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REVIEW ARTICLE

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

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ABSTRACT

Turmeric belongs to the belongs to the family Zingiberaceae, genus Curcuma and species Curcuma *longa.* It is also known as *Curcuma domestica; Curcuma aromatic.* Also known as Indian saffron. Turmeric's influence extends beyond the kitchen and apothecary. It has made its mark in art and culture. In Indian traditional dance, turmeric paste is applied to dancers' feet before performances, signifying purity and grace. It has also been used to create intricate rangoli designs and as a natural dye for clothing. Turmeric names in different languages are in Hindi: Haldi, Bengali: Halud, Father Gujarati: Haladhar, Haldi, Kannada: Arisiya, Konkani: Halad, Malayalam: Manjal, Marathi: Halde, Halad, Oriya: Haldi , Punjabi: Haldar, Haladhar, Haldi, Sanskrit: Haldi, Harita, Tamil: Manjal, Telugu: Pasupu, Urdu: Turmeric. In Sanskrit, turmeric has at least 53 different names, including *anestha* (not offered for sacrifice or homa), *bhadra* (auspicious or lucky), *bahula* (plenty), *dhirgharaja* (long in appearance), *gandhaplashika* (which produces good smell), *gauri* (to make fair), *gharshani* (to rub), haldi (that draws attention to its bright color), *haridra* (dear to hari, Lord Krishna), *harita* (greenish), *hemaragi* (exhibits golden color), *hemaragini* (gives the golden color), *hridayavilasini* (gives delight to heart, charming), *jayanti* (one that wins over diseases), *jawarantika* (which cures fevers), *kanchani* (exhibits golden color), *kaveri* (harlot), *krimighni* or *kashpa* (killer of worms), *kshamata* (capability), *laxmi* (prosperity), *mangalprada* (who bestows auspiciousness), *mangalya* (auspicious), *mehagni* (killer of fat), *nisha* (night), *nishakhya* (known as night), *nishawa* (clears darkness and imparts color), *patwaluka* (perfumed powder), *pavitra* (holy), *pinga* (reddish-brown), *pinja* (yellow-red powder), *pita* (yellow), *pitika* (which gives yellow color), *rabhangavasa* (which dissolves fat), *ranjani* (which gives color), *ratrimanika* (as beautiful as moonlight), *shifa* (fibrous root), *shobhna* (brilliant color), *shiva* (gracious), *shyama* (dark colored), *soubhagaya* (lucky), *survana* (golden color), *survanavara* (which exhibits golden color), *tamasini* (beautiful as night), *umavara* (Parvati, wife of Lord Shiva), *vairagi* (who remains free from desires), *varavarnini* (which gives fair complexion), *varna datri* (enhancer of body complexion), *varnini* (which gives color), *vishagni* (killer of poison), *yamini* (night), *yoshitapriya* (beloved of wife), and *yuvati* (young girl). Turmeric is the dried knobby shaped rhizome of the plant *Curcuma longa*. Noted for its bright yellow color, it is related to and similar in appearance to ginger. The origin of the Latin name *Curcuma* stems from the Arabic ord*al-kurkum* which was the original word for saffron. This is most likely since both saffron and turmeric are used to make yellow colored dyes. In many languages, the name "turmeric" literally means "yellow root". In ifferent languages turmeric is called: *kurkum* (Arabic & Hebrew), *huang jiang* (Mandarin Chinese), *curcuma* (French, German, Italian, Spanish), and *haldi* (Hindi). Turmeric belongs to the genus *Curcuma* (Zingiberaceae) and, is a commercially important crop because of its pharmacological, nutritional, religious, and cultural significance. The crop is indigenous to India and has a very long history of cultivation in Asia. The genus *Curcuma* contains about 80 species all over Asia. The other important species related to turmeric are *C. amada*, *C. angustifolia*, *C. aromatica*, *C. caesia* and *C. zedoaria.* Turmeric is a cross-pollinated, triploid species, which can be vegetatively propagated using its underground rhizomes. Curcuminoid compounds (Curcumin, demethoxycurcumin, and bisdemethoxycurcumin) isolated from the rhizomes of turmeric possess various pharmacological activities. In particular, curcumin is reported as a valuable anti-inflammatory, antioxidant and anti-microbial compound. Genetic improvement work on turmeric is typically limited to germplasm selection as hybridization is unsuccessful in many cases. In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding and Cultivation of Turmeric are discussed.

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INTRODUCTION

Turmeric belongs to the belongs to the family Zingiberaceae, genus *Curcuma* and species *Curcuma longa* (Suryawanshi *et al*., 2023; EEB, 2024; EPPO, 2024; *POWO, 2024;* UWSP, 2024; Wikidoc, 2024; Wikipedia, 2024; Wikipedia, 2024a). It is also known as *Curcuma domestica; Curcuma aromatica* (NCCIH,2024). Also known as Indian saffron. Turmeric's influence extends beyond the kitchen and apothecary. It has made its mark in art and culture. In Indian traditional dance, turmeric paste is applied to dancers' feet before performances, signifying purity and grace. It has also been used to create intricate rangoli designs and as a natural dye for clothing (Zofffoods, 2024). Turmeric names in different languages are in Hindi: Haldi, Bengali: Halud, Father Gujarati: Haladhar, Haldi, Kannada: Arisiya, Konkani: Halad, Malayalam: Manjal, Marathi: Halde, Halad, Oriya: Haldi , Punjabi: Haldar, Haladhar, Haldi, Sanskrit: Haldi, Harita, Tamil: Manjal, Telugu: Pasupu, Urdu: Turmeric (Shahdol, 2024; Wikidoc, 2024). In Sanskrit, turmeric has at least 53 different names, including *anestha* (not offered for sacrifice or homa), *bhadra* (auspicious or lucky), *bahula* (plenty), *dhirgharaja* (long in appearance), *gandhaplashika* (which produces good smell), *gauri* (to make fair), *gharshani* (to rub), haldi (that draws attention to its bright color), *haridra* (dear to hari, Lord Krishna), *harita* (greenish), *hemaragi* (exhibits golden color), *hemaragini* (gives the golden color), *hridayavilasini* (gives delight to heart, charming), *jayanti* (one that wins over diseases), *jawarantika* (which cures fevers), *kanchani* (exhibits golden color), *kaveri* (harlot), *krimighni* or *kashpa* (killer of worms), *kshamata* (capability), *laxmi* (prosperity), *mangalprada* (who bestows auspiciousness), *mangalya* (auspicious), *mehagni* (killer of fat), *nisha* (night), *nishakhya* (known as night), *nishawa* (clears darkness and imparts color), *patwaluka* (perfumed powder), *pavitra* (holy), *pinga* (reddish-brown), *pinja* (yellow-red powder), *pita* (yellow), *pitika* (which gives yellow color), *rabhangavasa* (which dissolves fat), *ranjani* (which gives color), *ratrimanika* (as beautiful as moonlight), *shifa* (fibrous root), *shobhna* (brilliant color), *shiva* (gracious), *shyama* (dark colored), *soubhagaya* (lucky), *survana* (golden color), *survanavara* (which exhibits golden color), *tamasini* (beautiful as night), *umavara* (Parvati, wife of Lord Shiva), *vairagi* (who remains free from desires), *varavarnini* (which gives fair complexion), *varna datri* (enhancer of body complexion), *varnini* (which gives color), *vishagni* (killer of poison), *yamini* (night), *yoshitapriya* (beloved of wife), and *yuvati* (young girl) (Benzieand Wachtel-Galor, 2011). The name possibly derives from Middle English or Early Modern English as *turmeryte* or *tarmaret*. It may be of Latin origin, *terra merita* ("meritorious earth").[18] The Latin specific epithet *longa* means long (Wikipedia, 2024). Turmeric is a mild digestive, being aromatic, a stimulant and a carminative Turmeric is one ofnature's most powerful healers (Bhowmik *et al*., 2009). The active ingredient in turmeric is curcumin. Tumeric has been used for over 2500 years in India, where it was most likely first used as a dye (Bhowmik *et al.,* 2009). The medicinal properties of this spice have been slowly revealing themselves over the centuries. Long known for its anti-inflammatory properties, recent research has revealed that turmeric is a natural wonder, proving beneficial in the treatment of many different health conditions from cancer to Alzheimer's disease (Bhowmik *et al.,* 2009). An ointment base on the spice is used as an antiseptic in India (Bhowmik *et al.,* 2009). Turmeric water is an Asian cosmetic applied to impart a golden glow to the complexion (Bhowmik *et al*., 2009). Curcumin has been shown to be active against *Staphlococcus aureus* (pus-producing infections). Anemia, cancer, diabetes, digestion, food poisoning, gallstones, indigestion, IBS, parasites, poor circulation, staph infections, and wounds (Bhowmik *et al.,* 2009). Turmeric decreases Kapha and so is used to remove mucus in the throat, watery discharges like leucorrhea, and any pus in the eyes, ears, or in wounds (Bhowmik *et al*., 2009). In Unani medicine, turmeric has been used for conditions such as liver obstruction and jaundice and has been applied externally for ulcers and inflammation (Bhowmik *et al*., 2009). Roasted turmeric has been used as an ingredient of a preparation used for dysentery. Turmeric has also been used in tooth powder or paste. Turmeric has been used for many conditions in traditional medicine in India, Pakistan and Bangladesh (Bhowmik *et al*., 2009). The rhizome is generally the part of the plant that is most widely used. It can be prepared in various ways and is reputed to alleviate asthma and coughs. Hot water extracts of the dried rhizome have been taken orally in Ayurvedic medicine to reduce inflammation (Bhowmik *et al*., 2009). Turmeric is also regarded as a 'rasayana' herb, which is a branch of Ayurvedic medicine. Here turmeric is used to counteract ageing processes (Bhowmik *et al.,* 2009). Turmeric is an ancient spice, a native of South East Asia, used from antiquity as dye and a condiment. It is cultivated primarily in Bengal, China, Taiwan, Sri Lanka, Java. Peru. Australia and the West Indies (Bhowmik *et al*., 2009). It is still used in rituals of the Hindu religion, and as a dye for holy robes, being natural, unsynthesized and cheap. Turmeric is in fact one of the cheapest spices. Although as a dye it is used similarly to saffron, the culinary uses of the two spices should not be confused and should never replace saffron in food dishes (Bhowmik *et al*., 2009). Its use dates back nearly 4000 years, to the Vedic culture in India where it was used as a culinary spice and had some religious significance. The name derives from the Latin terra merita “meritorious earth” referring to the colour of ground turmeric which resembles a mineral pigment (Bhowmik *et al.,* 2009). Turmeric has been used for 4,000 years to treat a variety of ailments. Several research studies have found that turmeric may, in fact, help treat a number of illnesses. However, it is important to remember several facts when you hear news reports about turmeric's medicinal properties (Bhowmik *et al*., 2009).

Natural plant products have been used throughout human history for various purposes. Having co-evolved with animal life, many of the plants from which these natural products are derived are billions of years old. Tens of thousands of these products are produced as secondary metabolites by higher plants as a natural defense mechanism against disease and infection (Benzieand Wachtel-Galor, 2011). Many of these natural products have pharmacological or biological activity that can be exploited in pharmaceutical drug discovery and drug design. Medicines derived from plants have played a pivotal role in the health care of many cultures, both ancient and modern (Benzieand Wachtel-Galor, 2011).The Indian system of holistic medicine known as “Ayurveda” uses mainly plant-based drugs or formulations to treat various ailments, including cancer. Of the at least 877 small-molecule drugs introduced worldwide between 1981 and 2002, the origins of most (61%) can be traced to natural products (Benzieand Wachtel-Galor, 2011). Although many synthetic drugs are produced through combinatorial chemistry, plant-based drugs are more suitable, at least in biochemical terms, for human use. Nonetheless, modern medicine has neither held in very high esteem nor encouraged the medicinal use of natural products (Benzieand Wachtel-Galor, 2011).Turmeric is a plant that has a very

long history of medicinal use, dating back nearly 4000 years. In Southeast Asia, turmeric is used not only as a principal spice but also as a component in religious ceremonies. Because of its brilliant yellow color, turmeric is also known as "Indian saffron." Modern medicine has begun to recognize its importance, as indicated by the over 3000 publications dealing with turmeric that came out within the last 25 years (Benzieand Wachtel-Galor, 2011).

Turmeric, the golden colored strongly flavored spice, is having a "moment." This ancient spice, celebrated for centuries as both food and medicine, has resurfaced within the health and nutrition communities thanks to curcumin, the healing substance that supplies its vibrant color (Avey, 2015). Curcumin has significant anti-inflammatory properties that are said to rival those found in ibuprofen. Unlike over-the-counter drugs, turmeric has no toxic effects on the body. Curcumin's powerful antioxidant advantages have been shown to protect healthy cells, particularly those found in the colon, from cancer-causing agents. It aids the body in destroying mutated cancer cells before they have a chance to spread to other areas. Turmeric also helps to lower cholesterol and prevent heart disease. All that, and it's tasty too! (Avey, 2015). The plant reaches barely three feet in height and produces both a flower and a rhizome, or stem that is found underground. The rhizome has an appearance similar to ginger; it is this root-like stem that produces the yellow turmeric spice. Though it can now be found throughout the tropics, India has been the largest producer of turmeric since ancient times (Avey, 2015).In recent years turmeric has attracted quite a bit of interest for its natural healing properties, but it has actually been used medicinally for over 4,500 years. Analyses of pots discovered near New Delhi uncovered residue from turmeric, ginger and garlic that dates back as early as 2500 BCE (Avey, 2015).It was around 500 BCE that turmeric emerged as an important part of Ayurvedic medicine. Ayurveda is an ancient Indian system of natural healing that is still practiced today. Ayurveda translates to science of life-- *ayur* meaning life and *Veda* meaning science or knowledge (Avey, 2015). Inhaling fumes from burning turmeric was said to alleviate congestion, turmeric juice aided with the healing of wounds and bruises, and turmeric paste was applied to all sorts of skin conditions from smallpox and chicken pox to blemishes and shingles (Avey, 2015). Ayurvedic literature contains over 100 different terms for turmeric, including *Jayanti*, meaning one who is victorious over diseases, and *matrimanika*, meaning as beautiful as moonlight (Avey, 2015).In Indian culture, the importance of turmeric goes far beyond medicine. The Hindu religion sees turmeric as auspicious and sacred. There is a wedding day tradition in which a string, dyed yellow with turmeric paste, is tied around the bride's neck by her groom. This necklace, known as a *mangala sutra*, indicates that the woman is married and capable of running a household. The tradition still continues in Hindu communities and has been compared to the Western exchange of wedding rings. In parts of southern India, a piece of the turmeric rhizome is worn as an amulet for protection against evil spirits (Avey, 2015).The vibrant yellow natural coloring of turmeric has also been used to dye clothing and thread for centuries. Saffron-hued Buddhist robes are dyed with turmeric. In Kerala, a state in southwest India, children were given turmeric-dyed clothing to wear during the Onam festival. The reason for this is unclear, though it likely has to do with the color's association with Lord Krishna (Avey, 2015).

Turmeric is an economically important spice and medicinal plant for production of curcuminoids, oleoresin, essential oil which are used in pharmaceutical and cosmetics industries. Presence of these contents in turmeric determine its quality (Ayer, 2017). Average productivity and quality of turmeric is not satisfactory because of the poor genetic materials and non-availability of quality materials (Ayer, 2017). Conventional clonal selection takes long time and slow progress to achieve the same level of quality improvement than molecular or biotechnological approaches. Use of molecular markers, transcriptome sequencing, real time PCR approaches can be applied as a supplement to conventional methods of breeding through clonal selection and advancing elite genotypes (Ayer, 2017). Traditionally turmeric is known as Haldi in India, Besar in Nepal and is under extensive cultivation in South Asian countries for medicinal, religious, culinary purposes and also as a cosmetic and dye. Dry recovery (curing percentage), curcumin and oleoresin contents determine the quality of turmeric and high variability has been observed in turmeric germplasm with respect to these characters (Ayer, 2017). Turmeric powder obtained from rhizomes of *C. longa* is extensively used as a spice, food preservative, natural dye in food industry and in cosmetics and drugs (Ayer, 2017). Curcuminoid, a phenylpropanoid derivative, is a mixture of curcumin (50–60 % of the curcuminoids), demethoxycurcumin and bisdemethoxycurcumin which imparts yellow colour to turmeric (Ayer, 2017). The medicinal properties of curcuminoids as anti-inflammatory, anti-oxidant, antimutagenic, anti-diabetic, anti-bacterial, hepato protective and expectorant are reported extensively. It is also well known in treating conditions ranging from arthritis and inflammation to Alzheimer's disease and cancer (Ayer, 2017). Because of widespread multipurpose use of this medicinal herb in pharmacological industry, spice industry and other culinary purpose use, quality improvement for enhanced phyto-constituents production in turmeric is of great importance in the present context (Ayer, 2017). Although India is a leading producer of turmeric and few high yielding cultivars are available in this crop, the average productivity and quality are not satisfactory (Ayer, 2017). Major problems are non-availability of requisite high yielding genotype, slow multiplication rate, low curcumin and essential oil content in available cultivars and loss due to disease during cultivation and storage. Crop improvement work in turmeric is so far confined mostly to clonal selection by exploiting the naturally occurring variations (Ayer, 2017). To put the turmeric cultivation as an industry, it is therefore essential to develop turmeric genotypes with improved drug yielding potential containing enhanced quality and quantity of essential oil, high curcumin, high oleoresin and rhizome yield (Ayer, 2017).

