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Advances in production technology of turmeric

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Abstract
Turmeric (*Curcuma longa* L.) is a tropical perennial rhizomatic spice crop belonging to the family Zingiberaceae and triploid species (2n = 3x = 63) commonly used as a spice, cosmetics and natural food dye. Turmeric is one of the most important ancient spices grown in India which plays an important role in the national economy. India is hub of spices as well as the largest producer and exporter of turmeric in the world and accounts for more than 46 per cent of the world trade. The highest genetic diversity is concentrated in India and Thailand, with at least 40 species in each area, followed by Burma, Bangladesh, Indonesia and Vietnam. Because of existing variability among cultivars, genotypes its increasing demand in both the food and pharmaceutical industries, Since knowledge of the production practices, processing and genetic variation in the turmeric is essential to increase in quantity and quality yields and the efficiency of selection in breeding programs, as well as to direct conservation strategies in germplasm collections. To achieve these goals with relation to sustainable production, we tend to review an outline of morphology, biology and cultivation production practices of turmeric in this paper.

Keywords: Turmeric, *Curcuma longa*, family Zingiberaceae

1. Introduction
Turmeric (*Curcuma longa* L.) is one of the most widely cultivated spice since from times of immemorial its uses dates back to 4000 years to Vedic culture in India where it is used as condiments in culinary. Turmeric is also known as the "golden spice" as well as the "spice of life". It is still used as a symbol of well-being and widely used in ceremonies and religious functions. Turmeric is valued for its deep yellow colour (0.2-8% curcumin) pungency (2.2-4.2% termerol) and aromatic flavor of volatile oil (1.5-5%). During Vedic period turmeric referred as "earthy herb of the Sun" with the orange-yellow rhizome it was regarded as the "scared spice".

1.1. Medicinal and Therapeutic Uses
In Ayurvedic medicine, turmeric is primarily used as a treatment for anti-inflammatory, hepatoprotective, antitumor, antiviral, wound healing and anti-cancerous properties, and is also beneficial in treating gastrointestinal and respiratory disorders (Shiyou *et al*., 2011) [24]. Curcumin and curcuminoids (6%) be one of the most promising compounds for Alzheimer's disease therapies (Shiyou *et al*., 2011) [24]. It has various useful properties with antioxidant activities and is useful in conditions such as inflammation, ulcer and cancer, it has the potential against various cancer, diabetes, allergies, arthritis. It is also used for digestive disorders; to reduce flatus, jaundice, menstrual difficulties, and colic; for abdominal pain and distension (Nasri *et al*., 2014) [19]. Culinary uses like in the form of powder and pastes (Spice: as alone or in curry powder and pastes, food coloring) oleoresin (medicine, and dietary supplement).

1.2 Origin and distribution
The genus *Curcuma longa* has a wide spread occurrence in the tropics of South East Asia. Turmeric has been distributed in India, South-East Asian countries and North Australia. In India, turmeric is extensively cultivated in the states of Telangana, Andhra Pradesh, Odisha, West Bengal, Tamil Nadu, Assam, Maharashtra, Karnataka, Bihar and Kerala.

1.3 Botany
Curcuma longa is a herbaceous perennial, underground rhizomatic crop belonging to the family Zingiberaceae, grows to a height 60-90 cm with a short stem and long leaves. The flowers are born in cone shaped spikes in the tuft of leaves. The spikes are shorter than the leaves and supported by stout peduncles, presence of greenish-white, ovate bracts. In each bract there are two flowers which are dense spikes. Fruit is a thick walled trilocular capsule with numerous arillate seeds. In turmeric high degree of fertility (71.1%) reported.

1.4 Area and production

India is the largest producer, consumer and exporter of turmeric in the world. In India, it is being cultivated in more than 20 states in an area of 238000 ha with an annual production of 11,33,000 MT. (Horticulture at glance 2019)

Indian Institute of Spices Research (IISR), Calicut, collects and conserves turmeric genotype by both *in-situ* and *ex-situ* conservation. Till date, the National Genotype Repository of Spices at IISR maintains more than 700 accessions of turmeric, including land races, improved varieties, open pollinated progenies (OP), related species and taxa (Shamina *et al.*, 1998) [23].

