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A REVIEW

Garcinaia Indica: A review on existing morphological and chemical variations

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SUMMARY

Garcinia indica is an indigenous tree and an important non–timber forest produce having multifarious uses in pharmaceutical, food and cosmetic industry. The ability of *Garcinia indica* to grow in different altitudes (upto to 800 metres from Mean Sea Level) and the polygamodioceous nature of tree gives variation between trees and populations. Variations are existing in colour, size, weight and chemical constituents of the fruit. Genetic variations between inter and intra populations reported provides wide opportunity for identifying suitable varieties/clones through conventional breeding and genetic improvement.

Key Words : Chemical, *Garcinia indica,* Genetic, Kokum, Populations, Variations

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The genus *Garcinia* is one of the largest genera of Clusiaceae or Guttiferae according to old classification (Cox, 1976). Clusiaceae is further divided into five subfamilies, one of which is Clusioideae. Sub-family Clusioideae has two tribes Clusiaceae and Garcicieae. Garcicieae has two genera namely *Garcinia* and *Mammea*. The genus *Garcinia* includes 200 species, out of these 30 species are reported to be grown in India (Korikanthimath and Desai, 2005 and Nadkarni *et al*., 2001). *Garcinia indica* Choisy is also known as Kokum commonly. It is also known as wild Mangosteen, Goa butter tree (Watt, 1890 and Baliga *et al*., 2011). The other vernacular names are Birand (Konkani), Brindon (Portuguese in Goa), Katambi, Punarpuli (Malayalam), Ratamba or Amsool (Marathi), Murugalu (Kannada).

In India, *Garcinia indica* is used for culinary and beverage purpose (for preparation of wine instead of grape) (Baliga *et al*., 2011). The dried rind is used as a

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substitute for tamarind in many places (Anonymous, 1956 and Jayaprakasha and Sakariah, 2002).Traditionally Goan and Konkani people mix kokum juice along with coconut milk and used as a drink after a meal which reduce the gastric problems (Menezes, 2001). In Indian traditional medicinal system Kokum plays a role in treating diarrhoea, inflammatory ailments, dermatitis, bowel problems, rheumatic pains and to prevent hyper perspiration. Fruits are used as antihelmintic and cardiotonic. Kokum juice from the rind is used against piles, colic problems, dysentery (Watt, 1890 and Baliga *et al*., 2011). Decoction of fruit rinds are traditionally used against diabetes. It also contains compounds that have antioxidant, antibacterial and antifungal properties. Scientific research indicates that the rind could be used against several cancer cell lines, including breast cancer, liver cancer and leukaemia. Besides these Kokum also exhibits anti-histamine and anti-inflammatory properties. Kokum butter from seed is another product, which is used commercially for cosmetic purpose such as Lip balm, lotions and soaps (Baliga *et al*., 2011). Kokum butter is also used traditionally to heal wounds, fissures in hands and is supposed to restore the elasticity of skin and used as a moisturiser and face creams (Jeyarani and Reddy, 1999 and Padhye *et al*., 2009).

Leaves of *G. indica* are used to treat skin ulcers, dyspepsia and hyperplasia. Kokum is well known for anti-obesity and UV-protecting activity due to the presence of chemical Hydroxy citric acid and Garcinol (a yellow fat-soluble pigment), respectively due to its antioxidant activity. The presence of red anthocyanin pigment present in the rinds of fruit is used in the dye industry as a natural colouring agent. Stable salts of calcium or potassium of (-)-HCA has become an important export commodity in India. Kokum juice is another major commercial product having a pH of 1.87 contains an organic acid namely, Hydroxy citric acid is a weight suppressing agent. The juice of the fruit is used as a mordant and the oil present in the seeds of Kokum is extensively used to adulterate ghee due to solid nature at room temperature. Kokum butter has a melting point of 39 to 43^{0}C, this property of Kokum butter make use in the preparation of heat resistant chocolate by resisting the melting of chocolate (Jeyarani and Reddy, 1999 and Maheshwari and Reddy, 2005).

G. indica is classified as one of 32 prioritized species by the National Medicinal Plant Board (NMPB). Even though, it is considered as an underutilised fruit due to unorganised and scattered plantation. Coupled with this, its uncertainty in bearing fruit and endemicity make them non-preferable by farmers. Along with these natural seedling populations, due to cross-pollination and heterozygous nature, the tree has abundant variation concerning growth, flowering and fruiting season, fruit yield and morphological and biochemical characteristics of fruits (Korikanthimath and Desai, 2005).

