

## Diversity of *Curcuma* Species and Their Industrial Applications

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The genus *Curcuma* L. (family Zingiberaceae) represents a remarkable group of perennial rhizomatous herbs distributed across tropical and subtropical Asia, exhibiting immense genetic, phytochemical and industrial diversity. Among its 80–90 recognized species, *Curcuma longa* L. (turmeric) stands out for its global commercial and medicinal significance. However, numerous wild, endemic and lesser-known species remain underexplored despite their potential in pharmaceuticals, nutraceuticals, cosmetics, food and eco-friendly industries. This review presents a comprehensive account of *Curcuma* diversity, phytochemical profiles, distribution, traditional uses, and industrial applications. The article also highlights advances in industrial processing and extraction technologies, alongside conservation priorities for rare and endangered taxa.

### Introduction

Turmeric, the “golden spice of life,” holds deep cultural and medicinal importance across South and Southeast Asia. Traditionally valued as a natural flavourant, colourant and healing agent, turmeric symbolizes purity and prosperity in Indian rituals. Beyond its household uses, turmeric and related *Curcuma* species have gained scientific and industrial importance due to their bioactive compounds, particularly curcuminoids and essential oils. Despite this, the genus remains taxonomically complex and underutilized. Exploring the diversity of *Curcuma* can unlock novel industrial, medicinal and ecological opportunities, reinforcing its role as a multipurpose crop for sustainable development.

*Curcuma longa* L. is a perennial herb of the family Zingiberaceae, native to India or Southeast Asia, and widely cultivated for its aromatic rhizomes. The crop is triploid ( $2n = 3x = 63$ ) and reproduces vegetatively through rhizomes. Approximately 80–90 species of *Curcuma* are recognized globally, of which 40 are reported in India and 17 in South India. Morphologically, *Curcuma* species exhibit considerable variation in rhizome colour, aroma, and inflorescence traits, reflecting adaptation to diverse ecological niches.

Historically, *Curcuma* has been cultivated and traded for over 5000 years. The name “*Curcuma*” derives from the Arabic *kurkum*, meaning saffron-like, while *longa* denotes the elongated rhizome form. The genus was first classified by Linnaeus in 1753. Recent developments, such as the establishment of the National Turmeric Board (2023) in India, have accelerated scientific and industrial initiatives focusing on *Curcuma* diversity, product development and export promotion.

### Species Diversity of *Curcuma*

The genus *Curcuma* exhibits extraordinary diversity in morphology, phytochemistry and utility. Notable species include:

- *C. longa* – The principal commercial species, rich in curcuminoids and essential oils such as turmerone, zingiberene and germacrone; used in foods, pharmaceuticals, cosmetics and textiles.

- *C. amada* (Mango ginger) – Possesses a mango-like aroma, used in pickles, confectionery and medicines for digestive and antimicrobial benefits.
- *C. aromatica* (Wild turmeric) – Rich in camphoraceous essential oil, widely utilized in cosmetics and skincare.
- *C. zedoaria* (White turmeric) – Yields fragrant essential oil for perfumery and herbal products.
- *C. caesia* (Black turmeric) – Contains camphor-scented blue rhizomes with medicinal and flavouring properties.
- *C. angustifolia* and *C. caulina* – Important sources of edible starch (East Indian arrowroot) used in baby foods and biodegradable films.
- *C. raktakanta*, *C. haritha*, and *C. ecalcarata* – Rare and endemic species with distinctive pigments, volatile oils and starch-rich rhizomes, offering prospects in eco-friendly dyes and natural preservatives.

Recent taxonomic explorations across India, Thailand, Vietnam and Indonesia have revealed several new species (*C. leonidii*, *C. arida*, *C. bella*, *C. pitukii*), underscoring the ongoing discovery potential within this genus.

### Phytochemistry and Medicinal Significance

The phytochemical diversity of *Curcuma* is dominated by curcuminoids (curcumin, demethoxycurcumin, bisdemethoxycurcumin) and volatile oils rich in sesquiterpenes (turmerone, germacrone, xanthorrhizol). These bioactives impart antioxidant, anti-inflammatory, antimicrobial, anticancer, hepatoprotective and neuroprotective properties. Species such as *C. xanthorrhiza* (Java turmeric) are particularly rich in xanthorrhizol and exhibit strong hepatoprotective activity, while *C. comosa* produces phytoestrogens beneficial in female reproductive health. Lesser-known species such as *C. amarissima* and *C. pseudomontana* show potential in wound healing and green nanotechnology applications.

### Industrial Processing and Curcumin Extraction

Modern turmeric processing involves washing, steaming, slicing and controlled drying of rhizomes to 12% moisture before grinding into powder. For high-purity curcumin extraction, industries employ quadra percolation and multi-effect vacuum evaporation systems under controlled conditions to retain bioactivity. The process yields Curcumin Liquid Extract (CLE) and concentrated curcumin (CC), later sterilized and converted to powder via vacuum or spray drying. This technologically advanced process preserves colour, aroma and bioefficacy, supporting applications across the food, cosmetic, pharmaceutical, and nutraceutical sectors.

