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REVIEW ARTICLE

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY AND BREEDING OF GINGER

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ABSTRACT

Ginger belongs to the family Zingiberaceae, genus *Zingiber* and species *Zingiber officinale.* Its generic name *Zingiber* is derived from the Greek zingiberis, which comes from the Sanskrit name of the spice, singabera. Ginger is the dried knobby shaped rhizome of the plant Zingiber officinale. The Latin name, zingiber, derives from interpretations of the name in Indic languages where ginger was described as "shaped like a deer's antler (horn)". Ginger goes by many names in different languages such as jiang (Chinese), adrak (Hindi), jengibre (Spanish), **zenzero** (Italian), gingembre (French), zanjabeel (Arabic), and ingwer (German). The English origin of the word "ginger" is from the mid-14th century, from Old English *gingifer*, which derives in turn from the Medieval Latin *gingiber*, *gingiber* from the Greek ζηγγίβερις *zingiberis* from the Prakrit (Middle Indic) *siṅgabera*, and *siṅgabera* from the Sanskrit *śṛṅgavera*. The Sanskrit word is thought to come from an ancient Dravidian word that also produced the Tamil and Malayalam term *iñcivēr* (from *vēr*, "root"); an alternative explanation is that the Sanskrit word comes from *srngam*, meaning "horn", and *vera*, meaning "body" (describing the shape of its root), but that may be folk etymology. The word probably was readopted in Middle English from the Old French *gingibre* (modern French *gingembre*). Ginger (*Zingiber officinale*) is a herbaceous flowering plant that belongs to the family Zingiberaceae. They are perennial plants that live for more than two years. Ginger is a rhizome which is a modification of the stem. It is native to Southeastern Asia and is known for its pungent smell. Common ginger is a herbaceous perennial with upright stems and narrow medium green leaves arranged in two ranks on each stem. The plant gets about 4 ft tall with leaves about 3/4 in wide and 7 inches long. Ginger grows from an aromatic tuberlike rhizome which is warty and branched. The inflorescence grows on a separate stem from the leaf stem, and forms a dense spike, up to 3 in tall. The bracts are green with translucent margins and the small flowers are yellow green with purple lips and cream colored blotches. Most gingers in cultivation are sterile cultivars grown for the edible rhizome, and the flower is rarely seen. The ginger plant has a long history of cultivation, having originated in Asia and is grown in India, Southeast Asia, West Africa and the Caribbean. Common name of Ginger in • Hindi: Adrak • Manipuri: Shing • Marathi: Alha, Aale • Tamil: Ingee, Inji • Malayalam: Inchi, Enchi • Telugu: Allam, Allamu, Allamu chettu, Shonti • Kannada: Alla, Shunthi • Bengali: Ada • Oriya: Ada • Urdu: Adrak, Adi • Assamese: Ada • Gujarati: Adu, Sunth • Sanskrit: Adraka • Nepali: Aduwa. Ginger, African ginger, Cochin ginger, Jamaican ginger, Race ginger. Ginger may also be referred to as true ginger, stem ginger, garden ginger or root ginger and it is believed to have originated in the Southeast Asia. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding of Ginger are discussed.

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INTRODUCTION

Ginger belongs to the family Zingiberaceae, genus *Zingiber* and species *Zingiber officinale* (Kaufman, 2016; NWE, 2024; Byjus, 2024). Its generic name *Zingiber* is derived from the Greek zingiberis, which comes from the Sanskrit name of the spice, singabera (Wang, 2020).

Ginger is the dried knobby shaped rhizome of the plant *Zingiber officinale*. The Latin name, *zingiber*, derives from interpretations of the name in Indic languages where ginger was described as "shaped like a deer's antler (hom)". Ginger goes by many names in different languages such as *jiang* (Chinese), *adrak* (Hindi), *jengibre* (Spanish), *zenzero* (Italian), *gingembre* (French), *zanjabeel* (Arabic), and *ingwer* (German) (McCormicks, 2024).

The English origin of the word "ginger" is from the mid-14th century, from Old English *gingifer*, which derives in turn from the Medieval Latin *gingiber*, *gingiber* from the Greek ζτγγίβερις *zingiberis* from the Prakrit (Middle Indic) *siṅgabera*, and *siṅgabera* from the Sanskrit *śṛṅgavera*. The Sanskrit word is thought to come from an ancient Dravidian word that also produced the Tamil and Malayalam term *iñcivēr* (from *vēr*, "root"); an alternative explanation is that the Sanskrit word comes from *srngam*, meaning "horn", and *vera*, meaning "body" (describing the shape of its root), but that may be folk etymology. The word probably was readopted in Middle English from the Old French *gingibre* (modern French *gingembre*) (Wikipedia, 2024). Ginger (*Zingiber officinale*) is a herbaceous flowering plant that belongs to the family Zingiberaceae. They are perennial plants that live for more than two years. Ginger is a rhizome which is a modification of the stem. It is native to Southeastern Asia and is known for its pungent smell (Byjus, 2024). Common ginger is a herbaceous perennial with upright stems and narrow medium green leaves arranged in two ranks on each stem. The plant gets about 4 ft tall with leaves about 3/4 in wide and 7 inches long. Ginger grows from an aromatic tuberlike rhizome which is warty and branched. The inflorescence grows on a separate stem from the leafstem, and forms a dense spike, up to 3 in tall. The bracts are green with translucent margins and the small flowers are yellow green with purple lips and cream colored blotches. Most gingers in cultivation are sterile cultivars grown for the edible rhizome, and the flower is rarely seen. The ginger plant has a long history of cultivation, having originated in Asia and is grown in India, Southeast Asia, West Africa and the Caribbean **(**Khale, 2024**).**

The Latin name, *Zingiber* is believed to derive from the ancient Tamil word, *ingiver* which basically means ginger rhizome. The plant currently has a large and diverse collection of common names reflecting its global popularity and in some languages, fresh and dried ginger have different names (TB, 2014; Kaufman, 2016).

The Different Vernacular Names of Ginger in India and Other Parts of the World are as follows (Jakribettu *et al*., 2016):

Language	**Names**
Scientific name	*Zingiber officinale* Rosc.
English	Ginger
Indian Languages	
Assamese	Ada
Bengali	Ada
Gujarati	Adu
Hindi	Adrak
Kannada	Shunti
Konkani	Shunti
Malayalam	Inji
Manipuri	Shing
Marathi	Aale
Mizo	Thingpuidum
Oriya	Ada
Pali	Singivera
Punjabi	Adaraka
Sanskrit	Adaraka
Tamil	Inji
Telugu	Allam
Urdu	Adrak
Other Languages	
Arabic	Zanjbeel
Burmese	Sif
Dutch	Gember
Filipino	Luya
French	Gingembre
German	Ingwer
Italian	Zenzero
Javanese	Jahe
Khmer	Khnyyi
Malay	Halia
Nepali	Sano Adwa
Russian	Imbir
Sinhala	Inguru
Spanish	Jengibre
Swahili	Tangawizi
Thai	K˘lng
Tibetan	Sga skya
Vietnamese	Gùng

Common name of Ginger in • Hindi: Adrak • Manipuri: Shing • Marathi: Alha, Aale • Tamil: Ingee, Inji • Malayalam: Inchi, Enchi • Telugu: Allam, Allamu, Allamu chettu, Shonti • Kannada: Alla, Shunthi • Bengali: Ada •Oriya: Ada •Urdu: ׀Adrak, Adi •Assamese: Ada •Gujarati: Adu, Sunth • Sanskrit: Adraka •Nepali: Aduwa **(**Khale, 2024**).** Ginger, African ginger, Cochin ginger, Jamaican ginger, Race ginger (McCormicks, 2024.

Ginger may also be referred to as true ginger, stem ginger, garden ginger or root ginger and it is believed to have originated in the Southeast Asia (Plantvillage, 2024). Ginger (*Zingiber officinale* Rosc.), one of the most valued horticultural crops of the world, is used extensively as spice and for its medicinal properties (Sajeev *et al.,* 2011). The species is distributed in tropical and subtropical Asia, Far East Asia and Africa. Although the origin is unknown, the species probably originated in tropical Asia and China, where it is under cultivation for centuries. In India, most of the popular commercial varieties are clonal selections from traditional cultivars (Sajeev *et al*., 2011). Breeding in ginger is seriously handicapped by poor flowering and seed set. Most of the crop improvement programmes of this species are confined to evaluation and selection of naturally occurring clonal variations. In such species, the extent of genetic diversity is low, unless samples are drawn from diverse agro-ecological conditions. Therefore, diversity analysis and identification of genetically distant clones or genotypes are central to the ginger improvement programme (Sajeev *et al*., 2011). The geographic location, high rainfall, climatic condition and limited human intervention make this region a unique area (NE Region) which is rich in genetic resources. The region is inhabited by many tribal communities with distinct agricultural production systems. This diversity in the cultivation practices has also influenced crop diversity in the region. The high diversity in different crop species from this region has been assessed by several workers. There is also a report on the genetic diversity of ginger from NE Indian region, but the study included only commercial varieties that are cultivated in Assam, one of the states of NE India. In this part of India ginger is cultivated under both shifting and permanent cultivation at altitudes varying from 50 m to 2000 m (Sajeev *et al.,* 2011). In the remote and inaccessible areas of NE Hills, tribal farmers have maintained a large number of unique crop germplasm as their identity and life support system. The current study deals with the genetic diversity of ginger germplasm of North-Eastern region of India and comparison of the same with some established varieties cultivated (as clones) in the region as well as other parts of India. In addition, attempt was also made to assess the genetic relationship between the ginger germplasm from hill and plane areas used in the study (Sajeev *et al*., 2011).

Ginger (*Zingiber officinale* Rosc.), originated in the Indo-Malayan region, is now widely distributed across the tropics of

Asia, Africa, America and Australia. It was domesticated in India and China, which represent the centre of origin of the species (Kizhakkayil and Sasikumar, 2011). Cultivated ginger though sterile, exhibits variations in rhizome and vegetative characters. The crop is gaining importance as a curative agent for a variety of ailments. Yield and quality traits (such as essential oil, fibre and oleoresin contents) along with volatile and non-volatile constituents are important determinants of the commodity's end product (Kizhakkayil and Sasikumar, 2011). Cultivar diversity for yield and morphological features is well known in ginger with few primitive types having excellent quality (Kizhakkayil and Sasikumar, 2011). Ginger (*Zingiber officinale* Rosc.), originated in the Indo-Malayan region, is now widely distributed across manym countries as a spice and medicinal plant. Traders took ginger from India to Mediterranean region during the 1st century CE (Current Era). The Arabs introduced ginger to East Africa in the 13th century CE and the Portugese spread it to West Africa and the Pacific islands for commercial cultivation (Kizhakkayil and Bhas, 2011). The major ginger growing countries include Australia, Brazil, Bangladesh, Cameroon, China, Costa Rica, Fiji Ghana, Guatemala, Hawaii, India, Indonesia, Jamaica, Mauritius, Malaysia, Nepal, New Zealand, Nigeria, Philippines, Sierra Leone, Sri Lanka, Taiwan, Thailand, Trinidad and Uganda covering a total area of 387,300 ha with a production of 1,476,900 MT. India is the world's largest producer of ginger at present (Kizhakkayil and Bhas, 2011). 'Cochin ginger', 'Wayanadan ginger' (India), 'Chinese ginger' (China), 'Buderim Gold' (Australia) 'Jamaican' (Jamaica) are globally traded products. Ginger in various forms is used as food flavorant, antioxidant and antimicrobial besides as deodorizing agent in food. Chinese, Indian, Tibetan and Arabic systems of medicine recognized the medicinal value of ginger since ancient times (Kizhakkayil and Bhas, 2011).

Ginger is one of the most commonly consumed dietary condiments in the world. The oleoresin (*i.e.*, oily resin) from the rhizomes (*i.e.*, roots) of ginger contains many bioactive components, such as [6]-gingerol (1-[4′-hydroxy-3′-methoxyphenyl]-5-hydroxy-3-decanone, which is the primary pungent ingredient that is believed to exert a variety of remarkable pharmacological and physiological activities. Although ginger is generally considered to be safe, the lack of a complete understanding of its mechanisms of action suggests caution in its therapeutic use. Ginger has been used for thousands of years for the treatment of numerous ailments, such as colds, nausea, arthritis, migraines, and hypertension (Bode and Dong, 2011). Ginger is a member of a plant family that includes cardamom and turmeric. Its spicy aroma is mainly due to presence of ketones, especially the gingerols, which appear to be the primary component of ginger studied in much of the health-related scientific research. The rhizome, which is the horizontal stem from which the roots grow, is the main portion of ginger that is consumed. Ginger's current name comes from the Middle English *gingivere*, but this spice dates back over 3000 years to the Sanskrit word *srngaveram*, meaning "horn root," based on its appearance. In Greek, it was called *ziggiberis*, and in Latin, *zinziberi* (Bode and Dong, 2011).

Ginger is a valued medicinal crop and has been used as a spice for over 2000 years. It is cultivated in many tropical and subtropical countries in which, China and India are the world's leading producers. The importance of ginger is gaining recently because of its low toxicity and its broad spectrum of biological and pharmacological applications including antitumor, antioxidant, anti-inflammatory, antiapoptotic, cytotoxic, anti-proliferative and anti-platelet activities. The ginger rhizome contains various biologically active compounds such as gingerol, shogaol, ginger protease, capsaicin and several sesqui terpenes like zingiberol, zingiberenol and these constituents may vary depending on the place of origin and whether the rhizomes are fresh or dry (Ashraf *et al.,* 2014). Besides this, most of the crop improvement programs of ginger are restricted to the assessment and selection of naturally occurring clonal variations. Therefore, diversity analysis and identification of genetically distant clones or genotypes are vital to the ginger improvement program (Ashraf *et al*., 2014). Till date several studies have been reported on genetic diversity study of different ginger varieties in India but to our knowledge very less or no study has ever been reported on diversity collected from all major ecological zones or provinces of India. Since ginger is a very poorly studied crop and its molecular information is limited, hence it is imperative to know the genetic diversity among different accessions from Indian subcontinent (Ashraf *et al.,* 2014).

