavour into syrups and compotes.

Beverages: Cloves are a key ingredient in mulled wine, adding warmth and spice. They can also enhance the flavour of chai tea and other spiced drinks.

Vegetable Dishes: Add cloves to pickling spices for a richer taste. Mix ground cloves into seasoning blends for roasted or sautéed vegetables.

Main Uses: 1) Food Industry: Cloves are used as a spice in various cuisines. 2)

Medicine: Clove oil has antimicrobial properties, making it popular in pharmaceuticals. 3)

Cosmetics: Used for its fragrance and potential skin benefits (Epicure. 2024).

Cloves are used in the cuisine of Asian, African, Mediterranean, and the Near and Middle East countries, lending flavor to meats (such as baked ham), curries, and marinades, as well as fruit (such as apples, pears, and rhubarb). Cloves may be used to give aromatic and flavor qualities to hot beverages, often combined with other ingredients such as lemon and sugar. They are a common element in spice blends (as part of the Malay *rempah empat beradik* –"four sibling spices"– besides cinnamon, cardamom and star anise for example[12]), including pumpkin pie spice and speculaas spices (Wikipedia, 2024). The use of clove for any medicinal purpose has not been approved by the US Food and Drug Administration, and its use may cause adverse effects if taken orally by people with liver disease, blood clotting and immune system disorders, or food allergies. Cloves are used in traditional medicine as an essential oil, which is used as an anodyne (analgesic) mainly for dental emergencies and other disorders. There is evidence that clove oil containing eugenol is effective for toothache pain and other types of pain, and one review reported the efficacy of eugenol combined with zinc oxide as an analgesic for alveolar osteitis. Clove essential oil may prevent the growth of *Enterococcus faecalis* bacteria which is often present in a root canal treatment failure. Studies to determine its effectiveness for fever reduction, as a mosquito repellent, and to prevent premature ejaculation have been inconclusive. It remains unproven whether blood sugar levels are reduced by cloves or clove oil. The essential oil may be used in aromatherapy (Wikipedia, 2024).

The use of clove in whole or ground form is mainly for culinary purposes and as a flavouring agent in food industry. Its flavour blends well with both sweet and savory dishes. It is highly valued in medicine as carminative, aromatic and stimulant. In Indonesia, the lion share of production is consumed in production of 'kretek' cigarettes. The antiseptic and antibiotic properties of clove oil are used in medicine especially in dentistry, oral and pharyngeal treatments. It has wider applications in preparations of toothpaste and mouthwashes, soaps and perfumes. It is also reported to help diabetics in sugar assimilations (Indianspices, 2024). Both cloves and the oil are stimulant, aromatic, and carminative. Cloves in substance or infusion are sometimes given to relieve nausea and vomiting, more especially the vomiting of pregnancy, to relieve flatulence, and to except weak digestion. The oil of cloves sometimes affords relief when introduced into the cavity of a carious tooth *(*Unitproj, 2024*)*.

Cloves are used as a culinary spice for flavoring a variety of foods, while the essential oil (clove oil or oil of cloves) is used in flavorings (such as in medicines or synthetic vanilla), and in perfume. Cloves are used widely for perfuming the air and are an important incense material in Chinese and Japanese culture. They also are employed medicinally, including as a natural analgesic

and antiseptic (NEW, 2024). Cloves can be used either whole or in a ground form for cooking and commonly flavor a variety of foods, from sweet to savory. They often are used as a flavoring for ketchup and sauces. However, cloves tend to be extremely strong and typically are used sparingly in cuisine. The spice is also smoked in a type of cigarette known as *kretek* in Indonesia. Cloves have historically been used in Indian cuisine (both North Indian and South Indian) as well as in Mexican cuisine, where it is often paired together with cumin and canela (cinnamon). In the north Indian cuisine, it is used in almost every sauce or side dish, mostly ground up along with other spices. They are also a key ingredient in tea along with green cardamoms. In the south Indian cuisine, it finds extensive use in the biryani dish (similar to the pilaf, but with the addition of local spice taste), and is normally added whole to enhance the presentation and flavor of the rice (NEW, 2024).

In Anglo-Saxon countries, it is common to stick a few Cloves in an Orange or Lemon to perfume a room or a closet. It is therefore often found in the composition of home fragrances and even anti-insect fragrances. Its strong smell would make unwanted visitors flee. Similarly, some have been using the Clove for a very long time to perfume their laundry. The quality of a Clove nail is measured by its thickness and purplish reddish-brown colour. They are supposed to break easily without the need to bend your fingers and let a little essential oil exude when you press them with your nails. The Clove can be used in cosmetics, in the elaboration of creams and lotions for imperfection skins. It is also said to be the ally of rough and damaged hair. Lets' not forget that Clove has a very important role in the cooking area. Clove is used in therapeutic medicine to heal teeth. This spice is often used in the composition of mouthwashes and toothpastes. It is also used in treatments and medicines to fight against any form of stomach pain or gastric problem. Clove is also known to stimulate the stomach and fight against fermentation and bloating. It stimulates the appetite and allows the faster activation of the digestive glands at all levels (Pages, 2024). Cloves are used in the cuisine of Asian, African, Mediterranean, and the Near and Middle East countries, lending flavor to meats (such as baked ham), curries, and marinades, as well as fruit (such as apples, pears, and rhubarb). Cloves may be used to give aromatic and flavor qualities to hot beverages, often combined with other ingredients such as lemon and sugar. They are a common element in spice blends (as part of the Malay *rempah empat beradik* –"four sibling spices"– besides cinnamon, cardamom and star anise for example, including pumpkin pie spice and speculaas spices. In Mexican cuisine, cloves are best known as *clavos de olor*, and often accompany cumin and cinnamon. They are also used in Peruvian cuisine, in a wide variety of dishes such as *carapulcra* and *arroz con leche*. A major component of clove's taste is imparted by the chemical eugenol,https://www.inaturalist.org/taxa/122770-Syzygium-aromaticum#cite_note-eugenol-14 and the quantity of the spice required is typically small. It pairs well with cinnamon, allspice, vanilla, red wine, basil, onion, citrus peel, star anise, and peppercorns (Wikipedia, 2024a).