Distribution:

The genus *Garcinia* is distributed in tropical regions such as Asia, Africa and Polynesia. In India, *Garcinia* is widely seen in the tropical forest of Western Ghats of Maharashtra, Goa, Karnataka and Kerala (Shetty and Kaveriappa, 2001 and Naithani *et al*., 1997) and also in the evergreen forest of Assam, Khasi, Janita hills, West Bengal and Surat district of Gujarat (Patil *et al.,* 2012). However, according to Abraham *et al*. (2007) the Western Ghats region is considered as a secondary centre of origin for *Garcinia* species, where six species are endemic. Some economically important species of *Garcinia* distributed in tropical Asia are *G. mangostana*, *G. indica*, *G. gummi-gutta*, *G. xanthochymus*, *G. hombroniana*, *G. cowa* and *G. Morella*. *Garcinia* contains 200 species out of which over 30 are found in India (Patil, 2005). Out of thirty species, *G. indica* is confined to India and Sri Lanka (Patil *et al*., 2005). Kokum is a large, perennial evergreen, polygamodioceous, cross-pollinated trees. It is tall, monopodial growing tree found in the Western Coast of India, in Northern Kerala, Coastal Karnataka, Goa and Konkan belt of Maharashtra upto an elevation of 800 metres. Besides, these regions it is also found in Andaman and Nicobar Islands, Orissa and North Eastern regions to a lesser extent (Rema and Krishnamurthy, 2000). The trees are found naturally in the hill slopes, secondary forest region, rocky plateaus, stream bunds etc. They are either found single or in clusters of 2-3 on elevations of Western Ghats forests. The Kokum trees naturally co-exist in the ecosystem along with other forest and fruit trees especially like Karonda, Jamun etc. Besides, the trees found in farmers' fields are reported to exist for ages, retained without cutting along with arecanut, coconut or cashew trees (Adsule *et al*., 2001). The Kokum grows in well-drained soil with partial or deep shade in the evergreen forest for the growth of seedling (Subash Chandran 1996).

Phenology :

Garcinia indica is polygamodioceous type of plant.

It is a slender, pyramid-shaped evergreen tree with drooping branches. The leaves are ovate or oblong, lanceolate, 6.25 to 8.75 cm long and 2.5 to 3.75 cm broad, dark green above and pale beneath. The tree grows upto 10-18 meters. It flowers from November to February with fruits ripening from April to May.

The Kokum tree is described with many types of flower patterns such as (i) separate trees for male flowers; (ii) separate trees for female flowers; (iii) trees with bisexual flowers (Sawant *et al*., 1999). The unisexuality aroused by inhibition or suppression of alternative sexual whorl and may have formed from hermaphrodites through evolutionary pathways such as androdioecy or gynodioecy (Wu and Cheung, 2000). Generally, flowering usually starts during November and goes upto February (Singh, 1993). It was reported in Ratnagiri district (Maharashtra) that in males, flowering occurs from November to January and in females, it's from December to February. Fruiting seasons is from April-May. The flowers are axillary or terminal. They are solitary or in the form of clusters. Flowering in male trees starts one week early as compare to others. Flowers are with four sepals, thick and fleshy, green in colour. Flowers are pale yellow colour, borne either singly or in the cluster. Calyx is sepaloid consisting of four sepals arranged in decussate pairs. The petals are four with yellow to purple (Malik *et al*., 2019). Male flower has numerous short filamentous anthers and anthers are two-celled and oblong. Stamens cohere at base forming anthophore. Female flower is solitary or sometimes they found in a group of 2-3 flowers whereas the male flowers are 3-4 in number. It was observed that male flower has an intermediate length of pedicel as compared to female flower which has short pedicel and bisexual (hermaphrodite). Female flowers have fewer stamens or staminodes which are arranged in two, four and eight tufts surrounding pistils. The male buds are short and roundish, whereas, the female buds are oval shape and vary in size; their weight also varies from 50g to 180g. Ovary has 4-8 functional ovules with axile placentation. Bisexual flowers bear typical flowers surrounded by a ring of stamen or staminodes around carpel. Hermaphrodite tree was observed with variations to the number of flowers, size of flower, length of the stalk (pedicel) and number of stamens. The male flower contains a greater number of stamens per flower (36 to 38) in comparison with bisexual flower. Anthesis occurs early in the morning *i.e.* 6 to 8 a m with anther dehiscence occurring about 20 minutes before anthesis. The stigma is receptive on the day of anthesis and for the following 3 days (Karnik and Gunjate, 1984). It was reported high fruit set in both open (natural cross) and hand (artificial cross) pollination in Kokum which could be due to the large number of pollen grain produced by Kokum trees (Karnik *et al*., 1978). According to Baskaran and Krishnan (2012), Kokum plant is suspected to have a strong basis for genetic self-incompatibility. In *G. indica*, the pollen grains from male flowers were spheroidal with about 20µM diameter, tetrazonocolporate. The exine is coarsely granulated ornate with thickness of 2µm. The pollen grains from female flowers were much smaller in size, *i.e.* about 10µM in diameter, exine was much thicker (3 µm) and the apertures were inconspicuous (Malik *et al*., 2019).

