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BIODIVERSITY AND CHARACTERIZATION OF INDIAN SPICES: A REVIEW

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ABSTRACT

Biodiversity is an integral component of a sustainable livelihood, providing resources for families, communities, nations, and future generations. The extent and status of biodiversity have a direct impact on overall development of both ecological equilibrium and society as a whole. India is a megadiverse country with 7-8% species of flora and fauna, including over 45,000 plant species. India, known as the "land of spices," is a major spice producing, consuming and exporting country, accounting for approximately 20-25% of global spice trade due to its diverse agro climatic conditions. The country is the centre of origin of black pepper, cardamom and dill besides being the major producer of important spices like ginger, turmeric and chilli. Apart from flavouring and seasoning, spices are widely used in indigenous medicines, pharmaceuticals, nutraceuticals, aroma therapy, preservatives, beverages, natural colours, perfumes, dental preparations, cosmetics and botanicals. Thus it plays a significant role in the economy of the country. In the field of agriculture for crop improvements, it is essential to preserve all the variability in the species gene pool of spices including wild relatives, land races and cultivars that are highly vulnerable and prone to extinction. Biodiversity and ecosystem services are inextricably linked with the spice production.

Keywords **:** Biodiversity, black pepper, cardamom, chilli, ginger, turmeric.

Introduction

Biodiversity is the most important functional component of a natural ecosystem. It aids to maintain ecological function and addresses the extent of natural diversity in the biosphere. As it is not uniform on the planet and displays significant latitudinal and altitudinal variations, so documentation of biodiversity is essential (Gudade *et al.*, 2015). Plant diversity provides a consistent and diverse supply of food, medicine, and raw materials for human beings. The majority of traditional medicine relies on naturally occurring plant extracts. It is essential to preserve all variability in the species gene pool of spice, including wild relatives, land races, and cultivars, which are extremely vulnerable and prone to extinction.

India is known as the "Land of Spices" due to its rich spice heritage and production supremacy. India grows more than 52-60 spice crops out of the 109 identified by the International Organisation for Standardisation (ISO). The country is the origin of a variety of spices, including black pepper, cardamom, and dill, as well as a major producer of ginger, turmeric, chilli, vanilla, tree spices such as nutmeg, clove, and Garcinia, and seed spices such as coriander, cumin, fennel, fenugreek, celery, and kalongi. Spice exports account for 41% of total export earnings from all horticulture crops in the country. Besides being the world's leading producer and exporter of spices, the country also has the world's largest domestic spice market. Since the outbreak of COVID-19, demand for Indian spices has increased due to their immunity-boosting properties. The Indian Institute of Spices Research in Kozhikode has done an outstanding job of collecting and conserving spice genetic resources, which include cultivated, wild, hybrid, and endangered species. The national repository of spice germplasm, which is housed in both *ex-situ* and *in-situ* conservatories, is replenished on a regular basis

through collection surveys in primary and secondary centres of origin.

Biodiversity in spices

Spice production is intrinsically connected to biodiversity and ecosystems. The relationship between biodiversity and agriculture is referred to as agricultural biodiversity. Biodiversity plays an important role in agriculture at different stages. Hence in this article biodiversity and characteristics of some important spices are discussed.

Black pepper

Black pepper (*Piper nigrum* L.), revered as the "King of spices" or "Black gold" belongs to the family Piperaceae and is thought to have originated in the sub-mountainous tracts of the Western Ghats of India (Rahiman *et al.,* 1979). *Piper* species can be found from sea level to the high Andes and Sub-Himalayas. The genus *Piper* includes approximately 1,000-2000 species. Various *Piper* species act as important medicinal plants. Some of the important species used in the indigenous medicine system include *P. longum*, *P. cubeba,* and *P. retrofractum* (Table 3).

The IISR in Kozhikode is the National Repository for black pepper germplasm, with 1503 wild accessions and 1669 cultivar accessions in its gene bank. This includes approximately nineteen indigenous species, nine exotic species, and over 80 local cultivars. Some of the most valuable germplasm collections include endangered species such as *P. arboreum* and *P. barberi*. *P. sugandhi*, *P. silentvalleyensis*, and *P. nigrum var. hirtellosum* are three new taxa discovered and described. A total of 3181 germplasms were maintained at IISR, Kozhikode, Kerala (Annual report, 2013-14).