Non-culinary uses

It is often added to betel quids to enhance aroma while chewing. The spice is used in a type of cigarette called *kretek* in Indonesia. Clove cigarettes were smoked throughout Europe, Asia, and the United States. Clove cigarettes are currently classified in the United States as cigars, the result of a ban on flavored cigarettes in September 2009. Clove essential oil may be used to inhibit mold growth on various types of foods. In addition to these non-culinary uses of clove, it can be used to protect wood in a system for cultural heritage conservation, and showed the efficacy of clove essential oil to be higher than a boron-based wood preservative. Cloves can be used to make a fragrant pomander when combined with an orange. When given as a gift in Victorian England, such a pomander indicated warmth of feeling (Wikipedia, 2024a). Clove oil is commonly used to anesthetize or euthanize laboratory or pet fish. Clove oil is a component of choji oil, which was traditionally used for the maintenance of Japanese swords (Wikipedia, 2024b). The vast majority of commercially cultivated cloves are used by the tobacco industry to flavor cigarettes. Cloves are also used commonly as spices, either in their whole form or after first grinding into powder (Plantvillage, 2024).

Traditional Ethnic Uses: Cloves are used in spice cookies and cakes. Much of the world crop is used in Indonesia for Clove cigarettes, called "kreteks" (Spiceadvice, 2024).

Uses of Oil: The clove essential oil may also be employed as insecticide. Park and Shin reported the possibility of employment of clove essential oil to control the japonesse terminte *Reticulitermes speratus* Kolbe. In the same way, Eamsobhana *et al.* found that clove essencial oil at 5% posses 100% of repellent activity against the chigger *Leptotrombidium imphalu* which could be a safer and cheaper alternative to synthetic repelents commonly associated to harmful side effects. A formulation containing 10% of clove essential oil was effective against the bit of *Aedes aegypti* (L.) and *Anopheles dirus* Peyton and Harrion with a protection time of (80.33±10.56) and (60.00±10.00) respectively, soy bean oil was employed as control (Cortés-Rojas *et al*., 2014). In a recent work, the structure-activity relationship of the main clove oil constituents and synthetic derivatives of eugenol against *Aedes aegypti* (Diptera: Culicidae) larvae were studied. The larvicidal methods are one of the most effective strategies to combat dengue, since there is not drug for treatment or a vaccine. Eugenol exhibited interesting results and could be a promising alternative to common insecticide. Eugenol, eugenol acetate and beta-caryophyllene were effective in repellency of red imported fire ants *Solenopsis invicta* (Hymenoptera: Formicidae), being eugenol the fastest acting compound. Clove oil was also effective spatial repellent for pestiferous social wasps *Vespula pensylvanica* (Saussure) and paper wasps mainly *Polistes dominulus* (Christ).

Clove oil can also serve as an anesthesia for a variety of fish. However, lengthy exposures can cause mortality and sub-acute morbidity. Clove oil could be employed as suppressor of potato tuber germination by affecting the lipid peroxidation and the enzymes activities of catalase, glutathione-S-transferase, peroxidase, polyphenol oxidase and superoxide dismutase (Cortés-Rojas *et al.,* 2014). According to the National Center for Biotechnology Information, multiple hazards are associated with clove oil. It may cause skin, eye, and respiratory irritation, or an allergic reaction on the skin. It is also flammable and could be fatal if it is swallowed and goes into the airway. In one case report, a 15-month-old child experienced liver failure after consuming 10 ml of

clove oil. Another incident involved a 2-year-old child who drank 5 to 10 ml of clove oil. The child experienced multiple medical problems, including coma, liver damage, and problems with blood clotting. Cloves may also increase the chance of bleeding or increase the body's response to warfarin. It is important to discuss the use of any herbal products with a medical professional so that they can review potential side effects and interactions (Metropulos, 2023).

Oil is used in traditional medicine including oral health. Cloves are known for their strong taste and smell and can be purchased ground or whole for use in cooking. Many cuisines include cloves, and it is also an ingredient in certain condiments, including ketchup and Worcestershire sauce. Some perfumes use cloves for the aroma and clove oil is sold for use as an essential oil. Cloves are commonly used in Ayurveda, which is traditional Indian medicine. They have also been used traditionally to cause a numbing sensation (Metropulos, 2023). Ground cloves can be used in similar ways as cinnamon and ginger and can be used to flavor applesauce, oatmeal, muffins, and cookies. This recipe for gingerbread cake with cream cheese frosting uses ground cloves.
Cloves are also sometimes used to make chai, which is a mixture of tea, spices, and milk popular in India and Pakistan. This cardamom ginger chai recipe incorporates cloves. Cloves can be used in savory dishes as in this recipe for baked chicken with artichokes, cinnamon, and preserved lemons and this one for slow-cooker braised beef with carrots & turnips (Metropulos, 2023). The buds contain 14 to 20 percent essential oil, the principal component of which is the aromatic oil eugenol. Cloves are strongly pungent owing to eugenol, which is extracted by distillation to yield oil of cloves. This oil is used to prepare microscopic slides for viewing and is also a local anesthetic for toothaches. Eugenol is used in germicides, perfumes, and mouthwashes, in the synthesis of vanillin, and as a sweetener or intensifier (EEB, 2024). The content of essential oil in cloves of good quality may exceed 15%. The oil itself is dominated by eugenol (70 to 85%), eugenol acetate (15%) and β-caryophyllene (5 to 12%), which together make up 99% of the oil. Cloves contain about 2% of the triterpene oleanolic acid (Gernot, 2024).