Kokum fruit consists of three major parts, *viz.,* pericarp, it is the rind or peel (contains the highest level of xanthones), pulp and seeds (found within the white pulp). The fruits are globose or spherical, 2.50 to 3.75cm in diameter, dark purple when ripe and enclosing medium-sized seeds. The fruit has 7-10 ridges and it takes 4-5 days to ripen (Kureel *et al*., 2009). The tree takes about 8 to10 years to reach the commercial bearing stage, when grown from seeds. The fruits are edible with a pleasant flavour and sour- sweetish palate (Anonymous, 1956). Generally, the fruits mature by late May or June that interferes with harvesting and processing. The early maturing varieties have also been introduced that is harvesting can be done during February-March.

Production and cultivation :

In Maharashtra, Kokum cultivation has been virtually monopoly in Konkan region, especially in Ratnagiri and Sindhudurg district. It is estimated that in Sindhudurg district the area under Kokum is about 108 hectares scattered along riverbanks, streams, valleys, roadsides and backyard wastelands (Patil *et al*., 2012). In Goa, the production level of Kokum is estimated at 10, 200 tons from 1200 ha and it has shown continuous rising as importance crop as evident by the market trends and export scenario (Korikanthimath and Desai, 2005). In Karnataka, Uttara Kannada district is the major producer of Kokum.It is also grown in Dakshina Kannada, Shimoga, Chickmanglore and Udupi regions (Shree Padre, 2012). Priya Devi *et al*. (2012) studied the spatial distribution and the variability assessment of *Garcinia indica* using DIVA-GIS software and reported eleven taluks of Goa were found to be promising zones and identified as the hotspots for its biodiversity by using

various richness and diversity indices. Similar studies were reported by Hijmans *et al*. (2005) using DIVA-GIS for the analysis of diversity and distribution of Kokum germplasm in Goa.

The detailed statistics regarding the production area and productivity is not available as Kokum is not planted in an organized manner. As per a baseline survey in 2010, Kokum is grown on about 1000 ha area in the Konkan region with production of about 4500 tonnes fruits. According to the survey conducted by Maharashtra forest department, out of the total 46,600 Kokum trees in the state of Maharashtra; 43,000 trees existed in Ratnagiri and Sindhudurg districts (Patil *et al*., 2012). It was also reported that in South Konkan, 1674 tonnes of Kokum fruits were used for the production of dried Kokum rind, 757 tonnes for preparation of Kokum syrup and 40 tonnes for manufacture of Kokum butter. Sawant (2005) reported that in India, the estimated production is 10,200 tonnes, of which 9000 tonnes are processed.

Morphological, chemical and genetic variation in *Garcinia indica* :

Variation in plants is the consequence of genetic and environmental factors and their interaction. Degree of variation depends upon the magnitude of these factors. However, the cause and the pattern of variation also depends on many defined and undefined factors. Variation can be interspecific and intraspecific leading to changes in physical, chemical and morphological of individual trees or population. In *Garcinia*, due to cross-pollination, the dioecious nature of wild population and the progenies grown from seeds leads to higher variability in various traits.

Morphological variation :

Distribution of Kokum from an altitude ranging from 6 metres to 650 metres and growing in various habitat patterns halters the Kokum to adapt various morphometric changes. The tree characters such as leaf length, thickness, canopy etc. have played a vital role to study morphometric variation. Priya Devi *et al*. (2013) studied the various morphological characters of Kokum at different places of Goa and found out variation occurs among the populations in the different parts of Goa (Plate1). The variation in tree canopy and fruit shape has been reported in Goa. The different canopy found were conical, pyramidical, pyramidical with drooping, spreading canopy and fruit shape were of oblong, pear, spherical and spherical with pointed end (Plate 2). Korikanthimath and Desai (2005) also reported the morphological variation in Kokum. It was reported that the fruit yield vary from 50-350 kg/tree, fruit weight from 21g-85g, rind thickness from 0.2-0.8 mm, number of segment 4-8, tree height from 6-12 metre in Goa. Kallaje (2000) studied the morphological variation (Fruit length, fruit weight, rind weight, seed and pulp weight) in Uttara Kannada district and found maximum variation in Yellapur and minimum in Devimani region. Similar, studies were conducted by Mrigal *et al*. (2010) and reported that variation in fruit weight and rind thickness ranges from 14.70-71.82 g and 0.20-0.38 mm, respectively. Hegde (2019) reported the variation in both morphological and chemical of *Garcinia indica*. It was reported that the variation in fruit colour such as dark red to crimson and also pure yellow (Plate 3), horizontal fruit diameter (3.22-4.90 cm), vertical diameter of fruits (2.78-4.74 cm), fresh weight of fruit (16.24-51.00 g), fresh weight of rind (9.40-26.22 g), number of seeds per fruit (2.60-7.00), fresh weight of pulp (6.04-26.56 g) and dry weight of rind (1.52-4.54 g). Further, discrepancies in chemical constituents such as HCA (7-13%), lactone content (4.9-10.5%) and citric acid content (0.1-2.8%) in both red and yellow fruit morphotypes were also reported from the study.

