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Effect of different Altitudes on Leaf Parameters of *Garcinia indica* (Choisy) in Uttara Kannada, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Garcinia indica is a native tree species found in the Western Ghats of India and is important for commerce, ecology and medicine. This study looks into the morphometric characteristics of *G. indica* leaves and how they vary in the Uttara Kannada area of Karnataka, India, across various altitude zones. Eight test locations were chosen and divided into four altitude zones (Zones A (plains), Zone B (up-ghat), Zone C (mid-ghat) and Zone D (Coastal)) each of which corresponded to a distinct elevation and rainfall level. Forty trees were used to gather leaf samples and measurements of the leaves' length, breadth, (fresh and dry leaf) weight and moisture content were noted. The findings showed that there was a considerable altitude-dependent variation in leaf characteristics, with Zone-A showing the largest mean leaf length (9.48 cm), breadth (3.68 cm) and Zone-C showing the highest leaf weight (0.85 g). Four leaf types were noted: lanceolate, elliptical, ovate and obovate. The elliptical leaf shape was found to be the most prevalent. The study

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emphasizes how bioclimatic factors affect the morphology of *G. indica* leaves and it suggests that altitude is a major factor in determining the size and weight of leaves. This study supports the conservation and widespread use of *G. indica* by shedding light on its variety and ability to adapt to different environments.

Keywords: Leaf parameters; garcinia indica; species; leaf morphometric features.

1. INTRODUCTION

The genus Garcinia, which belongs to the Cluciaceae family, has about 200 species found throughout the world's tropics, mostly in Asia, Africa and Polynesia. They are polygamous evergreen trees and many of them are endemic and commercially significant, as well as having powerful therapeutic effects [1]. *Garcinia indica* is an indigenous tree spice crop that originated and is produced in India's Western Ghats, Maharashtra's South Konkan area, Coorg, Wynad and Goa. It is found in evergreen and semi-evergreen woods as well as a home garden tree [2]. The tree may be found in abundance in Maharashtra's Konkan region, Goa, Karnataka's and Kerala's coastal parts, Assam's evergreen forests, Khasi and Jantia hills, West Bengal and Gujarat's evergreen forests. It is found in forests, riversides and wasteland, as well as being grown on a modest basis. The tree is mostly found along the Konkan region of Maharashtra's Ratnagiri district, Goa, Karnataka's Uttara Kannada, Udupi and Dakshina Kannada districts and Kerala's Kasaragod area. It is known by various names across India including Tallow tree in English, Murugalu in Kannada and in Malayalam it is called Punarpuli. Bindin, Biran, Bhirand, Bhinda, Kokum, Katambi, Panarpuli, Ratamba or Amsolare the other names for *G. indica* [3].

Garcinia indica is a tropical evergreen, slender tree with sloping branches, it reaches heights of 15 m. The thin bark is lined and the leaves are elliptic, oblong or oblong-lanceolate, deep-green glossy leaves, 5.5-8 cm long and 2.5-3 cm broad. The flowers are fleshy, dark pink, solitary or in spreading clusters during the month of November-February [4,5]. The fruit is brownish-grey or dark purple marbled with yellow and is crowned by the 4-parted fruit is round, about 4 cm (1.5 inc) in diameter with 5-8 seeds. *Garcinia indica* flourishes very well up to an elevation of about 800 m from MSL. It requires a warm and humid tropical climate. It thrives well in coastal areas receiving over 250 cm of rainfall. It grows well in lateritic, alluvial soils having a depth of 1.0 m and pH of 6.7. The mature kokum fruit is either dark purple or crimson with a yellow tint. It has 3-8 big seeds embedded in a red acid pulp in a regular pattern, similar to orange segments, in a white pulpy substance [6,7].

The fruit is round to oval in shape and weighs between 21 and 85 g. The fruit is mainly used for culinary purposes. Kokum is collected from the wild, grown in home gardens and cultivated at a limited scale as a rain-fed crop, the dried rind of the fruit is used primarily as an acidulent in cosmetic products and moisturizing and the rind has medicinal properties and is used in the treatment of piles, dysentery, tumours and heart complaints in the Western Ghats region, where it is estimated to be grown on an area of 1200 ha with an annual production of 10,400 tonnes [8].

Sobir et al*.,* [9] identified variability in *Garcinia mangostana* for morphological characters like tree shape, fruit shape and petal colour in several populations of Indonesia.