The compound responsible for the clove's aroma is eugenol. It is the main component in the essential oil extracted from cloves, comprising 72 to 90 percent. Eugenol has pronounced antiseptic and anesthetic properties, and is used as a germicide and in mouthwashes. Other important constituents include essential oils acetyl eugenol, beta-caryophylline, and vanillin, as well as crategolic acid, tannins, gallotannic acid, methyl salicylate (painkiller), several sesquiterpenes, the flavanoids eugenin, kaempferol, rhamnetin, and eugenitin, and such triterpenoids as oleanolic acid, stigmasterol and campesterol (NEW, 2024). Oil of cloves, also known as clove oil, is an essential oil from the clove plant, *Syzygium aromaticum*. There are three types of clove oil (NEW, 2024). Oil of cloves, also known as:

***Bud oil*,** derived from the flower-buds of *S. aromaticum*, consists of 60-90 percent eugenol, eugenyl acetate, caryophyllene, and other minor constituents.
***Leaf oil*,** derived from the leaves, consists of 82-88 percent eugenol with little or no eugenyl acetate, and minor constituents.
***Stem oil*,** derived from the twigs, consists of 90-95 percent eugenol, with other minor constituents.
The main oil-producing countries are Madagascar and Indonesia.

Oil of cloves is known best for its medicinal properties, having antiseptic, analgesic, and anesthetic properties. Many of these uses are detailed below under "medicinal uses." However, clove oil also is used in non-medicinal applications, such as for producing synthetic vanilla, as a flavor intensifier, and in perfumes. Clove oil also is used for anesthetizing and in higher doses euthanizing fish. It further has application in an all natural herbicide called "Perfectly Natural Weed & Grass Killer." The clove oil is the only active ingredient, and it is very effective at killing many types of plants. In addition, research has shown that clove oil is an effective mosquito repellent. Clove oil is also used in oil painting. The anti-oxidant effects of the eugenol delays the drying (oxidation) of the drying oils (linseed, safflower, poppy, walnut) in the paint on the palette. A drop per paint "nut' is usually added. Alternatively, the palette can be covered, with a small amount of clove oil applied to the inside of the cover to allow the clove oil to disperse, preventing the paint from reacting with the oxygen within the cover. This method has the advantage of slowing the drying of the paints once they are applied to the painting (NEW, 2024).

Oil of cloves is a natural analgesic and antiseptic used primarily in dentistry for its main ingredient eugenol. It can also be purchased in pharmacies over the counter, as a home remedy for dental pain relief, mainly toothache; it is also often found in the aromatherapy section of health food stores. The oil produced by cloves can be used in many things from flavoring medicine to remedies for bronchitis, the common cold, a cough, fever, sore throat and tending to infections. Oil of cloves is best known for its anesthetic properties. It is widely reported to be effective, and prior to the availability of safe, approved topical anesthetic drugs, was used by some dentists. Clove oil often is used to relieve pain caused by dry socket, a possible complication of tooth extraction. The antimicrobial and anti-fungal properties of clove oil allow its use for acne, warts, scars and parasites. The essential oil is used in aromatherapy when stimulation and warming is needed, especially for digestive problems. Topical application over the stomach or abdomen is said to warm the digestive tract. Cloves are used in Ayurveda and are called Lavang in India. Cloves are also used in Chinese medicine and in western herbalism and dentistry, where the essential oil is used as an anodyne (painkiller) for dental emergencies. Cloves are used as a carminative, to increase hydrochloric acid in the stomach, and to improve peristalsis. Cloves are also said to be a natural antihelmintic (expel parasitic worms). In Chinese medicine, cloves or *ding xiang* are considered acrid, warm, and aromatic, entering the kidney, spleen, and stomach meridians, and are notable in their ability to warm the middle, direct stomach qi downward, to treat hiccough and to fortify the kidney yang. Because the herb is so warming, it is contraindicated in any persons with fire symptoms and according to classical sources should not be used for anything except cold from yang deficiency. As such it is used in formulas for impotence or clear vaginal discharge due to yang deficiency, for vomiting and diarrhea due to spleen and stomach coldness (identified with hypochlorhydria), and, together with ginseng and the herb patchouli, for morning sickness. In West Africa, the Yorubas use cloves infused in water as a treatment for stomach upsets, vomiting, and diarrhea. The infusion is called Ogun Jedi-jedi (NEW, 2024).

Cooking Tips: Both whole and ground cloves are readily available. Whole cloves are used during cooking and are typically removed from the recipe before serving. Whole cloves can be ground at home using a coffee grinder or spice mill. Cloves have an extremely intense flavor, especially those that have been ground. Be careful when deciding how much to use in a recipe - a little goes a long way! (MCSI, 2024).