The rhizome of ginger is one of the most widely used spice of the family Zingiberaceae. India is the largest ginger producing country in the world and is cultivated in most of the Indian states. Ginger grown in different parts of the country varies considerably in its intrinsic physical and biochemical properties and its suitability for processing (Ravi *et al*., 2016). Association of plant character has always been helpful as a basis for selecting desired genotypes. Many varieties of ginger are available in India which are region specific, varying in plant habit, yield and quality parameters. The performance of ginger grown in Soppinabetta ecosystem of Uttara Kannada district of Karnataka has shown an immense potential for its commercial cultivation in large area. To improve yield and other characters, information on genetic variability is a great importance and is a prerequisite for the effective screening of superior genotypes (Ravi *et al*., 2016). Ginger the root of the plant *Zingiber officinale* Rosc. that belongs to the family Zingiberaceae, is globally one of the most commonly used spices and medicinal agents. The plant is known as *Sringavera* in the ancient Indian language of Sanskrit, and it is speculated that this term may have given way to *Zingiberi* in Greek and then to the Latin term *Zingiber* (Jakribettu *et al.,* 2016). Ginger is one of the most widely used spices by humankind the world over. It originated in tropical Asia, probably in southern China and India. However, the exact origin is unclear because it has been cultivated for millennia in both China and India, and has never been found in the wild. Ginger is mentioned in the earliest Chinese herbals. The plant has a long history of culinary and medicinal use in the cultures of these countries. The refreshing smell and the pungent, warm taste were highly valued. Ginger was known by the ancient Greeks and Romans. In Europe, during the Middle Ages, ginger was one of the spices used to flavour beer (Kaufman, 2016). Ginger is an upright, slender, perennial herb, about 1 m tall, usually cultivated as an annual, with purple flowers and a robust branched rhizome growing horizontally near the soil surface. It is grown in most tropical and subtropical countries of the world. As well as *Z. officinale*, the genus *Zingiber* contains another 100 species, allaromatic herbs. Only three of them have any commercial importance, usually grown in home gardens. The three species are *Zingiber montanum*, *Zingibers pectabile* and *Zingiber zerumbet*.

They are usually cultivated for their medicinal properties, for essential oils, as a spice or as an ornamental. Ginger rhizomes are widely used around the world as a spice or food additive, especially in Chinese, Indian and South-east Asian cookery. Ginger is used in three different forms: (i) fresh ginger; (ii) dried and ground ginger; and (iii) preserved ginger. Ginger is now grown as a commercial crop in Africa, Latin America and South-east Asia (Kaufman, 2016). Ginger is one of the major spices crop in Bangladesh, has got a wide range of cultivars in terms of yield and adaptability. Zingiberaceae is a valued medicinal crop and has been used as a spice for over 2000 years (Islam *et al.,* 2017). It is cultivated in many tropical and subtropical countries in which, China and India are the world's leading producers (Islam *et al.,* 2017). The importance of ginger is gaining recently because of its low toxicity and its broad spectrum of biological and pharmacological applications including antitumor, antioxidant, anti-inflammatory, antiapoptotic, cytotoxic, anti-proliferative and anti-platelet activities (Islam *et al*., 2017). In Bangladesh, ginger grows well in Rangpur, Nilphamari, Tangail, Rangamati, Bandarban, Khagrachari and Chittagong district (Islam *et al.,* 2017). Cropgenetic resources with a broad geneticbase and high variability are vital to crop improvement program. Assessment and characterization of the state of the existing genetic diversity within the taxon is critical for planning a meaningful breeding strategy (Islam *et al*., 2017). The variability among different lines of a species is known as genetic diversity. Genetic diversity arises either due to geographical separation. D^2 statistic proposed by Mahalanobi's is one of the potent techniques for measuring the genetic divergence both in intra and intercluster level. Genetic diversity plays an important role in plant breeding for the development of high yielding varieties. Such a study also permits to select the genetically divergent parents to obtain the desirable recombination of the segregating generations (Islam *et al*., 2017). India is known as the land of spices from the time immemorial and has been the leading country in the world for production, consumption and export of spices. Ginger is one of the oldest known spices valued for its aroma and pungency. Ginger is used both in fresh and dried form. It is utilised widely as spice, for pickles, candies and as a medicinal herb for the treatment of gastrointestinal diseases, including dyspepsia, nausea and diarrhea (Goudar *et al*., 2017). India occupies an unique position of being the largest producer and exporter of ginger in the world. A good amount of genetic variability has been reported among different varieties with regard to growth, yield and quality parameters under different agro-climatic conditions. Several cultivars of ginger are grown in different ginger growing areas in India. They are generally named after the localities or place where they are grown. These local cultivarsare selected, domesticated and planted for a long time under local natural conditions. They generally have greater adaptability, higher yield, better quality and unique use value. The available germplasm serves as most valuable natural reservoir for providing donor parent to improve the particular trait. Therefore, collection, conservation and evaluation of germplasm are essential for present as well as future crop improvement programmes (Goudar *et al.,* 2017).

Ginger is a slender monocotyledonous rhizomatous perennial herb, leaves are linear, sessile, glabrous, flowers are yellowish green, spikes are cylindrical and fruits are oblong capsules. Rhizomes are white to yellowish brown in colour, laterally flattened and irregularly branched. Few scales gave a covering to the growing tips. Rhizomes are smooth and if broken some fibrous elements of the vascular bundles comes out from the cut-ends (Jaidka *et al.,* 2018). Ginger of commerce is the underground rhizome of *Zingiber officinale* Rosc., belonging to the family Zingiberaceae is originated from South-East Asia. It is one of the oldest and most important spices, being cultivated inTropical Asia for over 3000 years (Akshitha *et al.,* 2019). Herbaceous perennial grown as annual crop and plant is erect, has many fibrous roots, aerial shoots (pseudostem) with leaves and the underground stem (rhizome). Several cultivars of ginger are grown in differentginger growing areas of India and they are generally named after the localities where they are grown (Akshitha *et al*., 2019). Ginger, an herbaceous perennial plant of the family Zingiberaceae, probably native to southeastern Asia, or its aromatic, pungent rhizome, is used as a spice, flavouring, food and medicine (Wang, 2020). Its use in India and China has been known from ancient times, and by the first century, traders had taken ginger into the Mediterranean region. By the eleventh century, it was well-known in England. The Spaniards brought it to the West Indies and Mexico soon after the conquest, and by 1547 ginger was being exported from Santiago to Spain (Wang, 2020). The aromatic substances of vegetable origin used in food as preservatives and flavours are known as spices (Kumari *et al.,* 2020).

Various plant parts such as fruits, seeds, flowers andbark have economic importance in human diet due to their peculiar flavouring properties based on their content of essential oils (Kumari *et al.,* 2020). Medicinal plants are generally knownas "Chemical Goldmines" as they contain a multitude of natural chemicals, which exert beneficial bioactivity in humans and animals (Kumari *et al*., 2020). Ginger is one of the most important spices, which is scientifically known as *Zingiber officinale* (Kumari *et al*., 2020). It is valued for its light yellow liquid (curcuma oil) with aromatic and persistent odour obtained from rhizomes. It is widely used in Ayurveda, Siddha, Chinese, Arabian, African, Caribbean and many other medicinal systems to cure a variety of diseases like pain, nausea, vomiting, asthma, cough, inflammation, dyspepsia, loss of appetite, palpitation, constipation and indigestion. The essential oil and oleoresin contributing to these properties are well known and these ingredients are often extracted and exported (Kumari *et al*., 2020). Ginger is one of the most important spices as well as medicinal crops of India, mainly cultivated in subtropical areas since many centuries and used at larger scale around the globe (Kumari *et al*., 2020).

Ginger (*Zingiber officinale* Roscoe), as a bulbous plant, has been cultivated for a very long time. It is believed that ginger is native to southern China, Southeast Asia, and India. It was introduced to the Mediterranean in the first century, Japan in the third century, England in the eleventh century, and America in 1585. It is now widely cultivated in tropical and subtropical regions of the world but mostly in Asia and Africa (Wang, 2020). Ginger, an herbaceous perennial plant of the family Zingiberaceae, probably native to southeastern Asia, or its aromatic, pungent rhizome, is used as a spice, flavouring, food and medicine. Its generic name *Zingiber* is derived from the Greek zingiberis, which comes from the Sanskrit name of the spice, singabera. Its use in India and China has been known from ancient times, and by the first century, traders had taken ginger into the Mediterranean region. By the eleventh century, it was well-known in England. The Spaniards brought it to the West Indies and Mexico soon after the conquest, and by 1547 ginger was being exported from Santiago to Spain (Wang, 2020).

It is now widely cultivated in tropical and subtropical regions of the world but mostly in Asia and Africa. The total harvest area of ginger in the world is more than 21,000 ha with a total production of more than 200,000 tons and an average yield of 10,000 kg per ha (Wang, 2020). Ginger is mainly used as spice and flavour agent for food. The characteristic fragrance and flavour of ginger are the result of volatile oils, primarily consisting of zingerone, shogaols and gingerols as the major pungent compound. A lot of studies have been carried out to discover the miracle of this plant (Wang, 2020).

Ginger is a commercially important herbaceous perennial, usually grown as an annual spice. It is extensively cultivated in the tropical to temperate climates of the world for its flavour, and pungency, and aromatic and healing characteristics associated with its essential oil and oleoresin contents (Patra *et al*., 2022). India has the largest share in total area under ginger cultivation (34.6%) and annual production (29%) in the world and exports 10–15% of its produce. However, average ginger productivity in India is only 3.6 $Mg \cdot ha^{-1}$, far below the global average (Patra *et al*., 2022). In the Gangetic plains of India, ginger is a promising high-value crop and is growing in popularity due to fetching high prices on the market. The resource-poor small and marginal farmers traditionally grow the crop under rainfed conditions. But due to uncertain or uneven rainfall distribution, the crop experiences water-stressed conditions at different physiological stages, resulting in lower marketable yield and rhizome quality. Many studies have addressed the individual response to integrated nutrient management or irrigation scheduling in improving growth and yield of ginger (Patra *et al*., 2022).

Ginger, the rhizome of *Zingiber officinale*, consisting of seven species, is mainly distributed in Asia. Since antiquity, ginger has been used for a wide array of unrelated ailments such as arthritis, rheumatism, sprains, muscular aches, pains, sore throats, cramps, constipation, indigestion, vomiting, hypertension, dementia, fever, infectious diseases, and helminthiasis. The main biological activities of ginger are immunomodulatory, antitumorigenic, anti-inflammatory, antiapoptotic, antihyperglycemic, antilipidemic, and antiemetic. Ginger is a potent antioxidant, and either mitigates or prevents the generation of free radicals. It is considered a safe herbal medicine with only a few side effects (Zhang *et al*., 2022). Ginger (*Zingiber officinale* Rosc.) is one of the biopharmaceutical plants that are widely cultivated by the community because it has many benefits and a high selling price. Ginger plants that are propagated vegetatively using rhizomes. Ginger rhizome is a widely used part for the refreshing beverage industry and traditional medicine industrial raw materials, standardized herbs and phytoarmaka (Prasetyo *et al.,* 2022). In Indonesia there are three types of ginger including ginger emprit (*Zingiber officinale* var *amarum*), Red ginger (*Zingiber officinale* var *rubrum*) and elephant ginger (*Zingiber officinale* var *officinarum*). The type of ginger has similar species names only different in the name of the variety so that the type of compound content does not differ much from each other (Prasetyo *et al*., 2022).

Ginger is one of the ancient oriental spice and is being grown in tropical and subtropical area for its rhizomes which is used both as dried spice and as a fresh vegetable, since time immemorial. Ginger comes under the family Zingiberaceae and commonly used as a spice, in pickles, candies, and as a medicine to treat gastrointestinal disorders such dyspepsia, nausea and diarrhea (Altaf *et al.,* 2023). Pollination is one of the major interactions that occur between animals and plants in which plants generate new generations while the animals obtain food and other secondary rewards. Currently, there are more than a hundred thousand articles on this topic recorded over the last ten years in Science Direct, JSTOR and Google Scholar associated with the keywords plant-animal interactions, pollination and plant-pollinator. In fact, most of these studies are on the factors that influence the interaction rather than on pollinators and floral visitors of a specific species of plant. Thus, there are numerous unreported pollinators of angiosperms and new species are continuously being reported for ginger plants (Appalasamy *et al*., 2023). They can reproduce asexually by vegetative rhizome propagation and sexually by the transfer of pollen from male to female flowers. Asexual reproduction commonly occurs naturally in ginger plants and is used to produce large quantities of ginger, as it is much easier and faster than by sexual reproduction. However, sexual reproduction can be used to produced new generations of better quality plants, both physically and genetically (Appalasamy *et al.,* 2023). Being a vegetatively propagated species, *their genetic diversity tends to be low*; however wide genetic variability is possible to found it in China and India. A tropical herb called ginger is grown for its food and medical benefits in many countries across the world, including China, Japan, India, Nigeria, Taiwan, Sri Lanka, Fiji, Hawai, Australia, and Korea. India is among these countries' top ginger growers, with the plant taking up the most space and yielding the most. Meghalaya, Orissa, Arunachal Pradesh, Gujarat, Karnataka, Kerala, and Assam are key ginger-producing states of India, and combined they account for roughly 65% of the nation's overall ginger productivity (Yadav *et al*., 2023).

Ginger plants grow shoots 3-4 feet tall from the rhizomes, gradually spreading outwards to eventually form a dense clump if not harvested. The shoots are actually pseudostems formed from a series of leaf sheaths wrapped tightly around one another. The blades of the medium green, alternate leaves are long and narrow (7 by ¾ inches), arranged in two ranks on each stem (Hort, 2024). Buds that have started to turn green are even more likely to grow. The rhizomes can be planted whole or divided into pieces (being sure there are at least two eyes per section). Allow any cut pieces to dry for a few days in a warm, dry spot and callus over before planting. Rhizomes can be soaked overnight in warm water before planting. Place the rhizomes about an inch deep in warm soil (whether in a container or in the ground, ginger grows only when soil temperature is over 68ºF and grows best with soil temperatures around 77ºF) with the growth buds pointing upward. Water lightly until growth begins. It may take a few weeks for shoots to show, as the plant has to develop roots first. Once leaves develop keep the soil evenly moist but not soggy. Some growers prefer to only partially fill the containers with growing medium before planting the rhizomes and then add additional growing medium in two increments a few months apart to encourage longer, larger rhizomes. In ground plants can be hilled up periodically to encourage larger rhizomes, too, but this is not necessary. Ginger loves hot, humid conditions and rich soil with lots of nutrients. In our cool climate the plants do well in full sun; in more southern locations the plants may need partial shade. Fertilize regularly during the growing season unless planted in very fertile soil. If planting in the ground, amend it first with lots of compost, rotted manure or

other rich organic matter. Mulch in-ground plants to retain soil warmth and moisture, and prevent competition from weeds. Water regularly but do not allow the soil or planting medium to remain soggy (Hort, 2024). In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding of Ginger are discussed.

