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Early Growth Dynamics of Selected Accessions of *Garcinia indica* (Choisy) in Eastern Dry Zone of Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A set of 60 accessions of *Garcinia indica* (Choisy), comprised of two to five years old, established as part of ex-situ field gene bank at the College of Horticulture, Bengaluru were evaluated for growth and development related characters over two consecutive years, 2019-20 and 2020-21. A set of 11 growth traits significantly varied in their relative per cent increase over successive years. Among all the growth parameters, tree volume recorded a maximum per cent increase of 186.56 per cent. The extent of variation as measured by range for different traits varied- plant height: 176.24cm to 350.44cm; number of branches: 22 to 42.24; length of branch 6.00 cm to 168.00cm; number of leaves: 59.00 to 80.00; stem girth: 11.28 cm to 35.17cm; canopy spread (East-West): 116.15cm to 267.33cm; canopy spread (North-South): 135.00 cm to 276.00 cm; and tree volume:

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1.68m3 to 13.91m3. Plant height was 150cm in 2019 and 220cm in 2020 in GI_SIR7; 210cm - 290cm in GI_DAN2, 320cm-380cm in GI_YAN4 and 330-410 in GI_KAN3, respectively in two, three, four and five-year-old age groups. The traits such as number of branches, length of the branch, number of leaves, stem girth, canopy spread East-West and tree volume increased gradually over two years of study. The results have significance in per se establishment of the species in non-traditional areas such as this agro-climatic zone.

Keywords: Garcinia indica; growth characters; plant age; growth dynamics.

1. INTRODUCTION

Genus *Garcinia*, the largest member of the family Clusiaceae (Guttiferae), which comprises more than 250 species, is widely distributed across the tropical world. Over 35 species of this family are found in India, of which six are endemic to the evergreen forests of *Western Ghats* [1]. The *Garcinia* species found in forests of India are *G.indica, G. cambogia, G. xanthochymus, G. dulcis, G. cowa, G. morella, G. spicata, G. lancifolia, G. pedunculata* and *G. kydia* [2]. The center of diversity of *Garcinia* species is the Malaysian region, with some species reaching India and the Micronesian islands and also extending to tropical Africa and the Neotropics [3,4]. In India, *Garcinia* species propagate widely in Maharashtra, Goa, coastal areas of Karnataka and Kerala, Assam, West Bengal and Gujarat in a semi-wide state. *Garcinia* species are evergreen trees and shrubs which thrive well in high rainfall areas of the tropics. The trees are dioecious and hence are cross-pollinated. The fruits of *Garcinia* species show the anti-obesity property because of the presence of the compound called (-)-Hydroxycitric acid (HCA), which made these species popular in the international market. The *kokum* fruit has been used for culinary and medicinal purposes since the age-old days. The rind of the *kokum* fruit is used to make fresh juice which is a natural coolant [5]. The dried rind is used as a substitute for tamarind in coastal areas. It also has many medicinal properties, such as antiseptic hypolipidemic, hydragogue, diuretic, anti-bacterial, anti-oxidant, and anti-obesity activity [6,7,8] and therefore is extensively used in pharmaceutical industries [9].

The most popular species of the genus *Garcinia* is *G. mangostana,* which is commonly known as mangosteen and has been named as 'queen of tropical fruits' for its unique pleasant taste and visual appearance of a crown-like structure [10]. The kokum has two fruit colour-morphs, regular red and rather rare yellow/white, different types - red and yellow, particularly spread over the *Western Ghat* central region in Uttara Kannada district. This particular species of the genus *Garcinia* has become popular in the recent past due to its fruits, which are rich in HCA content. The rind of the fruit contains about 24-30 per cent HCA, which is highest among the species of the genus *Garcinia [*11]. Many farmers are attempting to grow this species in non-traditional regions of Karnataka. For successful establishment a thorough understanding of the growth and development and establishment of *G. indica* especially during its initial few years is important. However, the early stage growth dynamics of G. indica is hardly understood. We report the early growth dynamics of selected accessions of *Garcinia indica* in the eastern dry zone of Karnataka, a region less known for this species cultivation.