Cardamom

Cardamom (*Elettaria cardamomum* Maton.), commonly known as the 'Queen of Spices', is the dried fruit of a tall perennial herbaceous plant in the Zingiberaceae family. Cardamom includes several plants from the *Elettaria* and *Amomum* genera. According to the two genera, one is known as true cardamom, green cardamom, or small cardamom (*Elettaria cardamomum*) and the other is recognized as large cardamom or black cardamom (*Amomum subulatum*) (Farooq *et al*., 2016).

Small cardamom is one of the most expensive, ancient, and valuable spice crops since antiquity. (Purseglove *et al.*, 1981). Guatemala is the biggest producer and exporter. The crop's natural habitat used to be in the former evergreen rainforests of South India's Western Ghats, at altitudes ranging from 600 to 1500 metres above sea level. Only a few spices in the genus Elettaria are found in Indonesia, Malaysia, Sri Lanka, India, and Sri Lanka (Holtum, 1950). There are around nine species found in Malaysia, Indonesia, and Sri Lanka under the genus *Elettaria* (Trans. Linn. Soc. 10: 250. 1811) (Table 1). Environmental risks such as deforestation, forest fires, pest and disease incidents, and the introduction of high-yielding varieties for large-scale cultivation are the main causes of genetic erosion. This will result in the extinction of land races which are valuable genetic resources that can be used in crop improvement programmes. The present germplasm holding in India is given in Table 2.

Table 1 : Different species of *Elettaria*

Species	Origin
Elettaria ensal (Gaertn.) Abeyw.	Sri Lanka
E. brachycalyx, *E. longipilosa, E. kapitensis, E. rubida* and *E. stoloniflora*	Sarawak, Malaysia
E. linearicrista	Sarawak(Malaysia) and Brunei
E. longituba and *E. multiflora*	Sumatra (Indonesia), Peninsular Malaysia

Table 2: Cardamom germplasm maintained in India (Parthasarathy *et al.,* 2010)

Centre	Cultivated	Related taxa	Total
ICRS, Appangala, Karnataka	403	13	416
ICRS, Myladumpara, Kerala	600	12	612
ICRS, Pampadumpara, Kerala	151	1	152
ICRS, RRS, Karnataka	161	-	161
ICRS, RRS, Pangthang in East Sikkim	-	-	254

ICRS: Indian Cardamom Research Institute, RRS: Regional Research Station

Ginger

Zingiber officinale Rosc., commonly known as ginger, is a spice and medicinal plant that originated in the Indo-Malayan region and is currently widely available in many countries (Purseglove *et al.,* 1981). India currently holds the top positions as the producer,

consumer, and exporter of ginger with 43.81% of the world's total production (Source: Wikipedia). 'Wayanadan ginger' (India), 'Cochin ginger', 'Buderim Gold' (Australia), 'Chinese ginger' (China), 'Jamaican' (Jamaica) are globally traded products (Parthasarathy *et al.,* 2010). In addition to being a food deodorizer, ginger comes in a variety of forms that are used as flavourings, antioxidants, and antimicrobials. Ginger's therapeutic benefits have long been acknowledged by the medical systems of China, India, Tibet, and Arabia. India and the surrounding South East Asian nations have the greatest variety in their cultivated ginger. The main areas of variability in India are Kerala and the North-eastern States. *Zingiber* belongs to the Zingiberaceae series, which has only one genus, *Zingiber*, and the tribe *Hedycheae,* which also includes genera like *Curcuma*, *Hedychium*, and *Kaempferia*. Aside from *Z. officinale*, the genus *Zingiber* contains numerous economically significant species (Table 4). There seven species of ginger from South India are reported by Gamble (1925). Eight species from the Western Ghat and surrounding regions were described by Sabu (1991). There are 659 accession of ginger in ex-situ gene bank at IISR, including 508 cultivars, 92 accessions of related taxa, and 59 exotic collections (Parthasarathy *et al.,* 2010).