Toxicity: Oil of cloves is considered safe in very small quantities (less than 1500 parts per million) as a food additive. However, clove oil is toxic to human cells. If ingested in sufficient quantity or injected, it has been shown to cause life-threatening complications, including Acute Respiratory Distress Syndrome, Fulminant Hepatic (Liver) Failure, and Central Nervous System Depression; the lethal oral dose is 3.752 g per kg body weight. The internal use of the essential oil should be restricted to three drops per day for an adult as excessive use can cause severe kidney damage. Large amounts of cloves should be avoided in pregnancy. Cloves can be irritating to the gastrointestinal tract, and should be avoided by people with gastric ulcers, colitis, or irritable bowel syndrome. In overdoses, cloves can cause vomiting, nausea, diarrhea, and upper gastrointestinal hemorrhage. Severe cases can lead to changes in liver function, dyspnea, loss of consciousness, hallucination, and even death (NEW, 2024). Clove oil is toxic in anything other than small therapeutic doses, and several cases of acute liver and kidney damage have been reported, principally in children. In foods, the level of clove oil used as a flavor ingredient does not exceed 0.06%, and is considered safe (Wikipedia, 2024b).

Chemical Composition: It consists of 82-88% eugenol, little amount of eugenyl acetate, and other minor constituents. Stem oils are evolved from the twigs of Eugenia caryophyllus. It consists of 90-95% eugenol, and some other minor constituents. A major component of clove taste is imparted by the chemical eugeno l. Eugenol is the main bioactive compound of clove, which is found in concentrations ranging from 9 381.70 to 14 650.00 mg per 100 g of fresh plant material l. With regard to the phenolic acids, gallicacid is the compound found in higher concentration (783.50 mg/100 g fresh weight). The chemical composition of the essential oil from the bud of clove. As can be seen from this table, 18 compounds, representing about 99.95% of the essential oil from clove, were characterized. The major components are as follows: eugenol (87.00%), eugenyl acetate (8.01%) and β-Caryophyllene (3.56%).This essential oil comprises in total 23 identified constituents, among them eugenol (76.8%), followed by β-caryophyllene (17.4%), α-humulene (2.1%), and eugenyl acetate (1.2%) as the main components (Yadav *et al.,* 2021). Moisture 5.4%; protein 6.3%; volatile oil 13.2%; fat (non volatile ether extract) 15.5%; crude fibre 11.1%; carbohydrates 57.7%; mineral matter 5.0%; ash 0.24%; calcium 0.7%; phosphorus 0.11%; iron 0.01%; sodium 0.25%; potassium 1.2%; vitamin B, 0.11 mg/100 g.; vitamin B, 0.04 mg/100 g.; niacin 1.5 mg/100 g.; vitamin C 80.9 mg/100 g. and vitamin A 175 International Units (I.U.), calorific value 430 calories per 100 g (Nikita, 2024). Cloves are a popular spice in cooking. According to the United States Department of Agriculture National Nutrient DatabaseTrusted Source, 2.1 grams (g) or 1 teaspoon of ground cloves contains: 6 kilocalories (kcal), 0.13 grams (g) of protein, 0.27 g total fat, 1.38 g carbohydrate, 0.7 g fiber. The same amount of ground cloves also provides 1.263 milligrams (mg) of manganese (Metropulos, 2023). There are three types of clove oil: 1) *Bud oil* is derived from the flower-buds of *S. aromaticum*. It consists of 60–90% eugenol, eugenol acetate, caryophyllene and other minor constituents. 2) *Leaf oil* is derived from the leaves of *S. aromaticum*. It consists of 70–82% eugenol, and some amounts of beta Caryophyllene and alpha Humulene. 3) *Stem oil* is derived from the twigs of *S. aromaticum*. It consists of 85–92% eugenol, with other minor constituents. Stem oil is closer in olfactive and flavor profile to bud oil (Wikipedia, 2024b).

Health Benefits

Traditional medicine isn't the only avenue for cloves foray into the sciences; the oil is used in dentistry to fight against oral bacteria, as well as being an anaesthetic. Clove has also been researched for its anti-fungal, anti-viral, anti-inflammatory, and antioxidant properties. The active component *eungenol* in clove is thought to be in large part responsible for these combative properties. There have even been further studies to test its effectiveness against fevers, or to reduce blood sugar levels, though the research on the subject isn't currently conclusive. Those into flavour, colour, spice, and deep levels of relaxation will want to further delve into the alluring world of clove. Whether you know it or not, the foods you eat and products you use could be utilising the essence of this red and white (and pink) flower. Just remember to thank clove the next time you have a toothache! If clove sounds like the oil for you, then head on and take a dab of this essential oil! (Utama, 2016). Pharmacologically, clove and its main constituents possess antimicrobial, antioxidant, anti-inflammatory, analgesic, anticancer & anesthetic effects. Moreover, they showed insecticidal, mosquito repellant, aphrodisiac, and antipyretic activities (Yadav *et al*., 2021):

Anti Cancer Activity- To stay protected from cancer eat more cloves, as the eugenol in clove possess strong anticarcinogenic properties and helps control lung cancer, breast cancer, and ovarian cancer at its early stages.Clove also reduced the abnormal crowding of cells in particular regions of lung tissue and checked the growth of pre-malignant cells by more than 85 per cent. In another in vitrostudy, researchers found that clove oil stopped the growth of several cancer cell lines, including but not limited to breast, cervical, and colon cancer. Clove extract also increased cell death and disrupted cell division in a colon cancer cell line.