2. MATERIAL AND METHODS

A set of 60 accessions of *Garcia indica* were selected for early growth dynamics from the *ex-situ* field gene bank established at the College of Horticulture, UHS Campus, GKVK Post, Bengaluru – 560065 and used in the present study. The *ex-situ* field gene bank of *Garcinia indica* was established as a part of the project entitled 'Centre for Biotechnology Research' in the Department of Biotechnology and Crop Improvement, funded by Karnataka Biotechnology and Information Technology Services (KBITS), Department of Information Technology and Biotechnology and Science and Technology (IT, BT and S&T), Government of Karnataka. In order to understand the early growth dynamics, plants of different age groups were selected as treatments and observations were recorded for 11 traits consecutively for two years. Observation on growth parameters, such as plant height, number of branches, length of branch, number of leaves from the fourth apex of top, leaf length, leaf width, leaf length to width ratio, stem girth, canopy spread and tree volume were recorded over two years. Two to five-year-old plants of 120 accessions of *G. indica* ecotypes located at the *ex situ* field gene bank.

Table 1. Details of *G. indica* accessions of *ex situ* field gene bank used in the study

Treatment	Plant number	Plant age	Sample ID	Treatment	Plant number	Plant age	Sample ID
	GI_2YP-1	2 Year	GI_ULL1		GI_3YP-1	3 Year	GI_MDG5
	GI_2YP-2	2 Year	GI_ULL2		GI_3YP-2	3 Year	GI_MDG6
	GI_2YP-3	2 Year	GI_MAN1		GI_3YP-3	3 Year	GI_SIR1
	GI_2YP-4	2 Year	GI_CHE1		GI_3YP-4	3 Year	GI_SIR2
	GI_2YP-5	2 Year	GI_KAR4		GI_3YP-5	3 Year	GI_DAN2
	GI_2YP-6	2 Year	GI_SIR7		GI_3YP-6	3 Year	GI_DAN3
	GI_2YP-7	2 Year	GI_DAN5		GI_3YP-7	3 Year	GI_DAN4
	GI_2YP-8	2 Year	GI_SIR6		GI_3YP-8	3 Year	GI_BEL2
	GI_2YP-9	2 Year	GI_SIR		GI_3YP-9	3 Year	GI_GOA5
	GI_2YP-10	2 Year	GI_SIR		GI_3YP-10	3 Year	GI_GOA6
	GI_2YP-11	2 Year	GI_SIR		GI_3YP-11	3 Year	GI_MDG3
	GI_2YP-12	2 Year	GI_SIR		GI_3YP-12	3 Year	GI_GOA3
	GI_2YP-13	2 Year	GI_SIR		GI_3YP-13	3 Year	GI_SIR3
	GI_2YP-14	2 Year	GI_SIR		GI_3YP-14	3 Year	GI_SIR4
	GI_2YP-15	2 Year	GI_SIR		GI_3YP-15	3 Year	GI_KOU6
T3	GI_4YP-1	4 Year	GI_SIR5	T4	GI_5YP-1	5 Year	GI_PUT-4
	GI_4YP-2	4 Year	GI_KAN8		GI_5YP-2	5 Year	GI_KAR5
	GI_4YP-3	4 Year	GI_KAN20		GI_5YP-3	5 Year	GI_KAR9
	GI_4YP-4	4 Year	GI_SID1		GI_5YP-4	5 Year	GI_KAR10
	GI_4YP-5	4 Year	GI_PUT-1		GI_5YP-5	5 Year	GI_KAR14
	GI_4YP-6	4 Year	GI_CHE5		GI_5YP-6	5 Year	GI_KAR15
	GI_4YP-7	4 Year	GI_CHE6		GI_5YP-7	5 Year	GI_KOK1
	GI_4YP-8	4 Year	GI_YAN3		GI_5YP-8	5 Year	GI_KAN3
	GI_4YP-9	4 Year	GI_YAN4		GI_5YP-9	5 Year	GI_KAN4
	GI_4YP-10	4 Year	GI_KOP2		GI_5YP-10	5 Year	GI_KAN5
	GI_4YP-11	4 Year	GI_BEL1		GI_5YP-11	5 Year	GI_KAN6
	GI_4YP-12	4 Year	GI_KUM1		GI_5YP-12	5 Year	GI_KAN12
	GI_4YP-13	4 Year	GI_KUM2		GI_5YP-13	5 Year	GI_KAN13
	GI_4YP-14	4 Year	GI_CHE3		GI_5YP-14	5 Year	GI_MDG4
	GI_4YP-15	4 Year	GI_KOU1		GI_5YP-15	5 Year	GI_KAN15
	GI_4YP-1	4 Year	GI_SIR5		GI_5YP-1	5 Year	GI_PUT-4

Table 2. Relative per cent change in growth parameters in G. indica Choisy accessions during 2019-20 and 2020-21