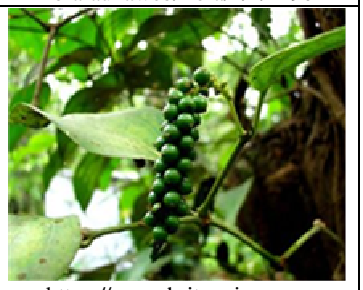
Turmeric

Turmeric (*Curcuma longa* L.) is a rhizomatous spice that propagates primarily through rhizomes. The genus *Curcuma* belongs to the Zingiberaceae family, contains approximately 117 species, 40 of which are distributed in India. *C. longa* is the most extensively cultivated species under the genus *Curcuma*. India holds the top position in terms of turmeric production, consumption, and exports. The distribution of the genus *Curcuma* is primarily Indo-Malayan. *C. aromatica* is a significant plant among the related species that is used in medicine and the manufacturing of cosmetic items. While *C. zeodoaria*, or Indian arrow root, is a major source of starch in many parts of India, *C. amada* is used as a vegetable. Other species that are useful for preparing arrow roots include *C. angustifolia*, *C. caulina*, *C. montana*, *C. leucorrhiza*, *C. decipiens*, *C. raktakanta*, *C. pseudomontana*, *C. erubescens*, *C. xanthorrhiza*, *C. malabarica*, and C. *harita*. (Parthasarathy *et al.,* 2010). There are roughly sixty horticultural cultivars or varieties. Turmeric ex-situ gene banks have been set up at NBPGR, Regional Station, Trichur, and IISR, Calicut. In addition to six exotic collections, the IISR turmeric conservatory has 1040 accessions, including 1,018 cultivars and 16 accessions of related taxa. Approximately 650 accessions of turmeric are also maintained at the NBPGR- Regional Station in Trichur, Kerala. Some important curcuma species are described in table 5.

Chilli

The popular spice crop chilli (*Capsicum annuum* L.) is highly valued for its flavour, aroma, and pungency. The substances that give chilli its intensity are capsaicin and related compounds called capsaicinoids. In some parts of the world, it is also referred to as hot peppers, red peppers, pod peppers, cayenne peppers, paprika, pimento, and capsicum (Babu *et al.,* 2021). It is one of the most valuable spice crops in trade. Chilli is thought to have originated in Central or South America (Pickersgill, 1971; Katherine and Christine, 2014), and was first cultivated in Mexico (Kraft *et al.,* 2014). In the late 16th century, European explorers brought chilli back to the Old World as part of the Columbian exchange, resulting in the spread of many chilli cultivars around the world and their use in both food and traditional medicine. The world's leading chilli exporters are India and China, accounting for 25% and 24% of total global exports, respectively (Gade *et al.,* 2020). Capsicum is classified into more than 30 species, five of which are domesticated: *C. annuum* L., *C. chinensis* Jacq., *C. baccatum*, *C. pubescens*, and *C. frutescens* L. (Heiser and Pickersgill, 1969). Among this, C. annuum is the most economically significant because of its widespread distribution (Pino *et al.,* 2007). Capsicum fruits vary greatly in colour, shape, and size between and within species (Eshbaugh, 1975). It is commonly used as a spice in the culinary and pharmaceutical industries (Rahman *et al.,* 1978). The National Bureau of Plant Genetic Resources (NBPGR) in New Delhi helps Indian researchers to collect, regenerate, characterise, conserve, and distribute chilli germplasm. However, at NBPGR, indigenous collections account for only 18% of total Capsicum collections, with exotics representing the vast majority of accessions (2412). The NBPGR has approximately 3000 Capsicum accessions under *ex situ* conservation.