Turmeric is one of the important perennial spice crop popularly known as "Indian saffron" belongs to family Zingiberaceae. It has chromosome number of 2n = 3x = 63 (Singh *et al*., 2018). It is originated in South East Asia and among which, India has achieved a predominant position as a largest producer of turmeric in the world. Besides India, it is cultivated in China, Taiwan, Indonesia, Sri Lanka, Thailand and other tropical countries but the highest diversity is concentrated in India and Thailand (Singh *et al*., 2018). Over eighty species are reported in the genus Curcuma from the Indo-Malayan region, from which forty are the indigenous ones (Singh *et al*., 2018). India is the largest producer, consumer and exporter of turmeric in the world, which accounts for more than 50 per cent of the world trade (Singh *et al.,* 2018). The area under turmeric cultivation in India is 1,85,000 hectares with an annual production of 9,57,000 metric tons and productivity is 5.17 metric tons per hectare (Singh *et al*., 2018). In North East India

especially Mizoram, Meghalaya and Assam are endowed with a wide range of genetic variability in *Curcuma longa* and other related Curcuma species due to geo-climatic conditions of the region favouring higher accumulation of curcumin in rhizomes (Singh *et al*., 2018). The curcumin content is one of the major criteria for its export to the global markets. Alleppey turmeric is the world's most outstanding and demanded grade, which is the richest source of curcumin (Singh *et al.,* 2018). Due to vegetative propagation and flowering complexities, the genetic improvement programmes in turmeric are largely restricted to clonal selection and induced mutation breeding. Moreover, limited viable seed settings in open-pollination and controlled crosses explore the possibility of recombination breeding through hybridization and hence few varieties such as IISR-Prabha and IISR-Pratibha have been released through progeny selection of open-pollinated seedlings (Singh *et al*., 2018). Even though, germplasm collection represents the main source of variability for turmeric genetic improvement (Singh *et al*., 2018). DNA marker technology has provided an efficient tool to facilitate plant genetic resource conservation and its efficient management (Singh *et al*., 2018). Turmeric, a plant in the ginger family, is native to Southeast Asia and is grown commercially in that region, primarily in India. Its rhizome (underground stem) is used as a culinary spice and traditional medicine (NCCIH, 2020). Historically, turmeric was used in Ayurveda and other traditional Indian medical systems, as well as Eastern Asian medical systems such as traditional Chinese medicine. In India, it was traditionally used for disorders of the skin, upper respiratory tract, joints, and digestive system (NCCIH, 2020).Today, turmeric is promoted as a dietary supplement for a variety of conditions, including arthritis, digestive disorders, respiratory infections, allergies, liver disease, depression, and many others (NCCIH, 2020).Turmeric is a common spice and a major ingredient in curry powder. Curcumin is a major component of turmeric, and the activities of turmeric are commonly attributed to curcuminoids. Curcumin gives turmeric its yellow color (NCCIH, 2020). Turmeric dietary supplements are made from the dried rhizome and typically contain a mixture of curcuminoids. Turmeric is also made into a paste for skin conditions (NCCIH, 2020).

Turmeric is a plant distributed throughout tropical and subtropical regions of the world and cultivated in Asian countries, mainly in China and India (Azeez and Lunghar, 2021).Turmeric belongs to the family *Zingiberaceae*, and it has been traditionally used for centuries in Asia for medicinal purposes and in cuisine (Azeez and Lunghar, 2021). India is the largest producer, consumer, and exporter of turmeric in terms of dried and ground tuber as a spice product (Azeez and Lunghar, 2021).Turmeric is a plant that has a very long history of medicinal use, dating back nearly 4000 years (Azeez and Lunghar, 2021). In Southeast Asia, turmeric is used not only as a principal spice but also as a component in religious ceremonies. Because of its brilliant yellow color, turmeric is known as "Indian saffron"(Azeez and Lunghar, 2021). The genus *Curcuma* is morphologically highly variable for the different conventional taxonomic traits (Azeez and Lunghar, 2021). *Curcuma* is perennial rhizomatous herbs, 50–200 cm tall, and the leaf shoot dying back during the dry period of tropical areas. Rhizomes are ovoid without branches or branched, fleshy, and aromatic. Rhizomes are usually light brown externally, but they can be of different shades of yellow, white, light to deep orange, bluish to deep blue, yellow with greenish borders internally (Azeez and Lunghar, 2021). India is the largest producer, followed by Thailand and other significant producers like Southeast Asian countries, Central and Latin America, and Taiwan. The global production of turmeric is around 11 lakh tonnes per annum. India dominates the production in global scenario contributing 78%, followed by China (8%), Myanmar (4%) and Nigeria, and Bangladesh together, and contributing to 6% of the global production. India produces nearly the world's entire turmeric crop and consumes 80% of it (Azeez and Lunghar, 2021). With its inherent qualities and high content of the essential bioactive compound curcumin, Indian turmeric is to be the best in the world (Azeez and Lunghar, 2021). Erode, a city in the South Indian state of Tamil Nadu, is the world's largest producer of and the most important trading center for turmeric. It is also known as "Yellow City," "Turmeric City," or "Textile City." Sangli, a city of Maharashtra, is second only to Erode in size and importance as a production and trading site for turmeric. Turmeric is one of the most useful herbal medicinal plants (Azeez and Lunghar, 2021).

Turmeric has been a famous root crop for its medicinal properties since pre-historical times. Lack of effective therapeutics for most viral diseases, higher cost of some antiviral therapies, and the emergence of antiviral drug resistance are increasingly reported (Srivastava *et al*., 2022). Drug resistance is predicted to be a leading cause of mortality globally by 2050, thus requiring intervention. The need for effective natural antiviral compounds to mitigate viral diseases, such as curcumin, calls for further studies (Srivastava *et al*., 2022). Curcumin, a primary curcuminoid compound, has demonstrated a broad activity as an antiviral agent. Due to the need to overcome drug resistance to chemically synthesised drugs, the best option is to improve and adapt the use of natural antiviral agents (Srivastava *et al.,* 2022). The antiviral potential of curcumin is hindered by its solubility and bioavailability. Recently, different techniques, such as the preparation of curcumin carbon quantum dots, have been used to improve curcumin antiviral activity (Srivastava *et al.,* 2022). Turmeric is a blossoming plant of the Zingiberaceae family. Since the prehistoric period, turmeric has been used in Asian medicine as a major part of Ayurveda, Siddha, Traditional Chinese, Unani medicine, and the animistic rituals of Austronesian peoples. It was initially used as a dye and then later for its supposed properties in folk medicine (Srivastava *et al*., 2022). The plant is a rhizomatous perennial herbaceous native to Southeast Asia and the Indian subcontinent, flourishing in temperate conditions and requiring a significant annual rainfall (Srivastava *et al*., 2022). Mostly the rhizomes are used fresh or boiled in water and dried, after which they are crushed into a deep orange-yellow powder that is commonly used as a colouring and flavouring agent in many Asian cuisines, especially curries, as well as for dyeing, thanks to the properties imparted by curcumin, the main turmeric constituent (Srivastava *et al*., 2022). Turmeric powder has an earthy, mustard-like fragrance and a warm, bitter black pepper flavour. Curcuma species diversity is greatest in India, followed by Thailand, and other tropical Asian countries have various wild Curcuma species (Srivastava *et al.,* 2022).

Curcuma longa L. is a member of the ginger family (Zingiberaceae) and is widely used by traditional healers to treat a wide rangeof ailments. Because of its high curcumin content, Indian turmeric is especially popular in compared to other countries (Suryawanshi *et al.,* 2023). *Curcumalonga* rhizomes are commonly referred to as Haldi or Turmeric. Rhizomes are underground horizontal stems that produce both shoots and roots (Suryawanshi *et al*., 2023). Turmeric includes curcuminoids, which are fat-

soluble polyphenolic pigments. The most important of these iscurcumin (deferulolyl methane), which is responsible for the yellow colour of Indian curries; others are demethoxy curcumin andbisdemethoxy curcumin (Suryawanshi *et al.,* 2023). Turmeric, commonly known as 'Indian saffron,' is a natural antibacterial agent. Turmeric contains nutritional as well as therapeutic benefits. Turmeric contains phytochemicals, making it a therapeutic plant Nonnutritive plant compounds (phytochemical components) can prevent illness (Suryawanshi *et al*., 2023). Turmeric root powder is used for its flavouring properties as a spice, dietary medicine, and for a variety of critical therapeutic advantages (Suryawanshi *et al*., 2023). For thousands of years, natural products have been employed in traditional medicine, and they have showed promise as a source ofcomponents for the development of novel pharmaceuticals (Suryawanshi *et al*., 2023). Turmeric is a Zingiberaceae (ginger) family herbaceous ever green plant. It is widely grown in Asia, primarily in India and China. Turmeric, which is said tohave originated in India, has been used for at least 2500 years (Suryawanshi *et al*., 2023). The turmeric plant grows throughout the tropics and subtropics of the world. The plant's origin is unknown, however it is assumed to have originated in south-east Asia, most likely in India. The plant is grown in every corner of India (Suryawanshi *et al.,* 2023). Turmeric powder is often used in curries and mustards as a colouring and flavouring agent. Turmeric has traditionally been used to preserve mouth hygiene in India (Suryawanshi *et al*., 2023). For millennia, it has been used for medical purposes in nations such as India and China to cure jaundice and other liver disorders (Suryawanshi *et al.*, 2023). The majority of the World's supply is produced in India, although turmeric is also grown in southern China, Taiwan, Japan, Burma, and Indonesia, as well as throughout the African continent (Suryawanshi *et al.,* 2023).

Turmeric is a perennial rhizomatous herbaceous plant of the Zingiberaceae family (Mariappan *et al*., 2023). Southeast India is home to this species. Curcumin, the main component in turmeric, is a powerful antioxidant with hepato protective characteristics (Mariappan *et al*., 2023). Turmeric supplementation did not increase assessed growth and feed utilization indicators appreciably, especially at higher supplementation levels (0.50%) (Mariappan *et al*., 2023). In the challenge infection with *Pseudomonas fluorescens*, the turmeric-supplemented groups had a decreased mortality rate, with the 0.50% turmeric-supplemented group having the best level of protection (Mariappan *et .al*, 2023).

Curcuma longa, popularly known as Turmeric, is a rhizomatous herbaceous perennial plant used in folk medicine for the treatment, prevention, and management of various illnesses such as cancer, diabetes, Arthritis, diarrhoea, inflammation, psoriasis, hepatobiliary diseases, gastric and peptic ulcers (Iweala *et al*., 2023). Study reviewed the ethnomedicinal potentials, phytochemicals, and pharmacological activities of *C. longa. In vitro* and *in vivo* studies reported that *C. longa* and its major bioactive constituent (curcumin) possess various pharmacological properties. These include; anticancer, antidiabetic, anti-osteoarthritis, antidiarrheal, cardioprotective, anti-oxidative, neuro protective, hepato protective, anti-microbial, reno protective and anti-inflammatory activities (Iweala *et al.,* 2023). This demonstrated that the various pharmacological activities of *C. longa* might be attributed to the presence of numerous bioactive compounds (Iweala *et al.,* 2023). Study showed that *C. longa* could be exploited by pharmaceutical industries to develop pharmaceutical products. However, there is a need for human clinical trials and quality control studies to establish effective and safe doses of *C. longa* and its major bioactive constituent-curcumin suitable for treating several diseases (Iweala *et al*., 2023).

Turmeric is cultivated in the tropical and subtropical regions around the world. Turmeric originates from the Indian subcontinent and South East Asian countries (Varma *et al*., 2023).Turmeric has been used in various traditional systems of medicine like Ayurveda, Siddha, and Chinese medicine for the treatment of various diseases (Varma *et al*., 2023).The diverse applications of turmeric include use in dietary spice, foods, textile industries, medicinal and nutraceutical fields (Varma *et al.,* 2023).The phytochemical analysis of the rhizome had revealed the presence of valuable phytochemical components *viz*, curcuminoids, volatile oils, proteins, dietary fiber, carbohydrates, and minerals (Varma *et al*., 2023). Curcuminoids form the class of molecules which include curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Depending on the variety, the percentage by weight of curcuminoids contribute to around 3%–8% in turmeric rhizome (Varma *et al*., 2023).The low toxicity of natural products has opened the way to use in nutraceuticals, dietary supplements, and functional foods and has gained significant popularity globally over the past few decades due to the increased potential health benefits (Varma *et al*., 2023).Most modern nutraceutical industries have focused on developing value-added products which are of natural origin using the incorporation of cutting-edge technologies. The major hurdle in the drug development is designing of the formulation, which has the potential to increase the bioefficacy and often comes as with increased bioavailability of the molecule. There are several promising technologies which are also in commercial use with enhanced pharmacological activities(Varma *et al*., 2023).The numerous health benefits of curcuminoids extend the applications to be used in wide variety of nutraceutical applications (Varma *et al.*, 2023).

Turmeric, perennial herbaceous plant of the ginger family, the tuberous rhizomes (underground stems), of which have been used from antiquity as a condiment, a textile dye, and medically as an aromatic stimulant (EEB, 2024).Native to southern India and Indonesia, turmeric is widely cultivated on the mainland and in the islands of the Indian Ocean (EEB, 2024). The rhizome has a pepper like aroma and a somewhat bitter warm taste and has a strong staining orange-yellow color (EEB, 2024). In ancient times turmeric was used as a perfume as well as a spice and dye (EEB, 2024). It is the ingredient that colors and flavors prepared mustard and is used in curry powder, relishes, pickles, and spiced butters for vegetables, in fish and egg dishes, and with poultry, rice, and pork. An essential flavor in many South Asian cuisines, turmeric is consumed daily by millions of people (EEB, 2024). In parts of Asia turmeric water has long been applied as a cosmetic to lend a golden glow to the complexion, and it has grown in popularity as an ingredient in cosmetics and skin care products elsewhere. It is also one of the sources of the brilliant color used to celebrate Holi in India and Nepal (EEB, 2024). Turmeric is a rhizomatous herbaceous perennial plant of the ginger family, Zingiberaceae which is native to tropical South Asia (Wikidoc, 2024). It needs temperatures between 20 and 30^0 C. and a considerable amount of annual rainfall to thrive (Wikidoc, 2024). Plants are gathered annually for their rhizomes, and re-seeded from some of those rhizomes in the following season (Wikidoc, 2024). Its rhizomes are boiled for several hours and then dried in

hot ovens, after which they are ground into a deep orange-yellow powder commonly used as a spice in curries and other South Asian cuisine, for dyeing, and to impart color to mustard condiments. Its active ingredient is curcumin and it has an earthy, bitter, peppery flavor and has a mustardy smell (Wikidoc, 2024). Sangli, a town in the southern part of the Indian state of Maharashtra, is the largest and most important trading centre for turmeric in Asia or perhaps in the entire world (Wikidoc, 2024).