Treatment	Plant height (cm)			Number of branches			Length of branch (cm)		
	2019	2020	Per cent Increase	2019	2020	Per cent Increase	2019	2020	Per cent Increase
GI-2YP	124.06[d]	193.00[c]	55.29	19.00[b]	22.00[c]	15.10	69.80[b]	101.00[b]	44.68
GI-3YP	188.00[c]	272.00[b]	44.68	20.00[b]	25.00[b]	25.00	86.00[b]	110.00[b]	27.89
GI-4YP	289.00[b]	346.33[a]	19.97	36.00[a]	46.46[a]	29.09	135.06[a]	167.00[a]	23.39
GI-5YP	304.00[a]	358.00[a]	18.54	38.06[a]	49.26[a]	29.42	143.00[a]	167.33[a]	17.23
Mean	**225.68**	**292.246**	**29.49**	**28.23**	**38.09**	**34.92**	**108.39**	**136.24**	**25.69**
S.Em.±	6.73	5.70		1.65	1.73		6.63	8.84	
C.V.	6.67	4.36		13.09	10.19		13.68	14.52	
C.D. (5%)	20.75	17.58		5.09	5.35		20.43	27.26	

Table 3. Relative per cent change in growth parameters in G. indica Choisy accessions during 2019-20 and 2020-21

Treatment	Number of leaves			Leaf length (cm)			Leaf width (cm)		
	2019	2020	Per cent Increase	2019	2020	Per cent Increase	2019	2020	Per cent Increase
GI-2YP	26.53d	42.00[d]	57.02	4.80[b]	6.46 [a]	34.58	3.00 [a]	3.00 [a]	0.00
GI-3YP	65.33[c]	77.13[c]	18.06	6.00a	6.19 [a]	3.16	3.00 [a]	3.00 [a]	0.00
GI-4YP	41.33[b]	54.46[b]	31.76	6.00[a]	6.26 [a]	9.24	3.00 [a]	3.00 [a]	0.00
GI-5YP	109.06[a]	118.46[a]	8.61	6.00[a]	6.26 [a]	4.33	3.00 [a]	3.00 [a]	9.89
Mean	**60.56**	**72.92**	**20.40**	**5.63**	**6.29**	**11.72**	**2.88**	**3.00**	**4.16**
S.Em.±	6.08	5.56		0.22	0.12		0.08	0.00	
C.V.	22.46	17.06		8.82	4.37		6.41	0.00	
C.D. (5%)	18.75	17.15		5.63	6.29	11.72	-	-	

Table 4. Relative per cent change in growth parameters in G. indica Choisy accessions during 2019-20 and 2020-21

Treatment	Leaf length width ratio			Stem girth (cm)			Canopy spread EW (cm)		
	2019	2020	Per cent Increase	2019	2020	Per cent Increase	2019	2020	Per cent Increase
GI-2YP	2.00 [a]	2.14 [a]	7.00	8.00 [a]	12.33[d]	54.12	94.46[d]	121.00[c]	28.08
GI-3YP	2.00 [a]	2.06 [a]	3.00	15.00 [a]	18.00[c]	20.75	122.33[c]	141.33[b]	15.53
GI-4YP	2.00 [a]	2.08 [a]	11.22	21.33 [a]	28.26[b]	32.48	195.19[b]	227.33a	16.46
GI-5YP	2.00 [a]	2.08 [a]	4.00	30.20 [a]	37.39 [a]	4.09	244.66[a]	270.00a	10.35
Mean	**1.97**	**2.09**	**6.09**	**18.58**	**23.96**	**28.95**	**164.16**	**189.91**	**15.68**
S.Em.±	0.06	0.03		1.09	1.88		9.18	6.86	
C.V.	7.02	3.95		13.19	17.56		12.51	8.08	
C.D. (5%)	0.19	-		3.37	5.79		28.31	21.15	

Table 5. Relative per cent change in growth parameters in G. indica Choisy accessions during 2019-20 and 2020-21

Treatment	Canopy spread NS (cm)			Tree volume		
	2019	**2020**	**Per cent Increase**	**2019**	**2020**	**Per cent Increase**
GI-2YP	99.46[b]	147.00[c]	47.45	0.67[d]	1.92[d]	186.56
GI-3YP	127.00[c]	160.00[c]	26.31	1.56[c]	3.32[c]	112.82
GI-4YP	208.26[b]	243.19[b]	16.77	6.56[b]	9.11[b]	38.87
GI-5YP	233.33[a]	290.66a	24.57	9.20a	14.69[a]	59.67
Mean	**166.93**	**210.12**	**25.87**	**4.50**	**7.26**	**61.33**
S.Em.±	5.13	9.52		0.19	0.52	
C.V.	6.87	10.13		9.56	16.28	
C.D. (5%)	15.82	29.33		0.59	1.62	