Gawankar *et al*. (2001) found that rind thickness and rind percentage of six promising accessions of Kokum varied from 0.30 to 0.48 cm and 34.08 to 79.13 percentage. Similarly, in another evaluation of 108 genotypes of Kokum, Kshirsagar *et al*. (2003) reported that ten promising Kokum accessions had rind percentage ranging from 38.53 to 72.73. Gawankar *et al*. (2003) also reported that high variability existed among the different Kokum seedling types under study in respect of rind thickness and percentage. “Konkan Amruta” a released variety was reported to have an average rind thickness of 0.45 cm and rind percentage of 50.94 (Patil *et al*., 2005) and “Konkan Hatis” from BSKKV Dapoli (Nagwekar *et al*., 2010). As the rind colour adds to the value of end product (amsol) and also exhibits the richness in pigmentation, diversity of the rind colour is also a very significant part of the study.

Chemical constituents and variations :

The genus *Garcinia* is a recognized source of therapeutically active secondary metabolites such as benzophenones, bioflavonoids and xanthones (Akoro *et*

al., 2018). *Garcinia* species are reported with oil glands and secretory canals and oleo gum resins and essential oils have been reported from different *Garcinia* species (Rameshkumar *et al*., 2016). The essential oils from *Garcinia* species have exhibited antioxidant, antimicrobial, cytotoxic and anti-inflammatory activities (Tan *et al*., 2018). Chemical components of *Garcinia indica* such as HCA, anthocyanin is economically important for the pharmaceutical industry and food industry. Various chemical studies have been conducted by the researchers to the study the variation. Korikanthimath and Desai (2005) reported anthocyanin pigment varies from 7.87 - 17.03mg/100g, TSS of juice from 6-12-degree Brix, acidity from 1.1-3.2. However, Kokum fruit rind contains 80% of moisture, 1% protein, 2.6% total ash, 1.7% tannin, 0.9% pectin, 4.1% total sugars, 1.4% crude fat, 5.9% organic acid (as HCA) and 2.4% pigments (Krishnamurthy *et al*., 1982). But, Shunmuganantham *et al*. (2014) observed the variation in total solids (6.4 to 13.2 %), total sugars (3.42 to 10.02%), reducing sugars (0.7 to 5.81%) and also total acids (6.4 to 9.4%) and it kept increasing during the development of the fruit. Jayaprakasha and Sakariah (2005) reported that the HCA content in leaves and fruit varies from 4.1–4.6 and 10.3–12.7%, respectively. Niveditha (2013) reported that the highest vitamin C content was found in Red morpho and least in green. However, highest HCA content was reported to be in green and red morpho type. But seed