Turmeric is a cross-pollinated, triploid (2n = 3x = 63) rhizome crop grown Worldwide. It ranks among the most popular crops globally, boasting a pungent favour and an attractive colour (Alam *et al.,* 2024).Turmeric serves various purposes, such as a spice, cosmetic, colourings agent, favouring and preservative, and is recognized universally for its aromatic, stimulative, and carminative properties (Alam *et al*., 2024). It is marketed in various forms, including spice, dye, oleoresin, complexion agent, and industrial starch source (Alam *et al.,* 2024). Additionally, turmeric is a key ingredient in many South Asian cuisines, and it is sometimes consumed as tea or in pill form (Alam *et al.,* 2024).It finds application in numerous industrial products, including sauces, mustards, dry seasonings, baking mixes, processed cheese, dry soups, and confections (Alam *et al*., 2024). Ayurvedic medicine also values turmeric, particularly for its bioactive element, curcumin (Alam *et al*., 2024). Curcuminoids, which are fat-soluble, polyphenolic pigments, impart a bright yellow colour to turmeric. Furthermore, turmeric is employed in formulating human medicines due to its anti-inflammatory and antiseptic properties, as well as its ability to inhibit carcinogenesis (Alam *et al.,* 2024). Globally, around 11 lakh metric tons of turmeric are produced annually, with India leading in production, consumption, and export. India accounts for 80% of the world's turmeric production, followed by China (8%), Myanmar (4%), Nigeria (3%), and Bangladesh (3%). Bangladesh, for instance, imports approximately 49,522 metric tons of turmeric from India each year (Alam *et al*., 2024). Turmeric primarily propagates through its underground rhizomes, with seed production being rare. Hybridization is generally unproductive, making genetic improvement limited to germplasm selection and mutation breeding (Alam *et al.,* 2024). Importance of germplasm collection for turmeric genetic improvement, contributing significantly to genetic diversity and variability. It is the basic indispensable element of all breeding programs. Exploiting the existing variability in germplasm collections is crucial for genotype selection inbreeding programs (Alam *et al*., 2024). In the realm of turmeric evaluation, various statistical tools and techniques play a crucial role in extracting meaningful insights and guiding the selection of superior genotypes. These tools are instrumental in handling the inherent variability within germplasm collections, ensuring a comprehensive understanding of the performance of different turmeric cultivars (Alam *et al*., 2024).

Turmeric, the ancient and sacred spice of India known as 'Indian saffron'isan important commercial spice crop grown in India (Agritech, 2024). It is used in diversified forms as a condiment, flavouring and colouring agent and as a principal ingredient in Indian culinary as curry powder. It has anti cancer and anti viral activities and hence finds use in the drug industry and cosmetic industry (Agritech, 2024). 'Kum-kum', popular with every house wife, is also a by-product of turmeric. It finds a place in offerings on religious and ceremonial occasions (Agritech, 2024). A type of starch isalso being extracted from a particular type of turmeric (Agritech, 2024). The increasing demand for natural products as food additives makes turmeric as ideal produce as a food colourant (Agritech, 2024). Turmeric is the dried rhizome of *Curcuma longa* L., a herbaceous perennial belonging to the family Zingiberaceae and a native of South Asia particularly India (Agritech, 2024). The plant is propagated from rhizomes. The leaves are long, broad, lanceolate and bright green. The flowers are pale yellow and borne on dense spikes. The pseudo stems are shorter than leaves. The rhizomes are ready for harvesting in about 7 to 9 months after planting (Agritech, 2024). India is the largest producer, consumer and exporter of turmeric in the world. Other major producers are Thailand, other Southeast Asian countries, Central and Latin America and Taiwan (Agritech, 2024). The global production of turmeric is around 11 lakh tonnes per annum. India dominates theworld production scenario contributing 78 % followed by China(8%), Myanmar (4%) and Nigeria and Bangala Desh together contributing to 6% of the global production (Agritech, 2024). India is the global leader in value added products of turmeric and exports. Other major exporters are Thailand, other Southeast Asian countries, Central and Latin America and Taiwan (Agritech, 2024). United Arab Emirates (UAE) is the major importer of turmeric from India accounting for 18% of the total exports followed by United States of America (USA)with 8%. The other leading importers are Bangala Desh, Japan, Sri Lanka, United Kingdom, Malaysia, South Africa, Netherland and Saudi Arabia. All these countries together account for 75% of the world imports and Asian countries are the main suppliers to the entire world. The remaining 25% is met by Europe, North America and Central and Latin American countries. United States of America imports 97% of its turmeric requirement from India and the remaining portion from the Islands of the Pacific and Thailand (Agritech, 2024)

ORIGIN AND DISTRIBUTION

The use of turmeric dates back nearly 4000 years to the Vedic culture in India, where it was used as a culinary spice and had some religious significance. According to Sanskrit medical treatises and Ayurvedic and Unani systems, turmeric has a long history of medicinal use in South Asia. Susruta's Ayurvedic *Compendium*, dating back to 250 BC, recommends an ointment containing turmeric to relieve the effects of poisoned food.Today, turmeric is widely cultivated in the tropics and goes by different names in different cultures and countries. In North India, turmeric is commonly called "haldi," a word derived from the Sanskrit word *haridra*, and in the south it is called "manjal," a word that is frequently used in ancient Tamil literature (Benzieand Wachtel-Galor, 2011). It probably reached China by 700 AD, East Africa by 800 AD, West Africa by 1200 AD, and Jamaica in the eighteenth century. In 1280, Marco Polo described this spice, marveling at a vegetable that exhibited qualities so similar to that of saffron (Benzieand Wachtel-Galor, 2011). Total 9 SSR markers were utilized to study the genetic relatedness among all thirty genotypes of turmeric. Six identified SSR markers are highly informative for genetic studies and are extremely useful in distinguishing the polymorphism rate at a specific locus in turmeric. Primer pair's *viz*., 11 and 12, 5 and 6 and 13 and 14 generated higher levels of polymorphism and these could be used to differentiate turmeric genotypes under study. The lecular diversity analysis indicated presence of ample genetic diversity among the genotypes studied, which were grouped into 2 clusters. Similarity ratio revealed high degree of similarity to the extent of 100 % between genotypes NVST-80 and Pratibha, NVST-55 and GNT-2 as well as

NVST-53 indicating identical finger prints due to common origin. Very low level of similarity was observed between NVST-85 and NVST70 indicating higher amount of diversity among the genotypes (Singh *et al*., 2018).

India or China or Indo-Malayan region is the home of turmeric (a diploid form) from which *C.domestica* is likely to have evolved by a process of triploidy, and subsequent continued selection and cultivation by vegetative propagation. But now, it is not grown in truly wild state. The crop has now become widely distributed throughout the tropics, but its cultivation as spice is largely confined to India, Sri Lanka, China, Pakistan, Indonesia, Haiti, Jamaica, Peru, Bangladesh, El-salvador and Taiwan (KSSDB, 2021). *Curcuma longa* is native to India and was introduced to other areas such as the Andaman Islands, Assam, Bangladesh, Belize, Borneo, Cambodia, Caroline Islands, China South-Central, China Southeast, Comoros, Congo, Cook Islands, Costa Rica, Cuba, Dominican Republic, East Himalaya, Easter Islands, Fiji, Gilbert Islands, Guinea-Bissau, Gulf of Guinea Islands, Haiti, Hawaii, Ivory Coast, Jawa, Leeward Islands and Lesser Sunda Islands (Srivastava *et al*., 2022).

India is the centre of turmeric diversity in particular Southern India (*i.e*., Tamil Nadu, and Kerala) (Dudekula *et al*., 2022). *Curcuma longa* (Turmeric) is native to India and is widely available in the following countries: Andaman Islands, Assam, Borneo, Bangladesh, Belize, China South-Central, China Southeast, Cambodia, Caroline Islands, Cook Islands, Costa Rica, Cuba, Comoros, Congo, Nigeria, Dominican Republic, East Himalaya, Easter Islands, Fiji, Gilbert Islands, Guinea Bissau, Gulf of Guinea Islands, Haiti, Hawaii, Ivory Coast, Jawa, Leeward Islands, Lesser Sunda Islands, Malaya, Marquesas, Mauritius, Myanmar, New Caled (Suryawanshi *et al*., 2023). Supposedly native to the Indo-Malayan region, the genus might have been domesticated in India as half of its species (including *C. longa*) are indigenous to India. At any rate, it has a long history in India, going back to the pre-Aryan Indian populations, and it has deep roots in Indian society, life, religion, and culture. Suffice to mention that it appears in the Vedic literature possibly as early as the period 1000-1500 BCE, and that devotees apply it on their forefront as an auspicious sign, as do also married women to denote their marital status *(*Touwaide and Appetiti, 2023*).*

Turmeric has been cultivated since ancient civilizations in India and later in China. Over time, it spread through trade routes to the Middle East, Africa (especially becoming a staple in Ethiopian cuisine), and Europe. Today, turmeric is grown in India, China, Myanmar, Nigeria, and Bangladesh. Many countries around the world (including the US) are major importers of turmeric. This plant holds economic value as a culinary spice, dye, medicine, and coloring agent. It is culturally significant in India and China where it is a staple in their traditional cuisine and medicine, and has been established in Ethiopia as well (UWSP, 2024). The greatest diversity of *Curcuma* species by number alone is in India, at around 40 to 45 species. Thailand has a comparable 30 to 40 species. Other countries in tropical Asia also have numerous wild species of *Curcuma*. Recent studies have also shown that the taxonomy of *C. longa* is problematic, with only the specimens from South India being identifiable as *C. longa*. The phylogeny, relationships, intraspecific and interspecific variation, and even identity of other species and cultivars in other parts of the world still need to be established and validated. Various species currently utilized and sold as "turmeric" in other parts of Asia have been shown to belong to several physically similar taxa, with overlapping local names(Wikipedia, 2024). India is the major producer, exporter, and consumer of turmeric and produces about 80% of the world's crop. Turmeric is grown in several other countries such as Pakistan, Malaysia, Myanmar, Vietnam, Thailand, the Philippines, Japan, China, Korea, Sri Lanka, the Caribbean Islands, and Central America (Mccormick, 2024). The use of turmeric dates back 4000 years to the Vedic culture in India, where it was used as a culinary spice and had also had religious and medicinal significance. Marco Polo, in AD 1280, mentioned turmeric in notes of his travels in China: "There is also a vegetable that has all the properties of true saffron, as well as the smell and the color, and yet it is not really saffron." In medieval Europe, turmeric was known as "Indian saffron". Since then, turmeric has been used as an inexpensive substitute for saffron. Turmeric is sacred in the Hindu religion and a turmeric dyed string known as the *mangala sutra* is worn by brides to signify readiness to marry and manage a household. Turmeric is also used to dye clothing and has been used for centuries to create the bright yellow hue of Buddhist robes (Mccormick, 2024). Tumeric is native to India. It is introduced into Andaman Is., Assam, Bangladesh, Belize, Borneo, Cambodia, Caroline Is., China South-Central, China Southeast, Comoros, Congo, Cook Is., Costa Rica, Cuba, Dominican Republic, East Himalaya, Easter Is., Fiji, Gilbert Is., Guinea-Bissau, Gulf of Guinea Is., Haiti, Hawaii, Ivory Coast, Jawa, Leeward Is., Lesser Sunda Is., Malaya, Marquesas, Mauritius, Myanmar, New Caledonia, New Guinea, Nicobar Is., Philippines, Pitcairn Is., Puerto Rico, Queensland, Réunion, Samoa, Society Is., Solomon Is., Sri Lanka, Sumatera, Taiwan, Thailand, Tibet, Tonga, Trinidad-Tobago, Tuamotu, Tubuai Is., Vanuatu, Vietnam, Windward Is (POWO, 2024).

TAXONOMY

Turmeric from *Curcuma longa* L. (fam. Zingiberaceae) is an almost mythic plant that attracts because of both the fascination of the East and, possibly more, its radiant color, of a deep, bright, and sunny yellow. Now mostly known in the form of a fine powder or short fragments of roots, Turmeric is the rhizome of Curcuma. Whereas Carl Linnaeus identified two species (*Curcum arotunda* and *C. longa*), these appeared to be two types of the rhizome of the *C. lunga* species: the central rhizome corresponding to Linnaeus' *C. rotunda* and the elongated, lateral one to *C. longa (*Touwaideand Appetiti, 2023*).*

Current taxonomy identifies possibly 80 species in the genus, half of which are indigenous to India.The species used for human consumption is principally *C. longa* (syn. *C. domestica* Val.) and secondarily *C. xanthorrhiza*Roxb. and *C. malabarica* Vel. The species *C. longa* itself appears in six different taxonomic varieties *(*Touwaide and Appetiti, 2023*):*

- *C. longa* var. *typica*
- *C. longa* var *atypica*
- *C. longa* var. *camphora*

- *C. longa* var *spiralifolia*
- *C. longamusacifolia*
- *C. longa* var. *platifolia*

Curcuma domestica belonging to the family *Zingiberaceae* is the plant from which are turmeric of commerce (dried rhizomes) is obtained. Though *C.domestica* is the correct botanical name for turmeric, *C.longa* is sometimes used in literature to describe the finger rhizome and *C.rotunda*for the bulbous central rhizomes (KSSDB, 2021; EPPO, 2024; Wikipedia, 2024; Plant Database, 2024).

Synonyms *(POWO, 2024).*

Homotypic Synonyms

- *Kua domestica* Medik. in Hist. &Commentat. Acad. Elect. Sci. Theod.-Palat. 6: 396 (1790), nom. superfl.
- *Stissera curcuma* Giseke in Prael. Ord. Nat. Pl.: 249 (1792), nom. superfl.

Heterotypic Synonyms

- *Amomum curcuma* Jacq. in Hort. Bot. Vindob. 3: 5 (1776)
- *Amomum latifolium* Lam. in Encycl. 1: 134 (1783)
- *Curcuma brog* Valeton in Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 48 (1918)
- *Curcuma domestica* Valeton in Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 31 (1918)
- *Curcuma longa* var. *vanaharidra* Velay., Pandrav., J.K.George&Varapr. in J. Econ. Taxon. Bot. 33: 173 (2009)
- *Curcuma ochrorhiza* Valeton in Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 45 (1918)
- *Curcuma soloensis* Valeton in Bull. Jard. Bot. Buitenzorg, sér. 2, 27: 46 (1918)
- *Curcuma tinctoria* Guibourt in Hist. Nat. Drogues Simples 2: 208 (1876)

Synonyms (Wikipedia, 2024d).

Curcuma wenyujin Y.H.Chen&C.Ling
•*Curcuma zedoaria* Roxb., sensu auct.

Nearly 40 species of Curcuma are known to exist in India, while only one species *C. longa* contributes to commercial production of turmeric of commerce (96%). It is an herbaceous perennial with underground rhizomes. It is a sterile triploid (3n = 63) and do not normally set viable seeds. The other species are *C. aromatica* (Kasthurimanjal), *C. caesia* (Black turmeric), *C. amada* (mango ginger), *C. zedoaria, C. purpurescens, C.mangga, C.heyneana, C. xanthorrhiza, C. aeruginosa, C. phaeocaulis*and *C. petiolata* are also cultivated in different parts of India. *C. aromatica*is cultivated to a lesser extent for Kasturi turmeric used in cosmetics (Ecourse, 2024). Turmeric types can be grouped into three based on maturity period as short, medium and long duration types. Short duration types are known as Kasturi. They mature in seven months, rhizomes possess pleasant aroma, good yielders of dried turmeric and rich in volatile oil content but low in curcumin and used in culinary preparation (Ecourse, 2024). Flowering is common in these types and seeds produce gametic seedlings. Medium duration Kesari types which mature in eight months are referred as intermediary types and are high yielders of fresh rhizomes than Kasturi types and rich in curcumin and volatile oil. Long duration types mature in nine months and are moderately good both for rhizome yield and other quality constituents. Flowering and seed set are rare in medium and long duration types (Ecourse, 2024).

The important characteristics of *C. longa, C.aromatica, C. amada, C. angustifolia and C. zedoaria*.

***C. longa* (Popularly known as Longa types):** Pseudostem is tall, robust with oblong elliptic leaves narrowed at the base. Plant reach a height up to 1m with 8 to 10 leaves. Spike is apical, length ranges between 10-18 cm. with pale yellow flowers. Starchy root tubers are not produced at the end of fibrous roots. Rhizomes are bigger in size with more curcumin content but moderate in volatile oil (Ecourse, 2024).

***C.aromatica* (Popularly known as Kasthuri types):** In this group, cultivars mature early, within 6-7 months. Pseudostem is short with elliptic/oblong leaves. Flowering is lateral, and being a tetraploid, fertile and viable seeds are produced. Plants produce peculiar root tubers at the end of the fibrous roots. Rhizomes possess pleasant unique aroma due to volatile oil but low in curcumin content. Rhizome production is less as compared to *C. longa* types. It is used in the preparation of dyes, cosmetics and drugs but not used as a spice or condiment (Ecourse, 2024).