2. Crop Improvement

A number of cultivars available in turmeric and are known mostly by the name of locality. There is a large considerable variability exists with regard to morphological, yield attributes and quality parameters. Presently Indian Institute of Spices Research, Calicut, research is done at the national level through AICRPS, which was initiated in 1971. The turmeric centers under AICRPS maintain about 1250 turmeric germplasm accessions. By utilizing these germplasm, 22 varieties have been developed and released for cultivation at various agro-climatic regions of the country through AlCRPS with high yield, pest/disease resistance and quality attributes.

Table 1.

Variety	Released from	Parentage	Yield (t/ha)	Dry recovery %	Curcumin %	Salient features
CO.1	TNAU Coimbatore	Vegetative mutant by x-ray irradiation of Erode local	30.5	19.5	3.2	Bold rhizomes and orange yellow colour, suitable for drought affected areas
BSR.1	TNAU Coimbatore	Clonal selection from Erode local irradiated with x rays	30.7	20.5	4.2	Adoptability in problematic soils and drought proned belts of Tamil Nadu
BSR.2	TNAU Coimbatore	Induced mutant from Erode local	32.7			Short duration cultivar with bigger rhizomes
Sugandham	SKSardar krushinagar Dantiwada	Clonal selection from germplasm	15.0	23.3	3.1	Thick, round, bold rhizomes with shorter internodes
Roma	HARS Pottangi	Clonal selection from T.Sunder	20.7	31	6.1	Suitable for both rainfed and irrigated regions
Suroma	HARS Pottangi	Clonal selection from T. Sunder by x-ray	20.0	26	6.1	Round and plumpy finger rhizome, field tolerance to leaf blotch.
Ranga	HARS, Pottangi	Clonal selection from Rajpuri local	29.0	24.8	6.3	Solid and spindle shaped mother rhizome.
Rasmi	HARS Pottangi	Clonal selection from Rajpuri	32.0	23	6.4	Solid bold rhizomes
Rajendra Sonia	Dept. of Horti RAU, Dholi, Bihar.	Selection from local germplasm	42.0	18	8.4	Bold and plumpy bright colour rhizome
Suvarna	IISR, Calicut Kerala	Selection from germplasm, collected from Assam	17.4	20	4.3	Bright orangish rhizome with slender fingers, field tolerant to insect pest and diseases
Suguna	IISR, Calicut, Kerala	Selection from germplasm, collected from AP	29.3	20.4	4.9	Early in maturing, field tolerant to rhizome rot
Sudarsana	IISR Calicut, Kerala	Collected from Singhat, Manipur	28.8	20.6	5.3	Early maturing, field tolerant to rhizome rot
IISR Prabha	IISR, Calicut	Open pollinated progeny selection	37.0	19.5	6.5	High yielding variety
IISR Prathibha	IISR, Calicut 2017 released	Open pollinated progeny selection	39.1	18.5	6.2	High yielding variety
IISR Kedaram	IISR, Calicut	Clonal selection from germplasm	34.5	18.9	5.5	Resistant to leaf blotch
IISR Alleppey Supreme	IISR, Calicut	Selection from Alleppey Finger turmeric	35.4	19	5.55	Tolerant to leaf blotch

(Shamina *et al.*, 1998) [23].

2.1 Species

- *Curcuma longa*: Cultivated one referred as Longa types
- *Curcuma aromaticum*: Rhizomes possess pleasant unique aroma due to volatile oil Popularly known as Kasthuri types
- *Curcuma amada*: Rhizome have odour of raw mangoes and popularly called as mango ginger. Used for preparation of pickels
- *Curcuma angustifolia*: Strach extracted from rhizomes, referred as Indian arrow root
- *Curcuma zedoaria*: Musky odour with smell of camphor and pungent bitter taste

3. Package of Practices

3.1 Soil

Different kinds of soils such as sandy loam to clay loam or alluvial soils are suitable. Well drained loamy soils are the best. Turmeric cannot withstand water stagnation or alkalinity.