### Industrial and Commercial Utilization

*Curcuma* species contribute to diverse industries:

- Pharmaceuticals: Curcumin tablets, nano-formulations, herbal tonics.
- Food and Beverages: Spices, flavouring agents, turmeric latte mixes.
- Cosmetics: Soaps, creams, lotions, perfumes and anti-aging formulations.
- Textile Industry: Natural yellow dyes for eco-friendly fabrics.
- Agriculture: Botanical insecticides and soil amendments.
- Nutraceuticals: Protein supplements, herbal extracts, functional foods.
- Eco-industries: Biodegradable packaging, natural inks and paints.

Prominent Indian companies such as Ambe Ns Agro Products, Shalimar Spices, and Landed Fresh Internationals play key roles in turmeric processing and export.

### Phylogenetic Groups and Distribution

Taxonomic studies in Thailand and neighbouring regions classify *Curcuma* into groups such as *Alismatifolia*, *Cochinchinensis*, *Ecomata*, *Longa*, and *Petiolata*, based on morphological and molecular characteristics. These groups vary in their ornamental, medicinal, and industrial importance, illustrating the genus's ecological and evolutionary breadth.

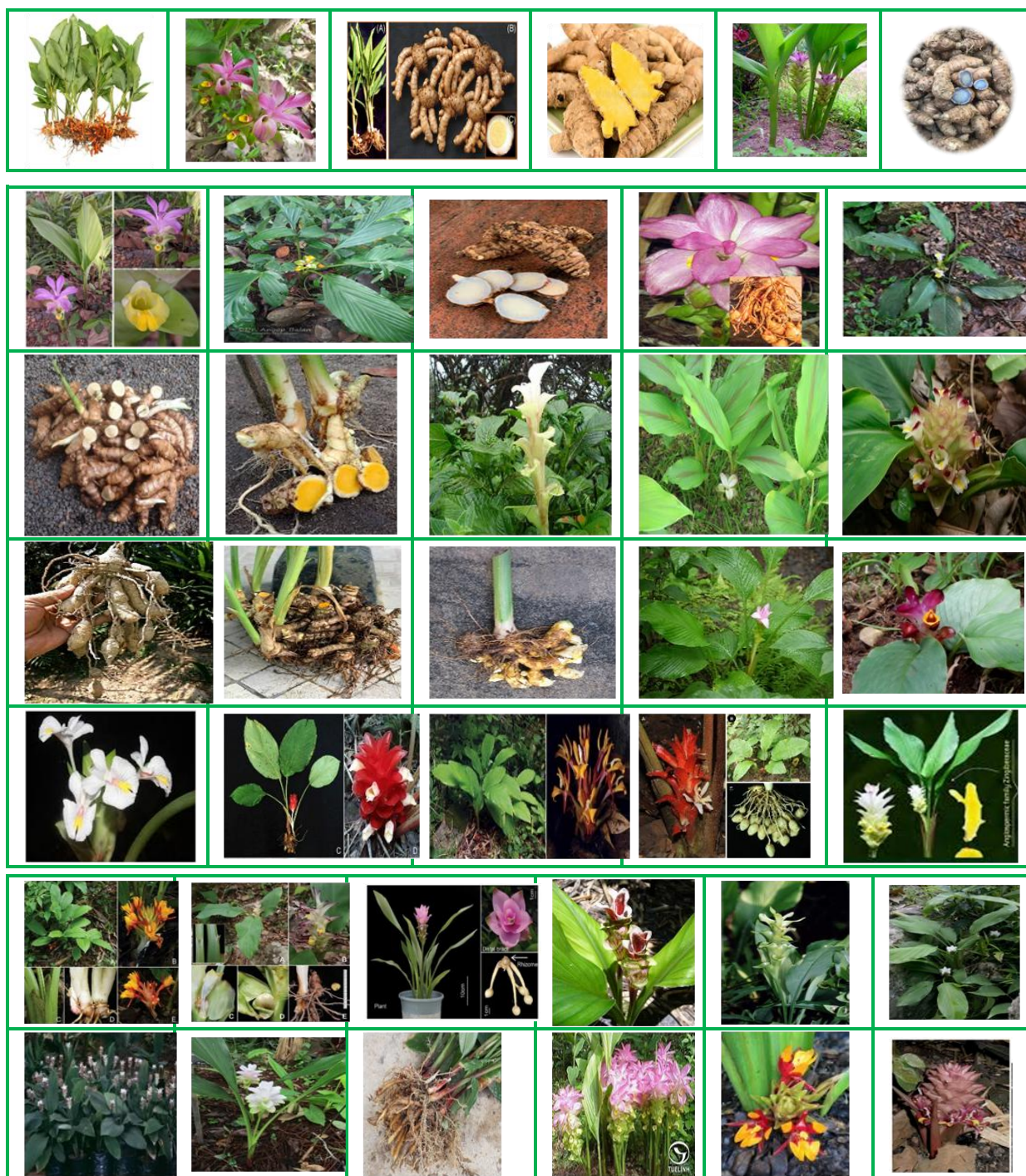