***C. amada (*Mango ginger):** Popularly known as mango ginger cultivated in India for its rhizomes, which have the odour of raw mangoes and it is used for the preparation of pickles , chutneys (Ecourse, 2024).

C. zedoaria: It is considered to be native of north- eastern India and to have spread in cultivation throughout the Indian subcontinent and Malaysia. The interior of the rhizome is yellow and when dried has an agreeable musky odour with a slight smell of camphor and a pungent bitter taste. Zedoary rhizomes are used in indigenous medicines in Asia and in perfumery in India (Ecourse, 2024).

BOTANICAL DESCRIPTION

A robust, perennial herbaceous plant that grows up to 1m tall with several leafy stems rising in a cluster from thick rhizomes and can slowly spread to form large clumps. Leafy shoots bear up to ten alternate distichous (arranged in two rows, one on each side of the stem) leaves. Leaves dark green above with a green midrib, very light green below, densely studded with pellucid dots. Leaf blades are thin, elliptic to oblong-lanceolate, up to 70 cm in length. Leaf petiole up to 10 cm long, broadly furrowed with narrow erect wings along the margins. The rhizome is fleshy with an ellipsoidal primary tuber at the base of each aerial stem, ringed with the bases of old scale leaves. When mature, it bears numerous straight or slightly curved cylindrical lateral rhizomes, called fingers, which are in turn repeatedly branched at approximate right angles, thus forming dense clumps. Bright orange in colour, both inside and outside, young tips white, a spicy smell is given off when the rhizome is bruised. When cut, the yellow sap stains fingers and cloth indelibly. Flowers tubular, white to yellow-white, opening one at a time and borne on erect spike-like inflorescences that are terminal on a central leafy shoot, appearing between leaf sheaths. Lower bracts pale green with white longitudinal streaks or white margins, upper ones white, sometimes pink-tipped. Bracteoles (small bract, especially on the pedicel of a flower) numerous, spirally-arranged and densely hairy, forming pockets, each with flowers inside. Turmeric does not bear fruit or seed. It reproduces asexually with new leaves produced by the rhizome (an underground horizontal stem) (Nparks, 1904). Individual plants grow to a height of 1 m, and have long, oblong leaves. Plants are gathered annually for their rhizomes, and are reseeded from some of those rhizomes in the following season. The rhizome, from which the turmeric is derived, is tuberous, with a rough and segmented skin. The rhizomes mature beneath the foliage in the ground. They are yellowish brown with a dull orange interior. The main rhizome is pointed or tapered at the distal end and measures 2.5–7.0 cm in length and 2.5 cm in diameter, with smaller tubers branching off. When the turmeric rhizome is dried, it can be ground to a yellow powder with a bitter, slightly acrid, yet sweet, taste (Benzieand Wachtel-Galor, 2011). Turmeric is a perennial herb and member of the *Zingiberaceae* family and is cultivated extensively in Asia, India, China, and countries with a tropical climate. It grows to a height of 1- 1.5 m and has large oblong leaves and funnel-shaped yellow or white flowers. The rhizome has a long history of culinary and medicinal use. Descriptions of turmeric use could be found as early as 650 BC in writings by Assyrians who used turmeric as a spice and coloring dye (Halland Bravo-Clouzet, 2013). Turmeric is an erect perennial herb but is grown as an annual. The primary tuber at the base of the aerial stem is ellipsoidal, bearing many rhizomes, straight or a little curved, with secondary branches in two rows, which may have tertiary branches, the whole forming a dense clump. The rhizomes have a distinctive taste and smell. They are brownish and scaly outside and bright orange in colour, inside. The leafy shoots are erect, less than 1 m in height, bearing 6-10 leaves with the leaf sheaths forming a pseudo stem (KSSDB, 2021). Turmeric is a herbaceous perennial plant that grows up to 1 m tall. The rhizomes are branching, bright to orange, cylindrical and scented. The leaves are placed in two rows and alternate. Leaf-sheath, petiole and leaf blade are the three parts of the leaf. A fake stem is created from the leaf sheaths. The petiole can range in length from 50 to 115 cm. Simple leaf blades range in length from 76 to 115 cm, with some reaching up to 230 cm. They are 38 to 45 cm wide and oblong to elliptical, narrowing at the tip. Stem bracts, which are white to green in colour and sometimes tinged reddish-purple, are located at the top of the inflorescence and have tapered upper ends. The flowers of hermaphrodites are threefold and zygomorphic. The three sepals are white, united and contain fluffy hairs; the three calyx teeth are uneven. The three vivid yellow petals are united into a 3-centimetre-long corolla tube. The three corolla lobes are triangular with soft-spiny top tips and measure1.0 to 1.5 cm in length. Only the median stamen of the inner circle is fertile, even though the average corolla lobe is larger than the two lateral ones (Srivastava *et al*., 2022). The base of the dust bag is spurred. The remaining stamens are transformed into staminodes. The staminodes on the outside are shorter than those on the inside. The labellum is yellowish, with a yellow ribbon in the centre, and is obovate, measuring 1.2 to 2.0 cm in length. Three carpels are held in place by a trilobed, sparsely hairy ovary. Three sections open up when the fruit capsule is opened. The blossoming season in East Asia is normally in August. An inflorescence stalk, 12 to 20 cm long and with many flowers, grows at the end of the false stem. The bracts are light green and elliptical to oblong shape with a blunt upper end, measuring 3 to 5 cm in length (Srivastava *et al.,* 2022).

Curcuma longa belongs to the Zingiberaceae family. It is a perennial herbaceous plant with tall leafy branches bearing up to twelveleaves that can grow up to two metres in height. The leaves are oblong or lanceolate, up to 1 m long, and dark green from above and pale green from below. The sheath and petiole are about the same length as the blade. *Curcuma longa* has a sterile, paleyellow and reddish bloom, with a green and purplish flowering bract. *Curcuma longa* has a rhizome that grows underground. The plant is mostly grown for its rhizome, which has tough segmented skins. The rhizome can grow to be 2.5-7.0 cm long and 2.5 cm in diameter. The rhizome has a pleasant aroma and a bitter taste. *Curcuma longa* plants are grown in the tropics and subtropics at temperatures between 20 and 30 degrees Celsius, with adequate rainfall (Suryawanshi *et al.,* 2023). *Curcuma longa* is a tall perennial rhizomatous erect herb (up to 1 m), with two to five aerial stems per plant of 90-100 cm and seven to twelve leaves in a green sheath that forms the stem. The lamina is lanceolate or elliptic, thin with acuminate tip, green or dark green on the upper surface and pale green below, with a length of 30 to 40 cm and a width of 8 to 12 cm. The inflorescence is a cylindrical fleshy, central spike with a length of 10 to 15 cm arising through the stem, and 30 flowers in a spike that open one at a time. The tubular corolla is whitish with a yellow tip. The small seeds are brown, ovoid. While those on the uppermost and lowermost bracts are sterile, the others are viable. At the base of the aerial parts, below the ground, the rhizomes are formed with one or more mother rhizomes, and primary, secondary and possibly also tertiary fingers, with the whole forming a compact clump. They are usually light brown externally, with different colors internally, from white, yellow with greenish borders or various shades of yellow, to a great many nuances of orange, from light to deep and even bluish to dee blue *(*Touwaide and Appetiti, 2023*).*

General: Turmeric is a *perennial, herbaceous* plant that grows up to 3ft tall.
Leaf morphology: The leaves of turmeric are broad, oblong, bright green, and have prominent parallel veins. They have sheaths near the base of the leaf before it attaches to the stem. The leaves are *alternately arranged*.
Floral morphology: Turmeric flowers have large, bright pink-to-purple petals on top of a long flower stalk.
Root: Turmeric has very shallow rhizomes that are thick, fleshy, and tan colored with darker brown stripes. If these structures are cut open they are bright orange and have a distinctive earthy smell. These roots are what turmeric is often known and used for (UWSP, 2024).

Turmeric is a perennial herbaceous plant that reaches up to 1 m tall. It has highly branched, yellow to orange, cylindrical, aromatic rhizomes. The leaves are alternate and arranged in two rows. They are divided into leaf sheath, petiole, and leaf blade. From the leaf sheaths, a false stem is formed. The petiole is 50 to 115 cm long. The simple leaf blades are usually 76 to 115 cm long and rarely up to 230 cm. They have a width of 38 to 45 cm and are oblong to elliptical, narrowing at the tip. At the top of the inflorescence, stem bracts are present on which no flowers occur; these are white to green and sometimes tinged reddish-purple, and the upper ends are tapered. The hermaphrodite flowers are zygomorphic and three old. The three sepals are 0.8 to 1.2 cm long, fused, and white, and have fluffy hairs; the three calyx teeth are unequal. The three bright-yellow petals are fused into a corolla tube up to 3 cm long. The three corolla lobes have a length of 1.0 to 1.5 cm and are triangular with soft-spiny upper ends. While the average corolla lobe is larger than the two lateral, only the median stamen of the inner circle is fertile. The dust bag is spurred at its base. All other stamens are converted to staminodes. The outer staminodes are shorter than the labellum. The labellum is yellowish, with a yellow ribbon in its center and it is obovate, with a length from 1.2 to 2.0 cm. Three carpels are under a constant, trilobed ovary adherent, which is sparsely hairy. The fruit capsule opens with three compartments. In East Asia, the flowering time is usually in August. Terminally on the false stem is an inflorescence stem, 12 to 20 cm long, containing many flowers. The bracts are light green and ovate to oblong with a blunt upper end with a length of 3 to 5 cm (Wikipedia, 2024).

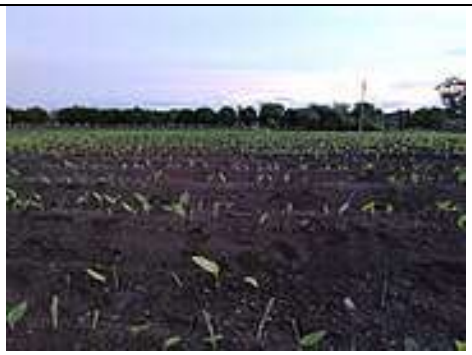
The yellow true flowers are surrounded by waxy bracts. Turmeric plants reach about 1 min height and bear long simple leaves with long petioles (leaf stems). The leaves emerge from the branching rhizomes that lie just below the soil surface. Older rhizomes are somewhat scaly and brown, while young rhizomes are pale yellow to brown-orange. The small yellow-orange flowers are borne in the axils of waxy bracts that are usually pale green or tinged with purple (EEB, 2024). Turmeric is a herbaceous perennial that reaches about three feet tall with grass-like leaves and greenish-yellow flowers. Turmeric thrives in rainy tropical areas such as the Indian subcontinent and Southeast Asia. Turmeric 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). The underground rhizome of turmeric consists of two distinct parts: the egg-shaped primary or mother rhizome, which is an extension of the stem, and the long cylindrical, multi-branched secondary rhizomes, growing downward from the primary rhizomes. The genus *Curcuma* consists of upwards of 100 different species. While *Curcuma longa* is the most widely used species (Mccormick, 2024). The wild turmeric is one among the 80 members of the plant family Zingiberaceae. The perennial foliage dies down in late autumn and the rhizomes remain dormant in winter. The inflorescence appears in early spring from the base of the rhizomes. During summer monsoon season and the immediately following weeks, the plant grows fast and vigorously. The stalk grows to about 20–30 centimetres tall, and is crowned with enlarged coloured bracts with pink tips. Leaves often appear even after the flowers. When in full growth the plants can reach a height of about 40 cm tall (Wikipedia, 2024d). An upright herb with large, oblong leaves that are dark green on the upper surface and pale green underneath. Its yellow-white flowers grow on a spike-like stalk and have small, brown seeds. Turmeric only reproduces via its underground stem (rhizome) which is thick and ringed with the bases of old leaves (KEW, 2024). Botanical description is given in Fig. 1.

Fresh Rhizomes

Germination

Seedlings

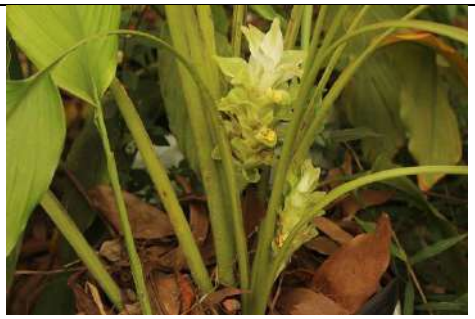
Continue …



Seedings

Plants

Plant with rhizomes



Inforences

Flower

Harvested Turmeric

Fig.1. Botanical Description

GENETICS AND CYTOGENETICS

Six different chromosome counts (2n = 22, 42, 63, 70, 77 and 105) were found, the last two representing new generic records. The basic chromosome number in the majority of Indian taxa (belonging to subgenus Curcuma) is x = 7; published counts correspond to 6x, 9x, 11x, 12x and 15x ploidy levels. Only a few species-specific C-values were found, but karyological and/or flow cytometric data may support taxonomic decisions in some species alliances with morphological similarities. Close evolutionary relationships among some cytotypes are suggested based on the similarity in homoploid genome sizes and geographical grouping (Leong-Skornickova *et al.*, 2007).

The fact that nine of 11 species studied were triploid indicates that triploidy may have some type of competitive advantage over the diploid and tetraploid. In addition, the triploids are popular commercially because of abundant rhizome production and this may contribute to their wide distributions. The chromosome number of *C. aromatica* was reported to be 2*n* = 42, 63, or 86. Variation also occurs in reports of the basic chromosome number, including *x* = 21; *x* = 7 or 8; and *x* = 7. Thus far, *x* = 21 appears to be considered acceptable as the basic chromosome number (Chen *et al*., 2013).

The chromosome number of cultivated turmeric was reported frequently as 2n=63 and basic chromosome number of the genus Curcuma is suggested as x=21 which in turn originated by dibasic amphidiploidy from x=9 and x=12 or by secondary polyploidy (ANU, 2018). Turmeric is one of the important perennial spice crop popularly known as “Indian saffron” belongs to family Zingiberaceae. It has chromosome number of 2n = 3x = 63 (Singh *et al*., 2018). *C. longa* genome has an estimated size of 1.33 Gbp with 2n = 63 chromosomes, but a wide range of genome size variation (4C values ranging from 4.30 to 8.84 pg) and chromosome number variation (2n = 48 to 2n = 64) in *C. longa* was suggested. Recent studies showed evidence for a ploidy level of 3X (2n = 63 chromosomes, basic chromosome number X = 21) (Chakraborty *et al.,* 2021). Turmeric (*Curcuma longa* L.) is a cross-pollinated, triploid (2n = 3x = 63) rhizome crop grown worldwide. It ranks among the most popular crops globally, boasting a pungent favour and an attractive colour (Alam *et al*., 2024).

GENETIC DIVERSITY

Turmeric is an industrially important plant used for production of curcumin, oleoresin and essential oil. In the present study we examined the genetic diversity among turmeric accessions from 10 different agro-climatic regions comprising 5 cultivars and 55 accessions. Two DNA-based molecular marker techniques, *viz.*, random amplified polymorphism DNA (RAPD) and inter simple sequence repeat (ISSR) were used to assess the genetic diversity in turmeric genotypes. A total of 17 polymorphic primers (11 RAPDs and 6 ISSRs) were used in this study. RAPD analysis of 60 genotypes yielded 94 fragments of which 75 were polymorphic with an average of 6.83 polymorphic fragments per primer. Number of amplified fragments with RAPD primers ranged from 3 to 13 with the size of amplicons ranging from 230 to 3000 bp in size. The polymorphism ranged from 45 to 100

with an average of 91.4%. The 6 ISSR primers produced 66 bands across 60 genotypes of which 52 were polymorphic with an average of 8.6 polymorphic fragments per primer. The number of amplified bands varied from 1 to 14 with size of amplicons ranging from 200 to 2000 bp. The percentage of polymorphism using ISSR primers ranged from 83 to 100 with an average of 95.4%. Nei's dendrogram for 60 samples using both RAPD and ISSR markers demonstrated an extent of 62% correlation between the genetic similarity and geographical location. The result of Nei's genetic diversity (*H*) generated from the POP gene analysis shows relatively low genetic diversity in turmeric accessions of South Eastern Ghat (P7), Western undulating zone (P8) with 0.181 and 0.199 value whereas highest genetic diversity (0.257) has been observed in Western central table land (P9). Knowledge on the genetic diversity of turmeric from different agro-climatic regions can be used to future breeding programs for increased curcumin, oleoresin and essential oil production to meet the ever-increasing demand of turmeric for industrial and pharmaceutical uses (Singh *et al*., 2012).