Parthsarathy and Nandakishore [10] studied Garcinia genetic resources collection, which includes 15 species from the Western Ghats and the Eastern Himalayas. The morphological characterizations of the species in these two ecosystems show that there is diversity within the same ecosystem and similarities between the species in these two ecosystems.

2. MATERIALS AND METHODS

The study was carried out in Karnataka's Agro-climatic Zone 9, particularly in the Uttara Kannada district of the Western Ghats, where *Garcinia indica* is available in evergreen to semi-evergreen forests and farmlands. The region experiences tropical monsoonal rainfall from June to September, ranging from 2500 to 4000 mm annually. Relative humidity reaches over 90% in July and August, dropping to 40% in March and April, with temperatures between 18°C and 31°C. To assess the effects of altitude and precipitation, eight sites were selected across four altitude zones: Plains (Zone-A, ≥600 m MSL), Up-Ghat (Zone-B, 500-600 m MSL), Mid-Ghat (Zone-C, 400-500 m MSL) and Coastal

(Zone-D ≤400 m MSL). Two sites per zone were chosen and five trees per site were taken as replicates. The study sites included four locations in Kumta taluk (Kathgal, Divage, Devimane, Ragihosalli) and four sites in Sirsi taluk (Janmane, Yeddalli, Islur and Banavasi). A Randomized Complete Block Design (RCBD) with three factors was used for statistical analysis. Leaf samples were collected from trees of girth class between 60-75 cm in January to March 2021. Two sites were selected per location and five trees per site were assessed for leaf morphology. 15 leaves were drawn from each tree within a tree 5 leaves were taken on each 3 sides of the tree crown randomly to analyze for color, shape, length (L) and width (W), with precise measurements using a calibrated scale.

In order to preserve the green colour and determine the ideal moisture level, the leaf was dried under the shade. The formula used to analyze the leaf moisture content is mentioned below.

Leaf moisture content=(Fresh leaf weight-Dry leaf weight)/(Fresh leaf weight)×100

3. RESULTS AND DISCUSSION

Table 2 indicates that leaf parameters *viz.,* leaf shape and leaf colour of *Garcinia indica* from different sites and Zones of Uttara Kannada district. The highest percentage of leaf shape was elliptical (47.5 %) followed by ovate (32.5 %) and lowest was recorded in lanceolate (7.5 %) shown in Fig. 1 The leaf colour variation in study area. The highest percentage of leaf colour was reported to be dark green (90 %) was also observed and the lowest was reported as light green (10 %).

Table 1. Geographical and climatic information of study area in Uttara Kannada district, Karnataka

Altitude Zone	Site (Location)	Altitude (m)	Mean annual rainfall (mm)	Annual rainy days	Mean annual temperature (°C)
Zone-A (Plain)	S_1 (Banavasi)	603.6	2545 - 3456	97	30.5
	S_2 (Islur)	670.4	2578 - 3269	97	30.9
Zone-B (Up-ghat)	S_1 (Yeddalli)	550.3	2784 – 3568	110	28.9
	S_2 (Janmane)	536.4	2756 – 3645	110	26.0
Zone-C (Mid-ghat)	S_1 (Devimane)	431.6	2986 – 3865	100	27.0
	S_2 (Ragihosalli)	436.3	3157 – 3945	100	25.0
Zone-D (Coastal)	S_1 (Kathgal)	52.4	3800 – 4722	120	25.6
	S_2 (Divage)	77.8	3800 - 4722	120	24.9

** Rainfall data by KSNDMC report 2019*

Picture. 1. Leave selected to analyse for shape, colour and other parameter

Table 2. Leaf shape and colour observed during the study

Leaf shape	Trees	Share (%)	Leaf colour	Trees	Share (%)
Elliptical	19	47.5	Dark green	36	90
Ovate	13	32.5			
Obovate	5	12.5	Light green	4	10
Lanceolate	3	7.5			
Total	40	100	Total	40	100