Anti diabetic Activity- Cloves also help keep your blood sugar levels in check and are known to promote insulin production, further controlling diabetes. Research shows that the compounds found in cloves may help keep blood sugar under control. As little as one teaspoon of the super-star spice is enough to reap benefits.

Anti Microbial Activity - Clove oil is used as an antiseptic in oral infections . This essential oil has been reported to inhibit the growth of molds, yeasts and bacteria. The high levels of eugenol contained in clove essential oil are responsible for its strong

biological and antimicrobial activities. Cloves have been shown to have antimicrobial properties, meaning they can help stop the growth of microorganisms like bacteria.

Anti viral activity- The antiviral activity of eugeniin, a compound isolated from *S. aromaticum* and from *Geum japonicum*, was tested against herpes virus strains being effective at 5 µg/mL, and it was deducted that one of the major targets of eugeniin is the viral DNA synthesis by the inhibition of the viral DNA polymerase. Eugenol was virucidal and showed no cytotoxicity at the concentrations tested.

Anti fungal activity- The present study indicates that clove oil and eugenol have considerable antifungal activity against clinically relevant fungi, including fluconazole-resistant strains, deserving further investigation for clinical application in the treatment of fungal infections. Studies have shown that clove essential oil is both fast and effective in killing fungal infections.

Analgesic activity-The results of the present study showed that aqueous extract of clove has analgesic effect in mice demonstrated by hot plate test which is reversible by naloxone. The role of opioid system in the analgesic effect of clove might be suggested. Clove oil contains the active ingredient eugenol, which is a natural anesthetic. It helps numb and reduce pain to ease a toothache. Eugenol also has natural anti-inflammatory properties. It may reduce swelling and irritation in the affected area.

Cloves offer some amazing health benefits because they contain antimicrobial properties, which can help fight bacteria and viruses while reducing inflammation. Laung contains many nutrients and carotene pigments. These spices also have an antioxidant effect on your body. The antioxidants fight free radicals in your body that can damage cells and lead to cancer or other diseases like Alzheimer's disease. Clove is great for helping with vision problems because it has vitamin A, which helps improve eyesight (Origin, 2022). Cloves contain many compounds that have anti-inflammatory properties. Eugenol is one of the most important compounds found in cloves. It helps reduce the inflammatory response in the body, reducing the risk of diseases. Eugenol acts as a potent antioxidant. Cloves are full of antioxidants. So it helps your body to fight free radicals, which damage your cells and can lead to disease. Cloves may also promote better liver function. Along with this, cloves are a great source of minerals such as potassium, Vitamin K (Origin, 2022). Apart from spices, cloves are used to prepare tea. If you are interested in getting a stronger dose of cloves, you can brew a cup of laung chai. There is nothing like sipping on this spicy and sweet drink to energize up from the inside out. The trouble starts when you cannot find an authentic laung chai at your convenience. Clove is one of the key components of Tea Origin. It is used in Masala Chai, Laung Elaichi Chai, and Laung Kali Mirch Chai. Cloves are also used in Kashmiri Saffron Kahwa. Clove, along with Rose petals and Saffron helps enhance the aroma of the kahwa (Origin, 2022).

Cloves have a variety of potential health benefits: **Oral health**

Cloves are the dried flower buds from the clove tree. Researchers are studying clove oil as a natural method for maintaining oral health due to its effect on plaque, gingivitis, and bacteria in the mouth. ReearchersTrusted Source compared the effectiveness of an herbal mouth rinse containing clove, basil, and tea tree oil with a commercially available essential oil mouth rinse. Both mouth rinses were effective against plaque and gingivitis, showing that they may help decrease oral inflammation and bacteria. The researchers also found that the mouth rinse that contained clove decreased the number of harmful bacteria more than the commercial mouth rinse (Metropulos, 2023).

Diabetes: A study in mice found that clove extract and nigericin, a component of clove extract, reduced insulin resistance in mouse muscle cells. Mice with diabetes that consumed nigericin also had less insulin resistance and improvements in glucose tolerance, insulin secretion, and beta cell function. Another animal studyTrusted Source looked at the effect of clove bud powder on laboratory markers in a rat model of diabetes. They found that blood sugar level was lower in rats that received the clove powder compared to those in the control group that did not receive the clove powder (Metropulos, 2023).

Cancer: Many herbs and spices are high in antioxidants, which are chemicals that play a part in reducing damage to cells that could lead to cancer. According to *Today's Dietitian*, "just 1/2 teaspoon of ground clove is said to contain more antioxidants than 1/2 cup of blueberries." In one laboratory studyTrusted Source, scientists found that clove extract was able to slow the growth of multiple types of human cancer cells. Clove extract also increased cell death in colon cancer cells. The same study also looked at the effect of clove extract on tumor growth in mice. Tumors grew significantly less in the mice treated with clove extract compared to those in the control group. In another studyTrusted Source, scientists looked at the effect of different preparations of clove extract on human breast cancer cells. They found that clove essential oil and ethanol extract of clove were both toxic to breast cancer cells. The authors reported that cloves might have a beneficial role in the future of cancer treatment since they can cause cell death and slow cell multiplication (Metropulos, 2023).