Thirty two genotypes of turmeric from all the north eastern state of India along with Duggirala Red as check variety were evaluated to study the genetic parameters in respect of yield and yield attributing characters. Fifty three traits were analyzed for phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h2) and expected genetic advance at 5 per cent selection intensity. The study revealed the presence of significant genetic variability, moderate to high heritability along with good genetic advance as percent of mean. The genotypes giving higher values of these characters indicated that the individual plant selection based on these characters may be given more emphasis and hence better selection process for further crop improvement programme. Thus, the result of the present study demonstrated that there exists variability among different turmeric genotypes of north eastern region of India indicating high potential for effective crop improvement and/or for further manipulation of the genetic resources through breeding as the genotypes in this region are good sources of genes for many desirable traits (Luiram *et al.,* 2018).

Turmeric, is traditionally known for its immense medicinal properties and has diverse therapeutic applications. However, the absence of a reference genome sequence is a limiting factor in understanding the genomic basis of the origin of its medicinal properties. In this study, we present the draft genome sequence of *C. longa*, belonging to Zingiberaceae plant family, constructed using 10x Genomics linked reads and Oxford Nanopore long reads. For comprehensive gene set prediction and for insights into its gene expression, transcriptome sequencing of leaf tissue was also performed. The draft genome assembly had a size of 1.02 Gbp with ~70% repetitive sequences, and contained 50,401 coding gene sequences. The phylogenetic position of *C. longa* was resolved through a comprehensive genome-wide analysis including 16 other plant species. Using 5,388 orthogroups, the comparative evolutionary analysis performed across 17 species including *C. longa* revealed evolution in genes associated with secondary metabolism, plant phytohormones signaling, and various biotic and abiotic stress tolerance responses. These mechanisms are crucial for perennial and rhizomatous plants such as *C. longa* for defense and environmental stress tolerance via production of secondary metabolites, which are associated with the wide range of medicinal properties in *C. longa* (Chakraborty *et al*., 2021).

We present the chromosomal-level genome for turmeric to explore the differences between tubers and rhizomes in the regulation of curcumin biosynthesis and the mechanism of tuber formation. We assembled the turmeric genome into 21 pseudochromosomes using Pacbio long reads complemented with Hi-C technologies, which has a total length of 1.11 Gb with scaffold N50 of 50.12 Mb and contains 49,612 protein−coding genes. Genomic evolutionary analysis indicated that turmeric and ginger have shared a recent WGD event. Contraction analysis of gene families showed possible roles for transcription factors, phytohormone signaling, and plant-pathogen interactions associated genes in adaptation to harsh environments. Transcriptomic data from tubers at different developmental stages indicated that candidate genes related to phytohormone signaling and carbohydrate metabolic responses may be associated with the induction of tuber formation. The difference in curcumin content between rhizomes and tubers reflected the remodeling of secondary metabolites under environmental stress, which was associated with plant defense in response to abiotic stresses. Overall, the availability of the *C. longa* genome provides insight into tuber formation and curcumin biosynthesis in turmeric as well as facilitating the understanding of other *Curcuma* species (Yin *et al.,* 2022).

We unravel the diversity among 200 Indian turmeric accessions based on rhizome yield traits and curcuminoids content. Clustering and correlation studies were also performed to group the turmeric accessions and to observe the relationship between the traits. Results revealed the presence of large variability among turmeric accessions including the major traits such as yield (24.77 g p^{-1} to 667.63 g p^{-1}), dry recovery percentage (13.42% to 29.18%), curcumin (0.41% to 2.17%), demethoxycurcumin (0.38% to 1.45%), bisdemethoxy curcumin (0.37% to 1.24%) and total curcuminoid content (1.26% to 4.55%). The superior germplasm identified for curcuminoids content were as follows; curcumin (CL 157 – 2.17% and CL 272 – 2.13%), demethoxy curcumin (CL 253 – 1.45% and CL 157 – 1.31%), bisdemethoxycurcumin (CL 216 – 1.24% and CL 57 – 1.11%) and total curcuminoid content (CL 157 – 4.55% and CL 272 – 4.37%). Clustering based on dendrogram, grouped 200 accessions into seven clusters. Among seven clusters, the maximum number of accessions were grouped into cluster II while cluster VII showed maximum mean value for majority of the traits. Correlation analysis revealed a significant relationship between the traits where the total curcuminoid content is significantly and positively correlated with the primary rhizome core diameter and length of the secondary rhizome. The selection of these particular traits may result in the identification of germplasm with high total curcuminoid content. Taken together, it is the first report on the large screening of turmeric accessions for variation in the rhizome yield traits and curcuminoids content. The genetic diversity revealed in this study could be useful for further crop improvement programs in turmeric to develop new varieties with high rhizome yield coupled with high curcuminoids content (Dudekula *et al*., 2022).

A study involving 53 turmeric genotypes evaluated for rhizome yield and related traits at Spices Research Center, Bogura, Bangladesh over three years (2019–22). A randomized complete block design was followed with two replications. ANOVA

revealed significant trait variations among genotypes. Genotype T0015 emerged as the highest yielder at 28.04 t/ha. High heritability (0.58–0.99) and genetic advance characterized plant height (PH), mother rhizome weight (WMR), primary and secondary finger weights (WPF and WSF), and yield per plant (YPP) across seasons. Genetic gain (GG) was prominent in these traits. Genotypic and phenotypic coefficient variations (GCV and PCV) (6.24–89.46 and 8.18–90.88, respectively) across three years highlighted mother rhizome weight's importance followed by numbers of primary finger (NPF), and WPF. Positive and significant correlations, especially with PH, WMR, WPF, and YPP, emphasized their relevance to fresh yield (FY). Multiple linear regression identified PH, number of mother rhizome (NMR) and WMR as key contributors, explaining 37–79% of FY variability. Cluster analysis grouped genotypes into five clusters with maximum distance observed between clusters II and III. The geometric adaptability index (GAI) assessed adaptability and superiority, revealing nine genotypes outperforming the best existing cultivar. Genotype T0117 as the top performer based on GAI, followed by T0103 and T0094. Mean rank analysis favoured T0121 as the best performer, succeeded by T0117, T0082 and T0106. The top ten genotypes (T0015, T0061, T0082, T0085, T0094, T0103, T0106, T0117, T0121 and T0129) were identified as superior based on yield and overall ranking, warranting further evaluation. These findings may induce a window for improving turmeric research and ultimately play a role in enhancing its cultivation and productivity (Alam *et al.,* 2024).

Turmeric plants produce a wide range of important and unique chemical compounds, such as curcumin, oleoresin, and essential oils, which are all the most important sources for turmeric-based industrial products. In this respect, the assessment of genetic diversity among available turmeric genotypes and germplasm core collections is an essential step to accelerate the genetic improvement process of production of its compounds and productivity. To this end, 22 turmeric genotypes selected from the germplasm collected from different regions were examined in the current study using the DNA-based simple sequence repeat (SSR) marker technique to investigate their genetic diversity, relation, and geographical distribution. Hence, 22 turmeric genotypes were evaluated by 26 SSR markers to determine the genetic variability. Among them, 5 primers showed 100% polymorphism, *viz.,* CuMiSat 19, CuMiSat 24, Clon 1, CSSR 14, and CSSR 18. On the other hand, among the studied turmeric genotypes, CL 258, CL 202, and CL 125 were identified as the most deviating and potentially useful genotypes for any further breeding program of turmeric plants. In addition to that, the linkage and divergence of these genotypes were further designed with unweighted pair group method with arithmetic mean (UPGMA) cluster analysis and obtained SSR primer data. As a result, based on the analysis of SHAN matrix using UPGMA, the estimated turmeric genotypes were divided into several clusters due to the significant relationships as well as the considerable genetic diversity among them. Then, the comprehensive UPGMA dendrogram was generated using Jaccard's similarity index based on SSR data. Notably, cluster-I and cluster-II shared a common node with a coefficient of 0.82%. Collectively, the obtained results of this investigation demonstrated that the SSR markers could be a useful tool in the introduction process of new and modern turmeric cultivars possessing tailor-made essential traits such as better adaptation and resilience to current climatic change scenarios along with high performance in terms of productivity as well as production of curcumin, oleoresin, and essential oil compounds which together make turmeric a promising industrial crop in the near future (Ravindran *et al*., 2024).

BREEDING

Breeding Methods (Ecourse, 2024)

Selection: Among the characters, plant height, rhizome yield, curing percentage , curcumin content, oleoresin content and resistance to leaf blotch and leaf spot diseases recorded higher percentage of genetic advance indicating scope for selection. Estimation of oil and curcumin contents in different cultivars of *C. longa* and *C. aromatica* indicated that variability for oil and curcumin content was high in *C. longa* compared to *C. aromatica* and for identifying cultivars with high curcumin and oil content, it may be worthwhile to carry out selection in *C. longa* alone. Hybridization: Hybridization work is limited in turmeric as commercial cultivars are sterile triploids of *C. longa.* Mutation breeding: Efforts were made to evolve improved varieties through mutation breeding which resulted in release of a few varieties, such as BSR 1, BSR 2, CO 1 and Suroma.

Varieties

Roma, Suroma, Saguna, Sudarshan, Prabha, Rashmi, B.S.R. Talent (Shahdol, 2024).

Yield

The estimated yield of turmeric is 25 to 30 tonnes per hectare (Shahdol, 2024).

Why Indian Turmeric is the Best (Wikipedia, 2024a)

Rich Curcumin Content: Indian turmeric is prized for its high curcumin levels, the bioactive compound known for its medicinal properties.

Varietal Diversity: Regions like Erode and Alleppey produce distinct varieties with unique flavors and colors.
Sustainability Practices: Many Indian farms focus on organic farming, minimizing chemical use for purer produce.
Global Reputation: Indian turmeric is a staple in global markets, trusted for its quality and compliance with export standards.
Versatility: Widely used in culinary, medicinal, and cosmetic industries, Indian turmeric offers unmatched versatility.

Uses

There are many other uses of turmeric (Bhowmik *et al.*, 2009).

- Improves the ability of the liver to remove toxic chemicals taken into the body.
- Stops the oxidation of the body's cholesterol which is the leading cause of diabetic heart disease and atherosclerosis
- Provides a natural source of vitamin B6 which keeps homocysteine levels low protecting the walls of the blood vessels
- Lowers cholesterol
- Provides protection from neurodegenerative diseases including Alzheimer's
- Aids in the treatment of cystic fibrosis
- Treats digestive Disorders
- Reduces inflammation of the middle layer of the eye
- Treats liver disease including cirrhosis, hepatitis, jaundice and enlarged hepatic ducts
- Relieves the pain of osteoarthritis
- Relieves menstrual cramp pain
- Heals bacterial infections
- Improves skin conditions and diseases including psoriasis
- Defends or potentially defends against HIV

In addition to its use as spice, it has other uses too. Turmeric is a natural source of yellow dye used for dying cotton, silk or wool without a mordant. Turmeric powder and water are used as cosmetics. Turmeric is considered a carminative, tonic, blood-purifier, vermicide and an antiseptic. The essential oil of turmeric is antiseptic. It is used in treating gall stones and gall complaints. The anti-microbial properties of essential oil from turmeric are reported against pathogenic bacteria and fungi (KSSDB, 2021). Turmeric is used in the form of masala, coloring material, medicine and medicine, in addition to religious activities, its utility in medicine and domestic use is as follows. As a main element of food, it is used to enhance the taste of food, it is most useful in food, turmeric has anti-cancer properties. Turmeric is used in beauty to brighten the skin. Turmeric is used as a pain reliever in case of internal bleeding (Shahdol, 2024).

Beauty and cosmetics: Turmeric extracts have been used to dye creams. Traditionally, women would rub turmeric into their cheeks to produce a golden glow. In India, people sometimes add an infusion of rhizome pieces to their bath water which is thought to improve skin tone (KEW, 2024).

Cultural: The bright, orange-yellow rhizomes of turmeric have auspicious connotations in India. They are often hung in kitchens and are sometimes tied to pots for good luck. In Hinduism, turmeric is associated with fertility, prosperity, and good luck and so it often features in weddings and other special occasions. Yellow and orange are both special colours in Hinduism and so turmeric dye is very popular during the Hindu festival Holi, which people celebrate by covering themselves with bright dyes (KEW, 2024).

Food and drink: Turmeric powder has a warm, bitter flavour like black pepper and an earthy, mustard-like aroma. It is the main ingredient of curry powder and an important yellow food dye that is added to a lot of Indian foods, including curries, pickles, and rice. In Europe and the USA, it is also widely used as a colouring agent in processed foods, sauces, and confectionery (KEW, 2024).

Health: Turmeric has been shown to have anti-cancer, anti-bacterial, anti-fungal, antioxidant and anti-inflammatory properties. There has been much interest in the use of turmeric for conditions such as irritable bowel syndrome, rheumatoid arthritis, and Alzheimer's disease. Some studies suggest it may have cholesterol lowering effects and it is considered to improve liver function. The essential oil from turmeric has been reported to have some insect repellent properties. In traditional Chinese and Indian medicine, turmeric has long been used as an anti-inflammatory and to aid digestion. It has also been used as an antiseptic and general tonic and applied externally to wounds and insect bites. In Ayurvedic medicine, turmeric has been used to counteract ageing processes. In Unani medicine, it has been used for conditions such as liver disorders and dysentery and has been applied externally for ulcers and inflammation. In India, Pakistan and Bangladesh, some traditional medicines reputed to alleviate asthma and coughs have been prepared from turmeric rhizomes (KEW, 2024).

Wild turmeric has rhizomes with a peculiar fragrance and cream color. The rhizomes are often used as a culinary ingredient, and in traditional medicine, for skin disorders and as an antibacterial agent. It is also commonly used in ethnic cosmetic products. As a culinary ingredient it is used in limited quantities as a natural food colour. Leaves are broad and very decorative, elliptic with a leaf stem running as long to the tip of the blade. A fresh stalk with flowers and leaves, cut to proper size and shape, can be used as a floral indoor decoration in vase for up to 10 days (Wikipedia, 2024d).

Food: Turmeric has found application in canned beverages, baked products, dairy products, ice cream, yogurt, yellow cakes, biscuits, popcorn-color, sweets, cake icings, cereals, sauces, gelatins, etc. It is a significant ingredient in most commercial curry powders. Turmeric (coded as E100 when used as a food additive) is used to protect food products from sunlight. The oleoresin is used for oil-containing products. The urcumin/polysorbate solution or curcumin powder dissolved in alcohol is used for water containing products. Over-coloring, such as in pickles, relishes and mustard, is sometimes used to compensate for fading. In combination with annatto (E160b), turmeric has been used to color cheeses, yogurt, dry mixes, salad dressings, winter butter and margarine. Turmeric is also used to give a yellow color to some prepared mustards, canned chicken broths and other foods (often

as a much cheaper replacement for saffron). Turmeric is widely used as a spice in Indian and other South Asian cooking. Momos (Nepali meat dumplings), a traditional dish in South Asia, are spiced with turmeric (Wikidoc, 2024).

Medicine: In the Ayurvedic medicine, turmeric is thought to have many medicinal properties and many in India use it as a readily available antiseptic for cuts and burns. Whenever there is a cut or a bruise, the home remedy is to reach for turmeric powder. Ayurvedic doctors say it has fluoride which is thought to be essential for teeth. It is also used as an antibacterial agent. It is taken in some Asian countries as a dietary supplement, which allegedly helps with stomach problems and other ailments. It is popular as a tea in Okinawa, Japan. It is currently being investigated for possible benefits in Alzheimer's disease, cancer and liver disorders. Turmeric, under the name Avea, is becoming popular to treat depression. It is only in recent years that Western scientists have increasingly recognised the medicinal properties of turmeric. According to a 2005 article in the Wall Street Journal titled, "Common Indian Spice Stirs Hope," research activity into curcumin, the active ingredient in turmeric, is exploding. Two hundred and fifty-six curcumin papers were published in the past year according to a search of the U.S. National Library of Medicine. Supplement sales have increased 35% from 2004, and the U.S. National Institutes of Health has four clinical trials underway to study curcumin treatment for pancreatic cancer, multiple myeloma, Alzheimer's, and colorectal cancer (Wikidoc, 2024).