Table 3: Species diversity of black pepper

Species	Native	Characteristics	Photographs
P. barberi Gamble	Western ghat of South India, primarily wet tropical biomes. * An endangered species listed in the Red Data Book	Slender climbing bushes. Petiole 1 cm long; stipule 1.5 cm long and lanceolate; leaves are oblong-lanceolate, abruptly acuminate at apex, acute or obtuse at base; lateral nerves 6 pairs, looped below the margins, glabrous and glossy above. Peduncles puberulus; bracts peltate, orbicular, entire; spike to 15 cm long, glabrous, slender, pendulous. Flowers are closely spaced; stigma has three lobes; berry measures 3.5 x 3.5 mm and has one stamen.	 https://www.wikidata.org/wiki/Q18035761
P. wightii Miq. / *P. Hymenthophyllum*	Western Ghats, Evergreen Forests, Endemic to Southern Western Ghats. Occur at high elevations only.	Robust, glabrous climber. Leaves are oblong in shape, with an acuminate tip, round to subcordate base, 3-5 ribs, coriaceous, and a midrib with 2-3 lateral nerves that resemble ribs. The petiole is 2 cm long. Strong, drooping 8-cm-long spike; 2-cm-long peduncle; curved, one-sided bracts. Stamens two; flowers spaced widely apart. Smooth, globose, reddish berry with up to 7 mm in diameter and 3 or 4 stigmatic lobes. Used as medicine.	 https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:683980-1
P. nigrum Linn	Occurs at low elevations of Western Ghat	Woody climber with broad shiny alternately arranged green leaves. Tiny flowers are in thin, dense spikes with roughly fifty flowers each. When the berries reach maturity, they turn from green, about 5 mm in diameter, to a reddish-yellow colour.	 https://www.britannica.com/plant/black-pepper-plant
P. betle L.	Central and eastern Peninsular Malaysia and distributed to East Africa and tropical countries of Asia. (Madhumita *et al.*, 2019)	Dioecious, perennial climber, mostly grown for its aromatic or sweet leaves. Simple, alternating, stipulate, bifarious, petiolate leaves are cordate to obliquely ovate, thick, and frequently uneven, measuring 5 to 20 cm in length and breadth. Plant is used to treat a variety of diseases, including the common cold, bronchial asthma, cough, stomachaches, and rheumatism.(Gundala *et al.,* 2014)	 https://www.nparks.gov.sg/florafaunaweb/flora/1/4/1490
P. cubeba,	Native to Java and Sumatra, hence sometimes called Java pepper.	It is a 5–15 m tall woody climbing perennial. The ovate leaves have a cordate or rounded base, a thick pedicle, and glabrous texture. Tiny glands are embedded in the lower surface of the leaves. They can grow up to 15 cm long and 6 cm wide, and they have strong margins. Small, dense, unisexual flowers with 2-3 stamens are arranged in 4-cm-long scaly spikes that are adhered to the peduncles (Drissi *et al.,* 2022). Cubeb, which is used in many medications, to flavour cigarettes and bitters, comes from this plant.	 https://www.britannica.com/plant/Piper-cubeba

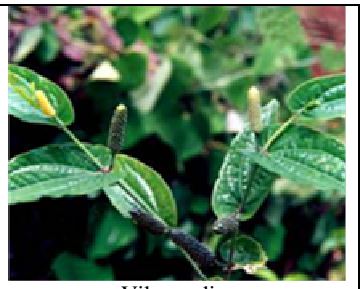
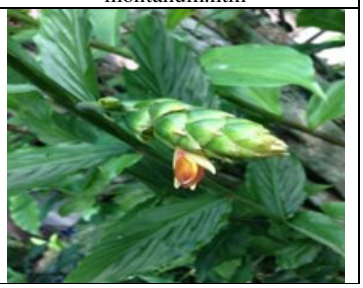
P. longum	South Asia (Mohapatra and Basak,2015)	The stems are flexuous, pubescent and terete. The leaves are simple. The petiole is grooved, of variable length and can reach 10 cm long. The blade is ovate, 6 –12 cm × 3 –12 cm, papery, the base cordate and asymmetrical. The inflorescence is a cylindrical and slightly curved spike which is 1.5 –5 cm long and opposite the leaves. The fruits are drupaceous, globose and 0.2 cm in diameter. Used for tuberculosis and respiratory tract infections	 Vikaspedia.
P. retrofractum	Native to Java island in Indonesia.	The leaves are approximately 10–12 cm in length and 3–3.5 cm in width. They are lanceolate, glabrous, and have an asymmetric base and acuminate apex. It has male spikes that are approximately 5 cm long and female spikes that are approximately 4 cm long and 0.5–1 cm wide. A portion of the ovaries are attached on the axis. It is either dioecious or monoecious. Its berries are tightly arranged along the axis and spherical (Tanaka and Van, 2007). It is used to treat asthma, coughs, colds, nausea, vomiting, and indigestion.	 https://en.wikipedia.org/wiki/Piper_retrofractum
P. sugandhi	Native to India, and is found in tropical and subtropical moist lowland forests. (Babu *et al*.,1995)	This ornamental terrestrial orchid can reach a height of 0.3-0.5 m and a trunk diameter of up to 5 cm. This plant produces edible flowers that can be used to make tea. The white flowers have a young centre and five petals.	
P. arboreum (Tree pepper)	Native to Mexico and S. Tropical America. (Hist. Pl. Guiane: 23, 1775)	It is an evergreen shrub or a small tree usually grows from 2 - 8 metres tall, occasionally to 11 metres. It produces the largest candle-like flower spikes. The macerated leaves and stems are used as an anti-venom. A decoction or cold water infusion of the leaves is used as a treatment for body aches and fevers (DeFilipps *et al.,* 2004).	 https://tropical.theferns.info/image.php?id=Piper+arboreum