Hossain *et al*., (2009) [9] found that growth, yield and quality of turmeric (*Curcuma longa* L.) higher when cultivated in pots with dark-red soil (pH 5.2), gray soil (pH 7.4) and red soil (pH 4.4) in Okinawa regions. Turmeric in dark-red soil had the highest yield (39.5 g/plant) with favorable color of the deep yellow and high curcumin (0.20%).

3.2 Climate
Tropical crop requiring warm and humid climate. Temperature range 21 C to 28° -35C. Growth ceases when, below 20°C it thrives well in localities with annual rainfall from 70 - 225 cm. It can be grown at an altitude of 1200 1500m. Turmeric is a partial shade tolerant plant that could be cultivated at around 59−73% RLI (Relative light intensity) for higher yield (238g/plant) and curcumin content (0.12-2.3%) in Okinawa. (Hossain *et al*., 2009) [9].

3.3 Propagation
Planting of turmeric by traditional method required more amount of quality planting material but less availability and highest cost are the main constraint. For sprouting of rhizome and its development it takes nearly five to six months. **(**Khandekar *et al*., 2019) [14].

3.3.1 Seed Material: Seed material used for propagation mother rhizome or finger rhizome.

a. Seed Selection: Both mother and finger rhizomes are used. The fingers are cut into pieces, each 4-5 cm long with 1-2 buds. Mother rhizomes are planted as such or split into two, each having one sound bud.
It is confined that use of 50-60 g mother rhizome resulted in maximum biometric characteristics like plant height (121.33 cm), leaf size of length (62.79 cm), breadth (18.05 cm) number of leaves per plant (7.33), number of tillers per plant (4.24), and stem girth (2.20 cm) (Angami *et al*., 2017) [1].
Bhanumurthy *et al*., (2018) [4] studied production of protray raised seedlings from single node cuttings of turmeric variety JTS-6 compared with check local variety. Among all variety TS-6 shows optimum yield (14.6 t/ha) Benefit/ Cost ratio ranged from 2.81 to 3.57.

Protray Techniques in turmeric
- Select healthy turmeric rhizomes for seed purpose. Treat the selected rhizomes with mancozeb (0.3%) and quinalphos (0.075%) for 30 min and store in well ventilated place
- One month before planting, the seed rhizomes are cut into single buds with small piece of rhizomes weighing 5-7 g
- Treat the single bud sprouts (mancozeb 0.3%) for 30 min before planting
- Fill the pro-trays (98 well) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with PGPR/Trichoderma 10g/kg of mixture
- Plant the turmeric bud sprouts in pro-trays. Maintain the pro-trays under shade net house (50%). Adopt need based irrigation with rose can or by using suitable sprinklers
- Seedlings will be ready within 30-35 days for transplanting (Indian Institute of Spices Research, Kozhikode)

Hossain *et al*., (2005) [8] studied on effects of seed rhizome size on growth and yield of turmeric (*Curcuma longa* L.) they opined that seed rhizomes with a greater diameter developed vigorous seedlings. The plants grown from 30 -40 g and 50 g shows maximum in plant height (140 cm) tiller number (3.5) and leaf number (12-14/plant) shoot dry weight (40 g/plant) which were significantly higher than those from lighter rhizome.

b. Seed Rate: Varies according to type of planting material, spacing and weight of rhizomes. Mother rhizomes: 2000-2500 kg/ha. Finger rhizomes: 1500-2000 kg/ha. As an intercrop in fruit garden: 400-500kg/ha.

c. Seed treatment: Rhizomes are treated with Mancozeb and Bavistin (1.5 and 2 g/1it) by dipping for 15-20 minutes for prevention of diseases and rhizomes fly during early period.
Malhotra *et al*., (2016) [17] found that the media combination of cocopeat+ FYM+ vermicompost+ VAM+ organic foliar spray ((panchagavya 1%), (jeevamrutham 1%) have significantly influence the sprouting percentage (76-98%) initially in 7-9 days and growth parameters of the turmeric transplants in the plug tray (5g rhizome weight) method.
Micropropagation studies conducted by (Thapa *et al*., 2017) [30] found that supplementations of 4.0 mg/litre BAP + 1.0 mg/ litre NAA gave the best result as well as early root initiation. In this case 95% of the inoculated explants induced multiple shoots within 8-10 days inoculation and the average number of shoots pre plant was 6.70.