ORIGIN AND DISTRIBUTION

Interestingly, ginger does not grow in the wild and its actual origins are uncertain. Indians and Chinese are believed to have produced ginger as a tonic root for over 5000 years to treat many ailments, and this plant is now cultivated throughout the humid tropics, with India being the largest producer. Ginger was used as a flavoring agent long before history was formally recorded. It was an exceedingly important article of trade and was exported from India to the Roman Empire over 2000 years ago, where it was especially valued for its medicinal properties. Ginger continued to be a highly sought after commodity in Europe even after the fall of the Roman Empire, with Arab merchants controlling the trade in ginger and other spices for centuries. In the thirteenth and fourteenth centuries, the value of a pound of ginger was equivalent to the cost of a sheep. By medieval times, it was being imported in preserved form to be used in sweets. Queen Elizabeth I of England is credited with the invention of the gingerbread man, which became a popular Christmas treat (Bode and Dong, 2011).

As a cultigen, *Z. officinale* is not known in its wild state but is cultivated extensively across India, Southeast Asia, tropical Africa, Pacific Ocean islands and Australia. The earliest account of ginger cultivation is probably the description of spices grown around the ancient port of Quilon, Kerala by Rabbi Benjamin Tudella who was travelling in the area between 1159 and 1173 CE. Between 1292-1293 CE, John de Montecorvina described ginger in his writings about the Coromandel Coast in South East India and around the same time, the Arabs introduced the crop to East Africa. In the sixteenth century, the Spanish brought it to the West Indies and Mexico whilst the Portuguese introduced it to West Africa. The main ginger producing countries are India, China, Nepal, Thailand and the Philippines. In 2011, the total world production was 2,025,571 tonnes with India (702,000 tonnes) the largest supplier, yielding 35 % of world production. In the Southeast Asia region, China leads both in terms of ginger production (425,503 tonnes in 2011) and the level of genetic diversity. Chinese farmers choose from a large range of cultivated varieties according the end use of the crop and the local growing conditions (TB, 2014).

Historical evidence indicates that ginger was originally indigenous to Southeast Asia (today's northeast India), and during medieval times, it was exported from India to other parts of the world. Today ginger also grows in many other parts of the world, including Nigeria, Sierra Leone, Indonesia, Bangladesh, Australia, Fiji, Jamaica, Nepal, Haiti, Mexico, and Hawaii. India and China are the leading providers of ginger to the world market. Ginger has been cultivated for thousands of years as a spice. It is an important cash crop in India and is grown primarily in the states of Kerala, Karnataka, and northeast India (Jakribettu *et al*., 2016). It has been used as a spice and medicine in India and China since ancient times. It was the first oriental spice known in Europe and having been obtained by the Greeks and Romans from Arab traders, who kept a secret of their origin of the spice in India. It was known to Discorides and Pliny in the first century A. D., the former frequently refers to it in his De Materia Medica describing its warming effects on the stomach and as an aid to digestion and antidote to poisons. The Sanskrit name Singhabera give rise to Green Lingiberi and later Latin Lingiber. It is mentioned in Koran. In Arabian nights it has been referred for its aphrodisiac properties. India enjoys from times immemorial a unique position in the production and export of ginger. Ginger was originated in Southern China. On world level, it grows in Jamaica, Nigeria, China, Taiwan, Australia, Japan etc. In India, it is grown in the states like Kerala, North Eastern States, Sikkim, Himachal Pradesh, Odisha, West Bengal, Karnataka, Andhra Pradesh and Maharashtra (Jaidka *et al*., 2018).

Ginger represents the long history of its cultivation in India and China and is supposed to be originating from Southeast Asia from where it was introduced to other parts of the world. The exact information about the plant's origin is unavailable due to its long history of cultivation in these regions. The species is found in its cultivated state and is not known in a wild state. A few other researchers explored it from Eastern Asia, Indo-Malayan region, Africa, America and Northern Australia where it is now distributed widely and used as spice for over 2000 years (Kumari *et al.,* 2020). The plant was domesticated for the first time in Asia or India where it was cultivated in wet tropics of southern India or Asia since ancient time, having high rainfall and fairly high temperature, but commonly some shady places. Other than these, it is also cultivated in different regions of West Africa and in West Indies, Jamaica, producing the top-grade ginger of the world (Kumari *et al*., 2020). The earliest recording of Chinese herbals gives an idea about ginger and confirms the use of ginger in culinary and medicinal practices of natives of Asian countries. The Greeks were also familiar with the ginger plant as it was cited by the Ancient Greek physician, botanist and apothecary Dioscorides (40–90 AD) in his works. Plinius Secundus (23–79 AD 79), a Roman writer, naturalist and philosopher, also explained the medicinal uses of ginger in his work, *Naturalis Historia*. During the ninth century, it was well recognized as a spice in Germany and France. In the thirteenth century, Arabian traders brought ginger from India to East Africa. In the sixteenth century, Portuguese brought ginger to West Africa and started its cultivation. Later on, its cultivation was initiated in Mexico by a Spaniard, Francesco de Mendoza. The long period of domestication might have played a major role in the evolution of this crops' sterility, propagated solely vegetatively (Kumari *et al*., 2020).

Ginger originated in Maritime Southeast Asia and was likely domesticated first by the Austronesian peoples. It was transported with them throughout the Indo-Pacific during the Austronesian expansion (c. 5,000 BP), reaching as far as Hawaii. Ginger is one of the first spices to have been exported from Asia, arriving in Europe with the spice trade, and was used by ancient Greeks and Romans. The distantly related dicots in the genus *Asarum* are commonly called wild ginger because of their similar taste. Ginger originated from Maritime Southeast Asia. It is a true cultigen and does not exist in its wild state. The most ancient evidence of its domestication is among the Austronesian peoples where it was among several species of ginger cultivated and exploited since ancient times. They cultivated other gingers including turmeric (*Curcuma longa*), white turmeric (*Curcuma zedoaria*), and bitter ginger (*Zingiber zerumbet*). The rhizomes and the leaves were used to

flavour food or eaten directly. The leaves were also used to weave mats. Aside from these uses, ginger had religious significance among Austronesians, being used in rituals for healing and for asking protection from spirits. It was also used in the blessing of Austronesian ships. Ginger was carried with them in their voyages as canoe plants during the Austronesian expansion, starting from around 5,000 BP. They introduced it to the Pacific Islands in prehistory, long before any contact with other civilizations. Reflexes of the Proto-Malayo-Polynesian word *laqia* are still found in Austronesian languages all the way to Hawaii. They also presumably introduced it to India along with other Southeast Asian food plants and Austronesian sailing technologies, during early contact by Austronesian sailors with the Dravidian-speaking peoples of Sri Lanka and South India at around 3,500 BP. It was also carried by Austronesian voyagers into Madagascar and the Comoros in the 1st millennium CE. From India, it was carried by traders into the Middle East and the Mediterranean by around the 1st century CE. It was primarily grown in southern India and the Greater Sunda Islands during the spice trade (Wikipedia, 2024). The Chinese have used ginger for over 5000 years as a digestive aid and anti-nausea remedy. In Traditional Chinese Medicine (TCM), ginger is considered a pungent, dry, warming, yang herb for ailments triggered by cold, damp weather. The Greeks wrapped ginger in bread for use after meals as a digestive aid. In medieval Europe it was incorporated directly into bread and confections as a digestif. Queen Elizabeth I of England is credited with the invention of the gingerbread man, which became a popular Christmas treat. Ginger was so valued by the Spanish that they established ginger plantations in Jamaica in the 1600's. "Canada Dry Ginger Ale" was patented in 1907 by Canadian pharmacist John J. McLaughlin, and became a popular beverage in America during prohibition. Fresh ginger root is typically light brown on the outside and pale yellow on the inside. Dried ground ginger has a fine texture and is light tan in hue. Crystallized ginger is darker yellow to amber in hue (McCormicks, 2024.

TAXONOMY

The genus *Zingiber* belongs to the family *Zingiberaceae* under the order Zingiberales and the tribe Zingibereae. *Zingiberaceae* includes three other tribes: *Hedychieae, Alpinieae and Globbeae*. The tribe *Zingibereae* has seven other genera: *Boesenbergia ,Camptandra, Roscoea*, *Kaempferia, Amomum, Hedychium* and *Curcuma* (Kizhakkayil and Bhas, 2011). Although there is some uncertainty about its descent, *Zingiber officinale* is believed to be a cultigen of Indian origin. The first documented reference to the plant is in *Hortus Indicus Malabaricus* by Van Rheede, published 1678-1693 and translated into English in 2003, using the local Indian name of *Inschi.* The genus *zingiber* was described by Boehmer and Ludvig in 1790 with the assigned type species for the genus being *Zingiber officinale* and in 1810, Roxburg described eleven Indian *zingiber* species, dividing them into two groups. A much fuller survey of Indian Zingiberaceae was undertaken by Baker in 1882 for The Flora of British India by J. D. Hooker and the four subgeneric classifications he described were accepted by Schumann who revised the family Zingiberaceae in 1904. The plant we now know as ginger (*Z. officinale*) was first described by Linnaeus as *Amonum zingiber*, the basionym for the species, and the genus name *Amonum* remains a synonym for *Zingiber* Boehm. In 1807, Roscoe, described the plant from a specimen in the Liverpool Botanic Garden, referring to Willdenow's treatment, itself an extension of Linnaeus' previous description. As the species name *zingiber* could not be used in the genus *Zingiber*, *Z. officinale* was adopted as the species name, and the lectotype assigned to *Z. officinale* Roscoe is that from Linnaeus' *Species Plantarum,* 1753, thereby replacing an earlier lectotype by Van Rheede in Hortus Malabaricus 1692 which was found to be incorrect . The base of *officinale* is the Latin word Officina which means workshop or pharmacy in early Latin, alluding to the medicinal uses of the plant, while the epithet *officinale* or *officinalis* is a medieval Latin word used for medicinal substances, mostly from plants. Until recently, the family was divided into four tribes: Hedychiaeae, Alpinaeae, Zingibereae and Globbeae but a study of the phylogeny of Zingiberaceae, undertaken by Kress resulted in a rearrangement of the Zingiberaceae into four subfamilies: Siphonochoideae, Tamijoideae, Alpinoideae and Zingiberoideae. This classification has now been adopted by the Angiosperm Phylogeny Group (TB, 2014).

Ginger which is composed of 50 genera and around 1500 species of perennial tropical herbs. Various ginger types have been characterized in Malaysia, for example, the 'haliyabetai', the true ginger possessing pale-coloured rhizomes and the 'haliya bara' and 'haliya indang' with very pungent reddish rhizomes used primarily in medicine. Taxonomically, the two main groups can be named: *Z. officinale* cv. group Officinale, which is cultivated throughout the tropics, and *Z. officinale* cv. group Rubrum ('haliya padi'), grown on a small scale in South-East Asia for medicinal use and as a spice. The latter differs from the former by having smaller, red rhizomes with a stronger and more pungent odour, the red colouring of the basal parts of leafy stems and petioles, larger leaves and the presence of a larger, scarlet-red mottled labellum. In Indonesia, three types of ginger have been distinguished: 'jahegajah', 'jahebadak' or 'jaheputihbesar'; 'jahemerah' or 'jahesunti'; and 'jaheputihkecil' or 'jaheemprit'. Their rhizomes differ in shape, colour, aroma and chemical composition. The English botanist William Roscoe gave the plant the name '*Zingiber officinale*' in 1807. The name '*Zingiber*' is via the Greek word 'zingiberis' derived from the Sanskrit word 'shringavera', which means 'shaped like a deer's antlers'; '*officinale*' indicates medicinal properties of the plant (Kaufman, 2016).

The plant belongs to genus *Zingiber*, family Zingiberaceae, in which four other genera of economic interest can be found (*Alpinia*, *Amomum*, *Curcuma* and *Elettaria*). The English botanist William Roscoe named the plant *Zingiber officinale* in 1807. The genus name is from the Greek word 'zingiberis', which is derived from the Sanskrit word 'shringavera', aptly meaning 'shaped like a deer's antlers', while 'officinale' pertains to the medicinal properties of the rhizomes. The genus *Zingiber* includes 80–90 (or even 150) species. Based on plant stature and yield ginger plants are classified into three groups *viz*., : (1) plants with small size with many tillers along with a small rhizome, (2) plants having medium size with an intermediate number of tillers and a medium-sized rhizome and (3) plants with large size and fewer tillers and which produce larger rhizomes (Kumari *et al.,* 2020). There is a taxonomic challenge when identifying the correct species as many synonyms are reported for ginger. There are eight plant names for the species *Zingiber officinale* in the plant database, of which two are accepted names and six are synonyms. Based on the size and color of the rhizome, common ginger can be

categorized into three varieties: giant ginger or white ginger (*Zingiber officinale* Rosc. var. *officinale*), small white ginger or emprit ginger Rhizome (*Zingiber. officinale* var. *amarum*), and red ginger (*Zingiber officinale* var. *rubrum*) (Zhang *et al*., 2022). Red ginger's synonyms are *Zingiber officinale* Roscoe var *Sunti* Val., *Zingiber amomum* L., *Zingiber cholmondeleyi* (F.M. Bailey) K. Schum., *Zingiber missionis* Wall., *Zingiber officinale* var. *macrorhizonum* Makino, *Zingiber officinale* var. *rubens* Makino, and *Zingiber sichuanense*. It is red, with a yellow to pink cross section on the outside of the rhizomes, while the base of the leaf shoot is red. It is an annual plant that grows up to 50–100 cm high. The rhizomes are thick and reddish-brown. It is morphologically similar to common ginger. It is smaller and more pungent than common ginger. The leaves are narrow and lancet-shaped, 5–25 cm in length and 8–20 mm in width. The plant has an ovoid-shaped composite that emerges from the rhizomes, with a stem length of 10–25 cm and small leaves at the base of the flower. The corollas are funnel-shaped, 2–2.5 cm long, and dark purple with creamy yellow spots. The petals are small, tubular, and tridentate. Unlike common ginger, its petiole is reddish, and the lip is scarlet red (Zhang *et al*., 2022).

Varieties/Species (Vandana, 2022).