Obesity; Scientists have also studied cloves regarding their potential effect on obesity. In a studyTrusted Source of mice, researchers found that clove extract reduced the incidence of obesity resulting from a high-fat diet. Mice who received the clove extract had lower body weight, less abdominal fat, and less liver fat than those in the control group (Metropulos, 2023).

Cloves provide a variety of health advantages in addition to their gastronomic appeal. They are an antioxidant powerhouse that fights free radicals and promotes general wellbeing. Their analgesic effects provide pain relief and have been utilized as a natural cure for toothaches and mouth irritation. Cloves may also help with digestive and respiratory health, making them a flexible complement to holistic wellness techniques. Furthermore, cloves have proven therapeutic effects as well as a wealth of critical minerals. They are a good source of beta carotene, the pigment that gives them their unique brown color. Beta carotenes have

antioxidant and pro-vitamin characteristics, and they ultimately convert to Vitamin A, which is essential for keeping healthy eyes and general well-being. Thus, including cloves into your diet not only tantalizes the taste senses but also benefits your general health tremendously (Thomas, 2023).

The use of clove for any medicinal purpose has not been approved by the US Food and Drug Administration, and its use may cause adverse effects if taken orally by people with liver disease, blood clotting and immune system disorders, or food allergies. Cloves are used in traditional medicine as an essential oil, which is used as an anodyne (analgesic) mainly for dental emergencies and other disorders. There is evidence that clove oil containing eugenol is effective for toothache pain and other types of pain, and one review reported the efficacy of eugenol combined with zinc oxide as an analgesic for alveolar osteitis. Clove essential oil may prevent the growth of *Enterococcus faecalis* bacteria which is often present in a root canal treatment failure. Studies to determine its effectiveness for fever reduction, as a mosquito repellent, and to prevent premature ejaculation have been inconclusive. It remains unproven whether blood sugar levels are reduced by cloves or clove oil. The essential oil may be used in aromatherapy (Wikiwand, 2024). Unlike most spices, clove has an obvious medical value. It contains eugenol which is an effective local anesthetic, and this has long been used in dentistry. Other constituents include salicylic acid. Although the smoking of clove cigarettes is a national habit in Indonesia, the entry of this aromatic tobacco in the U.S.A. was curtailed when suspicion arose that it could cause adult respiratory distress syndrome (ARDS). Clove, which is an aphrodisiac (with properties similar to those of rhinoceros horn – i.e. an imaginary symbol of potency), was a highly valued flavor, a possible food preservative, and a pharmaceutical panacea in past centuries. Now, it is a rarely appreciated spice and an old-fashioned drug that has little role in medicine or dentistry today *(*Unitproj, 2024).

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Side Effects and Risck: It is generally recommended not to ingest clove oil in large amounts. If swallowed, clove may cause a burning sensation. Applying it to the skin or using it as a wash is recommended instead: 1. Increases Bleeding. 2. Lowers sugar level in the blood. 3. Toxicity. 4. Causes Allergic Reaction. 5. Causes Seizures. 6. Makes the skin sensitive. 7. Causes Mouth Sensitivity. 8. Cause Respiratory problem. 9. Loss of sensation. 10. Erectile /Ejaculation Issues. 11. Itching, rash. 12. Mouth irritation, sore gums (Yadav *et al*., 2021).

CULTIVATION

Propagation: The common method of propagation is by Seeds. Seeds are extracted from ripe fruits and sown immediately. Viability of the seeds is short and it can be maintained for about two weeks if they are stored under moist conditions. The seeds are sown directly in the nursery beds or in pots during June by using dehusked seeds.Medium to large sized dehusked seeds (>1.4g) gave 46% success in germination. A trial on sowing the seeds by different methods with and without the pulpy seed coat and with radical upwards and downwards indicated that clove seeds sown in the horizontal position with micropylar end of the seed facing sideways registered increased germination (Thangaselvabai *et al*., 2010). Among the various methods of vegetative propagation, air layering, approach and soft wood grafting were found to be successful during spring. In air layering 20% success and in approach grafting 12 % success was noticed at HRS, Pechparai. At IISR, Calicut, about 80% success was obtained in the initial trials with approach grafting (Thangaselvabai *et al.,* 2010).

Clove is commercially propagated from seeds which are planted soon after harvest. Seeds should be collected and extracted from the fruits of healthy mother plants exhibiting desirable characteristics. The seeds are extracted by soaking the fruits in water and peeling the skin from the fruit. The seeds can be planted in prepared nursery beds or polyethylene bags containing a mixture of soil and aged manure and should be planted to a depth of 2 to 5 cm and spaced 12 to 15 cm apart. Germination usually occurs within 1 to 6 weeks. The seedlings should be shaded to protect them from harsh sunlight. The seedlings should be kept moist through regular watering and can be transplanted when they reach at least 30 cm in height. The seedlings should be hardened off by exposing them to increasing amounts of sunlight before they are transplanted to the field (Plantvillage, 2024).

Clove is propagated through seed. Usually the seeds become available for sowing from August to October. The seeds lose their viability within one week after harvest under normal conditions and hence it is necessary to sow them immediately after collection from the tree. The seeds can be sown with or without the fruit coat. Raised nursery beds are prepared in a shady place and the seeds are sown in rows adopting a spacing of about 12 cms. The seeds begin to germinate in four to five weeks after sowing. The seedlings are very slender and delicate and grow very slowly. Watering is necessary throughout the nursery period. The seedlings after about six months of nursery life are transferred to baskets made of bamboo or mud pots and nurtured properly under the shade

till they attain an age of 12 to 18 months. Clove can also be propagated vegetatively by grafting on its own stock. Clove can conveniently be grown mixed with other commercial crops like arecanut, coconut, nutmeg, etc. The shade cast by these crops will provide enough protection to clove from the sun (Nikita, 2024).