Table 4: Economically important Zingiber species.

Species	Native	Characteristics	Photographs
Z. officinale Roscoe	Tropical countries, China, USA	The leafy stems of ginger grow about 1 metre (about 3 feet) high. The leaves are 15 to 30 cm (6 to 12 inches) long, elongate, alternate in two vertical rows, and arise from sheaths enwrapping the stem. The flowers are in dense cone like spikes about 2.5 cm (1 inch) thick and 5 to 8 cm (2 to 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. Used as Spice, condiment, medicine. (Britannica, T., 2024)	 https://www.britannica.com/plant/ginger
Z. officinale var. rubra	Malaysia	It reaches up to a height of 50–100 cm. Its peel contains anthocyanidins, which give the rhizome its purple surface colour (Shimoda *et al.,* 2010).Use: Spice and Medicine (rheumatism, osteoporosis, asthma, and cough.) (Shimoda *et al.,* 2010).	

Z. officinale var. rubrum	Malaysia	It can reach a height of 50–100 cm. The rhizomes are thick brownish-red in colour. Compared to regular ginger, it is smaller and smells stronger. The leaves are lancet-shaped, with a length of 5 to 25 cm and a width of 8 to 20 mm. The plant has small leaves at the base of the flower and an ovoid-shaped composite that arises from the rhizomes with 10 and 25 cm stem length. The corollas are dark purple with creamy yellow spots, funnel-shaped, and 2-4 cm long (Zhang *et al.,* 2022). The petals are tridentate, small, and tubular with reddish petiole (Sivasothy *et al.,* 2011). Used as a spice and a medicine.	 https://globinmed.com/medicinal_herbs/zingiber-officinale-roscoe-var-rubrum/
Z. mioga Roscoe	Japan	It is a perennial herbaceous plant that grows in clumps of upright, unbranched stems that emerge from the rhizome and reach a height of 1-2 metres, with 20–25 leaves on each stem. The development of flower buds happens below ground (Gracie *et al.*, 2004), orchid-like flowers. The plant is occasionally grown for its leaves and can be found fresh in Japanese markets. **Use:** Beverages and spices	 https://images20.fotki.com/v1632/photos/9/1307919/9076288/Zingibermioga2-vi.jpg
Z. zerumbet (L.) Smith	Tropical Asia	It is a vigorous ginger with leafy stems growing to about 1.2 m tall. The 10-12 blade-shaped leaves 15-20 cm long grow in an alternate arrangement on thin, upright stem to 1.2 m tall. Among the leafy stems the conical or club-shaped flower heads burst forth on separate and shorter stalks. The flower heads are reddish-green 3-10 cm long with overlapping scales, enclosing small yellowish-white flowers that poke out a few at a time. The flower stalks usually remain hidden beneath the leaf stalks (Wagner *et al.,* 1990). **Use:** Medicinal and ornamental.	 *https://apps.lucidcentral.org/rainforest/images/entities/zingiber_zerumbet/1770023.jpg*
Z. montanum (Koenig) Link ex Dietr	India, Malaysia, Sri Lanka, Java	Internally, rhizomes have a light carrot colour. pseudostems with a height of 1.2–1.8 metres. Sessile or short-petiolate leaves; green sheaths with glabrous or pubescent edges; bilobed, sparsely pubescent ligule; linear to linear lanceolate blades; fusiform or cylindrical-ovate inflorescence; erect, 8–60 cm tall shoot (scape) with 5–7 cataphylls; mature bracts, ovate, obtuse to broadly so at apex, 3-3.5 × 1-1.7 cm, pubescent, greenish, black-lineolate margin, reddish-brown; bracteoles, ovate, 1-1.5 cm long, 3-dentate (Acevedo-Rodríguez and Strong, 2005). Use in conventional medicine.	 http://tropicalflowers.la.coocan.jp/Zingiberaceae/Zingiber%20montanum/Zingiber%20montanum.htm
Z. clarkii King	Sikkim Himalayas	Plant is medium sized grows up to about a 1.5m, have oblong-lanceolote leaves with distinctive ribs and a pale, slightly silvery-green colouration on the undersides. Inflorescence appears laterally from the stem. The flowers are an unusual speckled yellow-brownish colour and the fruit capsules turn an attractive bright red as they ripen. Used as ornamental plant.	