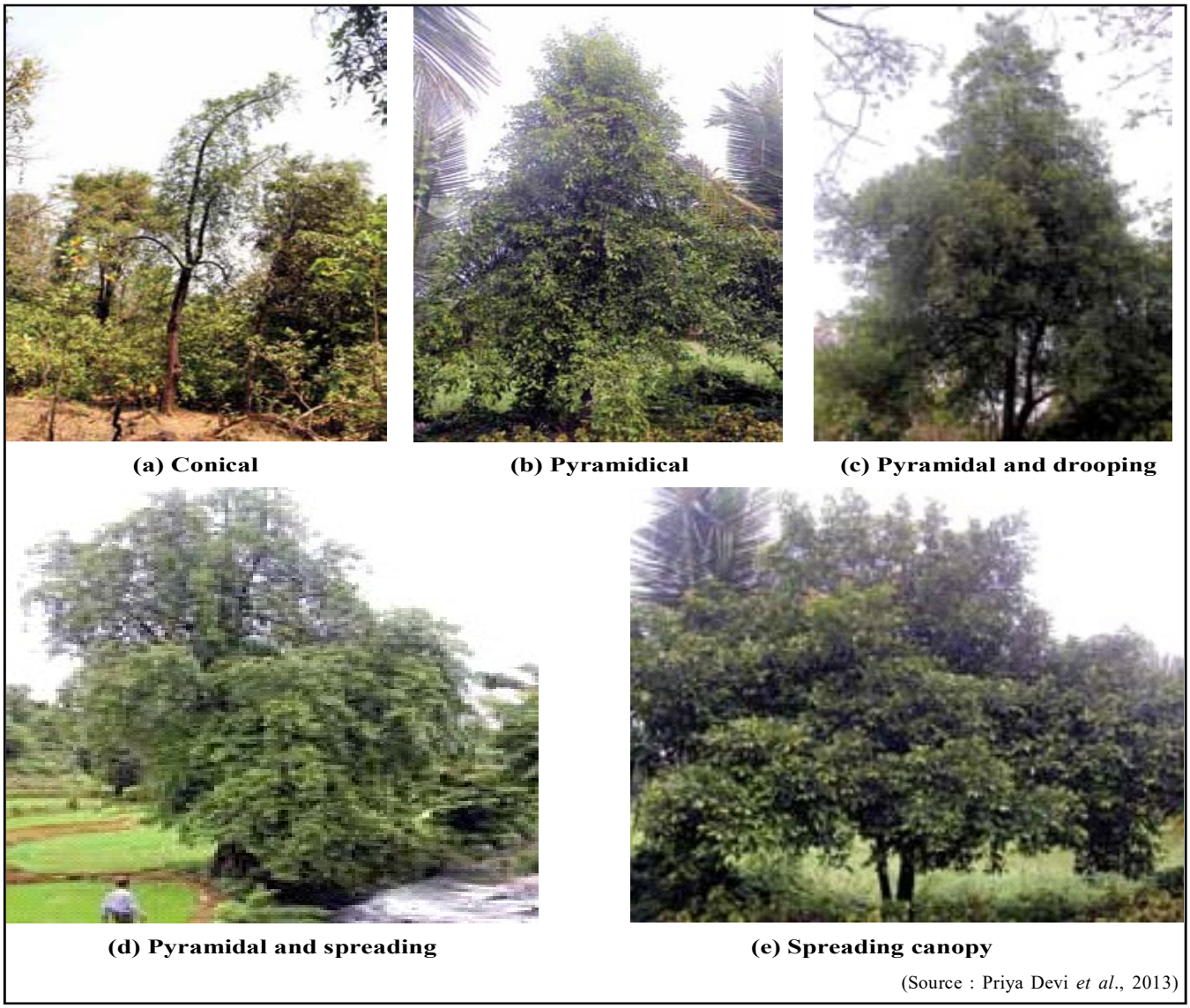
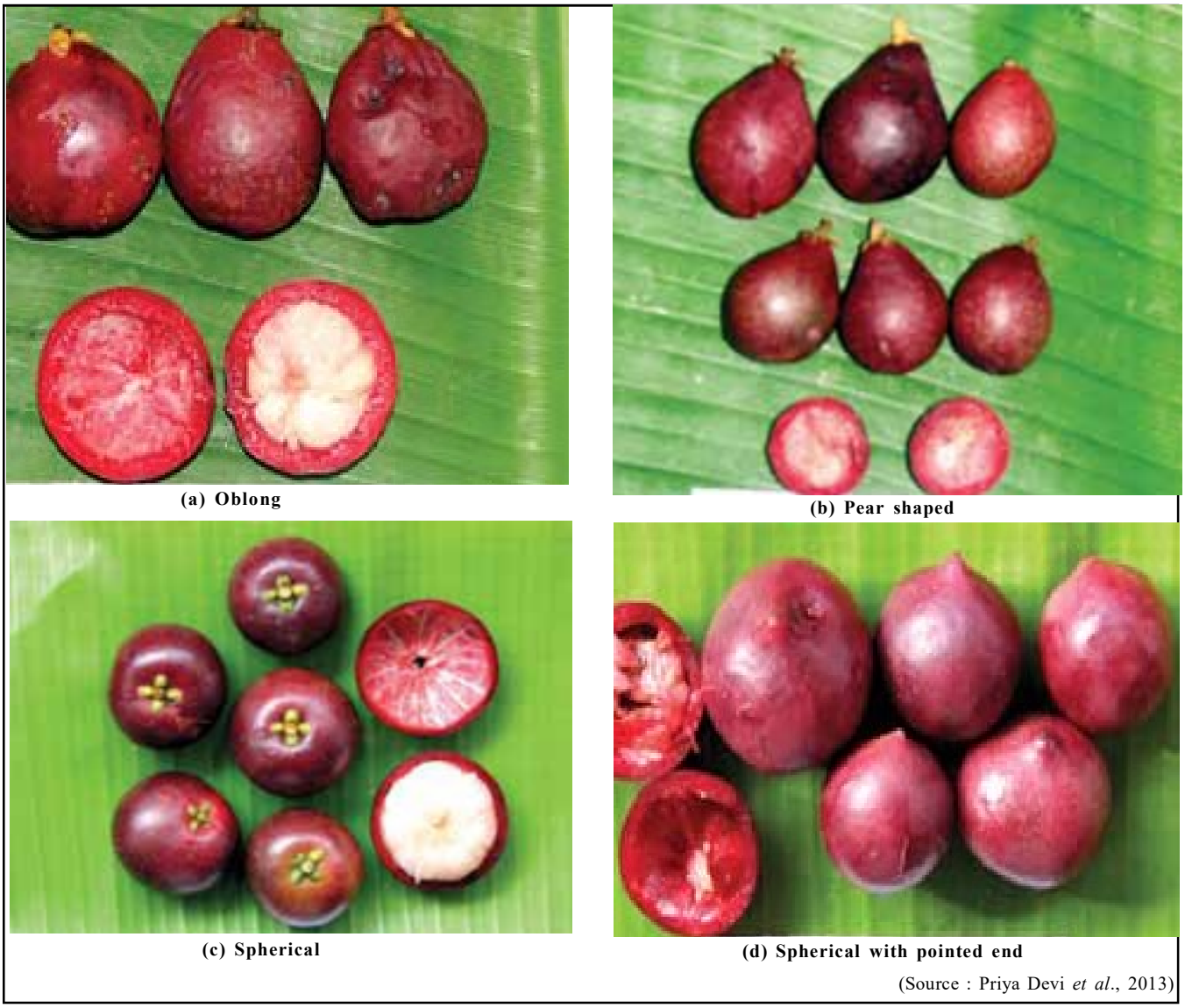