College of Horticulture, Bengaluru were used *Garcinia indica,* 60 trees which were in the age of two to five year were randomly selected for the experiment with four different age group *viz* two years, three years, four year and five year old plant with five replications. The *in situ* field gene consists of *Garcinia indica* plants of different age groups being grown in a uniform piece of land which is geographically situated at 13^0 05' Latitude and 77^0 33' East Longitude. In order to gain an understanding of the growth dynamics of *Garcinia indica* during the early growth phase, plants of different age groups were selected as treatments and observations were recorded consecutively for two years. The details of the age groups and components of treatments are presented in Table 1. An exclusive descriptor for *Garcinia indica* is not available, hence descriptor of mangosteen (*Garcinia mangostana*) that belong to the same genus was used for the study which was developed by IPGRI (2003).

3. RESULTS AND DISCUSSION

Relative changes in growth parameters of *G. indica* accessions varied. During 2019-20, all the four age group plants differed significantly from one another, wherein, GI-5YP showed maximum plant height (304.00 cm) followed by GI-4YP (289.00 cm), GI-3YP (188.00 cm) and GI-2YP (124.06 cm). During 2020-21, the only numerical difference was recorded between GI-2YP (193.00cm) and GI-3YP (346 cm) as well as between GI-4YP (368.00 cm) and GI-5YP (385.00 cm), while both sets significantly differed from each other. Further, GI-2YP showed a 55.29 per cent increase in plant height for two years of research followed by GI-3YP (44.68 %), GI-4YP (19.97%) and GI-5YP (18.54%) (Table 2). These results are in accordance with Sahu *et al*. [12] The maximum plant height may be attributed to the fact that better nourishment has benefited the expression of genetic potential through accelerated photosynthesis, assimilation, cell division at different ages [13].

Number of branches per plant differed significantly during the research period; GI-4YP and GI-5YP numerically differed: 36.00 & 38.06, 46.46 & 49.26, 48.46 & 52.00, respectively during 2019-20, 2020-21 and 2021-22. Wherein, these two accessions significantly differed with GI-2YP and GI-3YP during all three years of study. Furthermore, in GI-5YP, the largest per cent increase in the number of branches per plant was observed (29.42 per cent) followed by GI-4YP (29.09 %), GI-3YP (25.00 %) and GI-2YP (Table 2). Average length of branch differed numerically in GI-4YP and GI-5YP: 143.00 cm & 135.06 cm, 167.33 cm & 167.00 cm, respectively during 2019-20, 2020-21. Accessions GI-2YP and GI-3YP significantly differed during two years of study. Further, the maximum per cent increase in length of branches per plant from 2019-20 till 2020-21 was recorded in GI-2YP (44.68 %) followed by GI-3YP (27.89 %), GI-4YP (23.39 %) and GI-5YP (17.23 %) (Table 2). The observed changes in the growth parameters may be due to the uptake of nutrients which in turn increases shoot growth release of growth factors like auxins, gibberellin and cytokinin in the root and shoot tissues leading to growth [14,15].

The trait number of leaves per plant differed significantly over three years of study. During 2019-20, all the four age groups differed significantly from one another. The oldest plant in the study, GI-5YP, the recorded maximum number of leaves (109.06) followed by GI-4YP (65.33), GI-3YP (41.33) and GI-2YP (26.53). During 2020-21, a significant difference was recorded between different age groups with a maximum number of leaves was recorded in GI-5YP (118.46) followed by GI-4YP (77.13), GI-3YP (54.46) and GI-2YP (42.00), while both sets significantly differed from each other. Further, with respect to per cent increase over two years of the study indicated that GI-2YP recorded a 58.31 per cent increase in number of leaves followed by GI-3YP (31.76 %), GI-2YP (18.06 %) and GI-5YP (8.61 %) (Table 3). *G. indica* accessions of different age groups did not differ significantly for leaf length during two years of study. GI-2YP and GI-3YP during 2019-20 were numerically differed (6.00 cm and 4.80 cm). During 2019-20, all the four age groups did not differ from one another (6.00cm) except GI-2YP (4.80cm). During 2020-21, GI-2YP and GI-3YP differed numerically 6.46 cm and 6.19 cm, respectively (Table 3).