d. **Preservation of seed rhizomes**
Rhizomes for seed purpose are generally stored by heaping in well ventilated rooms after harvest and covered with turmeric leaves. The seed rhizomes can also be stored in pits with saw dust, sand along with leaves of *Stychnos nux-vomica* (*kanjiram*). The pits are to be covered with wooden planks with one or two openings for aeration. The rhizomes are to be dipped in aqueous quinalphos (0.075%) solution for 20-30 minutes if scale infestations are observed and in mancozeb (0.3%) to avoid storage losses (Rhizome rot) due to fungi. (Malhotra *et al*., 2016) [17].

3.4 Planting
Bhadouria *et al*., (2014) [2] studied effect of interaction on planting methods and spacing on growth and yield of turmeric they reported that growing turmeric at in combined influence of ridge bed method with 60 x 20 cm spacing shows maximum weight of primary rhizomes was 24.15 gm, weight of secondary rhizomes 31.65 gm per plant and fresh weight of rhizomes was up to 92.39 gm per plant.
Bahudur *et al*., (2000) [3] conducted experiment on effect of different spacing and potassium levels on the growth and yield of turmeric var. sindhuri. Wide spacing (50 x 20 cm+120kg/ha) produced the tallest plant (87.89 cm) medium spacing plants produced the plant height (87.89 cm), highest number of tillers per hill (3.42), leaves per plant (8.56), total dry weight per plant (53.79 g) and highest yield per plant (189.35 g).
A field experiment was conducted at Tepi National Spice Research Center to find out optimum planting material, population density and method of planting to enhance turmeric yield and quality (Temteme *et al*., 2017) [29]. Broader plant spacing (83,333 plant density /plant/ha) produced high rhizome weight (777.69 g/clump and 599.23 g/clump+ Ridge method primary rhizome weight (390.89g/ plant) secondary rhizome weight (133.16g/ plant), by using planting material as mother rhizome fresh rhizome yield increases (67273.3kg/ha).

3.4.1 Season of Planting: May to July depending on tract. In Maharashtra, May is the best time of planting rhizomes. Karnataka and Tamil Nadu April-May sowing done.

3.5 Manures and fertilizers

Turmeric exhaustive crop requires high soil fertility and applied nutrients for successful growth and yield. In Tamil Nadu, a nutrient dosage of 150: 60: 108 kg NPK ha-[1] has been generally recommended. Split application of nutrients, especially nitrogen and potassium, has been recommended to improve the yield and quality.

To study the effect of organic, inorganic and bio- fertilizers on yield and its attributes in turmeric variety Rajendra Sonia (Singh, 2011) [27] It was thus concluded that the combined application of inorganic N (100%) + *Azospirillum* 10kg/ha + FYM 5 t/ha improved the yield and yield attributing character of turmeric.

Velmuruganet *et al*., (2014) conducted experiment on Influence of organic manures and inorganic fertilizers on cured rhizome yield and quality of turmeric *cv*. BSR-2. Highest plant height (95.12 cm), number of leaves (20.62), number of tillers (4.32) curing per centage and cured rhizome yield (21.26%, 7080.17 kg ha) was recorded in the treatment farmyard manure + azospirillum + phosphobacteria + VAM.

Application of green leaf manure (*Glyricidia maculata*) @ 12t/ha along with rock phosphate @ 0.2 t/ha, wood ash @ 1 t/ha, *Azospirillum* @ 5kg/ha and PSB @ 5kg/ha was the best treatments for yield and quality of ginger and turmeric. (Suchanad *et al*., 2018) [28].

Application of organic manures with neem cake during crop growth stage of turmeric shows the taller plant height (79.30 cm), maximum number of tillers per plant (5.40), leaf number (5.40), leaf area (44.09) leaf area index (0.429), fresh weight of halum (190.05g), fresh weight of root (49.13 g), fresh weight of rhizome per plant (256.21 g) and dry weight of halum (15.21 g), dry weight of root (7.32 g), dry weight of rhizome per plant (40.35 g), total dry matter yield (6.85 t ha^{-1}) than those received other types of manures. (Kamal *et al*., 2012) [13].