- **Common Ginger -*Zingiber Officinale*:** Ginger is an important spice used in cooking and medicine. It has significant medicinal properties. Ginger grows best when exposed to direct sunlight.
- **Beehive Ginger - *Zingiber spectabile*:** The plant is also called Ginger wort and Malaysian ginger. The plant is commonly known in the West by the common name "beehive ginger", due to its unusual inflorescences which resemble a beehive. It has many medicinal uses.
- **Bitter Ginger - *Zingiber zerumbet* :** Its common names include Pinecone ginger, Lempoyang ginger, and Shampoo ginger. The leaves and leaf stalk are also fragrant. This ginger is slightly bitter and is used to enhance the flavor of food. The most common use of bitter ginger is in shampoo and conditioners.
- **Myoga Ginger -*Zingiber mioga*:** Other Name: Japanese Ginger. Myoga Ginger's flowers and shoots are used in cooking. They have a refreshing taste with a strong, piquant aroma.
- **Crepe Ginger -*Cheilocostus speciosus*:** Other names for ginger include Malay ginger and Cane reed. Known for its bright white blooms that resemble crepe paper. The flowers and buds are edible and have a pungent taste.
- **Hidden Ginger -*Curcuma petiolata*:** Other names include Queen Lily, Siam tulip, and hidden lily. Hidden Ginger is a plant native to Malaysia. It has an intense spicy flavor and a bitter taste. Its blossoms come in various shades of red, pink, or orange.
- **Butterfly Lily Ginger - *Hedychium coronarium*:** White Ginger, Flor De Mariposa, Mariposa Blanca, and Dolan Champa are the common names of this plant. It has fragrant flowers that resemble butterfly wings. Its spicy roots are used to flavor soupy dishes and the essential oil is good for fevers.
- **Shell Ginger - *Alpinia zerumbet*:** Also known as Variegated ginger and Getto plant. Shell ginger has oval-shaped leaves with green lines. It is commonly used as an ornamental plant. Its flowers emit a sweet fragrance. The leaves of this plant are used in cuisines.
- **Dancing Ladies Ginger - *Globba winitii*:** It is also called as White Dragon Flower. This is a unique flowering plant. The flower emits a sweet honeysuckle-like scent and looks like a dancing woman when moved by the wind.
- **Yellow Ginger - *Hedychium flavescens*:** It has been called various names including "Cream Garland Lillie", "Yellow Ginger Lily". Yellow gingers are often grown by gardeners because they produce beautiful, highly fragrant flowers. However, they're not as flavorful as regular gingers.
- **Red Ginger - *Alpinia purpurata*:** Other names for ginger include Ostrich plumes, Pink cone ginger, Jungle king, Teuila flower, and Tahitian ginger. It has a strong spicy smell but is most well known for its bright red or pink bracted flowers.
- **Torch Ginger -*Etlingera elatior*:** The other names of Torch ginger are Wild ginger, Combrang, Bunga kantan, Philippine waxflower, Red ginger lily, and Rose de porcelain. This beautiful tropical plant has large and colorful flowers that come in bright colors. The entire plant is edible and is used in many cuisines worldwide.
- **13. Mango Ginger - *Curcuma amada:*** Other Names: Mavina Shunti. The rhizomes are very similar to common ginger but lack its pungency, and instead have a raw mango flavor. They are used in making pickles in south India and chutneys in north India
- **Kahili Ginger - *Hedychium gardnerianum*:** It has other names including fragrant ginger lily and garland flower. This plant is native to the Himalayan regions. It is a flowering plant of the ginger family. It is a perennial which grows up to a height of 180cm and is grown primarily for ornamental purposes.
- **Thai Ginger - *Alpinia galangal*:** It is also called as Greater Galangal, Ginseng Ginger, Krachai Dum Ginger, Lengkuas, and Blue Ginger. Rhizomes of Thai gingers are used in Unani medicine. The rhizome has a pungent smell and strong taste reminiscent of citrus, black pepper, and pine needles.
- **Pineapple Ginger -*Tapeinochilos ananassae*:** Other names include Indonesian wax ginger and Lipstick ginger. It has evergreen leaves and yellow flowers within red bracts. As an indoor plant, their flowers are valued for their beauty.
- **Resurrection Lily - *Kaempferia rotunda*:** Other names include Peacock ginger, Variegated ginger lily, Indian crocus, and Round-rooted galangal. It is a plant with impressive foliage and lily flower-like blooms. The flowers are fragrant. Its tubers have an unpleasant spiciness and are used similarly to ginger.
- **Siam Tulip - *Curcuma alismatifolia:*** It is called Pink ginger tulips, summer tulip. It bears pink flowers with a reddish hue. It can grow as an indoor plant and is also sold as a cut flower.
- **Snap Ginger -*Alpinia calcarata*:** Cardamom ginger and Indian ginger are its other names. Snap Gingers are named after their yellow-red flowers which resemble Snapdragons. The leaves of Snap Gingers have a sweet, soothing fragrance that resemble that of Cinnamon bark.

Different Species (Forestry, 2023).

- ***Zingiber officinale* (Common Ginger):** This is the most well-known species and is cultivated for its edible rhizomes, which are used as ginger in cooking and for various medicinal purposes.

- ***Alpinia purpurata* (Red Ginger):** Red ginger is known for its vibrant red or pink inflorescences, which are often used in floral arrangements. It's an ornamental species with large, showy flowers.
- ***Hedychium coronarium* (White Ginger Lily):** This species features large, fragrant white flowers and is commonly grown for its ornamental value. The flowers are used in garlands and leis.
- ***Kaempferia galangal* (Galangal):** Galangal is a rhizomatous ginger species used in Southeast Asian cuisine. It has a distinct, sharp flavor and is often used in curries and traditional dishes.
- ***Curcuma longa* (Turmeric):** Turmeric is another well-known ginger species, famous for its bright orange-yellow rhizomes. It's a key ingredient in many dishes, and its active compound, curcumin, is prized for its potential health benefits.
- ***Costus woodsonii* (Indian Head Ginger):** This species is notable for its unique, spiral-shaped inflorescence and striking red bracts. It's grown as an ornamental plant.
- ***Zingiber zerumbet* (Shampoo Ginger):** Shampoo ginger is recognized for its conelike inflorescence, which contains a fragrant liquid that can be used as a natural shampoo or body wash.
- ***Etlingera elatior* (Torch Ginger):** Torch ginger plants produce tall, striking inflorescences that resemble torches. These inflorescences are often used in decorative arrangements and traditional Asian dishes.
- ***Achasma sylvestre* (Wild Ginger):** This species is native to North America and has a spicy aroma but is not used in culinary applications. It's primarily a native plant in woodland ecosystems.

Other Scientific Names (Kaufman, 2016).

Amomum zingiber L. (1753)
Curcumia longifolia Wall.
Zingiber cholmondeleyi (F.M.Bailey) K.Schum.
Zingiber majus Rumph.
Zingiber missionis Wall.
Zingiber zingiber (L.) H. Karst.

BOTANICAL DESCRIPTION

Plant Description: *Z. officinale* is a herbaceous perennial comprising a rhizome, fibrous roots and aerial shoots. The aerial shoots are pseudostems consisting of many narrow leaves borne on very short petioles, with overlapping sheaths at the bases and can reach 1.5m in height. Leaf blades are 5-30cm long and 8-20mm wide with ligules present at the junction of leaves and sheaths. The leaves are lanceolate, distichous and glabrous with a prominent midrib. The underground stem or rhizome has a fleshy, yellow interior with secretory cells and ethereal oils. Nodes are present along the stem, which, apart from the first few, bear axillary buds which develop, allowing the rhizome to enlarge following a sympodial growth pattern. Both fibrous and fleshy roots are present; the fibrous roots, with root hairs, provide absorption of water and nutrients whilst the thicker, fleshy roots also provide stability. The flowering spikes, or scapes, which arise directly from the rhizome, are formed of overlapping bracts, each of which contains a single axillary flower encircled by a scarious bracteole (TB, 2014).

Flowering, which is probably dependent on climatic and cultivation factors, is not common and when it does occur, the insect pollinated inflorescence is ephemeral.The ginger in the tropical glasshouse at Reading flowered for over 6 months shortly after planting. A characteristic of the ginger flower is the colourful labellum (petaloid stamen). The single, remaining anther is free and fertile; the inferior ovary globose; the tubular corolla divided into three lobes at the top and the style is long. The fruit is a loculicidally dehiscent fleshy capsule containing seed with a distinctive white aril (TB, 2014). Erect, slender, perennial herb usually grown as an annual crop, with a thickened, fleshy, subterranean rhizome and with one or more aerial leafy stems, up to 1.25 m tall. Rhizome robust fleshy, up to 2 cm thick, growing horizontally underground but at shallow depth, irregularly branched but normally only in the vertical plane, covered with deciduous, thin scales which leave ring-like scars; epidermis corky, pale yellow to reddish, irregularly wrinkled in the dried rhizome; flesh pale yellow, aromatic; on dried rhizomes scars of leafy stems visible as shallow cup-like holes. Stem erect, unbranched, mainly formed by the leaf sheaths, pale green, often reddish at base; scales covering the lower part oblong, about 6 cm x 1 cm, scarcely white-pilose outside, with prominent parallel veins and scarious margins. Leaves distichous; sheath prominently veined, densely appressed pilose, especially so in the upper part, with white, scarious, glabrous margins; ligule up to 5 mm long, bi-lobed, glabrous to sparsely pilose, scarious; blade linear to lanceolate, up to 30 cm x 2 cm, acuminate at apex, finely parallel-veined, glabrous above, scarcely pilose below, light to dark green. Inflorescence arises direct from rhizome, spiciform, 15-30 cm long; scape slender, 10-20 cm long, below the spike covered with scales as on the leafy stem bases, the upper ones sometimes with short leafy tips; spike ovoid to narrow ellipsoidal, 4-7 cm x 1.5-2.5 cm, light green; bracts appressed, ovate to elliptical, 2-3 cm x 1.5-2 cm, yellow-green, margin scarious, incurved, the lower ones with slender whitish acute tips, glabrous, finely parallel-lined; in the axil of each bract one flower may be produced; flowers fragile, short-lived, surrounded by a spatha-like bracteole; bracteole narrower and slightly longer than the bract, usually persisting and enclosing the fruit; calyx tubular-spathaceous, 10-12 mm long, whitish; corolla tubular, pale yellow, widening at top into 3 lobes, tube 18-25 mm long, dorsal lobe long ovate, 15-25 mm x 7-8 mm, with beak-like rounded apex curved over the anther, ventral lobes oblong, 13-15 mm x 2-3 mm, apex rounded, 3-veined, strongly recurved; labellum about circular in outline, 12-15 mm in diameter, tubular at base (tube 3 4 mm), 3-lobed above; central lobe obovate, 12 mm x 9 mm, side lobes elliptical, 5 mm x 3.5 mm labellum pale yellow outside, inside dark purple or red at top and at margins, mixed with yellowish spots, scattered pilose at throat; filament about 1.5 mm long, anther 2-celled, ellipsoidal, 7-9 mm x 3 mm, pale yellow, connectivum prolonged into a slender, curved, purple, beak-like appendage 7 mm long, enclosing the upper part of the style; ovary globose, 2 mm in diameter, 3-locular; style filiform, 3.5 cm long, white, slightly recurved and widening at top, ending in a funnel-shaped white stigma which is ringed with stiff hairs around its upper margin; 2-3 fleshy, sublinear, white nectaries, 5 mm long, are situated against the style on top of the ovary. Fruit a thin-walled capsule, 3-valved, red. Seed small, arillate, black (Kaufman, 2016).

The leafy stems of ginger grow about a metre high. The leaves are 6–12 inches (15–30 cm) long, elongate, alternate in two

vertical rows and arise from sheaths enwrapping the stem. The flowers are in dense cone-like spikes about 1-inch thick and 2–3 inches long that are composed of overlapping green bracts, which may be edged with yellow. Each bract encloses a single, small, yellow-green and purple flower. The consumed portion of the ginger plant is the rhizome, often called "ginger root", although it is not an actual root. The rhizome is the horizontal stem of the plant that sends out the roots (Wang, 2020). The leafy stems of ginger grow about a metre high. The leaves are 6–12 inches(15–30 cm) long, elongate, alternate in two vertical rows and arise from sheaths enwrapping the stem. The flowers are in dense cone-like spikes about 1-inch thick and 2–3 inches long that are composed of overlapping green bracts, which may be edged with yellow. Each bract encloses a single, small, yellow-green and purple flower. The consumed portion of the ginger plant is the rhizome, often called "ginger root", although it is not an actual root. The rhizome is the horizontal stem ofthe plant that sends out theroots (Wang, 2020).

Zingiber officinale is a monocotyledonous herb of the wet tropical region. It is a 2–4-foot-tall perennial herb with grass-like leaves up to a foot in length. It has an underground rhizome that is used for culinary and medicinal purposes. The underground parts contain several small, solid rhizomes, more often branched like a palm, but the shape of rhizomes mainly depends on soil texture of the site of cultivation. Rhizome grown in loose soil are more valuable due to their straight and undeformed nature as loose and friable soil provides less mechanical resistance in their development. The rhizomes are surrounded by small scales and bear several fines, fibrous roots, which branch frequently in the surface soil. Gingerplants having slender aerial stem, which raises up to 1 m height and is closely wrapped by sheathing leaf bases. The light green leaves arranged in an alternate manner are oblong with strongly pointed end, having around 15 cm length and 2 cmwidth with a pronounced mid-rib, and tend to be rolled upwards. Normally, the inflorescence is leafless but sometimes leafy which is a reproductive shoot about 30 cm long and appears directly from rhizomes. The emergence of flower in gingerplants depends upon growing conditions of that place. In some parts of the world, it produces flowers very rarely, while in other parts it flowers at a regular basis. Whenflowering, seeds are produced only occasionally. The inflorescence known as spikeis about 6 cm long and has solitary flowers in the axils of greenish-yellow bracts. Pale yellow flowers have a short calyx tube and longer corolla tube (1.5–2.5 cm) which bursts at the mouth into three unequal, pointed lobes, the upper one bowed down as a hood over the anther. Ginger flowers have only a single functional stamenwith a short filament, two distinct pollen sacs and a broad connective prolonged into a spur. A slender style passes between these two pollen sacs and is detained by them. The lower lip ofthe flower is known as labellum shaped by a large purple and yellow mottled staminode, which is merged to the corolla tube. It is thought that it is derived from three non-functional stamens. The inferior ovary is composed of three cells and consists ofnumerous ovules in axile placentation, but hardly develops as a fruit. Ifit develops into a fruit, the fruit is thin walled with three valved structures known as capsule, comprising numerous small, black, angled seeds (Kumari *et al.,* 2020).

Ginger is a 2-4 feet tall slender perennial with grass-like leaves and greenish-yellow flowers. Once the leaves ofthe plant die, the thick rhizomes, about 6 inches long, are dug up.