Cosmetics: Turmeric is currently used in the formulation of some sunscreens. Turmeric paste is used by some Indian women to keep them free of superfluous hair. Turmeric paste is applied to bride and groom before marriage in some places of India and Pakistan, where it is believed turmeric gives glow to skin and keeps some harmful bacteria away from the body. It also acts as an excellent anti-scarring agent when mixed with milk and applied on skin (Wikidoc, 2024). The Government of Thailand is funding a project to extract and isolate tetra hydro curcuminoids (THC) from turmeric. THCs (not to be confused with tetra hydro cannabinol, also known as THC) are colorless compounds that might have antioxidant and skin lightening properties and might be used to treat skin inflammations, making these compounds useful in cosmetics formulations (Wikidoc, 2024).

Dye: Turmeric makes a poor fabric dye as it is not very lightfast (the degree to which a dye resists fading due to light exposure) (Wikidoc, 2024).

Gardening: Turmeric can also be used to deter ants. The exact reasons why turmeric repels ants is unknown, but anecdotal evidence suggests it works (Wikidoc, 2024).

Most turmeric is used in the dried powder form to impart a golden yellow color. Turmeric is used in spice blends of the Caribbean, India, North Africa, the Middle East, and Indonesia such as curry powder and rendangs. It is the main ingredient in Madras style yellow curry powder, which was invented by the British in the 19th century. Turmeric is used in a hot drink called "turmeric latte" or "golden milk" that is made with coconut milk. In addition to its use as a flavoring, turmeric is a powerful coloring agent. It is traditionally used to color and flavor prepared mustard, pickles, relish, chutneys, and rice dishes as well as butter and cheese (Mccormick, 2024). Turmeric's popularity as a super food and natural remedy has soared in recent years. Its active compound, curcumin, is the subject of numerous scientific studies for its potential health benefits. Turmeric supplements, teas, and tonics have flooded the market, catering to those seeking its anti-inflammatory and antioxidant properties. In the culinary world, turmeric has transcended cultural boundaries. It has found its way into smoothie bowls, golden lattes, and even ice cream. Its earthy flavour and vibrant color continue to captivate chefs and food enthusiasts alike. The history of turmeric is a tapestry woven with threads of culture, trade, and tradition. From its humble origins in India to its global prominence, turmeric has not only tantalized your taste buds but also enriched your understanding of the interconnectedness of the world. Its journey through time is a testament to the enduring allure of this golden spice, as it continues to shape our health, our cuisine, and our cultures in the modern era. So, the next time you savour a dish infused with the warmth of turmeric, remember the millennia of history that have gone into that single, delectable bioactive ingredient (Zofffoods, 2024). Turmeric is one of the main ingredients of curry powder, and is used to give it the characteristic yellow color. It is also delicious added to rice dishes, seafood, and mustards and pickles. Turmeric is also more widely used as a colorant for textiles and food products. It is sometimes substituted for saffron as it is much less expensive, but produces the same yellow color. Turmeric has also been used as an alternative to medicine and can be made into a drink. Indian turmeric, often called the "Golden Spice," holds a significant position in global markets for its versatile benefits. Its rich curcumin content makes it a natural powerhouse of anti-inflammatory and antioxidant properties, aiding in managing arthritis, improving skin health, and boosting overall immunity. In food products, turmeric enhances flavor, provides vibrant color, and supports digestion. It's also integral to Ayurvedic medicine and modern wellness practices. Indian turmeric stands out due to its superior quality, sustainable farming practices, and global trust, making it an essential choice for health, beauty, and culinary industries (Wikipedia, 2024a). Turmeric is one of the key ingredients in many Asian dishes, imparting a mustard-like, earthy aroma and pungent, slightly bitter flavor to foods. It is used mostly in savory dishes, but also is used in some sweet dishes, such as the cake *sfouf*. In India, turmeric leaf is used to prepare special sweet dishes, *patoleo*, by layering rice flour and coconut-jaggery mixture on the leaf, then closing and steaming it in a special utensil (*chondrõ*). Most turmeric is used in the form of rhizome powder to impart a golden yellow color. It is used in many products such as canned beverages, baked products, dairy products, ice cream, yogurt, yellow cakes, orange juice, biscuits, popcorn, cereals and sauces. It is a principal ingredient in curry powders. Although typically used in its dried, powdered form, turmeric also is used fresh, like ginger.Turmeric is used widely as a spice in South Asian and Middle Eastern cooking. Various Iranian *khoresh* recipes begin with onions caramelized in oil and turmeric. The Moroccan spice mix rasel hanout typically includes turmeric. In South Africa, turmeric is used to give boiled white rice a golden color, known as *geelrys* (yellow rice) traditionally served with bobotie. In Vietnamese cuisine, turmeric powder is used to color and enhance the flavors of certain dishes, such as *bánh xèo*, *bánh khọt*, and *mìQuảng*. The staple Cambodian curry paste, *kroeung*, used in many dishes, including fish amok, typically contains fresh turmeric. In Indonesia, turmeric leaves are used for Minang or Padang curry base of Sumatra, such as *rendang*, *sate padang*, and many other varieties. In the Philippines, turmeric is used in the preparation

and cooking of *kuning*, *satti*, and some variants of *adobo*. In Thailand, fresh turmeric rhizomes are used widely in many dishes, in particular in the southern Thai cuisine, such as yellow curry and turmeric soup. Turmeric is used in a hot drink called "turmeric latte" or "golden milk" that is made with milk, frequently coconut milk. The turmeric milk drink known as *haldīdūdh* means turmeric in Hindi) is a traditional Indian recipe. Sold in the US and UK, the drink known as "golden milk" uses nondairy milk and sweetener, and sometimes black pepper after the traditional recipe (which may also use ghee).Turmeric is approved for use as a food color, assigned the code E100. The oleoresin is used for oil-containing products. In combination with annatto (E160b), turmeric has been used to color numerous food products. Turmeric is used to give a yellow color to some prepared mustards, canned chicken broths, and other foods—often as a much cheaper replacement for saffron (Wikipedia, 2024).

The European Medicines Agency concluded that turmeric herbal teas, or other forms taken by mouth, on the basis of their long-standing traditional use, could be used to relieve mild digestive problems, such as feelings of fullness and flatulence. Turmeric grows wild in the forests of South and Southeast Asia, where it is collected for use in classical Indian medicine (Siddha or Ayurveda). In Eastern India, the plant is used as one of the nine components of *nabapatrika* along with young plantain or banana plant, taro leaves, barley (*jayanti*), wood apple (*bilva*), pomegranate (*darimba*), *Saraca indica*, *manaka* (*Arum*), or *manakochu*, and rice paddy. The Haldi ceremony called *gayeholud* in Bengal (literally "yellow on the body") is a ceremony observed during wedding celebrations of people of Indian culture all throughout the Indian subcontinent (Wikipedia, 2024). In Tamil Nadu and Andhra Pradesh, as a part of the Tamil–Telugu marriage ritual, dried turmeric tuber tied with string is used to create a Thali necklace. In western and coastal India, during weddings of the Marathi and Konkani people, Kannada Brahmins, turmeric tubers are tied with strings by the couple to their wrists during a ceremony, *Kankana Bandhana*. In many Hindu communities, turmeric paste is applied to the bride and groom as part of pre-wedding festivities known as the haldi ceremony. Turmeric makes a poor fabric dye, as it is not light fast, but is commonly used in Indian clothing, such as saris and Buddhist monks' robes. During the late Edo period (1603–1867), turmeric was used to dilute or substitute more expensive safflower dyestuff in the production of *beniitajime shibori*.Friedrich Ratzel reported in *The History of Mankind* during 1896, that in Micronesia, turmeric powder was applied for embellishment of body, clothing, utensils, and ceremonial uses. Native Hawaiians who introduced it to Hawaii make a bright yellow dye out of it (Wikipedia, 2024).

The rhizomes of this plant are boiled and dried to form a light, airy, bright yellow powder that can be used as a spice in cooking. Rhizomes can also be eaten raw or grated in small quantities. Turmeric in this form is also a major ingredient in curry powder. Turmeric is also used as a coloring agent in manufactured products and has historically and culturally been used as a dye for clothing in Indian culture. This plant has historically been used for diverse medicinal uses although little rigorous scientific testing has been done on turmeric's medicinal properties in modern times. Major components of this plant, most especially curcumin (a component of the rhizome that gives it its yellow color and many medicinal properties). Turmeric and curcumin has been used as a cure for inflammation, arthritis, depression, liver disease, digestive stimulant, allergies, skin conditions, and anti-cancer tumours. This plant also has natural antimicrobial and antifungal properties. Although little rigorous scientific studies have been done on the safety of turmeric as a medicine, it has been consumed and used in these ways for millennia by many different cultures (UWSP, 2024).

Traditional Medicine: In folk medicine, turmeric has been used in therapeutic preparations over the centuries in different parts of the world. In Ayurvedic practices, turmeric is thought to have many medicinal properties including strengthening the overall energy of the body, relieving gas, dispelling worms, improving digestion, regulating menstruation, dissolving gallstones, and relieving arthritis. Many South Asian countries use it as an antiseptic for cuts, burns, and bruises, and as an antibacterial agent. In Pakistan, it is used as an anti-inflammatory agent, and as a remedy for gastrointestinal discomfort associated with irritable bowel syndrome and other digestive disorders. In Pakistan and Afghanistan, turmeric is used to cleanse wounds and stimulate their recovery by applying it on a piece of burnt cloth that is placed over a wound. Indians use turmeric, in addition to its Ayurvedic applications, to purify blood and remedy skin conditions. Turmeric paste is used by women in some parts of India to remove superfluous hair. Turmeric paste is applied to the skin of the bride and groom before marriage in some parts of India, Bangladesh, and Pakistan, where it is believed to make the skin glow and keep harmful bacteria away from the body. Turmeric is currently used in the formulation of several sunscreens. Several multinational companies are involved in making face creams based on turmeric (Benzieand Wachtel-Galor, 2011).

In Ayurvedic medicine, turmeric is a well-documented treatment for various respiratory conditions (e.g., asthma, bronchial hyperactivity, and allergy), as well as for liver disorders, anorexia, rheumatism, diabetic wounds, runny nose, cough, and sinusitis. In traditional Chinese medicine, it is used to treat diseases associated with abdominal pain. From ancient times, as prescribed by Ayurveda, turmeric has been used to treat sprains and swelling. In both Ayurvedic and traditional Chinese medicine, turmeric is considered a bitter digestive and a carminative. Unani practitioners also use turmeric to expel phlegm or *kapha*, as well as to open blood vessels in order to improve blood circulation. It can be incorporated into foods, including rice and bean dishes, to improve digestion and reduce gas and bloating. It is a cholagogue, stimulating bile production in the liver and encouraging excretion of bile via the gallbladder, which improves the body's ability to digest fats. Sometimes, turmeric mixed with milk or water is taken to treat intestinal disorders as well as colds and sore throats (Benzieand Wachtel-Galor, 2011).

India produces nearly all of the world's turmeric crop and consumes 80% of it. With its inherent qualities and high content of the important bioactive compound curcumin, Indian turmeric is considered to be the best in the world. Erode, a city in the South Indian state of Tamil Nadu, is the world's largest producer of and the most important trading center for turmeric. It is also known as "Yellow City," "Turmeric City," or "Textile City." Sangli, a city of Maharashtra, is second only to Erode in size and importance as a production and trading site for turmeric. Before turmeric can be used, the turmeric rhizomes must be processed.

Rhizomes are boiled or steamed to remove the raw odour, gelatinize the starch, and produce a more uniformly colored product. In the traditional Indian process, rhizomes were placed in pans or earthenware filled with water and then covered with leaves and a layer of cow dung. The ammonia in the cow dung reacted with the turmeric to give the final product. For hygienic reasons, this method has been discouraged. In present-day processing, rhizomes are placed in shallow pans in large iron vats containing 0.05–0.1% alkaline water (*e.g.,* solution of sodium bicarbonate). The rhizomes are then boiled for between 40–45 minutes (in India) or 6 hours (in Hazare, Pakistan), depending on the variety. The rhizomes are removed from the water and dried in the sun immediately to prevent overcooking. The final moisture content should be between 8% and 10% (wet basis). When finger tapping of the rhizome produces a metallic sound, it is sufficiently dry. The dried rhizomes are polished to remove the rough surface. Sometimes, lead chromate is used to produce a better finish, but for obvious reasons this practice should be actively discouraged. The powder maintains its coloring properties indefinitely, although the flavor may diminish over time. Protecting the turmeric powder from sunlight retards the rate of deterioration (Benzieand Wachtel-Galor, 2011).

Pharmacological Properties

A. Antidiabetic Effect: A hexane extract (containing ar-turmerone), an ethanolic extract (containing ar-turmerone, curcumin, demethoxycurcumin, and bisdemethoxycurcumin), and an ethanolic extract from the hexane extraction residue (containing curcumin, demethoxycurcumin, and bisdemethoxycurcumin) were found to stimulate adipocyte differentiation dose-dependently. According to the findings, turmeric ethanolic extract containing both curcuminoids and sesquiterpenoids is more hypoglycemic than either curcuminoids or sesquiterpenoids alone. The insulin change was substantially higher 30 and 60 minutes following the OGTT with C. longa. The insulin AUCs were likewise considerably greater after C. longa ingestion following the OGTT (Suryawanshi *et al.,* 2023).

B. Hepatoprotective properties – Turmeric has been shown in studies to protect the liver from a range of hepatotoxic insults, including carbon tetrachloride (CCl4), galactosamine, and acetaminophen (paracetamol). Turmeric's hepatoprotective qualities are mostly due to its antioxidant characteristics as well as its ability to inhibit the generation of proinflammatory cytokines. Curcumin supplementation dramatically reduced liver damage. Turmeric lowered Aspergillus parasiticus infection and suppressed fungal aflatoxin formation by 90%. Aflatoxin-induced biliaryhyperplasia, lipid alterations, and necrosis were likewise reversed by turmeric and curcumin. Sodium curcuminate, a curcumin salt, also has choleretic characteristics since it increases biliary excretion of bile salts, cholesterol, and bilirubin, as well as bile solubility, potentially preventing and treating cholelithiasis. Curcumin also protects cells from paracetamol-induced lipid peroxidation. This could be due to the antioxidative characteristics of curcumin's phenolic groups (Suryawanshi *et al*., 2023).

C. Anti-cancer property- Anti-cancer properties Animal studies show that inhibition occurs at all three stages of carcinogenesis: initiation, promotion, and progression. Curcumin regulates transcription factors that control phase I and II carcinogen detoxification during initiation and promotion.; downregulates proinflammatory cytokines, free radical-activated transcription factors, and the vicyclo oxygenase and lipoxygenase pathways involved in arachidonic acid metabolism; and scavenges free radicals. Curcumin has been shown in animal experiments and in vitro research using human cell lines to suppress carcinogenesis at three stages: tumour promotion, angiogenesis, and tumour growth. Turmeric and curcumin have been shown in both in vitro and in vivo studies to reduce the effect of several prevalent mutagens and carcinogens in a variety of cell types. Turmeric and curcumin are anticarcinogenic due to their direct antioxidant and free-radical scavenging properties, as well as their potential to indirectly boost glutathione levels, assisting in hepatic detoxification of mutagens and carcinogens, and blocking nitrosamine production. Curcumin also kills cancer cells and inhibits angiogenesis. The effectiveness of turmeric extract in decreasing chemically-induced tumours was investigated. When compared to controls, the use of curcumin and turmeric extract during carcinogenesis and promotion resulted in fewer papilloma creation. This suggests that the greatest characteristics of curcumin and turmeric extract are produced during tumour promotion (Suryawanshi *et al.,* 2023). D. Anti-microbial properties- Turmeric extract and essential oil of Curcuma longa suppress the growth of a variety of bacteria, parasites, and harmful fungi. Turmeric-enriched meals were observed to reduce small intestine lesion scores while enhancing weight gain in chicks infected with the caecal parasite Eimera maxima. Another study discovered that applying turmeric oil topically to guinea pigs infected with dermatophytes, pathogenic moulds, or yeast suppressed dermatophyte and pathogenic fungus growth. Seven days after turmeric treatment, lesions in guinea pigs infected with dermatophytes and fungus improved and eliminated. Curcumin also exhibits anti-Plasmodium falciparum and anti-Leishmania major organism action. Antifungal, antibacterial, phytotoxic, cytotoxic, and insecticidal properties of an ethanolic extract of turmeric were investigated. Trichophyton longifusus and Microsporumcanis were resistant to the extract's antifungal and antibacterial properties, but not Staphylococcus aureus. Lemna minor was discovered to be poisonous (Suryawanshi *et al.,* 2023).