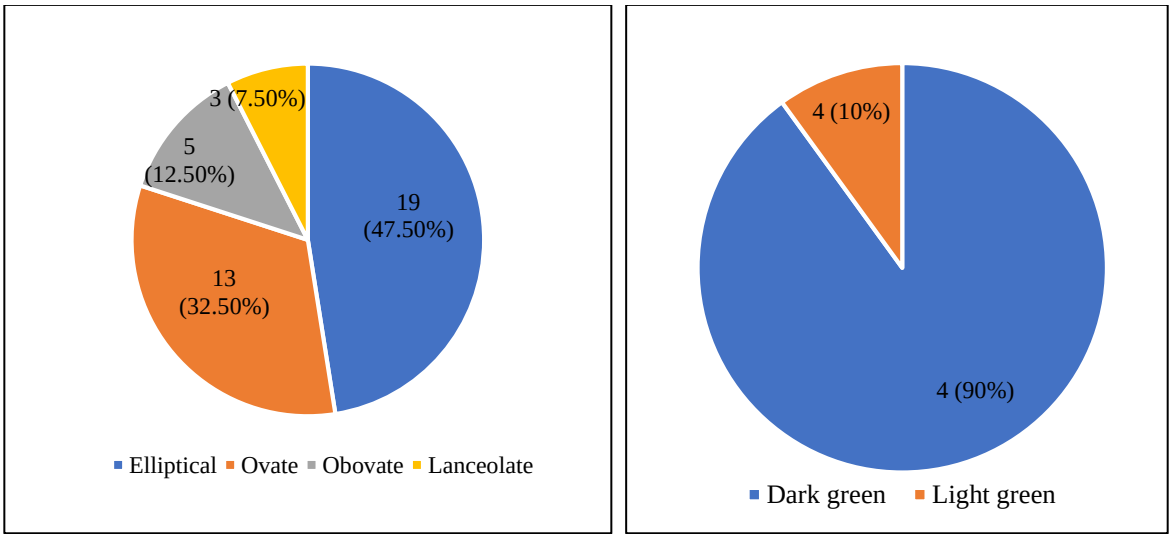

Fig. 1. Percentage of leaf shapes and Leaf colour variation in *Garcinia indica*

Variations in leaf morphometric traits of *G. indica viz*., leaf length (cm), leaf width (cm), fresh leaf weight (g), dry leaf weight (g) and leaf moisture content were presented in Table 3. The results revealed that there was a significant difference between the Zones in the case of leaf parameters. Leaf length of *Garcinia indica* among different zones the highest mean leaf length was recorded in Zone-A (9.84 cm) and the lowest mean was recorded in Zone-D (8.09 cm). Among the different sites of zones, site S1 of Zone-A recorded the highest leaf length (9.94 cm), lowest leaf length was recorded in site S2 of Zone-D (7.77 cm). Among the individual tree bases, the highest leaf length was recorded G4 (10.82 cm) of S1 of Zone-A and the lowest was recorded G39 (7.28 cm) of S2 of Zone-D.

The leaf width variation among individual trees, sites and zones. Among different zones, the widest mean leaf width was reported in Zone-A (3.68 cm) and the shortest was recorded in Zone-D (3.50 cm). Among the different sites, the widest leaf width was recorded in site S2 (3.82 cm) of Zone-B and the shortest was recorded at site S2 (3.39 cm) of Zone-C. The leaf width ranges from 2.99 to 4.33 cm. The widest leaf width was recorded in G16 (4.23 cm) of site S2 of Zone-B and the shortest leaf width was recorded in G31 (2.99 cm) of site S1 of Zone-D.

The fresh leaf weight among different zones, sites and individual trees. Among different zones, the highest mean fresh leaf weight was reported in Zone-C (0.85 g) and the lowest was reported in Zone-D (0.57 g). Whereas among the different sites, the highest fresh leaf weight was recorded in site S2 (0.90 g) of Zone-A and the lowest was recorded in sites S1 and S2 (0.57 g) of Zone-D. On an individual tree basis, the highest leaf fresh weight was recorded in both G9 and G29 (1.03 g) of Site S2 in Zone-A and Zone-C respectively and the lowest fresh leaf weight was recorded in G31 (0.40 g) of Site S1 of Zone-D.

The dry leaf weight in Zones, sites and individual trees. The highest mean dry leaf weight was recorded in Zone-C (0.20 g) and the lowest was recorded in Zone-D (0.16). Whereas among of different sites, the highest dry leaf weight was recorded in Site S1 and S2 (0.20 g) of Zone-C and the lowest was recorded in Site S1 (0.15 g) of Zone-D. Dry leaf weight on an individual tree basis. The maximum dry leaf weight was recorded in G21 and G29 (0.23 g) of site S1 and S2 of Zone-C and the minimum dry leaf weight was recorded in G31 (0.10 g) of Site S1 of Zone-D.