Ginger is often referred to as a root but this is technically incorrect. Rhizomes are underground stems that grow horizontally underground (and have smaller roots growing from them) (McCormicks, 2024. It is a herbaceous perennial plant that grows upto 1 metre high. The leaves grow in an alternate manner and are long and elongate in nature. It produces white and pink clusters of flower buds that grow into yellow flowers on maturity. The flowers are arranged in a cone-like spike that is covered with overlapping green bracts. It is a monocotyledon plant. The underground stem modification forms into a rhizome that is widely used as a spice. The rhizome is palmately branched and bears leafy shoots. The leafy shoots are a pseudostem formed from the leafy sheaths and bears 8-12 distichous leaves. The inflorescence arises directly from the rhizome (Byjus, 2024). Ginger, *Zingiber officinale*, is an erect, herbaceous perennial plant in the family Zingiberaceae grown for its edible rhizome (underground stem) which is widely used as a spice. The rhizome is brown, with a corky outer layer and pale-yellow scented center. The above ground shoot is erect and reed-like with linear leaves that are arranged alternately on the stem. The shoots originate from a multiple bases and wrap around one another. The leaves can reach 7 cm (2.75 in) in length and 1.9 cm (0.7 in) broad. Flowering heads are borne on shorter stems and the plant produces cone shaped, pale yellow flowers . The ginger plant can reach 0.6–1.2 m in height (2–4 ft) and is grown as an annual plant (Plantvillage, 2024).

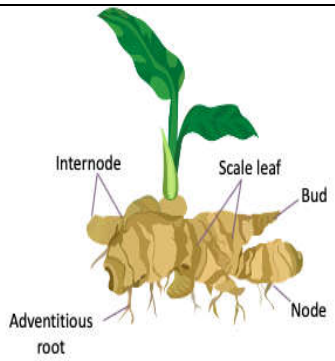
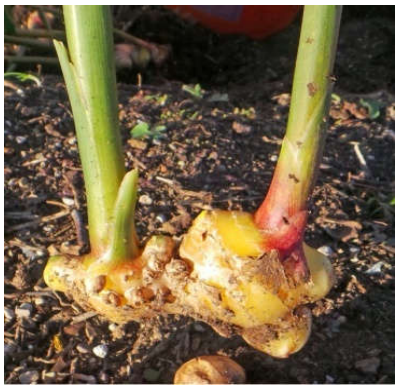
Zingiberaceae, the "ginger family," is a family of flowering plants consisting of aromatic perennial plants with creeping horizontal or tuberous rhizomes. A rhizome is a horizontal stem that is usually found underground, often sending out roots and shoots from its nodes. Some plants have rhizomes that grow above ground or that sit at the soil surface. Rhizomes, which also may be referred to as creeping rootstalks or rootstocks, differ from stolons in that a rhizome is the main stem of the plant, has short internodes, and sends out roots from the bottom ofthe nodes and new upward-growing shoots from the top of the nodes; a stolon sprouts from an existing stem, has long internodes, and generates new shoots at the end (*e.g.,* the strawberry plant (NWE, 2024).

The Zingiberaceae family comprises over 50 genera and more than 1,300 species, distributed throughout tropical Africa, Asia, and the Americas. Members of the family have distichous leaves with basal sheaths that overlap to form a pseudostem. The plants are either self-supporting or epiphytic. Flowers are hermaphroditic, usually strongly zygomorphic, in determinate cymose inflorescences, and subtended by conspicuous, spirally arranged bracts. The perianth is comprised of two whorls, a fused tubular calyx, and a tubular corolla with one lobe larger than the other two. Flowers typically have two of their stamenoids (sterile stamens) fused to form a petaloid lip, and have only one fertile stamen. The ovary is inferior and topped by two nectaries, the stigma is funnel-shaped (NWE, 2024). The genus *Zingiber* contains the true gingers, many ofwhich have medicinal and culinary value in many parts ofthe world. Each ginger species has a different culinary usage; for example, myoga is valued for the stem and flowers. The most well-known member of *Zingiber* is *Z. officinale*, also known as garden ginger. It is an erect plant, that grows three to four feet tall (0.9 - 1.2 meters), and has thin, sharp leaves that are six to 12 inches long (15 - 30 centimeters). It has yellowish-green flowers that grow in dense spikes and a tangled, branched, scaly, beige "root" (rhizome)

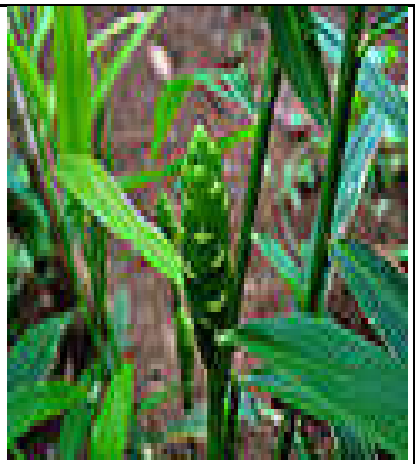
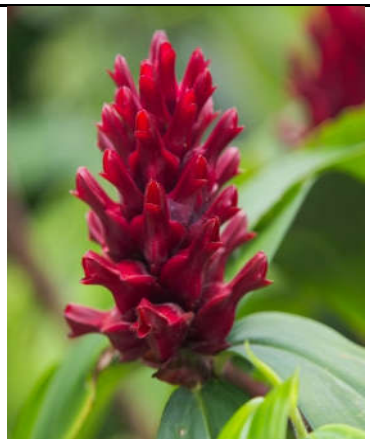
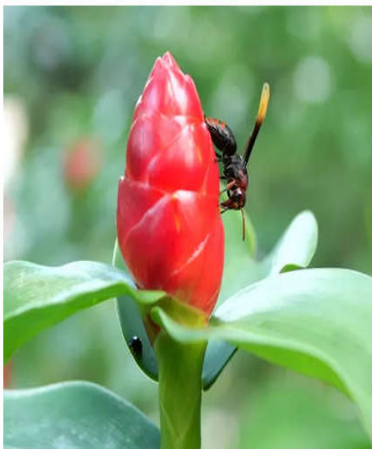
that can be one to six inches long (2.5 - 15 cm) and is aromatic, with a sharp, pungent taste. The flesh ranges in color from a pale greenish yellow to ivory. This rhizome usually is dried and ground to produce a spice for various dishes, or may be used fresh in cooking, and oil also is extracted for use (NWE, 2024). Ginger produces clusters of white and pink flower buds that bloom into yellow flowers. Because of the aesthetic appeal and the adaptivity of the plant to warm climates, ginger is often used as landscaping around subtropical homes. It is a perennial reed-like plant with annual leafy stems. Historically, it seems that primarily two different methods of treating the root to kill it and prevent sprouting have been used: when the stalk withers, it either is immediately scalded, or washed and scraped. The former method, applied generally to the older and poorer roots, produces Black Ginger, the latter, gives White Ginger. The natural color of the "white" scraped ginger is a pale buff—it is often whitened by bleaching or liming, but generally at the expense of some of its real value (NWE, 2024). It is a herbaceous perennial plant that grows upto 1 metre high. The leaves grow in an alternate manner and are long and elongate in nature. It produces white and pink clusters of flower buds that grow into yellow flowers on maturity. The flowers are arranged in a cone-like spike that is covered with overlapping green bracts. It is a monocotyledon plant. The underground stem modification forms into a rhizome that is widely used as a spice. The rhizome is palmately branched and bears leafy shoots. The leafy shoots are a pseudostem formed from the leafy sheaths and bears 8-12 distichous leaves. The inflorescence arises directly from the rhizome (Byjus, 2024). Botanical description is given in Fig. 1.

Pollination: The plant-biotic pollinator interaction is crucial for the survival of both organisms. Insects are recognised as effective biotic pollinators. As there are few specific studies on the pollination of angiosperms, the emphasis of this review is on understanding the pollination process by reviewing the knowledge of the ginger-insect pollinator interaction in Asia. Currently the plant-pollinator interaction of only 5% of Asian species of Zingiberaceae is evaluated. Previous studies indicate that bees, such as, halictidand blue-banded bees are, among the many floral vistors, the most important pollinators of ginger plants in Asia. The results suggest that the floral period of large white ginger starts 4-7th months and it is affected by environment. Normal temperature and relative humidity, may cause the period of ginger flowering is longer. Plants flowering are very affected by climate conditions, especially air temperature. The time required since flower initiation (primordial) stage until flower wilt is 70-80 days, while periods of flower bloom until wilt is only 12-18 h. Flower morphology indicates that anther position was lower than stigma. The period of blooming was just a few hours, and pistil was receptive at ±2.5 h after bloom, which was indicated by presence of maximum secretion. No pollinator to visit when the flower is blooming (Melati *et al*., 2015). Large white ginger (*Zingiber officinale* Rosc.var.*officinale*) is a medicinal herb belongs to the family *Zingiberaceae*, in which the rhizome is utilized for spice or raw material of traditional medicines. Members of this family are perennials that frequently have sympodial (forked) or horn-like fleshy rhizomes (underground stems). Most species in the Zingiberaceae produce flowers, which develop on separate shoots arising from rhizomes. Ginger flowers are covered by bract (leaflike structures), from each bract emerges one complete flower. Bracts are spirally arranged, and the flower clusters are spiral and cone-like called as spike. The Zingiberaceae flower resembles an orchid because of its labellum (two or three fused stamens) joined with a pair of petal-like sterile stamens. Nectar is present in the slender flower tubes. The brightly coloured flowers may bloom for only a few hours and are thought to be pollinated by insects. Zingiberaceae is a large family of animal-pollinated tropical monocotyledons. Major pollinators include bees, hawkmoths and birds. Members of the Zingiberaceae family also display a broad range of pollination and breeding systems (Melati *et al*., 2015). The flowers of large white ginger are not of particular concern because propagation is commonly undertaken by using rhizomes and its flower is not parts of ornamental flower. On the other hand, big white ginger rarely produced flowers under normal condition, and even if the flowers are produced, they rarely produce seeds. Flowers usually open during day time and fall on the next day. Ratio between fertile pollen and germinated pollen grains depended on the quantity of pollen grains germinated on stigma or whether self incompatibility operates (Melati *et al.,* 2015). Fertility of red ginger pollen (*Zingiber officinale* var. *Rubrum*) highly vary from 6 to 45% which was sufficient for fertilization. The failure fruit and seeds formation may be caused by a number of factors such as failure of pollination-due to limited pollinators. It is therefore possible that the absence of pollinators may cause ginger seldom produce seeds. Biology of ginger flowers have not been studied comprehensively especially on the flower, seed formation and factors affecting it. Understanding on the floral biology is important for conventional breeding purposes (Melati *et al*., 2015).

The corollas of ginger flowers are white in colour and each – normally bisexual – flower is enclosed by a bract (a leaf-like structure). But sometimes ginger also shows monoecious unisexual flowers. Three calyx types are present in the ginger flower, among these one is larger than the others and light yellow transparent, so that when the flowers begin to bloom, they seem to with a tinge of red, which, in fact, is the colour of the labellum pro- tected by calyx. The labellum is pale yellow inside and dark red inside and mixed with yellow spots. When the flowers bloom, pistil stalk shaped curved edges touching the labellum. Bracts are arranged in a spiral manner and the inflorescence is known as spike which is a conical shape structure where flowers occur in clusters. The presence of a labellum (two or three fused stamens) which is joined with a pair of petal-like sterile stamen shows the close relationship of Zingiberaceae flower with orchids. The slender flower tubes are the source of nectar in ginger. The bloom- ing of a bright flower occurs only for a few hours in the afternoon until late afternoon (01:00–05:00 pm), and this is pollination period for the single flower by insects. The flower of large white ginger is less valuable for the production as it is mainly propagated by rhizome and because these flowers are not used for ornamental purpose. On the other side, under normal climatic condition, these plants flower very rarely, and even if they produce flowers, seed setting is very rare. The quantity of pollen grains germinated on stigma or self-incompatibility reaction decides the ratio of fertile pollen and non-fertile pollens. Large variations were observed in fertility of red ginger pollen which varies from 6 to 45 per cent. It was reported that flowering in ginger starts from 4 to 7 months after planting, depending upon climatic conditions. High temperature leads to early and more flowering, but normal temperature and humidity lead to flowering for a longer time (Kumari *et al*., 2020).

		
Botany of ginger plant	**Ginger rhizomes with buds**	**Ginger rhizome with fresh shoot**
		
Growth from a rhizome	**Place the rhizome in the soil with the buds pointing upward**	**Rhizome in the soil**
		
Ginger rhizomes have a very delicate skin, especially when young	**Young ginger shoots and rhizome**	**Ginger field**

Continue …..

		
Ginger inflorescence	**Ginger inflorescence**	**Ginger inflorescence**
		
Ginger inflorescence	**Ginger inflorescence**	**Ginger inflorescence**
		
Ginger inflorescence	**Ginger flower about to bloom**	**Flower**

Continue ….

Ginger flower stamen

Flower --- side view

Ginger harvest

Ginger plant with rhizome

Modified rhizome stem.

Fresh ginger rhizome

Rhizomes of ginger

Dried ginger

Ginger section

Fig. 1. Botanical Description

The plant pollinator interaction is the key to the survival of flowering plants. Pollination starts with the visit of a pollinator, followed by pollination and ends in plant reproduction. Many factors enhance the interaction and increase the likelihood of successful pollination. All the criteria involved in pollination vary greatly in angiosperms. The overview of the Zingiberaceae-pollinator interaction in Asia presented indicate that the level of understanding is poor and there is a need for further studies. Understanding the interaction in terms of spatial and temporal factors will help in the conservation of plants and pollinators and ensure the continued survival of both organisms (Appalasamy *et al*., 2023). Ginger is a flowering plant whose rhizome, ginger root or ginger, is widely used as a spice and a folk medicine. It is a herbaceous perennial which grows annual pseudostems (false stems made of the rolled bases of leaves) about one meter tall, bearing narrow leaf blades. The inflorescences bear flowers having pale yellow petals with purple edges, and arise directly from the rhizome on separate shoots. Ginger produces clusters of white and pink flower buds that bloom into yellow flowers. Because of its aesthetic appeal and the adaptation of the plant to warm climates, it is often used as landscaping around subtropical homes. It is a perennial reed-like plant with annual leafy stems, about a meter tall. Traditionally, the rhizome is gathered when the stalk withers; it is immediately scalded, or washed and scraped, to kill it and prevent sprouting. The fragrant perisperm of the Zingiberaceae is used as sweetmeats by Bantu, and also as a condiment and sialagogue (Wikipedia, 2024).

There is no natural fruit or seed set in ginger due to sterile pollen grains and self- incompatibility reaction. Nevertheless, artificial supplementation of required chemicals and nutrient to young flowers along with in vitro pollination helps in the development of fruit and later on the plants that can be generated from these fruits . The successful application of in vitro pollination to overcome the pre-fertilization barriers for getting successful fruit set was reported (Kumari *et al*., 2020).