E. Anti-depressant properties- Curcuma longa extract restored the decrease in serotonin, and dopamine concentrations while increasing serotonin turnover, cortisol levels, and serum corticotrophin-releasing factor. The effect of curcumin was investigated in a chronic moderate stress (CMS) paradigm. CMS-treated rats consume much less sucrose and have greater levels of IL-6, TNF, CRF, and cortisol than control rats. Treatment with ethanolic extract restored sucrose intake to normal control levels, reduced the CMS-induced increase in blood IL-6 and TNF- levels, and restored CRF levels to normal levels in serum and the medulla oblongata. It also returned blood cortisol levels to normal. Turmeric has antidepressant properties that are mediated through the inhibition of monoamine oxidation (Suryawanshi *et al.,* 2023). F. Cardiovascular diseases - Turmeric has been shown to reduce cholesterol and triglyceride levels, reduce LDL susceptibility to lipid peroxidation, and prevent platelet aggregation. Turmeric extract lowered LDL lipid peroxidation susceptibility while also reducing plasma cholesterol and triglyceride levels. Turmeric extract has been shown to reduce cholesterol levels via lowering cholesterol uptake in the intestines and increasing cholesterol

conversion to bile acids in the liver. It is hypothesised that *C. longa* components reduce platelet aggregation by enhancing prostacyclin synthesis and lowering thromboxane synthesis (Suryawanshi *et al.,* 2023).

Health benefits (Bhowmik *et al*., 2009).

- It is a natural antiseptic and antibacterial agent, useful in disinfecting cuts and burns.
- When combined with cauliflower, it has shown to prevent prostate cancer and stop the growth of existing prostate cancer.
- Prevented breast cancer from spreading to the lungs in mice.
- May prevent melanoma and cause existing melanoma cells to commit suicide.
- Reduces the risk of childhood leukemia.
- Is a natural liver detoxifier.
- May prevent and slow the progression of Alzheimer's disease by removing amyloyd plaque buildup in the brain.
- May prevent metastases from occurring in many different forms of cancer.
- It is a potent natural anti-inflammatory that works as well as many anti-inflammatory drugs but without the side effects.
- Has shown promise in slowing the progression of multiple sclerosis in mice.
- Is a natural painkiller and cox-2 inhibitor.
- May aid in fat metabolism and help in weight management.
- Has long been used in Chinese medicine as a treatment for depression.
- Because of its anti-inflammatory properties, it is a natural treatment for arthritis and rheumatoid arthritis.
- Boosts the effects of chemo drug paclitaxel and reduces its side effects.
- Promising studies are underway on the effects of turmeric on pancreatic cancer.
- Studies are ongoing in the positive effects of turmeric on multiple myeloma.
- Has been shown to stop the growth of new blood vessels in tumors.
- Speeds up wound healing and assists in remodeling of damaged skin.
- May help in the treatment of psoriasis andother inflammatory skin conditions.

The Chinese and Ayurvedic (Indian) systems of medicine list turmeric as an ingredients used to treat various illnesses such as rheumatism, bodyache, skin diseases, intestinal worms, diarrhea, intermittent fevers, hepatic disorders, biliousness, urinary discharges, dyspepsia, inflammations, constipation, leukoderma, amenorrhea, and colic (Hall and Bravo-Clouzet, 2013). Turmeric is the most important spice, food preservative, and coloring agent in India. Turmeric is also used extensively in the traditional systems of medicine like Ayurveda, Unani, and Siddha, the various folk medicines and as a household remedy for various diseases. Turmeric also possesses immense ceremonial value and is an important constituent in the various religious functions and traditions in India. Turmeric belongs to family Zingiberaceae and although indigenous to India is today also cultivated in Sri Lanka, Indonesia, Bangladesh, Burma, and Pakistan. India accounts for more than 90% of the total output of the world. Turmeric is a perennial herb having a short stem with large simple oblong leaves. Its tubers (rhizomes) are oblong or ovate or pyriform and are often branched. Externally, the rhizomes are yellowish brown, while the internal surface is orange in color. They possess the characteristic odor and are slightly pungent bitter to taste. Depending on these organoleptic features, various varietals of turmeric are found, the most important being the Krishna, Suvarna, Rajendra, Sonia, Suguna, and Sudarshana (Hegde *et al*., 2013). Turmeric and curcumin have been studied in numerous clinical trials for various human diseases and conditions, with no high-quality evidence of any anti-disease effect or health benefit. There is no scientific evidence that curcumin reduces inflammation, as of 2020.https://en.wikipedia.org/wiki/Turmeric#cite_note-nelson-9 There is weak evidence that turmeric extracts may be beneficial for relieving symptoms of knee osteoarthritis, as well as for reducing pain and muscle damage following physical exercise. There is good evidence that turmeric is an allergen (Wikipedia, 2024).

Cooking Tips: Turmeric is best when paired with other spices and herbs such as warm spices with complimentary flavor profiles such as cinnamon, black pepper, and ginger. Partner turmeric with coconut milk to create authentic homemade curries or golden milk. Use turmeric to add a splash of color and flavor to your favorite dishes. Add 1/4 tsp to the water when cooking 1 cup rice to give a yellow color. Or try adding ½ teaspoon of turmeric to store bought (or homemade) mac and cheese for a healthful and colorful boost. Fresh turmeric can be found in some gourmet markets. Before using, peel as you would ginger root. The root can then be grated or chopped. Helpful tip: turmeric can stain cooking equipment. To combat this, you can coat wooden utensils with mineral oil before use or try washing out stains using a mix of baking soda, soap, and hot water (Mccormick, 2024).

Powder and Oil: Turmeric powder is about 60–70% carbohydrates, 6–13% water, 6–8% protein, 5–10% fat, 3–7% dietary minerals, 3–7% essential oils, 2–7% dietary fiber, and 1–6% curcuminoids. The golden yellow color of turmeric is due to curcumin. Phytochemical components of turmeric include diarylheptanoids, a class including numerous curcuminoids, such as curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Curcumin constitutes up to 3.14% of assayed commercial samples of turmeric powder (the average was 1.51%); curry powder contains much less (an average of 0.29%) (Wikipedia, 2024). Some 34 essential oils are present in turmeric, among which turmerone, germacrone, atlantone, and zingiberene are major constituents (Wikipedia, 2024).

Nutritional Value: Cured turmeric has moisture 5.8%; protein 8.6%; fat 8.9%; carbohydrates 63.0%; fibre 6.9%; mineral matter 6.8%; calcium 0.2%; phosphorus 0.26%; iron 0.05%; sodium 0.01%; potassium 2.5%; vitamin-A 175 IU/100 g; vitamin-B_1 0.09 mg/100 g; vitamin-B_2 0.19 mg/100g; vitamin-C 49.8 mg/100 g; and niacin 4.8 mg/100 g. It has a calorific value or food energy 390 calories/100 g. The colouring principle in turmeric is curcumin. Turmeric is an important spice among the rice-easting people (KSSDB, 2021).

Production: Among the two major varieties of turmeric, the Chinna Nadan variety is grown widely. Erode Turmeric occupies more than 70% of the turmeric grown in Erode and Coimbatore districts. As of 2021, the variety is grown in 50,000 acres across Tamil Nadu. The turmeric is exported to countries like Bangladesh, Malaysia (Wikipedia, 2024c). India is the largest producer and exporter of turmeric in the world having an area of 1,08,000 hectares. Among the turmeric growing states, Andhra Pradesh stands first with 30 per cent of the total annual national production of 2,95,000 tonnes, followed by Maharastra, Tamil Nadu, Kerala, Karnataka, Orissa, Assam, Bihar and West Bengal. Out of total production, 12,588 tonnes is being exported to Libya, Moracco, USA, Iran, Japan, UK and Singapore, earning nearly Rs. 171.6 million as foreign exchange (KSSDB, 2021).

Trade and Commerce: During the Age of Exploration, turmeric was among the sought-after spices that motivated European maritime expeditions. The spice trade, dominated by the Portuguese and Dutch, had a profound impact on the economies of both Europe and Asia(Zofffoods, 2024). As colonial powers expanded their influence, they introduced turmeric cultivation in regions like the Caribbean and Africa. This resulted in a diversification of turmeric's geographical sources and trade routes. However, it also brought about challenges such as forced labour and exploitation of indigenous knowledge (Zofffoods, 2024).

CULTIVATION

Climate: Turmeric prefers warm and humid climate and can be cultivated in most of the tropics and subtropics provided rainfall is adequate or irrigation facilities are available. An annual rainfall of 100-200 cm is ideal. It can be grown from sea level to 1220 m. above MSL at the temperature range of 15-35^{O}C. High temperature and low humidity cause slow emergence of the pseudostem and leaves (Agriculture, 2020; KSSDB, 2021; Prasath *et al.*, 2024).

Soil: Turmeric can be grown in various types of soil, however, a well-drained loamy or alluvial soils with good organic matter status in a pH range of 5.00 to 7.5 is optimum for the crop. The crop cannot withstand water logging. Gravelly, stony and heavy clay soils are unsuitable for the crop because of their interference with the development of rhizomes (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

Varieties: Several cultivars are distinguished in our country by the names of localities in which they are grown. The widely grown cultivars in Karnataka are as follows:

***Kasturi*:** The core of the rhizome is pale yellow to white. It gives a sweet fragrance after curing.

Mundaga: The rhizomes are large and thick with many fingers.

Balaga: The corns are not so thick. The number of fingers are also less.

Yalachaga: The rhizome are small and few in number but has more number of fingers (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

The other popular cultivars grown in different states are Kesari, Kuvvur, Amrutapani, Kothapeta, Duggrala, Tekurpet, Mydukur, Aromoor, Vontimitta, Sugandham, Nandyal, Avanigadda (Andhra Pradesh); Erode, Salem (Tamil Nadu); Aleppy, Mannuthy Local (Kerala) Shillong, Tall Karbi (Assam); Rajpuri, Evaigon (Maharastra); Duhgi, Jobedi, Katingia (Orissa) and Gorakhpur (Uttar Pradesh) (Agriculture, 2020; KSSDB, 2021; Prasath *et al.*, 2024)

Some of the improved varieties of turmeric (Agriculture, 2020; KSSDB, 2021; Prasath *et al.*, 2024).

Variety	Average yield of fresh rhizomes (t/ha)	Duration (days)	Dry recovery (%)	Cur-cumin (%)	Oleore-sin (%)	Recommended for
BSR-1	30.70	285	20.5	4.20	4.0	Tamil Nadu
BSR-2^{+}	37.5	240-245	20.0	3.75	-	Tamil Nadu
Co 1	30.50	285	19.5	3.20	6.7	Tamil Nadu
IISR Prabha	37.47	205	19.5	6.53	15.0	Kerala and Tamil Nadu
IISR Prathiba	39.12	225	18.5	6.21	16.2	Kerala and Tamil Nadu
Kanti	7.90**	240-270	-	7.18	-	-
Krishna	9.20	240	16.4	2.80	3.8	Maharashtra
Megha Turmeric-1	23.0	-	-	-	-	Meghalaya
Rajendra Sonia	4.80	225	18.0	8.40	-	North Bihar
Ranga	29.00	250	24.8	6.30	13.5	Orissa, Tamil Nadu, Andhra Pradesh and Kerala
Rasmi	31.30	240	23.0	6.40	13.4	Orissa, Tamil nadu, Andhra Pradesh and Kerala
Roma	20.70	250	31.0	9.30*	13.2	Tamil Nadu, Himachala Pradesh, Andhra Pradesh and Kerala
Sobha	5.74**	-	-	7.19	15.9	-
Sudarsana	28.80	190	12.0	5.30*	15.0	Kerala and Andhra Pradesh
Sugandham	15.00	210	23.3	3.10	11.0	Gujarat Tolerant to pests
Suguna	29.30	190	12.0	7.30*	13.5	Kerala and Andhra Pradesh
Suroma	20.00	253.0	26.0	9.30	13.1	Orissa, Tamil Nadu and Himachal Pradesh
Suvarna	17.40	200	20.0	4.30	13.5	Kerala, Karnataka and Andhra Pradesh

The variety RH-10 released as a clonal selection matures in 288 days and is resistant to leaf-blotch. Pant pectabh is also an improved variety. The varieties PCT-13 has been identified as source of resistance for the rhizome-rot disease. The genetic resources holding of turmeric in India is 1136 (Agriculture, 2020; KSSDB, 2021; Prasath *et al.*, 2024)

Cultivation

Propagation: Turmeric does not grow from seed. Commonly propagated by dividing and planting the rhizome. Rhizome Depth: 10-15 cm. Space Between Plants: 30 cm. Space Between Rows: 40 cm. Days for Sprouting: 14–30 days. Unless you live in the tropics, where it can be planted anytime, plant in late spring. Turmeric is generally propagated by using whole or split mother rhizomes. The synseed technology and also micro-propagation protocols for rapid multiplication have been developed for turmeric(Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024)

Land preparation: The land should be ploughed five to seven times thoroughly to a depth of 22-25 cm followed by two to three plantings, and all the weeds are cleared away. Well rotten Farm Yard Manure or compost at the rate of 40 t/ha should be mixed in the soil. After land preparation is completed the field is laidout either in to beds of 1-1.5 m width, 15-25 cm height and of convenient length or by forming ridges and furrows (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

Planting: Healthy and disease –free rhizomes should be stored during harvest in underground pits. By the beginning of April, when the seed rhizomes start sprouting, they should be taken out from the pits for planting. Care should be taken to protect the sprouting buds from mechanical injury. The planting should be started with the commencement of monsoon. Whole or split mother rhizomes as well as finger rhizomes (25-30 g each) are used as planting material (@ 2.5 t/ha). The seed rhizomes are treated with 0.3 per cent Dithane M-45 and 0.1 per cent quinalphos prior to storage and again at the time of sowing to minimise both rhizome rot as well as rhizome scales. The spacings are 30 cm x 25 cm on beds. In case of ridges and furrows, the ridges are 45-60 cm apart and the rhizomes are planted at 25 cm along the side of ridges (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Manures and fertilizers: Basal dose of Farm Yard Manure @ 40 tonnes per hectare is applied at the time of land preparation. Under rainfed conditions, fertilizer dose of 30:30:60 or 60:30:90 kg of NPK per hectare is recommended while, in irrigated conditions the fertilizer requirement is 60:30:90 kg of NPK. The fertilizers are applied in three split doses. The whole of P_2O_5 and half the dose of K_2O are applied as basal and N is supplied in two split doses after 45 (60% of the recommended N) and 90 (40% of the recommended N) days after planting along with the remaining half dose of K_2O (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Irrigation: Turmeric can be grown either as a rainfed crop (Kerala, Orissa and North–eastern states) or an irrigated crop (Andhra Pradesh and Tamil Nadu) depending on location. In case of irrigated crop, depending on weather and soil conditions, 15-40 irrigations may be necessary at 7-10 days intervals(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Mulching: Immediately after planting, the field is mulched with green leaves at 15 tonnes per hectare. The same is repeated after 50 days of planting when the rhizomes have sprouted out fully (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024).

Interculture: Weeds should be controlled manually or by the use of herbicides. Usually, it is done thrice at 60, 120 and 150 days after planting, depending upon the weed intensity. Early weeding may be avoided by the use of 2,4-D as a pre-emergent herbicide. Earthing up is done 60 days after planting(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Inter cropping and crop rotation: Turmeric comes up well under sparse shade also. It can be grown as an intecrop in coconut gardens like ginger or as mixed crop with red gram, chilli, colocasia, vegetables, maize and ragi. In wetlands it can be rotated with paddy, sugarcane, banana or vegetables. In garden lands, rotation is done with rainfed paddy or mixed with redgram, maize, groundnut and sunflower(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024),

Pests

Shoot borer* (Conogethespunctiferalis*)-As in ginger, shoot borer is an important pest of turmeric also. The larvae bore into pseudostems and feed on growing shoot resulting in yellowing and drying of infested shoots. Presence of bore holes in the pseudostem through which frass is extruded and the withered central shoot (dead heart) are characteristic symptoms of pest infestation. Spraying Monocrotophos (0.075%), or Dimethoate (0.1%) or Quinalphos (0.025%) during July-October at monthly intervals controls the pest infestation. *Hexameris* Sp., hymenopteran parasitoids have been identified as bio-control agents for this pest (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024).