The trait leaf width did not differ over three years of study. During all three years of the study, the leaf width was 3.00 cm. Further, with respect to per cent increase over two years of the study indicated that GI-5YP recorded a 9.89 per cent increase in leaf width which GI-2YP, GI-3YP and GI4YP recorded zero per cent increase (Table 3). During all the three years of study, plants of different ages did not differ for the trait leaf length to width ratio. GI-5YP differed from GI-4YP, GI-3YP and GI-2YP. During 2019-20, the leaf length to width ratio was similar (2.00 cm) during 2020-21, maximum leaf length to width ratio was

recorded in GI-2YP (2.14) followed by GI-4YP, GI-5YP (2.08) and GI-3YP (2.06). Furthermore, in terms of per cent percent increase throughout two years of research, indicated that GI-2YP recorded a 27.38 per cent increase in leaf length to width ratio followed by GI-4YP (11.22), GI-5YP (4.00) and GI-3YP (3.00) (Table 4). Nitrogen is a constituent of amino acid, nucleotides, nucleic acids, several co-enzymes, auxins, cytokinins and alkaloids, which induce cell elongation, cell enlargement and cell division. Boughalleb *et al*. [16] reported the maximum number of leaves in nursery plants of lemon and orange by the application of fertilizer and adaptability of the plants. Baviskar *et al*. [17] revealed that applied fertilizers and congenial environment increase the number of leaves in guava. This trait differed significantly across different age group accessions across three years of study.

During 2019-20, all the four age groups differed significantly from one another wherein, GI-5YP recorded maximum stem girth (30.20 cm) followed by GI-4YP (21.33 cm), GI-3YP (15.00 cm) and GI-2YP (8.00 cm). During 2020-21, maximum stem girth was recorded in GI-5YP (37.39 cm) followed by GI-4YP (28.26 cm), GI-3YP (18.00 cm) and GI- 2YP (12.33 cm). Further, with respect to per cent increase over two years of the study indicated that GI-2YP recorded 54.12 per cent increase in stem girth followed by GI-4YP (32.48 %), GI-3YP (20.75 %) and GI-5YP (4.09 %) (Table 4) The improved stem girth may be due to the increase in shoot length and number of leaves which might have resulted in the production of more quantities of carbohydrates and subsequently their translocation toward the stem [18,19].

G. indica accessions of different age groups differed significantly for canopy spread. GI-3YP and GI-4YP numerically differed (227.33 cm and 141.33 cm, respectively). During 2021-22, GI-5YP differed significantly from GI-4YP, whereas, GI-2YP and GI-3YP differed numerically from one another. Further, with respect to per cent increase over two year of the study indicated that GI-2YP recorded 28.08 per cent increase in canopy spread (East-West) followed by GI-4YP (16.46 %), GI-3YP (15.53 %) and GI-5YP (10.35 %) (Table 4). Different age groups differed significantly for canopy spread (North-South) during two years of research. GI-2YP and GI-3YP were differed numerically *i.e.,* 160.00 cm & 147.00 cm during 2019-20. During 2019-20, all the four age groups differed significantly from one another, wherein, GI-5YP recorded maximum canopy spread (233.33 cm) followed by GI-4YP (208.26 cm), GI-3YP (127.00 cm) and GI-2YP (99.46 cm).

During 2020-21, numerical differences were recorded between GI-2YP (147.00 cm) and GI-3YP (160.00 cm), while both the sets differed significantly from each other, Further, with respect to per cent increase over two years of study, indicated that GI-2YP recorded 47.45 per cent increase in canopy spread (North-South) followed by GI-3YP (26.31 %), GI-5YP (24.57%) and GI-4YP (16.77%) (Table 4). During 2019-20, all the four age groups differed significantly. GI-5YP recorded maximum tree volume (9.20 m^3) followed by GI-4YP (6.56 m^3), GI-3YP (1.56 m^3) and GI-2YP (0.67 m^3). Similarly, during 2020-21, all four ages group differed significantly from one another: GI-5YP recorded maximum tree volume (14.69 m^3) followed by GI-4YP (9.11 m^3), GI-3YP (3. 32 m^3) and GI-2YP (1.92 m^3). Further, with respect to per cent increase over two year of study indicated that GI-2YP recorded 186.56 per cent increase in plant height followed by GI-3YP (112.82 %), GI-5YP (59.67 %) and GI-4YP (38.87 %) (Table 5). These findings have practical applications in terms of crop improvement programmes of *Garcinia* species and the spread of this crop to new non-traditional regions.

4. CONCLUSION

The age groups *Garcinia indica* differed significantly for relative growth of morphological characters such as plant height, the number of branches, length of branch, stem girth, canopy spread and tree volume.. Out of four different age group maximum per cent increase in plant height, length of branch, number of leaves, leaf length, length width ratio, stem girth and canopy spread in GI-2YP, maximum number of branches in GI-3YP, maximum leaf width in GI-5YP and maximum tree volume in GI-4YP. Overall, *G. indica* grows faster in two-year-old plants than older age groups.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but the advancement of knowledge.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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