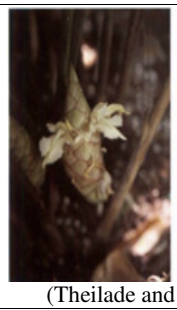
			tropicalbritain.com.
Z. aromaticum Val	Tropical Asia	Plant grows up to 2 m. At young stage the cones are green, but with maturity the base of cone are turning striking red with yellow flowers. Young rhizome tips, yellow flowers and shoots are used to season foods. It can be cooked with rice or eaten raw. Used as flavouring, medicinal, and decorative purposes.	 suncoasttropicals.com.
Z. rubens Roxb (Bengal ginger)	Indo-Malaya	The leafy stems can reach a height of six feet. The plants blooms in summer. The inflorescence is carried by a short stalk that is densely packed with bright red bracts. Flowers appear as single inside the bracts with a striking pattern lip. Bright red seed capsules are present. **Uses:** Spice, herbal remedy, and decorative plant.	 eFlora of India
Z. ottensii Valet	South East Asia	Rhizomatous herb with 18–25 leaves that grows to a height of 1-1.9 m. The entire plant has an aromatic scent; when crushed, the leaves and inflorescence release a spicy, sweet aroma. Under direct sunlight, the green leaves turn a faded yellowish green colour. Broad, spindle-shaped inflorescence with two to three flowers are open at a time. Peduncle is dull green with 30 cm in length. Red or dull-bright reddish brown bracts, progressively smaller at the apex. The bracts support pale cream to very pale dull yellow flowers. **Uses:** Decorative and medicinal.	 bambooland.com
Z. corallinum Hance	South East Asia	Medium-sized plants produce long, pointed, red-bracted inflorescences close to the ground. According to Nair (2013), the foliage has a medium green colour. The plant is widely used in the washing, perfume, and cosmetics sectors due to its distinct scent and potent antimicrobial and insecticidal properties (Deng *et al.,* 2022) Uses: Ornamental and chinese medicine.	
Z. argenteum	Sarawak, Malaysia	The plant is tiny, with a pseudostem that reaches only 75 centimetres. The leaves have a silvery green upper surface with a dark green cloud along the midrib, and a green lower surface. They can reach a maximum length of 15–18 cm. It bears broadly elliptic, 8–9 cm long spikes and cream-colored flowers. Bright orange in colour, the lower bracts turn red as it moves (Nair, 2013) **Use:** Decorative.	  (Theilade and Mood, 1997)