Table 3. Effect of altitude Zones and sites variation on leaf parameters

Altitude zone	Tree	Leaf length (cm)		Leaf width (cm)		Fresh leaf weight (g)		Dry leaf weight (g)		Leaf moisture Content (%)	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Zone A	G1-G6	9.20	9.79	3.67	3.81	0.66	0.88	0.16	0.19	61.054	61.552
	G2-G7	9.49	9.93	3.69	3.56	0.69	0.86	0.16	0.19	60.607	62.326
	G3-G8	10.55	9.45	3.49	3.72	0.65	0.90	0.18	0.19	58.016	62.455
	G4-G9	10.82	10.46	3.58	3.97	0.86	1.03	0.19	0.21	61.270	63.057
	G5-G10	9.65	9.05	3.85	3.49	0.76	0.84	0.17	0.18	60.939	62.068
	Mean of site	**9.94**	**9.74**	**3.65**	**3.71**	**0.72**	**0.50**	**0.17**	**0.19**	**(60.377) 75.55**	**(62.292) 78.41**
	Mean of zone	**9.84[a]**		**3.68[a]**		**0.81[ab]**		**0.18[b]**		**(61.334) 76.98[a]**	
Zone B	G11-G16	7.96	9.45	3.03	4.23	0.53	0.87	0.13	0.19	59.552	61.822
	G12-G17	8.13	8.40	3.05	3.63	0.60	0.65	0.14	0.17	60.900	59.283
	G13-G18	8.40	8.87	3.80	3.81	0.78	0.70	0.19	0.17	59.695	59.961
	G14-G19	8.29	8.67	3.63	3.49	0.73	0.67	0.16	0.17	61.436	59.107
	G15-G20	9.16	9.20	3.30	3.93	0.70	0.77	0.17	0.18	59.923	60.484
	Mean of site	**8.39**	**8.92**	**3.36**	**3.82**	**0.67**	**0.73**	**0.16**	**0.18**	**(60.301) 75.47**	**(60.131) 75.22**
	Mean of zone	**8.65[b]**		**3.59[ab]**		**0.71[b]**		**0.17[b]**		**(60.216) 75.34[b]**	
Zone C	G21-G26	8.27	8.55	3.55	3.45	0.66	0.74	0.18	0.18	57.668	59.92
	G22-G27	7.83	8.46	3.78	3.53	0.75	0.88	0.17	0.21	61.129	60.558
	G23-G28	8.29	9.13	3.78	3.49	0.83	0.88	0.20	0.21	60.146	60.938
	G24-G29	9.06	9.55	3.82	3.12	0.94	1.03	0.23	0.23	59.949	61.873
	G25-G30	8.31	9.15	3.77	3.37	0.91	0.84	0.22	0.19	60.445	61.548
	Mean of site	**8.35**	**8.97**	**3.74**	**3.39**	**0.82**	**0.88**	**0.20**	**0.20**	**(59.867) 74.78**	**(60.969) 76.47**
	Mean of zone	**8.66[b]**		**3.57[ab]**		**0.85[a]**		**0.20[a]**		**(60.418) 75.62[b]**	
Zone D	G31-G36	7.78	7.55	2.99	3.40	0.40	0.57	0.10	0.17	60.770	56.711
	G32-G37	8.26	8.42	3.33	3.34	0.50	0.58	0.15	0.17	55.472	56.880
	G33-G38	8.71	8.08	3.88	3.43	0.68	0.55	0.18	0.17	58.278	55.491
	G34-G39	8.59	7.28	3.55	3.59	0.59	0.55	0.17	0.16	57.231	57.018
	G35-G40	8.65	7.52	3.82	3.65	0.67	0.60	0.17	0.18	58.729	57.049
	Mean of site	**8.40**	**7.77**	**3.51**	**3.48**	**0.57**	**0.57**	**0.15**	**0.17**	**(58.096) 72.03**	**(56.630) 69.76**
	Mean of zone	**8.09[b]**		**3.50[b]**		**0.57[b]**		**0.16[b]**		**(57.363) 70.89[b]**	
		CD @ 5%	SEm ±	CD @ 5%	SEm ±	CD @ 5%	SEm ±	CD @ 5%	SEm ±	CD @ 5%	SEm ±