GENETICS AND CYTOGENETICS

Most cultivated varieties are sterile. Chromosome numbers 2n=22. Different cultivars vary in karyotype (Kaufman, 2016). Several workers reported the somatic chromosome number of ginger as n = 11. The diploid chromosome number $2n = 22$ was displayed by all the cultivars. Application of colchicine at sprouting bud of ginger rhizome helped in development of autotetraploid ginger, $2n = 44$. The length of the diploid chromosomes ranged from 1.6 µm to 4.3 µm and had median and submedian centromeres. Diploid ginger showed a pollen fertility of 13%, whereas in the case of tetraploid, ginger fertility was 85%. The high sterility in diploid ginger is mostly due to heterozygosity for gross structural changes of chromosomes. Structural hybridity involving interchanges and inversions was reported in *Zingiber officinale* (Kumari *et al*., 2020). To confirm the results of flow cytometry analysis, chromosome number counting was also conducted as shown in Fig. 2. Both the normal-type plants (Fig. 2A) and the three plants of the VT1 (Fig. 2B) were found to have 22 chromosomes. Nevertheless, it was observed that the root-tip cells with 44 (Fig. 2C) and 22 chromosomes (Fig 2D) co-existed in all the plants of the VT2, which was consistent with the results of their DNA content analysis. Previous studies showed that the basic chromosome number of ginger is x = 11. Therefore, the results of flow cytometry analysis and chromosome counting in this study confirmed that the normal-type plants of 'Wuling' ginger and the VT1 were both diploid ($2n = 2x = 22$), while the VT2 was mixoploid with diploid and tetraploid cells ($2n = 4x = 44$) (Zhao *et al*., 2023).

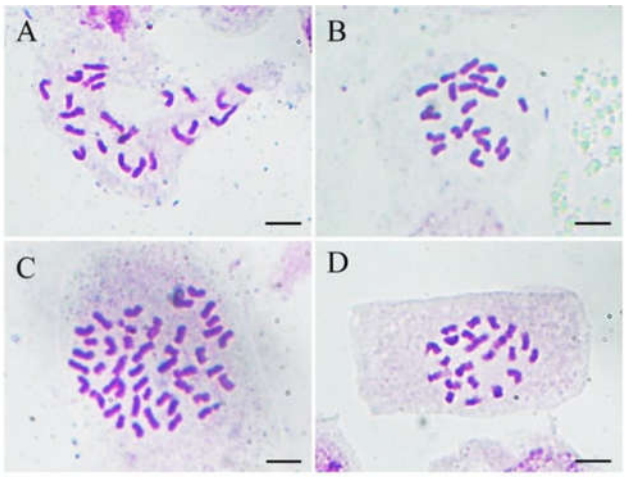


Fig. 2 : Micrographs (×1000) of somatic chromosomes in the root tips of the normal-type ginger (A), the VT1 (B), and the VT2 (C,D). Scale bars = 10 µm

GENETIC DIVERSITY

Using rice microsatellite markers assessed the genetic variability among three genera of the family *Zingiberaceae:* Zingiber, Alpinia and Curcuma and found the origin of the genera diverse covering eight Asian countries. Zingiber contains 150 species and four sections distributed throughout tropical Asia, China, Japan and tropical Australia besides the subspecies (varieties): *Z. officinale* var. *rubra, Z. officinale* var. *rubrum* and *Z. officinale* (Fig. 3) (Kizhakkayil and Bhas, 2011).

Fig. 3. Variability for rhizome features in Indian ginger germplasm (a) 'Varada', (b) 'Mahima', (c) 'Rejatha', (d) 'Suprabha', (e) 'Sabarimala', (f) 'Kozhikkalan', (g) 'Kakakalan', (h) 'Ellakallan', (i) 'Nadia', (j) 'Rio-de-Janeiro', (k) 'Silent valley' and (l) 'Himachal'

Identification of clonal or genotypic variations is a prerequisite for ginger improvement programmes. Genetic diversity analysis was carried out in a set of forty-nine ginger clones cultivated in North-East India using random amplified

polymorphic DNA (RAPD) markers. The set included clones of released varieties and clones collected from various parts of North East India. Jaccard's genetic similarity, cluster analysis and principal component analysis identified five clusters. Cluster V included four clones traditionally cultivated in the Indian state of Meghalaya known for production of high-quality ginger indicating that the clones were a good candidate for ginger improvement. Specific bands for these clones were also identified. Principal component analysis of the molecular data supported grouping of the clones into six hypothetical populations based on their source or location of collection (Sajeev *et al.,* 2011).

Ginger is an economically important plant, valued all over the world. The existing variation among 16 promising cultivars as observed through differential rhizome yield (181.9 to 477.3 g) was proved to have a genetic basis using different genetic markers such as karyotype, 4C nuclear DNA content and random amplified polymorphic DNA (RAPD). The karyotypic analysis revealed a differential distribution of A, B, C, D and E type of chromosomes among different cultivars as represented by different karyotype formulas. A significant variation of 4C DNA content was recorded in ginger at an intraspecific level with values ranging from 17.1 to 24.3 pg. RAPD analysis revealed a differential polymorphism of DNA showing a number of polymorphic bands ranging from 26 to 70 among 16 cultivars. The RAPD primers OPC02, OPA02, OPD20 and OPN06 showing strong resolving power were able to distinguish all 16 cultivars. The extent of genetic diversity among these cultivars was computed through parameters of gene diversity, sum of allele numbers per locus and Shannon's information indices. Cluster analysis, Nei's genetic similarity and genetic distances, distribution of cultivars into special distance classes and principal coordinate analysis and the analysis of molecular variance suggested a conspicuous genetic diversity among different cultivars studied. The genetic variation thus detected among promising cultivars of ginger has significance for ginger improvement programs (Naik *et al.,* 2014). The present investigation was undertaken for the assessment of 12 accessions of *Zingiber officinale* Rosc. collected from subcontinent of India by RAPD markers. DNA was isolated using CTAB method. Thirteen out of twenty primers screened were informative and produced 275 amplification products, among which 261 products (94.90%) were found to be polymorphic. The percentage polymorphism of all 12 accessions ranged from 88.23% to 100%. Most of the RAPD markers studied showed different levels of genetic polymorphism. The data of 275 RAPD bands were used to generate Jaccard's similarity coefficients and to construct a dendrogram by means of UPGMA. Results showed that ginger undergoes genetic variation due to a wide range of ecological conditions. This investigation was an understanding of genetic variation within the accessions (Ashraf *et al*., 2014).

The genetic variability, heritability and genetic advance over mean were estimated for yield and quality traits in sixteen ginger germplasms. Wide genetic variation was observed for all genotypes for plant height, number of leaves per plant and fresh yield per plant and. Considering genetic parameters, high GCV was found highest for number of leaves (28.64%) followed by oleoresin content (20.64%) and fresh yield per plant (18.12%), respectively. In all cases, phenotypic variances were higher than the genotypic variances. Based on high heritability (h2 b.s.) fresh yield per plant (89.20%), oleoresin content (80.30%), stem girth (79.39%), number of leaves per plant (75.69%) and plant height (67.93) were found superior and high GAM was observed for number of leaves (51.32%), oleoresin content (38.11%) and fresh yield per plant (35.26%) found superior traits and representing additive genetic variance. Effective selection would be made considering these traits (Ravi *et al*., 2016). The experiment was carried out at the research field of Spices Research Centre, Shibganj, Bogra, Bangladesh to find out the genetic diversity among 20 germplasms of ginger during Rabi 2013-14 using morphological traits. D^2 analysis of 20 ginger lines and analysis of variance were done. The lines were grouped into five clusters. The inter-cluster distance was larger than the intra-cluster distances. Maximum inter-cluster distance was found between cluster I and IV (48.17) followed by cluster III and IV (42.55) and me and II (30.97) and me and V (27.84). It may be concluded that the line in cluster I and the line in cluster III, grouped here is superior to all other clusters and could be used for future breeding work (Islam *et al*., 2017).

The results showed that in Pandeglang were eplored. 2 types of ginger planted, namely red ginger and small white ginger (emprit), scattered in all accessions. Based on the morphological characteristics, the two types of ginger had similarities on the shape of stem, the color of stem, the shape of leaf, the tip of leaf, the base of leaf, and the shape of root (Fig. 4) (Prasetyo *et al*., 2022).

A B

Fig. 4. Morphological character of rhizome shape and color (A= red ginger; B= small white ginger (emprit)

A set of 45 ginger collections were collected from several parts of Karnataka was subjected to field evaluation in augmented block design by using four checks in four blocks. This investigation was conducted to study the genetic variability of ginger collections for growth and yield parameters. For all of the parameters studied, there was a broad genetic variation among the collections; high PCV and GCV was recorded in dry rhizome yield per hectare, followed by rhizome yield per hectare, length of the primary rhizome, rhizome yield per plant and number of secondary rhizome, respectively. In every case, high phenotypic variances were observed than the genotypic variances. Depends on high heritability together with high genetic advance as per cent of mean, number of secondary rhizomes, length of the primary rhizome, rhizome yield per plant, length of secondary rhizome, girth of secondary rhizome, girth of primary rhizome and number of primary rhizomes were identified as superior traits and exhibit additive genetic variance. These characteristics would be considered in effective selection (Altaf *et al*., 2023). The ginger breeding program has encountered challenges due to the limited genetic diversity. In the selection process, it is imperative to have a broad range of genetic variations to allow for an efficient search for the most effective plant types. Despite a decline in the prominence of traditional mutation breeding, induced mutations remain extremely important, aided by a range of biotechnological tools. The utilization of in vitro culture

techniques serves as a viable alternative for the propagation of plants and as a mechanism for enhancing varietal improvement (Oladosu *et al*., 2024).

BREEDING

Germplasm

More than 400 accessions of ginger are maintained at the Indian Institute for Spice Research in Calicut, Kerala, India. The Indian Institute for Spice Research selected the following Indian cultivars for their high yield and high oil content (Jakribettu *et al.,* 2016). Major collections of ginger germplasm are maintained at the ICAR-Indian Institute of Spices Research (IISR) in Kozhikode, Kerala, India and the Research Institute for Spices and Medicinal Crops, Bogor, Indonesia. The ginger germplasm conservatory at IISR consists of 645 accessions that include exotic cultivars, indigenous collections, improved cultivars, mutants, tetraploids, and related species. In addition, 443 accessions are being maintained at different centers of the All India-Coordinated Research Project on Spices and the National Bureau of Plant Genetic Resources (NBPGR), Regional Station, Thrissur (Kaufman, 2016). There are many genetic resources which were collected and preserved in the word. Zingiberis family includes about 50 genera and 1300 species of ginger which are known to exist worldwide. They occur in different parts of the world, namely, Japan, Australia, Haiti, Bangladesh, Jamaica, Sri Lanka and Nigeria. However, most of the varieties used in commercial production were reported from India and China (Wang, 2020).

Breeding

Breeding of ginger has been severely hampered by poor flowering and seed set. Moreover, cultivars are rather uniform because of vegetative propagation. Hence most of the crop improvement programmes are confined to the evaluation and selection of the naturally occurring clonal variation and the introduction of cultivars from abroad. In India, work is also being done on in vitro selection and mutation induction for resistance to rhizome rot and bacterial wilt (Kaufman, 2016). Breeding of ginger through selection and hybridization is seriously handicapped by lack of variability, absence of natural seed set and exclusive vegetative propagation. Sexual reproduction is not reported in ginger, however the geographical spread accompanied by genetic differentiation into locally adapted population augmented by mutation is the main factor responsible for diversity in this clonally propagated crop. The knowledge of the variability structuring could allow not only the description of genotypes but also development of a conservation strategy for future breeding purposes (Akshitha *et al*., 2019). As ginger is propagated through vegetative means, flowers are seldom formed and no seed setting takes place. Conventional breeding methods like hybridization is not possible because of this nature of the crop. Therefore, selection is the easiest method of improving the crop as compare to mutation and polyploidy breeding. Genetic variability can be utilized to improve the crop through selection. Propagated through vegetative means, the crop could accumulate mutants over a period of time would have rendered the collection to be a mixture of germplasm (Altaf *et al*., 2023).

Breeding Methods: In clonally propagated crops like ginger, the two important components of biodiver-sity are species diversity and varietal diversity which permits selection forces to act on it. The evolution of this crop experienced a lot of changes in its physiological and anatomical structure due to the long history of domestication of gingers into diverse geographical niches. This variability was not so dominant in cultivars grown in the same region compared to the ones growing in different geographically distant locations. The presence of this genetic variability gives a chance for utilization in crop improvement and sustain able development (Kumari *et al.,* 2020).

The main purpose of crop improvement is to develop high-yielding varieties withwide adaptation, high-quality parameters (oil, oleoresins) and low fibre, besides resistance to major pest and diseases such as rhizome rot and shoot borer. Several methods such as introduction, selection, mutation, polyploidy breeding and also biotechnological approaches are being used for improving the ginger cultivars in India as well as other parts of world. Hybridization is not practicable in ginger due to sterility (Kumari *et al.,* 2020).

Selection: During the initial years of crop improvement, foremost importance was given for the collection of a large number of germplasm from different localities, their comparative yield evaluation and selection of superior types based on yield and quality traits. The yield potential and unique feature of rhizome vary according to existing factors in the particular region. The high yield potential and quality of the exotic cultivar 'Rio-de-Janeiro' were proven by various researchers. The yields of the cultivars 'Himachal', 'Kuruppampadi', 'China' and 'Maran' are analogous to 'Rio-de-Janeiro'.

The most popular varieties among farmers are 'Rio-de-Janeiro', 'Himachal Pradesh', 'Kuruppampadi', 'Maran', 'Nadia' and 'Burdwan'. The highest yield of variety 'Thingapuri' was observed in Odisha. The best quality character, i.e. the highest oleoresin content, was observed in 'Rio-de-Janeiro' and 'Maran', while the highest essential oil content was found in 'Karakkal'. The cultivars 'China' and 'Nadia' were the lowest in crude fibre content, whereas a higher fibre content was observed in 'Kuruppampadi', 'Maran', 'Jugijan', 'Ernad Manjeri', 'Nadia', 'Poona', 'Himachal Pradesh', 'Tura' and 'Arippa' (Kumari *et al*., 2020).

Mutation Breeding: In sterile vegetatively propagated plants, variability can be created by exposing the plant organs to physical and chemical mutagens. Once the induced variability is fixed, it can be maintained by vegetative propagation. It was reported that the use of ethyl methane sulfonate (EMS) as a chemical mutagen leads to reduced growth and increased cytological irregularities. Gamma rays also showed a similar effect as chemical mutagens. It was observed that most of the induced changes appearing in the R_1 generation were in chimeric form and expressed a stunted or semi-dwarfing effect and were inhibitory on production of rhizomes (Kumari *et al.,* 2020).