3.6 Irrigation

Irrigation is provided @ 7-10 days interval depending on soil moisture condition. A total of 20-25 irrigations are given, during the life period of the crop.

Krishnamurthy *et al*., (2015) [15] conducted experiment on Effect of fertigation on fue, quality and economics of cultivation in turmeric (*Curcuma longa* L.) *cv*. BSR- 2 revealed that the fertilizer use efficiencies were higher in fertigation treatment with 50 % level of N and K either with water soluble or straight fertilizers (Urea + Multi K) which recorded yields of 33.4 kg and 33.1 kg (T_4) cured rhizomes each kilogram^{-1} of nutrient combination applied in the study.

3.7 Intercultural Operation

Sidhu *et al*., (2016) [25] conducted experiment on effect of mulching, spacing and intercropping of green gram (*Vigna radiate*) on growth, yield and quality of turmeric (*Curcuma longa* L.) opined that maximum plant height (74.7 cm) number of tillers (2.3/plant) fresh rhizome yield (176.4 q/ha) processed rhizome yield of turmeric (48.9 q/ha) when inter row spacing of 37.5 cm provided along with mulch.

Misra, 2012 [18] studied on effect of planting distance on yield performance of turmeric varieties intercropped with guava plantation. The result asses that turmeric yield (219.76 q/ha) was higher when inter crop with guava with 20 X 20 cm planting distance. Execute of Narendra Haldi was better than the other two varieties (NDH-2 and NDH-3) in terms of yield (226.66q/ha).

Simazine or atrazine @ 2kg/ha effectively controlled weed growth in turmeric based cropping systems with pulses and Alachlor @ 2kg/ha used as pre emergence to reduced weed infestation in turmeric. (Misra, 2012) [18].

3.8 Intercropping

Mixed crops like chilli,onion, brinjal and maize can be taken. Intercropping in coconut and arecanut. In Maharashtra, it is recommended to grown French bean as an intercrop.

A field experiment was conducted to asses effects of *Azospirillum*, *Azotobacter*, Phosphate solubilizing bacteria (PSB) and Arbuscular mycorrhiza fungi (AMF) coupled with three levels (100, 75 and 50% of RDF) of inorganic NPK fertilizers on growth and yield of turmeric *cv*. Suguna grown as intercrop with Arecanut (Roy and Hore, 2009) [22]. Maximum plant height (73.85 cm) number of tillers(3.67) number of leaves (23.6) weight of clump (4.26), yield (34.44 t ha^{-1}) were observed in treatments NPK (75%) + *Azospirillum* + AMF.

3.9 Plant protection

3.9.1 Diseases

Rhizome rot and root rot (*Pythium aphanidermatum*) and Leaf bloth *(Taphrina maculans)* Chavan *et al*., (2017) [5] studied on efficacy of fungicides and bioagents against *Pythium aphanidermatum* causing rhizome rot of turmeric. The fungicides with significantly least mycelial growth were Copper oxychloride (97.36 %), followed by Chlorothalonil (76.16 %), Mancozeb (70.62 %) to reduce *Pythium aphanidermatum* infestation which cause yield losses up to 30-89%.

Lowest disease severity (31.57%) and highest fresh rhizome yield (27.67t/ha) was recorded in Ridomil (500 ppm) which was on par with thiophanate methyl (0.1%), carbendazim (0.1%), Blitox (0.3%) and Antracol (0.3%). (Singh *et al*., 2000) [26].

The two years field study indicated that rhizome treatment in hot water at 47°C for 30 min and soil application of *T. harzianum* @ 2.5 kg/ 50 kg FYM/ha, followed by three drenching of Mancozeb @ 0.25% was most effective in limiting the incidence of soft rot on turmeric besides results in improving the growth and yield (Dhor *et al*., 2015) [7].

3.9.2 Insect pest

Shoot borer *(Conogethes puctiferalis*) Rhizome scale (*Aspiodiotus hartii)* and Nematodes (*Meloidogyne spp)* Treatment T_6- Neem cake + *Paecilomyces lilacinus*(3.75g/3kg soil) performed better with maximum plant height (72.00 cm), fresh rhizome weight (325.00 g), dry rhizome weight (65.00g) and least number of galls (23.50) and lowest soil nematode population (153.25) (Prabu *et al*., 2018) [20].