Plate 1: Variation in the tree canopy of *Garcinia indica*



(a) Oblong

(b) Pear shaped

(c) Spherical

(d) Spherical with pointed end

(Source : Priya Devi *et al*., 2013)

Plate 2 : Variation in fruit shape in *Garcinia indica*

oil content was found be more or less similar in four different morpho types, with maximum content in red and orange morphotype (58.84-58.94%). She also studied the morpho chemical variation of *Garcinia indica* in Utara Kannada district of Sirsi and reported variation in anthocyanin content in different fruit morpho types whereas Red morpho type had the highest anthocyanin followed by orange, yellow and green. However, there was no significant variation in the total sugar content in different morphotypes. Similar studies were conducted in *Garcinia gummi-gutta* by Bohra and Waman (2019) in Andaman and Nicobar Island and reported the total carotenoids and total chlorophyll content were maximum in morphotype GG-02 when compared to GG-05 morpho type. Parthasarathy (2014) reported the total free fatty acid, saturated fatty acid, saponification value and Vitamin E was found to be maximum for *Garcinia indica* followed by *Garcinia gummi-gutta*. Similar studies were also conducted by Menon *et al*. (2019) on six different species of *Garcinia* in North -East India. Sesquiterpenes (a secondary metabolite) was found to be a major compound in all species.

The commercially important parts of *Garcinia indica* are fruit and seed. The main component of *Garcinia indica* fruit is hydroxy citric acid (HCA) (Swami *et al*., 2014). It consists of citric acid with a hydroxyl group on the second carbon. HCA is the main components of weight suppressing agents. ATP citrate

Plate 3 : Variation in fruit colour of *Garcinia indica* (a) Red morpho type (b) Orange morpho type (c) Green morphotype (d) Yellow morphotype

lyase (EC 4.1.3.8) cleaves which citrate into OAA and acetyl COA. Acetyl COA is required for the synthesis of fatty acid. HCA inhibits this reaction and further reduction in the availability of Acetyl COA leading to suppression of FA synthesis and lipogenesis. This, in turn, reduces the food intake, increased energy expenditure, suppression of fatty acid synthesis and increase in the synthesis of glycogen at liver inducing weight loss (Jena *et al*.,2002). The derivates of HCA is widely incorporated in pharmaceutical industry for cardio protection and endurance in exercise. HCA content in *Garcinia indica* fruit was 20-30% (Jena *et al*., 2002) and 10.3–12.7% (Ananthakrishnan and Rameshkumar, 2016). According to Pandey *et al*. (2015) the leaves of *Garcinia indica* have highest HCA content 120 mg/g leaf methanol extract, followed by *Garcinia gummi-gutta*. It was also reported total acid content (HCA and HCA lactone) was more in *Garcinia gummi-gutta* (308 mg/g) when compared to *Garcinia indica* (276 mg/g). However, along with HCA, minor quantities of HCA lactone, citric acid, malic acid and tartaric acid is also present (Parthasarathy *et al*., 2014). Shameer *et al*. (2016) evaluated the morphological and chemical profiling of *G. gummi-gutta* varieties (*G. gummi-gutta* var gummi-gutta, *G. gummi-gutta* var conicarpa, *G. gummi-gutta* var. papilla) revealed 75 % similarity in varieties in *G. gummi-gutta* var gummi-gutta and *G. gummi-gutta* var. papilla whereas, distinct morphological and chemical characteristics for *G. gummi-gutta* var. conicarpa, which needs re-establishing it as the distinct species.