Polyploidy Breeding: Successful stable tetraploids in ginger with $2n = 44$ were developed by treating the sprouts with 0.25 per cent aqueous colchicine. The polyploids have the features like vigour growth, larger rhizome size and early flowering than the diploid. However, in polyploid rhizomes, lower oil content was observed compared to diploid rhizomes (Kumari *et al.,* 2020).

Biotechnological Approaches: Limited variability in ginger genotypes is mainly due to absence of seed setting which hinders the crop improvement programmes. The diseases such as rhizome rot caused by *Pythium aphanidermatum* and bacterial wilt caused by *Ralstonia solanacearum* are the major production constraints in ginger cultivation. Use of biotechnological tool can be considered as boon for ginger improvement due to its wider application (Kumari *et al.,* 2020).

Major Cultivars

Though clonally propagated, variability is rather high in ginger. Many improved clones were developed in the past decades through clonal selection. Cultivar diversity is richest in China followed by India and much less in other ginger growing countries. In China there are sparse seedling types and dense seedling types. In addition there are cultivars exclusively for the use of fresh consumption, for dry processing and for the ornamental market. Among the cultivars Zaoyang of Hubei province is a very important one, as is Chenggu Yello (Shaxi province), Yulin round fleshy ginger (Guangxi province), Bamboo root ginger and Mian Yang Ginger (Sichuan), Xuanchange ginger (Ahuii), Yuxi yellow ginger (Yunan), and Taiwan fleshy ginger (Kaufman, 2016). Several cultivars of ginger are grown in different ginger growing areas in India and they are generally named after the localities where they are grown. Some of the prominent indigenous cultivars are Maran, Kuruppampadi, Ernad, Wayanad, Himachal and Nadia. The exotic cultivar 'Rio-de-Janeiro' from Brazil has also become very popular among cultivators (Kaufman, 2016).

The improved varieties of ginger are given in Tasble 1 (Kaufman, 2016).

Table 1. Improved varieties of ginger

Variety	
Indian Institute of Spices Research, Kozhikode – 673 012, Kerala	
IISR Varada	
IISR Mahima	
IISR Rejatha	
High Altitude Research Station, Orissa University of Agriculture and Technology, Pottangi – 764 039, Orissa	
Suprabha	
Suruchi	
Suravi	
Subhada	
Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh – 173 230	
Himagiri	
Kerala Agricultural University, Thrissur – 680 656, Kerala	
Athira	
Karthika	
Aswathy	

The field experiment was taken up to evaluate the ginger genotypes for growth and yield parameters at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during 2015-2016. The genotype Humnabad Local was found superior among the twelve genotypes. Humnabad Local has recorded maximumplant height (56.60 cm), number oftillers per plant (24.33), number of leaves perplant (257.60) at180 days after planting. It also has recorded highest fresh rhizome yield per plant (235.26 g), yield per plot (7.18 kg), yield per hectare (23.93 t/ha), dry rhizome yield per hectare (6.29 t/ha) and dry recovery percentage (26.32 %). Hence, Humnabad Local performed best among the genotypes evaluated (Goudar *et al*., 2017). Several cultivars of ginger are grown in different growing regions in India and are generally named from the region in which they are mostly cultivated as in Table 2 (Jaidka *et al*., 2018; Kumari *et al*., 2020).

Table 2. Some of the area-wise commonly cultivated varieties of ginger in India

Cultivar	Area of cultivation
Thingpui, Jorhat, Nadia, Maran	Assam
Burdwan	West Bengal
Wynad local, Wynad Manantody, EmadKuruppampadi	Kerala
Karakkal	Karnataka
Narasapattam	Andhra Pradesh
China	Exotic from China
Rio-de-Janeiro	Exotic from Brazil
Variety	**Source**
IISR-Varada	IISR Calicut
IISR-Mahima	IISR Calicut
IISR Rajatha	IISR Calicut
Suprabha	HARS
Suravi	
Himagiri	YSPU, HP

Twenty seven ginger genotypes, *viz*. IISR Varada, IISR Mahima, IISR Rejatha, Suprabha, Suravi, Suruchi, Sourabh, Athira, Karthika, Aswathy, KAU Chandra, Mohini, Rio de Janeiro, Nadia, Maran, Himachal, Bhaise, Gorubathane, Mahim, Zaheerabad local, Arunachal Pradesh local, Acc. 247, Acc. 65, Acc. 578, Acc. 219, Acc. 833 and RG 3 were characterized for two consecutive years 2016–17 and 2017–18 at ICAR-Indian Institute of Spices Research, Experimental Farm, Peruvannamuzhi, Kozhikode, Kerala in a randomized block design (Akshitha *et al.,* 2019). Several cultivars of ginger are grown in different ginger-growing areas in India, and they are generally named after the localities where they are grown. Some of the prominent indigenous cultivars of ginger grown in India are Himachal, Maran, Kuruppampady, Wayanad, Varadha. Exotic cultivars such as Rio de Janeiro have also become very popular among cultivars. Maran, Nadia, Karakkal and Rigodi are suited for high dry ginger. Varieties like Ernadn Chrnad, China and Rio de Janeiro provide high oleoresin content. Sleve local, Narasapattam and Himachal are suited for high volatile oil. Rio de Janeiro, China, Wayanad, Maran and Varadha are suited for green ginger. The production of many very popular varieties used in China is exporting to other countries. The most famous varieties includes Laiwu ginger, Tongling ginger, Pinghu ginger, Laifeng ginger. Due to vegetatively propagated characteristic, in vitro techniques, namely, micropropagation techniques, somatic embryogenesis, somatic hybridization, gemplasm conservation, transgenics and mutation breeding, are mostly used (Wang, 2020).

CULTIVATION

Propagation: Ginger is propagated vegetatively by pieces of rhizome called seed pieces or sets. They are normally produced by cutting rhizomes into 3-6 cm long pieces of 30-60 g, with at least one growing point or bud. Medium to large-sized seed pieces produce more vigorous plantlets and higher yields than small ones. To prevent diseases, seed pieces may be dipped in a fungicide solution and air-dried prior to planting. Seed pieces can be pre-germinated to obtain uniform plants, reduce the number of missing hills in the field and allow for once-over harvesting. Pre-germination may be promoted by placing the sets 2.5 cm apart on raised beds, covered with compost, sawdust or manure or both and kept moist The sets are ready for transplanting after 3-5 weeks or when the sprouts are 1-2 cm long (Kaufman, 2016). Ginger is usually vegetatively propagated from small portions of rhizome from the previous year's harvest. The rhizomes that are used for cuttings are mostly stored in covered pits. The cuttings have to be disease-free, 3-4 cm long, weighing 20-30 g each, and should have at least one bud ('eye'), preferably two. The rhizome pieces, usually called 'seed pieces', 'seed rhizomes' or 'sets', have to be cut a few days ahead of planting to let the cut surfaces dry. This prevents rotting and other forms of decay. Medium- to large-sized seed pieces produce more vigorous plantlets and higher yields than small ones. To prevent diseases, seed pieces may be dipped in a fungicide solution and air-dried prior to planting. Seed pieces can be pre-germinated to obtain uniform plants, reduce the number of missing hills in the field and allow for once-over harvesting. Pre-germination may be promoted by placing the sets 2.5 cm apart on raised beds, covered with compost, sawdust or manure or both, and kept moist. The sets are ready for transplanting after 3-5 weeks or when the sprouts are 1-2 cm long. Though transplanting in ginger is not conventional, it is found profitable. A transplanting technique in ginger by using single bud sprouts (about 5 g) has been standardized to produce good quality planting material with reduced cost. The yield level of ginger transplants is on-par with conventional planting system. The technique involves raising transplants from single sprout seed rhizomes in the pro-tray and planted in the field after 30-40 days. The advantages of this technology are production of healthy planting materials and reduction in seed rhizome quantity and eventually reduced cost on seeds. Planting rates of seed rhizomes range from 850 to 2500 kg/ha. The rhizome pieces have to be planted in well-prepared soil at a depth of about 5-10 cm. The soil has to be moist and about 25°C. Spacing can be 40 cm in the row and 40 cm between the rows, but narrower spacings are also used. Seed rhizomes can be planted on beds or ridges (Kaufman, 2016).

Production: In 2020, global production of ginger was 4.3 million tonnes, led by India with 43% of the world total. Nigeria, China, and Nepal also had substantial production. Though it is grown in many areas across the globe, ginger is "among the earliest recorded spices to be cultivated and exported from southwest India". India holds the seventh position in ginger export worldwide, however is the "largest producer of ginger in the world". Regions in southwest and Northeast India are most suitable for ginger production due to their warm and humid climate, average rainfall and land space (Wikipedia, 2024). Though India is the largest ginger producer in the world, it fails to play the role of a large exporter and only accounts for about 1.17% of total ginger exports. Ginger farming in India is a costly and risky business, as farmers do not gain much money from exports and "more than 65% of the total cost incurred is toward labor and seed material purchase". The farm owner may benefit given that there is no losses in production or price decreases, which is not easily avoidable. Production of dry ginger proves to have a higher benefit-cost ratio, as well as ginger cultivated in intercropping systems rather than as a pure crop (Wikipedia, 2024). The size of the ginger rhizome is essential to the production of ginger. The larger the rhizome piece, the faster ginger will be produced and therefore the faster it will be sold onto the market. Prior to planting the seed rhizomes, farmers are required to treat the seeds to prevent pests, and rhizome rot and other seed-borne diseases. There are various ways farmers do seed treatment in India. These include dipping the seeds in cow dung emulsion, smoking the seeds before storage, or hot water treatment. Once the seeds are properly treated, the farmland in which they are to be planted must be thoroughly dug or ploughed by the farmer to break up the soil. After the soil is sufficiently ploughed (at least 3-5 times), water channels are made 18–24 m apart to irrigate the crop (Wikipedia, 2024). The next step is planting the rhizome seed. In India, planting the irrigated ginger crop is usually done in the months between March and June as those months account for the beginning of the monsoon, or rainy season. Once the planting stage is done, farmers go on to mulch the crop to conserve moisture and check weed growth, as well as check surface run-off to conserve soil. Mulching is done by applying mulch (green leaves for example) to the plant beds directly after planting and again 45 and 90 days into growth. After mulching comes hilling, which is the stirring and breaking up of soil to check weed growth, break the firmness of the soil from rain, and conserve soil moisture. Farmers must ensure that their ginger crops are receiving supplemental irrigation if rainfall is low in their region. In India, farmers must irrigate their ginger crops every two weeks at the least between September and November (when the monsoon is over) to ensure maximum yield and high quality product (Wikipedia, 2024). The final farming stage for ginger is the harvesting stage and for items such as vegetable, soda, and candy, harvesting should be done between four and five months of planting, whereas when the rhizome is planted for products such as dried ginger or ginger oil, harvesting must be done eight to ten months after planting. Dry ginger is one of the most popular forms of ginger in commerce. Ginger rhizomes for dry ginger are harvested at full maturity (8–10 months). After soaking them in water, the outer skin is scraped off with a bamboo splinter or wooden knife by hand as it is too delicate a process to be done by machinery. The whole dried rhizomes are ground in the consuming centres. Fresh ginger does not need further processing after harvest, and is harvested much younger (Wikipedia, 2024).

Harvesting: Timing of harvesting of ginger rhizomes depends on their intended use, as the relative content (on a dry weight basis) of essential oil, pungent constituents and fibre increases with age of the crop. The content of essential oil and the pungent principles of the rhizomes reaches a maximum about 9 months after planting, decreasing later on, whereas the fibre content continues to increase. The rhizomes are usually lifted with a spade or other tool, and separated from leaves and roots. Next, the rhizomes are washed and sundried. When intended for consumption as a fresh vegetable (green ginger), rhizomes may be harvested about 5 months after planting. For the production of preserved ginger, they are usually harvested 5-7 months after planting, before they are fully mature and while

still tender, succulent and mild in pungency, and with low fibre content. For dried ginger, mature rhizomes that have developed a full aroma, flavour and pungency are used. These are harvested 8-9 months after planting, when leaves begin to yellow and stems start to lodge. Harvesting is accomplished either by hand with a spade, hoe or digging fork, or by mechanical diggers. Harvesting should be done very carefully, to minimize damage to the rhizomes (Kaufman, 2016).

Yield: Generally, it can be assumed that ginger rhizomes lose about 75-80% of their weight during drying. Yields of dried rhizomes from small-holdings are usually below 3 t/ha, compared with 10-15 t/ha obtained on commercial farms in Australia. In Africa and the Caribbean, yields are seldom higher than 2 t/ha. In the Philippines, the average commercial yield of fresh ginger is 6-7 t/ha (Kaufman, 2016). The bulk of the production of ginger is consumed locally in the producing countries, mainly as fresh ginger. Ginger is grown by smallholders and commercially in many countries – China, India, Nigeria, Thailand, Japan, Indonesia, Philippines, Sri Lanka, Jamaica, Ghana, Fiji Islands, Bangladesh, Nepal, Vietnam, Korea, and to a lesser extent in many other countries. In 2014 total world production was 2,156,453 t, with 93.2% produced in Asia, 6.0% in Africa, 0.6% in the Americas and 0.2% in Oceania. The top five producers were India (655,000 t), China (450,686 t), Nepal (276,150 t), Indonesia (266,145 t) and Thailand (161,404 t) (Kaufman, 2016).

Indigenous to warm tropical climates, ginger is widely grown in Asia, Africa, India, Jamaica, Nigeria, Indonesia, Bangladesh, Thailand, the Philippines, Mexico and Hawaii. It is also cultivated in Fiji, Brazil, Sierra Leone, Japan and Australia. Nigeria is identified as a top-ranking country for area of cultivation with a share of 56% of the total global area followed by India (24%), China (4.5%), Indonesia (3.4%) and Bangladesh (2.3%). Among the top producing countries, India ranked first with total biomass production of33% followed by China (21%), Nigeria (13%) and Bangladesh (11%) in the world. It is grown in most of the Indianstates. However, 65 per cent of country's total production is contributed by 15 states, namely, Andhra Pradesh, Andaman and Nicobar Islands, Assam, Karnataka, Odisha, Meghalaya, Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Bihar, Chhattisgarh, Madhya Pradesh, Maharashtra and Gujarat (Kumari *et al*., 2020). World ginger production is estimated to be 4.90 million tonnes with an area of 0.45 million hectares and it is mainly distributed in India, Indonesia, China, Nigeria, Thailand, Bangladesh, Philippines, Nepal and Jamaica. India is the largest producer of ginger contributing to about 45.31 per cent, followed by China, Nepal, Nigeria, Thailand and Bangladesh (Altaf *et al*., 2023).