Table 5: Important species of *Curcuma* and their characteristics

Species	Native	Characteristics	Photographs
C. longa	Tropical South East Asia	It is perennial herbaceous plant can grow up to 1 m in height. Its rhizomes are aromatic, cylindrical, yellow to orange, and heavily branched with two rows of alternate leaves. At the top of the inflorescence, stem bracts are present on which no flowers occur. Flowers are white to green and occasionally have a reddish-purple tinge.	
C. amada	India	It is a herb. Rhizomes are light yellow from inside and white towards the periphery with green mango like smell. Tall pseudo stem of 30-35 cm. The leaves are lanceolate and oblong. Peduncle is 20-22 cm long with five–six sheaths covering it; a lateral or central inflorescence covered by 5-6 sheaths with 12–18 cm long spike	 India Biodiversity portal
C. angustifolia	India	It is a perennial flowering plant with small spiked inflorescences of three or four yellow, funnel-shaped flowers surrounded by pink terminal bracts (Ravindran *et al.* 2007). The bracts are boat-shaped and cover the entire perianth of the flower. *C. angustifolia* flowers feature double anthers, a slender style, and a globular stigma. Flowers are typically seen at the onset of the monsoon season. The leaves are typically simple, green, glabrous, and lanceolate, with entire margins. Plants can reach a height of 0.9-1.2 m.	 India Biodiversity portal
C. aromatica	Western Ghats of South India	The plant produce inflorescence during early spring. The stalk reaches a height of approximately 20-30 cm, topped with larger, pink-tipped bracts. Frequently, leaves emerge even after the blooms. It is utilised in ethnic cosmetic goods. (Sikha *et al.,* 2015).	 Nura *et al.,* 2020
C. caesia	Northeast India (Ravindran *et al*., 2007)	It is a perennial herb having bluish-black rhizomes (Syamkumar and Sasikumar, 2007), growing erectly up to a height of 1.0-1.5m. The plant has a large tuberous rhizome, broad and vertical oblong leaves with reddish border flower (Paliwal *et al.,* 2011). Leaves are about 30–60 cm long and up to 15 cm broad, broadly lanceolate or oblong, glabrous, with a deep ferruginous purple cloud down the middle, which penetrates to the lower surface. Used as medicine.	 eFlora of India
C. zeodoaria	South Asia and Southeast Asia	The rhizome is thick and tuberous, with many branches. The leaf shoots are large, reaching heights of up to one metre. The plant produces fragrant yellow flowers with red and green bracts. The interior of the rhizome is white, with a mango-like fragrance. (Wikipedia). Use: Culinary and medical.	 Vikaspedia

C. ferruginea	N. E. India to Myanmar	It is a large herb with large rootstock bearing pale yellow stalk less fragrant tubers. The leaves are fairly large, grouped, and have a reddish-brown tint in the centre of the upper surface. The leaves are bright green,1-1.5 m long and 4–12 cm broad. The pseudo stem and leaf sheath are red or rusty-red. Flowers bear on lateral spike of 20-25 cm long. (Source: Flowers of India-Rusty wild turmeric).	 eFlora of India
C. caulina (Indian arrowroot)	India (Maharashtra)	It is an annual herb that reaches a height of 50–100 cm. The plant produces numerous hanging tubers from its perennial rhizomes. Leaves are up to 1/2 m long, oblong and lance-like. Flowers are white or yellow and grow in 10 to 15 cm long spike. Bracts are pinkish-white or greenish-white in colour. In Kerala, the powdered root is used to make porridges and consumed during Upvas.	 eFlora of India
C. malabarica	India	It is cultivated extensively in South India for its starch, which is said to have therapeutic qualities, and has bluish white fleshed rhizomes with a camphoraceous odour (Alan & Nair, 2010)).	
C. montana	East Himalaya to Assam	Rhizome is light yellow, short, pseudo stem up to 30 cm in height. Spike-terminal, obovate, purplish above, and thinly pubescent leaves measure 30 cm. The flowers are yellow-pink in colour. (India Biodiversity portal).	 eFlora of India

Table 6: Some important species of *Capsicum* and their characteristics

Species	Native	Characteristics	Photographs
C. annuum	Northern South America	The plant is a small shrub or herb that reaches a height of 0.3 to 1.2 metres. Its glossy leaves can grow up to 7.5 cm and have a roughly oval shape with smooth margins. White, star-shaped flowers produce in leaf axils alone and are about 1 cm wide. Fruits measure 9.5 cm in length and 1 cm in width. They are glossy, red, and twisted, tapering to a thin, curled tip. Its surface is hairless and wrinkly. (Sottosanti, 2023).	 National park-Flora and Fauna Web
C. baccatum	South America	The flowers are white or cream in colour, with a green or gold corolla. Flowers are insects or self-pollinated. The pods typically hang down and have a citrus or fruity flavour.	 Wikipedia