***Leaf roller* (*Udaspesfolus*):** The pest is abundant in the field during August-October. Spraying Carbaryl (0.1%), Dimethoate or Phosphamidon (0.05% each) control the pest (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

***Rhizome scale* (*Aspidiellahartii*):** The pest infests both in field and in storage. In field, the plants wither and dry during severe infestation. In storage, shriveling of buds and rhizomes are observed due to pest attack. Dipping the seed rhizomes of turmeric in Quinalphos (0.025%) or Fenitrothion (0.05%) for 5 minutes after harvest and before planting/storage + spraying of phosphomedon

(0.05%) in the field controls the pest infestation.The larvae of the crane fly (*Libnotespunctipennis*) and rhizomes fly (*Calobataalbimana*) have been reported to bore the rhizomes (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

***Nematodes* (*Meloidogyne incognita*):** Affected plants show stunted growth, yellowing, marginal and tip drying of leaves, reduced tillering and galling and rotting of roots. High population of *M.incognita* causes yellowing and severe stunting and withering in large patches. Plants die prematurely leaving a poor crop stand at harvest. Infested rhizomes lose their bright yellow colour(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

***Radopholus similes* -** The infested plants show tendency to aging and dry faster than healthy plants. Infested rhizomes are of yolk-yellow colour compared with the golden yellow colour of healthy rhizomes and have shallow water-soaked brownish areas on the surface. Roots show rotting and most of the decayed roots are devoid of cortex and stelar portion. Application of Thimet @ 10-15 kg/ha or Phorate 10 kg/ha at the time of field prepration or Aldicarb and Carbofuran (1-3 kg a.i/ha) 3 weeks after planting controls the nematode infestation. The varieties Kodour and Chayapasupu are resistant to root-knot nematodes. The other species of nematodes reported to cause damage to this crop are *Longidorous elongatus, Xiphinemaelongatum, Hoplolaimusseinhorstii, Helicotylenchusmulticinctus, Tylenchorhychus martini, Pratylenchusdelattrei* and *Rotylenchulusreniformis* (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024)

Diseases

***Leaf blotch*:** The disease is caused by *Taphrina maculans*. The disease starts as small scattered oily looking translucent spots on the lower leaves when the plants are in 3-to-4-leaf stage. The leaf spots later turn dirty yellow and deepen to colour of gold and sometimes to hay shade. The adjacent individual leaf spots of 1-2 mm in diameter coalesce forming reddish brown blotches leading to varying degrees of leaf blight. Foliar sprays with Dithane Z-78 (0.2%) or Dithane M-45 (0.25%) at 15 days interval controls the disease (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Leaf spot: It is caused by *Collectotrichumcapsici.* Infection is confined usually to leaf blades and occasionally extends to leaf sheath also. Disease appears as elliptic to oblong spots of variable size on both surfaces, but more on upper surface. These spots gradually enlarge in size and coalesce to cover entire leaf area of form large necrotic patches. The spots vary from 4-5 cm in length and 2-3 cm in breadth. A fully developed spot has grayish white center with brown margin surrounded by yellowish in defined halo. In severe infections, leaves dry up and defoliate. Spraying of Bordeaux mixture (1%) or Dithane M-45 (0.25%) controls the disease (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

***Rhizome rot*:** The disease is caused by *Pythium graminicolum* and *Pythium aphanidermatum*. This is an important disease prevalent in all turmeric growing areas. The disease appears in patches in the field. The leaves of infected plants become yellow and exhibit gradual drying along the margins. Water-soaked lesions develop on the pseudostem and become soft to touch. The root system is adversely affected. Roots rot completely. As the disease progresses, infection gradually spreads. Infected rhizomes turn brown in colour. In case of severe attack., yield is reduced considerably. Planting of healthy rhizomes and seed treatment with Dithane M-45 (0.25%) + Carbendazim (0.1%) for 60 minutes and drying under shade for 24 hours before sowing/storage are the recommended control measures. The seed rhizomes should be dipped in Blitox 50 (0.3%) before storage or Carbendazim or Bordeaux mixture at the first apperance of the disease symptoms to control the disease. *Trichoderma harziarum*, *Trichoderma hamatum* or *Trichoderma viride* can be used as bio-control agents for this disease (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

Harvesting and yield: Turmeric comes to maturity in 7-10 months after planting depending upon the variety. The noticeable maturity indices are complete yellowing of leaves and drying up of plants including the pseudo stem. Usually the land is ploughed or dug with spade and the whole clump is lifted with the plant, including the base of the stem. While doing so we must see that the rhizomes are not injured. The leafy tops are then cut off, the roots removed, and the rhizomes are thoroughly washed with water to remove the adhering earth. The fingers (daughter rhizomes) are separated forms the rounds (mother rhizomes) manually. The yield in turmeric has been observed to vary too much. However, yield of about 20-25 tonnes of raw turmeric per hectare in case of irrigated and 6-9 tonnes per hectare in case of rainfed crop is considered satisfactory.After keeping the required quantity of rhizomes for planting the rest of the bulk is cured and polished (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

Processing: The quality of cured turmeric is assessed on the basis of several factors such as curcumin content, the organoleptic character, the general appearance, size and physical form of the rhizome. The method of curing in turmeric consists of boiling or steaming the prepared fresh rhizomes in water, drying in the sun and finally peeling or polishing. The following steps are involved in processing (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Cleaning: The harvested rhizomes are cleaned off other extraneous matter adhering to them and the roots removed. Only good fingers separated from the rhizomes are used for curing (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Boiling: The process is aimed at destroying the vitality of the fresh rhizomes and to obviate raw odour, to reduce the drying time, to gelatinize the starch and give a more uniformly coloured product.The fingers and mother rhizomes are separated and cured separately, since mother rhizomes take a little longer time to cook. Boiling is done in galvanized iron vats or pan or other containers of suitable size. A pan of 1 m length, 0.62 m breadth and 0.48 m depth is found to be suitable. Cleaned fingers (approximately 50 kg) are taken in trough of size 0.9 m x 0.55 m x 0.4 m made of GI sheet with extended parallel handle. This

perforated trough in which fingers are kept is then immersed in the pan. An alkaline solution prepared by dissolving 100 g sodium bicarbonate ($NaHCO_3$) or sodium carbonate ($NaCO_3$) in 100 ml of water is poured into the trough so as to immerse the turmeric fingers. The whole mass is boiled till the fingers become soft. This can be tested by piercing with a wooden needle. If the needle passes through the rhizome without much resistance, the softness is confirmed. Usually the boiling is continued for 45 to 60 minutes until frothing occurs and white fumes appear emitting a characteristic turmeric odour (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024). Cooked fingers are takenout of the pan by lifting the trough and draining the solution into the pan. Alkalinity of the boiling water helps the development of Orange - yellow tinge to the core of the turmeric. The drained solution in the pan can also be used for cooking another lot of turmeric along with fresh solution prepared for the purpose. Usually, the cooking of turmeric is to be done within 2 or 3 days after harvesting. The colour and aroma of the final product depends much on the stage at which boiling is stopped. Therefore, skilled persons should be compiled for this job. Both delayed cooking and over cooking will spoil the quality of the final product (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024)

Drying: The cooked fingers are sun dried by spreading out on a bamboo mat or on the drying floor for 5-7 days until the moisture reduces to 8-10 per cent which is fit enough for storage and sale. Sun drying of sliced turmeric in particular gives a slight surface bleaching effect on the colour. During the night-hours, the material should be heaped and covered over to protect it from dew. It takes 10-15 days for the rhizomes to become thoroughly dry, when they become quite hard and brittle, and break (with the fingers) with a metallic sound (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Polishing: The operation is done in order to smoothen the rough and hard outer surface of the boiled and then dried turmeric. It also improves the colour of the product from dirty-brown to bright-yellow. As such there are two types of polishing they are Hand polishing and Machine polishing (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Hand Polishing: This method is simple, which involves rubbing the turmeric fingers wrapped in several folds of gunny cloth on hard surface with hands or trampling them under feet or shaking the rhizomes mixed with stones in a long narrow gunny bag or in bamboo basket. The improved method mounted on a central axis, the sides of which are made or expanded metal mesh. When the drum filled with turmeric is rotated, the abrasion of surface against the mesh as well as by mutual rubbing against each other will give effective polishing (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

***Machine Polishing*:** The machine used for polishing consists of a hexagonal wooden drum mounted on central axis and rotated by power. These power driven drums are gaining popularity because higher degree of polishing (smoothness) can be attained by this method. Capacity of these drums is also high compared to hand operated ones and hence the output is also more (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024).

Colouring: Colour of turmeric always attracts buyers. Thus, giving the required colour externally to the rhizome is an important item of work in the processing of turmeric. For this the boiled, dried and half-polished fingers are taken in a basket, which is shaken continuously in a prepared emulsion. They are later sun dried. The colour emulsion comprises of alum (0.04 kg), turmeric powder (2 kg), castor seed (0.14 g) or sodium bisulphate (30 g) and concentrated HCl (30 ml) (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Grading (Indian standards): Turmeric is included in the list of spices which must have an 'Agmark' grading before they can be exported from India. Three grades of finger turmeric, two of bulb turmeric and one grade of powdered turmeric are specified, as follows (Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024):

- Finger turmeric, other than Alleppy variety is subgraded into 'Special' 'Good' and 'Fair'.
- Alleppey finger turmeric is sub-graded into 'Good' and 'Fair'.
- Rajapore finger turmeric is sub-graded into 'Special'. 'Good' and 'Fair'.

The maximum limit for extraneous matter in the prime sub-grades of the above grades of whole turmeric is 1.0 per cent. In the case of Alleppey finger turmeric exported to the United States, the content of extraneous matter according to the specifications of the American Spice Trade Association is usually less then 0.5 per cent. In case of Turmeric powder, the characteristics are more exacting. Maximum percentage limits are specified for moisture, total ash, acid insoluble ash and starch. Processing is given in Fig. 2.

Fresh Rhizomes

Drying Rhizomes

Cleaning Rhizomes with boiling water

Continue…


Dried Rhizomes


Polished termeric


Powders

Fig. 2. Processing

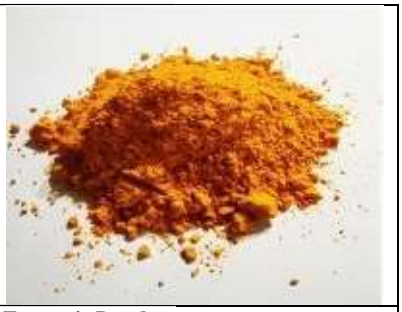
Value added products: The value added products of turmeric are curcuminoids, dehydrated turmeric powder, oil, oleoresin (Agriculture, 2020; KSSDB, 2021; Prasath *et al.,* 2024).

Estimation of curcumin content: For this, the cured rhizomes should be ground to a fine powder and 0.1 g of the powder should be extracted with 40 ml of distilled alcohol by refluxing over a water cooled condenser for 2 ½ hours. The extract should then be filtered into a 100 ml volumetric flask and made upto volume with alcohol. An aliquot of 5 ml should be transferred to a 100 ml volumetric flask and again the volume is made up. The absorbance of the solution could be measured at 425 nm with alcohol as the blank. Curcumin is highly aromatic with musky odour and a pungent bitter taste, when it comes in contact with alkali it turns red and is called '*Kum kum*'(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024).

Turmeric oleoresin: It is a highly viscous orange-brown product containing 30-35% curcumin, 15-20% volatile oil and has a characteric turmeric aroma. Turmeric oleoresin is prepared by extraction of a good quality turmeric powder with solvents like acetone, alcohol or ethylene – dichloride and subsequent desolventisation to meet the specifications. Since turmeric oleoresin is highly viscous, it is mixed with dilutents like propylene glycol or vegetable oil, to obtain a homogenous pourable product, such products, though have a lower colour value, are more suitable for specific end uses. New generation products based on turmeric oleoresin include spice emulsions/aqua resins and encapsulated water dispersable powders with advantages like dispersibility in oil or water, and ease of application. A stablished curcumin colourant has been prepared by spray drying turmeric oleoresin with an organic acid, a buffer, a dispersant and an encapsulating material. Also, a powdered colouring agent, where in curcumin is completed with gelatin in acetic acid has been reported(Agriculture, 2020; KSSDB, 2021; Prasath *et al*., 2024). Value Added Products is given in Fig. 3.


Polished Turmeric


Dried Turmeric


Turmeric Powder


Turmeric Oleoresin

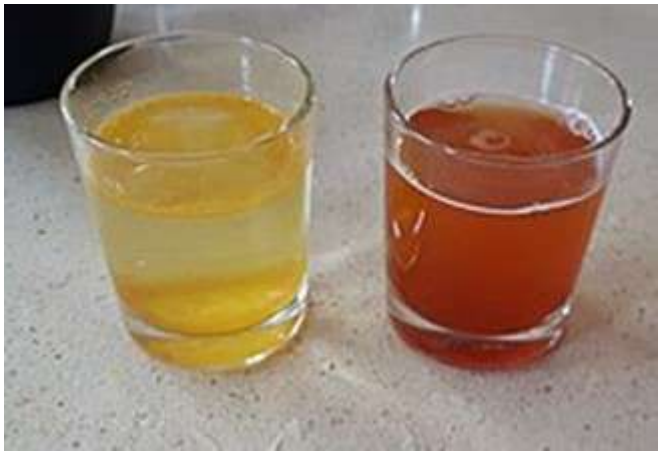

Turmeric Oil


Oil


Turmeric Oleoresin

Fig. 3. Value Added Products

Appearance: The flesh of the Turmeric rhizome is orange-brown, yellow or reddish-yellow in color. Ground dried turmeric is soft and fine and bright yellow-orange in color. Compounds in turmeric called "curcuminoids" are responsible for its bright color.Flavor Characteristics are bitter, green, medicinal, minty, musty, and woody. The rhizomes contain 2–5% of volatile oil and compounds called "turmerones" are responsible for the characteristic flavor of turmeric. Compared to its cousin, ginger, the flavor of turmeric is not nearly as spicy (Mccormick, 2024).



Indicator: Turmeric dispersed in water is yellow under acid and red under alkaline conditions Turmeric paper, also called curcuma paper or in German literature, *Curcumapapier*, is paper steeped in a tincture of turmeric and allowed to dry. It is used in chemical analysis as an indicator for acidity and alkalinity. The paper is yellow in acidic and neutral solutions and turns brown to reddish-brown in alkaline solutions, with transition between pH of 7.4 and 9.2 (Wikipedia, 2024).

Adulteration: As turmeric and other spices are commonly sold by weight, the potential exists for powders of toxic, cheaper agents with a similar color to be added, such as lead oxide ("red lead"). These additives give turmeric an orange-red color instead of its native gold-yellow, and such conditions led the US Food and Drug Administration (FDA) to issue import alerts from 2013 to 2019 on turmeric originating in India and Bangladesh. Imported into the United States in 2014 were approximately 5.4 million kilograms of turmeric, some of which was used for food coloring, traditional medicine, or dietary supplement. Lead detection in turmeric products led to recalls across the United States, Canada, Japan, Korea, and the United Kingdom through 2016. Lead chromate, a bright yellow chemical compound, was found as an adulterant of turmeric in Bangladesh, where turmeric is used commonly in foods and the contamination levels were up to 500 times higher than the national limit. Researchers identified a chain of sources adulterating the turmeric with lead chromate: from farmers to merchants selling low-grade turmeric roots to "polishers" who added lead chromate for yellow color enhancement, to wholesalers for market distribution, all unaware of the potential consequences of lead toxicity. Another common adulterant in turmeric, metanil yellow (also known as acid yellow 36), is considered by the BritishFood Standards Agency as an illegal dye for use in foods (Wikipedia, 2024).

Safety: The use of turmeric as a spice and as a household remedy has been known to be safe for centuries. To date, no studies in either animals or humans have discovered any toxic effects associated with the use of turmeric, and it is clear that turmeric is not toxic even at very high doses. The U.S. Food and Drug Administration (FDA) has conducted its own clinical trials with turmeric and published a 300-page monograph. The FDA has declared turmeric and its active component curcumin as GRAS (generally regarded as safe). Thus, in the United States, turmeric and its components are currently being used in mustard, cereals, chips, cheese, butter, and other products. In a phase I clinical study on the safety and tolerance of turmeric oil use, the oil was administered orally to healthy volunteers for 3 months. No side effects of turmeric oil intake were observed in 3 months on body weight, blood pressure, and hematological, renal, or hepatic toxicity (Benzieand Wachtel-Galor, 2011).

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