## Conservation and Genetic Resource Management

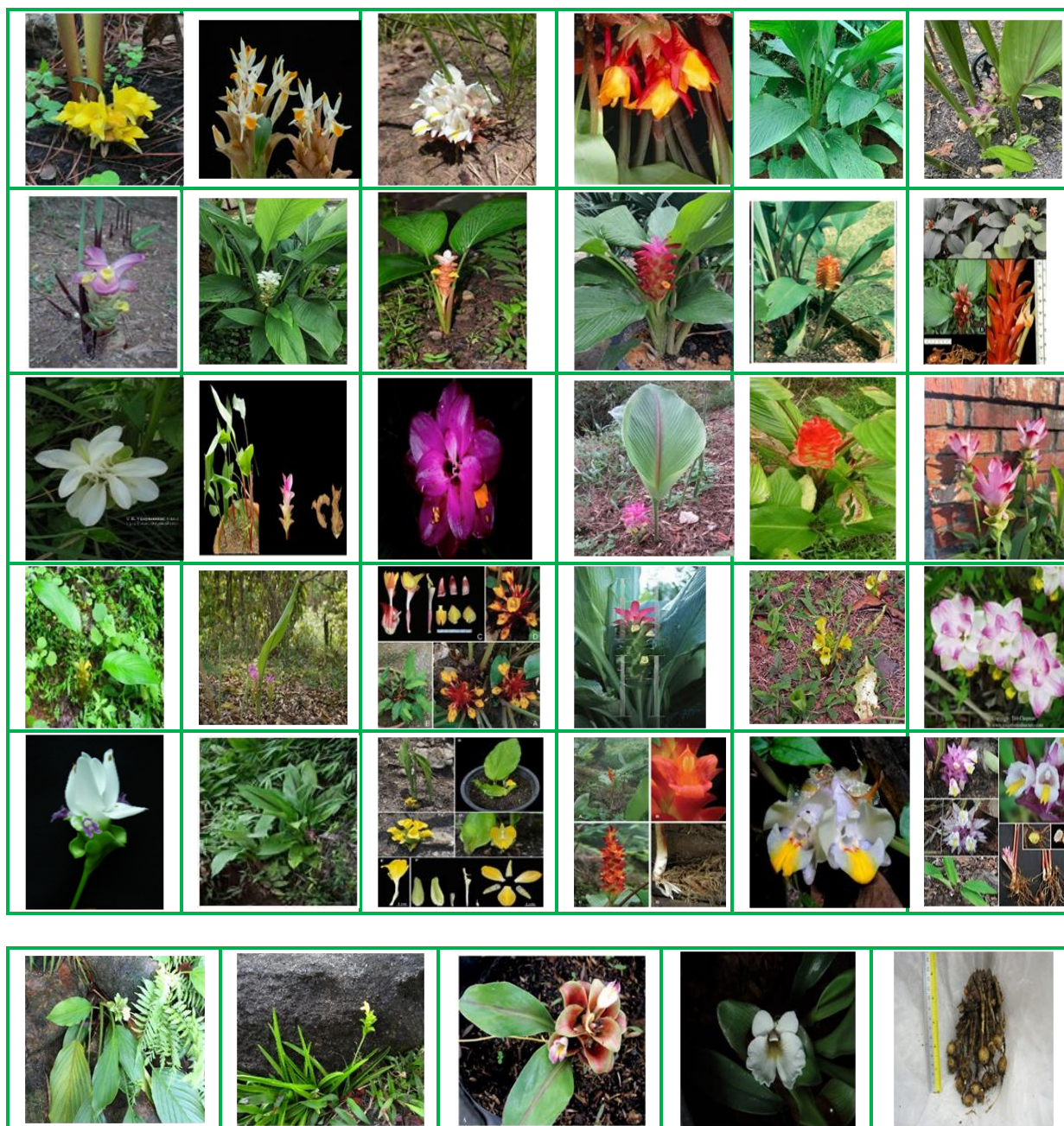
Several *Curcuma* species face threats due to habitat loss, overharvesting and limited cultivation. Endemic and endangered taxa such as *C. bhatii* (Udupi turmeric), *C. aruna*, *C. arracanensis*, and *C. yunnanensis* require urgent in situ and ex situ conservation. Germplasm collection, molecular characterization, and breeding programs can aid in preserving genetic diversity and identifying elite lines for industrial utilization.

## Conclusion

The genus *Curcuma* embodies a rich intersection of biodiversity, traditional wisdom and industrial value. While *C. longa* dominates global markets, numerous wild and lesser-known species hold untapped potential for pharmaceuticals, cosmetics, nutraceuticals, and sustainable industries. Advanced extraction technologies, coupled with conservation and value-addition initiatives, can transform *Curcuma* diversity into sustainable economic and ecological assets. Continued interdisciplinary research integrating taxonomy, biotechnology and industry collaboration will be key to unlocking the full promise of this golden genus.







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