C. cardenasii	Andes, and found in Bolivia and Peru.	This is a woody-stemmed perennial plant. It can reach a height of 2-3 feet and a width of 1-1.5 feet. The leaves are pubescent, lanceolate, and narrow. At the internodes, plants often produce one or two flowers. The petioles have pendant, campanulate flowers and grow upright (Brian *et al.,* 2001). The corolla has two colours: purple and white. (Pickersgill, 1997).	 Wikipedia
C. chacoense	South America	Compact perennial shrubs that reach heights of 80 cm to 1 metre. The tiny white flowers, which have five petals, bloom in the summer. At final maturity, the fruit become roundish/triangular in shape of about 2.5 cm long and 0.5 cm wide, colour changes from green to either bright red or yellow. (Wikipedia)	 Wikipedia
C. chinense	America	The plants differ widely in terms of appearance and traits. The flowers, are small and white with five petals. The fruit comes in a wide variety of shapes and colours, with the most popular mature colours being red, orange, and yellow. (Wikipedia)	 Wikipedia
C. eximium	New World, specifically the Andean region of South America. (Tewksbury *et al.,* 2006)	It is identified by its distinctive purple flowers. The flowers have an entire calyx and bell-shaped corolla that come in various shades of purple. Mature fruit are small, shiny, non-pulpy berries. The seeds are yellow. In Bolivia, it is used as a spice (Heiser, 1958; Zewdie, 2003).	 www.tradewindesfruit.com
C. flexuosum	New World, specifically the southern regions of Brazil (Tewksbury *et al.,* 2006)	Its flowers are unusually white, green, and occasionally purple. The entire calyx and campanulate corolla of the flowers vary in colour, but they are typically green in the centre and turn white near the petal margins. Mature fruit are small, berry-shaped, 7 mm-long bullets that ripen to red (Heiser, 1958).	 Wikipedia

C. lanceolatum	Guatemala and in the neighbouring countries of Mexico	It is an upright, slender, bushy plant that grows to a height of 1 to 5 m. Leaves appear in pairs. The flowers are solitary (rarely in pairs), born in the axils of 1.5 to 3 cm long shoots, slender flower stalks extending to 3 to 5 cm until the fruit ripens. The fivefold flowers have yellowish-white or reddish-purple petals that are slightly hairy at the tips (Bosland, 2000). Berries are round, 7–10 mm in diameter, orange-red, packed with flesh, and not at all spicy. The seeds are 2 to 2.5 mm in size and are either whitish or black. The plant is self-compatible (Tong, 2003).	 https://eol.org/pages/5701542
C. mirabile	Rainforests of Brazil	The plant has five short to long calyx appendages, a purple corolla with a white margin and a yellowish-green or yellowish-white centre, dichotomous branching, glabrous or glabrescent pubescence, short petioles, elliptic to ovate leaves, few flowers (two to seven) per node, and greenish-golden yellow fruits (Barboza *et al.,*2022).	 Barboza *et al.,*2022
C. pubescens	Central and South America	It grows as shrub up to 4 m height, but sometimes as climbing plants. Plants live up to 15 years, which gives it tree-like appearance. The flowers appear singly or in pairs (rarely up to four) on the shoots. The calyx has five triangular pointed teeth, which have in the fruit a length of about 1 mm (Livsey, 2011.)	 Wikipedia
C. rhomboideum	Native to Mexico, Central America, and Andean region of South America.	It is a perennial shrub that is pubescent due to its dense trichome covering. Its rhomboidal to elliptically-shaped leaves are the most distinctive feature. The flowers feature a yellow bell-shaped corolla and a calyx with five teeth. (Scaldaferro, 2015; Barboza and Bianchetti, 2005). Mature fruit has two to six seeds per fruit and is pea-sized, bright red to black when it's fresh, and darkens as it dries. (Barboza, 2011).	 Wikipedia

Conclusion

Spices such as pepper, cardamom, turmeric, ginger and chili play an important role in the world economy. Apart from adding flavor and color to cooking, the medicinal properties of all these spices have attracted people to spice cultivation. Modern researchers are increasingly looking towards biological resources to find treatments and cures for illnesses. Some of the species of those spice crops become endangered today due to lack of conservation and overexploitation. So it is very important to know about the biodiversity of these important spices and conserve them through in-situ or ex-situ.

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