Soil and Climate Requirement: Deep and rich loams with high humus content are best suited for clove cultivation. In India, clove has developed well in the open sandy loams and the laterite soils of South Kerala region. But the best growth is seen in black loams of the semi forest regions. Clove abhors water logging and, therefore, perfect drainage is essential. Clove is strictly a tropical plant and it requires a warm humid climate. Although there has been a general belief that clove requires proximity to sea for the proper development and cropping, experience in India has shown that the trees do well in the submontane regions and have been found to perform better than those in other areas. Humid atmospheric condition and an annual rainfall of 150 to 250 cm. are the other ideal requirements of the crop. Clove thrives altitude of 800 to 900 metres (Nikita, 2024).

Transplanting: Young clove trees should be planted in pre-dug pits which are approximately 60 cm × 60 cm ×60 cm or large enough to accommodate the root ball. The recommended spacing for clove trees is 8 m but closer spacings are commonly used. Trees planted in the field should be provided with temporary shading to alleviate stress. Shade can be provided through intercropping with other crops such as banana, cassava or coconut but trees such as Gliricidia are also used as these can be pruned to alter the amount of light reaching the cloves throughout the year (Plantvillage, 2024).

General care and maintenance: Once the temporary shade plants are removed, the plantation should be kept free from weeds by weeding once or twice each year or by applying a layer of mulch around the trees. Mulch helps prevent the roots being damaged by the physical removal of the weeds. Trees may require additional irrigation during dry periods to prevent them becoming stressed which harms their production. The trees should also be provided with nutrients in the form of fertilizer or manure. The composition and amount of fertilizer required is dependent on the region and soil type (Plantvillage, 2024).

Harvesting and Curing: Clove tree begins to yield from the seventh or eighth years after planting. The full bearing stage is attained after about 15 to 20 years. The flowering season is September-October in the plains and December-January in high altitudes. The buds are ready for harvest in about four months. Just before flowering there is fresh flush of young leaves and soon after this, the flower buds begin to appear. The optimum stage for picking clove buds is indicated by the change in the colour from green to slightly pinkish tinge. The unopened clove buds are carefully picked with hand when they turn pink in colour. It is necessary to pick the buds before they open, otherwise, the value of spice will be lost to a considerable extent. The harvested buds are spread evenly to dry in the sun either on grass-mats or on cement drying floor. During nights the buds should be stored under cover, lest they re-absorb moisture. Normally it is possible to dry the cloves in four to five days under direct sun and in about four hours when they are heated in zinc trays over a regulated fire. Fully dried buds develop the characteristic dark brown colour and crisp. If the produce is uniformly good, approximately 8,000 to 10,000 cloves would weigh one kilogram. Clove is graded according to its appearance and impurity content. Good quality clove should be brownish black in colour, with full and plump crown, somewhat rough to the touch and without wrinkles and it should not contain more than 16% moisture and 5% foreign matter. Also it should have fine aroma and flavour and should readily exude oil when the stem is pressed with the finger nail (Nikita, 2024).

The complete inflorescence (flower) should be picked just before the first buds open to ensure maximum size and oil content of the buds. The harvest is often conducted over 3 to 8 pickings during the season as buds mature. After harvesting, the buds are laid out to dry in the sun for several days (Plantvillage, 2024). There is considerable variation in the yield of clove. Under favourable conditions well grown trees may yield as much 4 to 8 kg. of cloves. It is, however, common to meet with low yielding tree in clove plantations, sometimes in large numbers, resulting in low and uneconomic production, particularly in certain years. The average yield from a bearing tree in a well maintained plantation, in India is reported to be about 2.5 kg. Considering that the percentage of bearing tree will be around 60, one hectare of plantation containing about 250 trees will yield about 375 kg. of cloves (Nikita, 2024).

Producers: According to FAO, Indonesia produced almost 80 percent of the world's clove output in 2005 followed at a distance by Madagascar and Tanzania. Cloves are also grown in Pakistan, India, Sri Lanka and Mauritius, as well as the West Indies (NEW, 2024). In Britain in the seventeenth and eighteenth centuries, cloves were worth at least their weight in gold, due to the high price of importing them. Today, according to the Food and Agriculture Organization (FAO), Indonesia produces most of the cloves, with almost 80 percent of the world's clove output in 2005, but with most of that consumed internally. The clove has become a commercial success, with products including clove drops being released and enjoyed by die-hard clove fans (NEW, 2024). The most important production area today is the island of Pemba, which together with Zanzibar forms one part of the state of Tanzania. The whole island of Pemba is covered with clove gardens, and it is reported that the island can be smelled on any ship approaching it. The short-lived Sultanate of Zanzibar and Pemba (1963–1964) had a flag showing two clove buds. Cloves are also grown on other East African islands, most notably, Madagascar. In Indonesia, clove production has recovered from poor decades after World War II, such that the country was forced to import cloves to satisfy the huge domestic market. Since the 1980s, Indonesia is again producing in large scale, although little of the Indonesian crop gets exported (Gernot,2024). Madagascar and Indonesia are the main producers of clove oil (Wikipedia, 2024b).