Altitude zone	Tree	Leaf length (cm)		Leaf width (cm)		Fresh leaf weight (g)		Dry leaf weight (g)		Leaf moisture Content (%)	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
For Zone		0.278	0.099	0.129	0.046	0.048	0.017	0.010	0.004	0.746	0.265
For Site		NS	0.070	NS	0.032	0.034	0.012	0.007	0.003	NS	0.187
For Tree		0.310	0.110	NS	0.051	0.054	0.019	0.011	0.004	NS	0.296
Zone x Site		0.392	0.139	0.182	0.065	0.068	0.024	NS	0.005	1.055	0.375
Zone x Tree		0.621	0.220	0.289	0.102	0.107	0.038	NS	0.008	NS	0.592
Site x Tree		0.439	0.156	0.204	0.072	0.076	0.027	0.016	0.006	NS	0.419
Zone x Site x Tree		NS	0.312	0.408	0.145	NS	0.054	NS	0.011	2.359	0.838

❖ *Leaf moisture content bracket value indicates that the values are angular transformed*

The percentage of variation in leaf moisture content among different zones, sites and individual trees. The maximum mean percentage of leaf moisture content was observed in Zone-A (76.98 %) and the minimum was observed in Zone-D (70.89 %). Whereas among the different sites, the maximum percentage of leaf moisture content was observed in site S2 (78.41 %) of Zone-A and the minimum was observed in site S2 (69.76 %) of Zone-D. Leaf moisture content on individual trees basis leaf moisture content ranges from 67.87 % to 79.49 %. The highest percentage of leaf moisture content was observed in G9 (79.49 %) of Site S2 of Zone-A and the lowest was observed in G32 (67.87 %) site S1 of Zone-D.

Similar results were reported by Madappa and Bopaiah [11] where studied on *Garcinia gummi-gutta* growing in Western Ghat regions of Kodagu, Dakshina Kannada, Uttara Kannada and parts of Kerala. The plant species leaf size was reported variations. The average size of leaf length ranges from 9.7 to 14.1 cm, leaf width of 2.8 to 5.1 cm and average weight of the fresh leaf before drying is 1.212 to 2.440 mg on *Garcinia gummi-gutta*.

Priyadevi et al., [12] leaf length showed a good variation ranging from a minimum of 6.24 to 11.95 cm. The leaf width of all accessions studied varied from 2.42 to 5.25 cm.

The present study indicates that, there was variation among both Zones and sites. Maximum leaf length and width of *Garcinia indica* were observed in the higher altitude region. Similar observations were made by Priyadevi et al*.,* [12] where he observed the variation in case of leaf traits were predominant in altitude Zones, he also observed leaf were heavier in higher altitude regions compared to lower altitudes.

Four different-shaped leaves were observed in the study area. within the 40 trees, 19 trees showed Elliptical shaped (47.5 %) leaves followed by 13 trees with Ovate (32.5 %), 5 trees with obovate (12.5 %) and 3 trees with Lanceolate shaped (7.5 %) leaves. Similar observations were made by Priyadevi et al*.,* [12] says that presence of several differently shaped leaves of *Garcinia indica* from different accessions of the Western Ghats in Goa, including above mentioned shapes.

The research is focused on phenotypic variance in various altitude zones and leaf moisture content; these variations can be attributed to genetics or altitude, but in this study, attitude plays a larger role in explaining variation than genetics. However, genetic analysis is not carried out.

4. CONCLUSION

The present work influence how bioclimatic conditions especially high ghat and rainfall have influence the leaf morphometric features of *Garcinia indica*. Variations in leaf width, length and weight were noted throughout many altitude zones; Zone-A (Plains) showed the best leaf length and breadth; Zone-C (Mid-ghat) showed best leaf weight. These results give insightful information for choosing planting material as trees from Zone-A, which are higher elevations, would be more suited for places where greater leaf size is required, while trees from Zone-C could be perfect for areas where higher leaf biomass is vital. Since leaf size and weight directly affect the yield and quality of bioactive chemicals, this is especially pertinent for sectors using *Garcinia indica* in food processing, medications and cosmetics. Moreover, the identification of particular sites with better leaf traits (such as S2 of G16 for leaf width, G4 for leaf length and G9 and G29 for leaf weight) can direct the choice of superior genotypes for propagation and commercial farming, so improving resource management and economic viability in the *Garcinia indica* value chain.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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