Anthocyanin is another phytochemical present in *Garcinia indica* fruit rinds constituting 2.4% of total fruit biomass. These are water-soluble colouring agents and are used in the food industry. The pigments cyanidin-3-glucoside and cyanidin-3-sambubioside are the anthocyanin pigment which imparts colour to the fruit (Nayak and Rastogi, 2010). These pigments are present in the ratio of 4:1 (Nayak *et al*., 2010). The variation in shades of colour is attributed by the presence of Hydroxyl and Methoxyl group present in the anthocyanin structural skeleton (Fig.1-3). The free radical scavenging ability of anthocyanin is due to the 3' and 4' -OH in the benzene ring with a saturated 2,3- double bonds. Anthocyanins prevent ascorbic acid oxidation, scavenge free radicals, show inhibitory effects against oxidative enzymes and reduce the risk of cancer and heart diseases (Bridle and Timberlake,1997). Different glycosylation and hydroxylation positions determine their potential as an antioxidant (Wang *et al*., 1997). With an increase in hydroxyl groups in B-ring, antioxidant activity increases when present as glucosides. Corresponding aglycones have weaker activities (Tsushima *et al*., 1996). These two anthocyanins were first identified by thin-layer chromatography using acetic acid: HCl: water in the ratio of 15:3:82 (Nayak *et al*., 2010). The respective sugars associated with these two pigments are glucose and

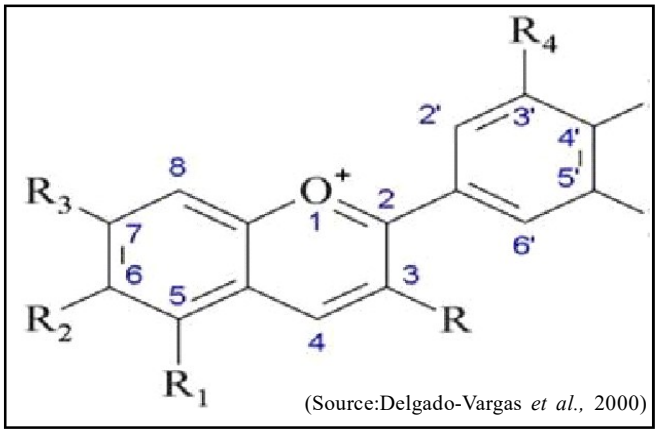
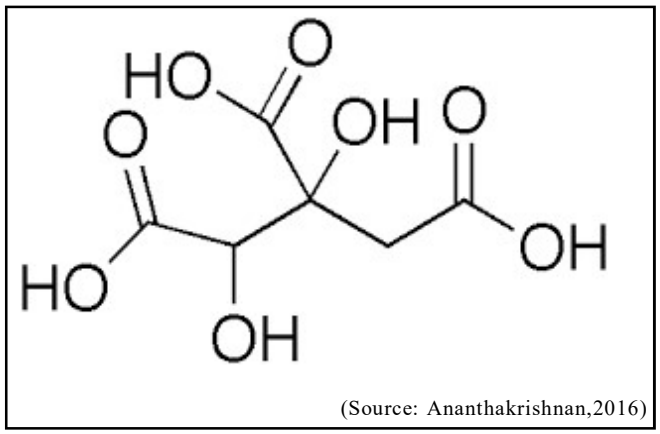
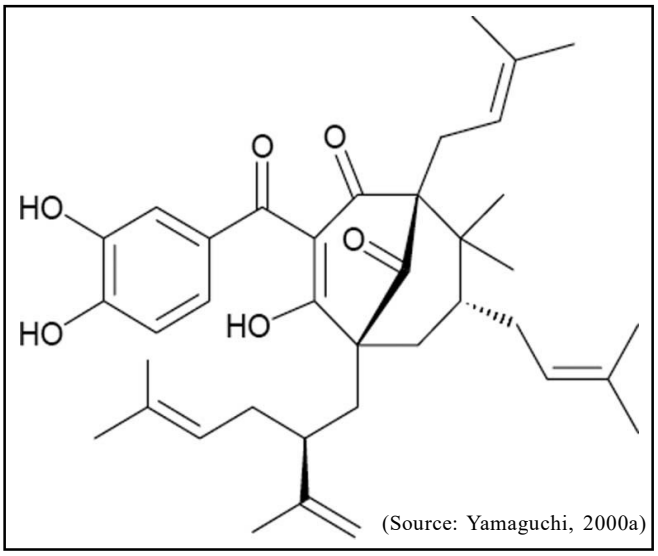


Fig.2 : General structure of anthocyanidin pigment



(Source: Ananthakrishnan,2016)

Fig.1: Structure of Hydroxy citric acid



(Source: Yamaguchi, 2000a)

Fig. 3 : The general structure of garcinol

xylose. The extract of anthocyanins contains water, pigment and sugars. Due to high water content, these extracts have a low shelf-life and thus, commercially they have to be concentrated. This also can further reduce the transportation and storage cost. Concentration of such colour by conventional evaporation or distillation results in loss of hue and chroma. Thus, membrane processes such as microfiltration, ultra-filtration or reverse osmosis are employed. But these methods have few drawbacks such as the need of high pressure, membrane clogging, maximum achievable concentration and reduction in the gradient. A novel forward osmosis method is also developed for concentration of Kokum anthocyanins using semi-permeable nonporous active skin layer of cellulose triacetate embedded in a nylon mesh with NaCl solution as an osmotic agent (Nayak and Rastogi, 2010).