Growth and Development: The first shoots of ginger appear 10-15 days after planting the rhizomes and new shoots appear continuously until about 4 weeks months after planting. Each shoot has about 8-12 leaves. Flowering is cultivar-dependent. Some cultivars flower rarely, others regularly, especially when grown undisturbed as perennials. In Malaysia, ginger flowers only rarely. Ginger fruits are seldom produced. Ginger rhizomes normally only branch in the vertical plane, so they are flat on the sides and stand upright in the soil. They have a main axis, with at least one side axis to the left and the right, with these side axes again forming two side axes. Only some of the side axes develop aboveground shoots (Kaufman, 2016). Before planting ginger, the field should be thoroughly prepared to a fine tilth, free of weeds, roots and residues of previous crops. Normally, ginger is planted in rows, with 25-30(-50) cm between rows and 15-35 cm within the row. In the Philippines, the recommended planting distance is 50-70 cm between rows and 30 cm within the row. The normal planting depth is 5-12 cm, with one seedpiece per hole. In the fully mechanized estates in Queensland, 8-10 t of sets are needed to plant 1 ha: under less intensive conditions in India and Sri Lanka 1.5-4 t/ha are needed (Kaufman, 2016). At planting time, the soil must be moist and not dry out once the sets are planted. The preferred soil temperature at planting is 25°C and should not exceed 30°C. Planting in the Philippines takes place in May. Recommended planting time is March-April in India, and September in Queensland (Kaufman, 2016). It is recommended to practise rotation and to grow ginger only once in 3-4 years, to reduce the incidence of pests and soilborne diseases. Ginger is often found in intercropping systems. It is often the first crop on land taken into cultivation (Kaufman, 2016). Timing of harvesting of ginger rhizomes depends on their intended use, as the relative content (on a dry weight basis) of essential oil, pungent constituents and fibre increases with age of the crop. The content of essential oil and the pungent principles of the rhizomes reaches a maximum about 9 months after planting, decreasing later on, whereas the fibre content continues to increase. When intended for consumption as a fresh vegetable (green ginger), rhizomes may be harvested about 5 months after planting. For the production of preserved ginger, they are usually harvested 5-7 months after planting, before they are fully mature and while still tender, succulent and mild in pungency, and with low fibre content. For dried ginger, mature rhizomes that have developed a full aroma, flavour and pungency are used. These are harvested 8-9 months after planting, when leaves begin to yellow and stems start to lodge. Harvesting is accomplished either by hand with a spade, hoe or digging fork, or by mechanical diggers. Harvesting should be done very carefully, to minimize damage to the rhizomes (Kaufman, 2016).

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from uncoated ones, as the epidermal tissue is rich in oil-containing cells. The presence of pungent compounds responsible for the taste of ginger oil can be substantially reduced by poor post-harvest handling or improper distillation (Kaufman, 2016).

Transportation and export of ginger: Ginger is sent through various stages to be transported to its final destination either domestically or internationally, and the journey begins when farmers sell a portion of their produce to village traders who collect produce right at the farm gate. Once the produce is collected, it is transported to the closest assembly market where it is then taken to main regional or district level marketing centres. Farmers with a large yield of produce will directly take their produce to the local or regional markets. Once the produce has "reached [the] regional level markets, they are cleaned, graded, and packed in sacks of about 60 kg". They are then moved to terminal markets such as in New Delhi, Kochi, and Bombay (Wikipedia, 2024). States from which ginger is exported follow the marketing channels of vegetable marketing in India, and the steps are similar to those when transported domestically. However, instead of reaching a terminal market after the regional forwarding centres, the produce will reach an export market and be sent offby vehicle, plane or boat to reach its final international destination where it will arrive to a local retail market and finally reach the consumer once purchased. Dry ginger is most popularly traded between Asian countries through a unique distribution system involving a network of small retail outlets. Fresh and preserved ginger are often sold directly to supermarket chains, and in some countries fresh ginger is seen exclusively in small shops unique to certain ethnic communities. India frequently exports its ginger and other vegetable produce to nearby Pakistan and Bangladesh, as well as "Saudi Arabia, the United Arab Emirates, Morocco, the United States, Yemen Republic, the United Kingdom, and Netherlands" (Wikipedia, 2024).https://www.inaturalist.org/taxa/122971-Zingiber-officinale#cite_note-:3-39

Postharvest Treatment: To prepare dried ginger, fresh rhizomes are washed and soil particles, roots and shoots are removed. Rhizomes are then killed by immersion in boiling water for ten minutes, or by peeling, scraping or slicing, and then dried. Rhizomes with the peel either carefully scraped off ('uncoated' or 'white' ginger) or retained ('coated' or 'black' ginger) are usually sundried for several days to yield the dried ginger of commerce. Uncoated ginger is sometimes treated with lime to improve its white colour and reduce insect attack. Dried rhizomes can be pulverized to produce ground ginger. In Australia, mechanical washing and drying are practised (Kaufman, 2016). Ginger oil and oleoresin can be obtained from fresh or dried rhizomes. Ginger oil is obtained by steam distillation, oleoresin by extraction with organic solvents such as acetone, alcohol or ether. Both coated and uncoated ginger can be used for oil distillation and oleoresin extraction, but coated rhizomes are preferred. Oil yields from coated rhizomes are higher than from uncoated ones, as the epidermal tissue is rich in oil-containing cells. The presence of pungent compounds responsible for the taste of ginger oil can be substantially reduced by poor post-harvest handling or improper distillation. Ginger rhizomes are often heavily contaminated with microorganisms that can be treated with gamma irradiation to avoid health problems. In most importing countries, dried ginger has to meet strict quality and cleanliness criteria, commonly based on the American Spice Trade Association (ASTA) specifications (Kaufman, 2016). Rhizomes to be used as planting material can be stored in many ways. A simple method is to leave a part of the field unharvested, cut the foliage, cover the field with mulch and dig up the rhizomes when needed. Other methods are pit storage, used. *e.g.* in India, where mature rhizomes are treated with a fungicide, shade-dried and placed in pits, which are then covered, and storage in smoke houses. Cold storage is not recommended, because rhizome viability is gradually reduced and may become zero after short periods below 0°C (Kaufman, 2016).

Precautions: Allergic reactions to ginger generally result in a rash and though generally recognized as safe, ginger can cause heartburn, bloating, gas, belching, and nausea, particularly if taken in powdered form. Unchewed fresh ginger may result in intestinal blockage, and individuals who have had ulcers, inflammatory bowel disease or blocked intestines may react badly to large quantities of fresh ginger. There are also suggestions that ginger may affect blood pressure, clotting, and heart rhythms (NWE, 2024).

Post-harvest Technology

Curing: Ginger is marketed both in peeled and unpeeled forms.in scraped ginger, the epidermal layer of the fresh rhizomes is scraped off with a sharpened bamboo-splinter and then rhizomes are washed in water and dried in the sun for7- 10 days. This produce is uniformly turned during drying. As the essential oil is in the epidermal cells, excessive or careless scraping results in the loss of oil and depreciated quality of the spice (Jaidka *et al.,* 2018).

Bleaching: In the Middle East countries, which buy a very large part of Indian produce, higher demand is for white, polished rhizomes free from specks or spots, for this purpose, the raw rhizomes are soaked in water for a day and later inthick milk of lime. This material is dried in sun and then rubbed with gunny bags pieces to remove the last remnants of the skin. This treatment imparts a smooth finish to the product (Jaidka *et al.,* 2018).

Grading: The rhizomes prior to storage are graded according to their shape, size, number of fingers, colour, scales etc (Jaidka *et al.,* 2018).

Storage of seed ginger: In order to get good germination, the seed rhizomes are to be stored properly in pits under shade. For seed materials, big and healthy rhizomes from disease free plants are selected immediately after harvest. For this purpose, healthy and disease free clumps are marked in the field when the crop is 6-8 months old and still green. The seed rhizomes are treated with a solution containing 0.1% Quinalphos and 0.3% Dithane M-45 for 30minutes. In H P, depending on the severity of diseases seed rhizomes are treated twice i.e. before storage and planting with (0.01% Bavistin+ 0.25% Dithane M-45+1% Chlorpyriphos) solution for two hours.one litre solution is sufficient for treating one kg seed rhizomes. The same solution is used for treating the pit also. Drain the solution and dry the rhizomes under shade. The rhizomes are stored in the pits of convenient size in sheds. One quintal of rhizomes can be stored in one cubic meter pits (Jaidka *et al.,* 2018).

World market: The types of ginger entering the world market are identified by their origin of production. Each type

possesses a characteristic aroma and flavour mainly influenced by cultivar, ecological conditions and the production and post-harvest practices employed. Major ginger types come from Jamaica, Nigeria, Sierra Leone, India, Australia and China. Jamaican ginger is highly reputed because of its good appearance and delicate aroma and flavour. Nigerian ginger has a coarser flavour and aroma, with pronounced camphoraceous notes; its high oil content and strong pungency makes it in demand for oil distillation and oleoresin extraction, as is the case with Sierra Leone ginger. Indian ginger has a lemon-like flavour and aroma, is more starchy, rather pungent, and sought after by ginger beer manufacturers. Chinese ginger has been the standard for ginger preserved in syrup. Most gingers are suitable for oleoresin production, but Jamaican ginger oleoresin is preferred by soft-drink manufacturers and African ginger oleoresin by the meat industry (Kaufman, 2016). Ginger is traded in the world market as processed ginger (dried ginger after scraping out the outer skin), ginger powder, ginger oleoresin and ginger oil. Countries like China, Thailand, Vietnam, Korea and Japan are leading in the per capita consumption of ginger. China are the world leaders in exports, in 2013 they exported 381,981 tonnes at a value of $0.4 billion. The top 5 importers in 2016 where Bangladesh (69, 311 t), Japan (67,148 t), Pakistan (62,145 t) the United States (57,533 t) and Malaysia (40, 972 t). Ginger production in many countries has been hampered due to diseases such as *Pythium* rot and bacterial wilt. Australia is the world leader in ginger value added products. Buderim Ginger Limited is an Australian-owned company that is the world's largest processor and marketer of sugar-based ginger products (Kaufman, 2016). It is one of the important spices all over the world and India is the largest producer, consumer and exporter of the world. It is marketed in different forms such as raw ginger, bleached dry ginger, ginger candy, ginger powder, ginger oil, ginger squash, ginger beer, ginger flakes (Jaidka *et al*., 2018).

Uses: Ginger is a common spice used worldwide, whether for meals or as a folk medicine. Ginger can be used for a variety of food items such as vegetables, candy, soda, pickles, and alcoholic beverages. Ginger is a fragrant kitchen spice. Young ginger rhizomes are juicy and fleshy with a mild taste. They are often pickled in vinegar or sherry as a snack or cooked as an ingredient in many dishes. They can be steeped in boiling water to make ginger herb tea, to which honey may be added. Ginger can be made into candy or ginger wine. Mature ginger rhizomes are fibrous and nearly dry. The juice from ginger roots is often used as a seasoning in Indian recipes and is a common ingredient of Chinese, Korean, Japanese, Vietnamese, and many South Asian cuisines for flavoring dishes such as seafood, meat, and vegetarian dishes (Wikipedia, 2024). In Indian cuisine, ginger is a key ingredient, especially in thicker gravies, as well as in many other dishes, both vegetarian and meat-based. Ginger has a role in traditional Ayurvedic medicine. It is an ingredient in traditional Indian drinks, both cold and hot, including spiced *masala chai*. Fresh ginger is one of the main spices used for making pulse and lentil curries and other vegetable preparations. Fresh ginger together with peeled garlic cloves is crushed or ground to form ginger garlic masala. Fresh, as well as dried, ginger is used to spice tea and coffee, especially in winter. In south India, "sambharam" is a summer yogurt drink made with ginger as a key ingredient, along with green chillies, salt and curry leaves. Ginger powder is used in food preparations intended primarily for pregnant or nursing women, the most popular one being *katlu*, which is a mixture of gum resin, *ghee*, nuts, and sugar. Ginger is also consumed in candied and pickled form. In Japan, ginger is pickled to make *beni shōga* and *gari* or grated and used raw on tofu or noodles. It is made into a candy called *shoga no sato zuke*.

In the traditional Korean *kimchi*, ginger is either finely minced or just juiced to avoid the fibrous texture and added to the ingredients of the spicy paste just before the fermenting process (Wikipedia, 2024). Adverse effects: Although generally recognized as safe, ginger can cause heartburn and other side effects, particularly if taken in powdered form. It may adversely affect individuals with gallstones, and may interfere with the effects of anticoagulants, such as warfarin or aspirin, and other prescription drugs (Wikipedia, 2024).

Medicinal Value: *Zingiber officinale* var. *rubrum* (red ginger) is widely used in traditional medicine in Asia. Unlike other gingers, it is not used as a spice in cuisines. To date, a total of 169 chemical constituents have been reported from red ginger. The constituents include vanilloids, monoterpenes, sesquiterpenes, diterpenes, flavonoids, amino acids, etc. Red ginger has many therapeutic roles in various diseases, including inflammatory diseases, vomiting, rubella, atherosclerosis, tuberculosis, growth disorders, and cancer. Scientific evidence suggests that red ginger exhibits immunomodulatory, antihypertensive, antihyperlipidemic, antihyperuricemic, antimicrobial, and cytotoxic activities. These biological activities are the underlying causes of red ginger's therapeutic benefits (Zhang *et al*., 2022).

Economical Uses: Ginger is safely used in medicine, pharmaceutical and food industries. The under- ground stem (rhizome) is the highly demanded trade product. The stimulating aroma and the pungent taste are the key features of ginger to make it an essential ingredient of most world cuisine and of the food processing industry. In western countries, ginger is used in gingerbread, biscuits, cakes, puddings, soups, pickles, beer and wine. The unique flavour property of ginger is basically the combination of pungency and aromatic essential oil. The aroma of ginger is due to 1 to 3% of volatile oils with the main compounds bisabolene, zingiberene and zingiberol, while pungency is due to the non-volatile gingerols, shogaols, paradols and zingerone (Kumari *et al*., 2020). he importance of ginger is considered in traditional Chinese, Indian and Japanese medicine for over 25 centuries. Ginger has several diverse medicinal uses and important to promote digestion and as an antiflatulent or carminative to reduce gas and bloating. It also acts as an anti-inflammatory against rheumatic pain and arthritis but also against inflammation caused by gamma radiation. Ginger is also reported to have possible antitumorigenic effects. It has antiemetic properties used during pregnancy. Ginger is recognized as a plant with a high content of antioxidative compounds by several researchers (Kumari *et al*., 2020).

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