3.10 Harvesting and Yield

Turmeric is harvested when leaves start yellowing and ultimately the stem dries down. Starts from February and continues till April. Rhizomes are ready for harvest in 7-9 months after planting. Harvesting consists of digging of underground clumps of rhizomes with Pick axe or digging fork. Fingers are separated from mother rhizomes.

Hossain, 2010 conducted research on effects of harvest time on shoot biomass and yield of turmeric (*Curcuma longa* L.) in Okinawa, Japan. Results are revealed that per cent of dry yield to fresh yield was higher i.e 14−22 in December and 15−24 in January; and yield-shoot ratio in dry weight was 1.2, 0.9−2.2.

3.10.1 Yield
* 250-300 q/ha for fresh rhizomes. In Maharashtra the average yield is 225 q/ha. and cured produce 20-25 % of fresh rhizome.

3.11 Processing
- **Cleaning and Drying:** Jose and Joy, 2009 [12] conducted experiment on solar tunnel drying of turmeric (*Curcuma longa* linn. Syn. *C. Domestic* val.) for quality improvement. The results proved that conventional processing could maintain the intrinsic quality up to a certain level, but extrinsic quality could not be achieved. Solar tunnel drying method is an effective alternative to traditional open sun drying, where retention of curcumin (5.83%) volatile oil (4.74%) and oleoresin (12.4%) was high, with less drying time.
  The quantitative analysis showed that the traditional drying i.e., open sun drying had taken 11 days to dry the rhizomes while solar biomass drier took only 1.5 days and produced better quality produce (Prasad *et al*., 2006) [21].

- **Curing:** It involves cleaning of fresh rhizomes, boiling in water and drying in sun.
  Jayashree *et al*., (2016) [11] studied on processing of turmeric (*Curcuma longa*) by different curing methods and its effect on quality they opined that turmeric cured by cooking in boiling water for 40, 60, 90 min, took 11 days for complete drying, maximum retention of curcumin (5.91%) and essential oil (3.6%) was obtained for rhizomes cured for 40 min. While turmeric rhizomes cured by steam cooking for 30, 45 and 60 min took 24, 23 and 12 days for drying.

- **Polishing:** Dried rhizomes are smoothing and polishing outer surface by manual or mechanical rubbing. Polishing drum rotates are employed.

- **Colouring:** Boiled and half polished rhizomes are added with turmeric powder to give good appearance. Sodium carbonate (0.05- 0.1%) Sodium bisulphite (20 g) and lime are used for increasing colour intensity (CFTRI)

- **Grading**

1. **Fingers**: Fingers usually range in size from 2.5 to 7.5 cm in length and may be over 1 cm in diameter.
2. **Bulbs**: These are central 'mother' rhizomes, which are ovate in shape and are of shorter length and having larger diameter than the fingers.
3. **Splits**: Splits are the bulbs that have been split into halves or quarters to facilitate curing and subsequent drying.
4. **Turmeric powder**: Allepy turmeric, Lakhdong turmeric and Madrass turmeric

3.12 Quality specifications for export
The ASTA and FDA chemical and physical specification of turmeric are as follows:

Table 2.

Whole insect dead (by count)	Excretes mammalian (mb/lb)	Excreta other (mg/lb)	Mould (% wt)	Insect defiled/ infected (%wt)	Extraneous matter (% wt)
3	3	2	3	2.5	5

Ash level % w/w (min.)	Acid insoluble ash % w/w (max.)	Moisture content % (max.)	Volatile oil curcumin % (min.)
8	1	10	5

3.13 Value added products
- **Turmeric Oil:** The oil is pale yellow to orange yellow in colour. The aroma of oil is due to turmerone (25.3%) and a-tumerone (18.3%). Turmeric oleoresin is obtained by solvent extraction method and is highly valued
- **Turmeric powder**: Used to flavour and to colour foodstuff and used as dye in textile industry
- **Essential oils:** Turmeric dried and cured generally yields 1.5-5% volatile oils, aromatic types yield higher oils 5.3-6.8% (Kesar types of medium duration)

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