Another major secondary metabolite present in *Garcinia indica* is are polyisoprenyl benzophenones, xanthones and bioflavonoids. Garcinol is one of the benzophenone derivate which have anti-cancerous property. It also shows antioxidative, anti-ulcer, anti-glycation activity (Krishnamurthy and Sampathu, 1998; Yamaguchi *et al*., 2000a and Yamaguchi *et al*., 2000b). Garcinol ($C_{38}H_{50}O_6$, Melting point 122°C), which is a yellow colour fat-soluble pigment. It is crystallized out from the hexane extract of the fruit rinds of *Garcinia indica.* It was found to be the potent inhibitor of the enzyme histone acetyltransferase. Garcinol showed three times greater DPPH (1,1 diphenyl-2- picrylhydrazyl) free scavenging activity than DL-*a*-tocopherol by weight in aqueous ethanol solution. Hence, it was regarded as a potent antioxidant and a glycation inhibitor (Yamaguchi *et al*., 2000a). Garcinol can also be used as a natural to impart a yellow colour to butter and *Ghee*.

The seed kernels of *G. indica* contains hard and brittle fat (MP-39 to 43°C) upto 45 % yield, which is commercially known as 'Kokum butter'. Kokum butter contains about 30% of fat content. Extensive studies have been carried out on the fatty acid composition of Kokum butter and Kokum fat was found to be rich in stearic acid ($C_{17}H_{35}COOH$) and oleic acid ($C_{17}H_{33}COOH$) (Krishnamurthy *et al*., 1982 and Jeyarani and Reddy, 1999). Quantitative analysis of Kokum butter revealed that in addition to fatty acids, it contains glycerides such as oleodistearin and steroidogenic (Lipp and Adam, 1998). Seed oil is a source of palmitic acid, stearic acid, oleic acid and linoleic acid. Reports show that seed oil of *G. indica*, because of high content of fatty acid methyl esters, can be used as biofuel or can be mixed with other fuels to enhance its efficiency (Hosamani *et al.*, 2009).

Priya Devi *et al*. (2012) reported that in Goa out of all 268 accession total acids in fruits *i.e.* fresh rind ranged from a minimum of 1.22 per cent to a maximum of 11.24 per cent with a grand mean of 4.12 per cent. Total acids in juice ranged from a minimum of 0.43 per cent to a maximum of 10.97 per cent, with a grand mean of 3.72 per cent. Manjunatha *et al*. (2007) reported that the seed oil content differed significantly among different germplasm of *Garcinia indica*. Maximum and minimum oil content was observed in CPTDK-31 and CPTUK-5, respectively which ranges from 23.73% to 37.39%. Hegde *et al*. (2010) revealed that higher fruit yielding tree have HCA content ranged from 7.0 to 13.0% in

Garcinia indica. However, Antony *et al*. (1998) reported that qualitative analysis of total acid content ranged from 19-26% in *G. indica* and *G. cambogia*. Chew and Lim (2018) reported the variation of anthocyanin content in *G. mangostana*, *G. hombroniana* and *G. atroviridis*.

Genetic variation :

Genetic diversity studies using molecular markers reported the inter and intra-species relationship among the *Garcinia* species, *viz*., *G. cambogia, G. cowa, G. hombroniana, G. indica, G. mangostana* and *G. xanthochymus*. Parthasarathy *et al*. (2013) reported the maximum diversity of *G. cambogia* from the populations of Kerala and the heterogeneity index within the species of *G. cowa*, *G. gummi-gutta*, *G. indica* and *G. xanthochymus* was between 0.81 and 0.82. According to Sobir *et al*. (2013) *G. mangostana* have apomixis reproductive pattern where the progenies are similar to their mother, showing less variation and also reported the variability existed between the various regions of Indonesia due to the mutation occurred during growth or maybe by the multi-events of natural hybridization. Shunmugananthan *et al*. (2016) reported the physiological, chemical and genetic variations among the various accession of *Garcinia indica* collected from Goa. Low and high genetic variability within and between populations, respectively, was reported from the five populations in Maharashtra using molecular markers (Thatte *et al*., 2012). Similar study conducted in natural populations of Kokum in Northern Western Ghats showed 93.87% polymorphism between the population and 84.80% polymorphism within the population (Palkar and Sellappan, 2019).

Conclusion :

Garcinia indica is widely used in pharmaceutical, food and cosmetic industry. The fruits produced from plantations in Maharashtra, Goa and Karnataka and also from the forests meet the demand. The review reveals variations at morphological, chemical and genetic levels. There is ample scope for utilizing these variations in different eco-climatic conditions to increase yield, sustainability and also to identify site specific high yielding varieties/clones.

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