Environmental Impact: Clove trees contribute positively to the environment. They support biodiversity by creating habitats for different species and play a role in carbon sequestration, which helps fight climate change. Sustainability in clove farming involves using practices that do not harm the soil or surrounding ecosystems. These practices include organic farming and

reducing the use of harmful pesticides. Additionally, clove trees support local ecosystems and contribute to maintaining the health of the soil. By avoiding over-harvesting and ensuring replanting, the balance of the ecosystem can be maintained. This promotes long-term environmental stability. Furthermore, cloves have a significant impact on urban green spaces. They can be used in green screens and living walls to reduce particulate matter in the air, helping improve urban air quality. Adopting sustainable practices can ensure that clove cultivation remains environmentally friendly. Research and ongoing studies aim to enhance these methods, ensuring minimal negative impact and promoting better environmental health. Clove farming also plays a role in community sustainability by providing income and resources to local farmers. This economic stability encourages the adoption of environmentally friendly practices (Epicure. 2024).

Processing

Buds: The first harvesting of cloves takes place when the trees are six to eight years of age and continues then for up to 50 years; some trees reportedly live for up to 150 years. The trees are surprisingly sensitive and will usually only deliver one bumper crop in four years, the success of following crops being largely dependent on the degree of sympathy employed in the previous harvest. Rough handling and breaking of branches will generate debilitating shock in clove trees, diminishing subsequent yields. In Sir James Frazer's famous work, The Golden Bough, he described the attitude of the native people to their crops: 'When the clove trees are in blossom, they are treated like pregnant women. No noise may be made near them; no light or fire may be carried past them at night; no-one may approach them with his hat on, all must uncover in their presence. These precautions are observed lest the tree should be alarmed and bear no fruit, or should drop its fruit too soon like the untimely delivery of a woman who has been frightened in her pregnancy.' Although modern attitudes have changed, the planting and harvesting of cloves still has religious significance in some villages. Clove clusters are picked by hand when the buds are at full size, but before any petals have fallen to expose the stamens. As they do not all reach harvesting stage at the same time, a picker must be skilled enough to know the best clusters to pick and put in baskets. The filled baskets are returned to a central area, where the flower buds are removed from the flower stems by twisting the cluster against the palm of the hand. The snapped-off buds are spread out to dry on woven mats, where the tropical sun dries them in a few days to their characteristic reddish-brown colour. During drying, enzymes create the volatile oil eugenol, which is also present in lesser concentration in dried clove stems. A traditional way to gauge correct dryness of cloves is to hold them tightly in one's hand and if they hurt, the spiky sections are hard, an indication of being properly dried. Having lost about two-thirds of their weight, one kilogram of cloves may consist of up to 15 000 buds (Hemphil, 2018).

Leaves: Clove leaves are also harvested to produce clove leaf oil by steam distillation. This volatile oil is used in perfumery and food and beverage manufacturing. Because the harvesting of leafy branches for this oil seriously diminishes yields of cloves and makes the trees susceptible to fungal infection, it is not a common practice among the major producing countries (Hemphil, 2018).

Buying and Storage: When buying whole cloves, look for clean, well-presented buds, as this is one of the best indications of how much care has been taken in the harvesting process. Each bud should be intact, still retaining the little soft, friable ball on the top. Look out for short clove-sized sticks which are in fact clove stems. Clove stems contain about 30% of the volatile oil in a clove, and are one of the most popular ways for unscrupulous spice traders to adulterate their goods. Another 'trick of the trade' has been to boil cloves in water to extract some of the oil, after which the depleted cloves are dried and sold. Only buy ground cloves from a reputable establishment that can assure you they have been recently milled, as when they're ground, cloves lose their volatile oil fairly quickly. Ground cloves should be dark brown, because light-brown powder that is somewhat fibrous and gritty is probably heavily cut with ground clove stem. Store whole and ground cloves in airtight packaging and keep away from extremes of heat, light and humidity (Hemphil, 2018). Store in cool, dark, dry places (Spiceadvice, 2024).

Taste: Cloves are one of the most intensely flavored spices: high quality cloves contain 15-20% essential oil. The characteristic flavor of cloves mainly comes from the aromatic compound "eugenol" which comprises upwards of 85% of the essential oil composition. Cloves can also cause a numbing sensation in the mouth. This is because the eugenol found in cloves is a natural anesthetic such that it was traditionally used to numb and reduce toothache pain (MCSI, 2024). Cloves are strong, pungent, and sweet (Spiceadvice, 2024). Strongly aromatic and very intensive fragrance; fiery and burning taste (Gernot,2024).

Economic Importance: Cloves are a valuable commodity in the global spice market. They hold economic significance for several countries, especially those that cultivate and export them (Epicure. 2024).

Exporters: Indonesia: Major producer and exporter supplying a large portion of the world's cloves. India: Regions like Nilgiris and Kottayam are significant clove-growing areas (Epicure. 2024).

Employment: Clove farming provides livelihoods for numerous households. In places like Indonesia, clove cultivation is a vital economic activity (Epicure. 2024).

Revenue Generation: Clove cultivation and trade generate significant revenue for exporting countries. Farmers benefit from the high market value of cloves and clove-derived products (Epicure. 2024).

Price Fluctuations: Clove prices can be impacted by several factors: 1) Consumer Preferences: Shifts can affect demand. 2) Economic Conditions: Global economic changes may influence prices. 3) Political Instability: May interrupt supply chains and impact market prices. This section illustrates that cloves are not just a kitchen staple but a significant economic asset and contributor to the global spice trade (Epicure. 2024).

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