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Plasticity for (-) - Hydroxycitric acid (HCA) content in ecotypes of *Garcinia indica* (Kokum) of Western Ghats

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Abstract
Western Ghats of India is the centre for biological diversity many plant species including *Garcinia indica*. Biologically important compound (-) - Hydroxycitric acid (HCA) is a popular anti-obesity compound extracted from the fruits of *Garcinia indica*. The present study was conducted to understand the extent of variation for the content of –(-)HCA in the fruits of *Garcinia indica* ecotypes prevailing in Western Ghats of Karnataka. The autoclave assisted extraction and the spectrophotometric analysis of 120 ecotypes of *G. indica* revealed significant variation in HCA content in the fruits. The average per cent HCA content on dry weight basis in fruits of *G. indica* was 17.90. The average mean HCA content of *G. indica* ecotypes in Uttara Kannada region (regarded as Uttara Kannada population) was highest (20.60%). compared to other ecotypes. The results indicated that there is a good genetic plasticity for HCA content among the ecotypes of *G. indica* prevailing in Western Ghats of Karnataka and there exists ample opportunity to exercise selection for the genotypes with higher –(-)HCA content.

Keywords: Hydroxycitric acid, *Garcinia indica*, Western Ghats

Introduction
The genus *Garcinia* comprises about 250 species in which 43 species are found in India, distributed across the tropical forests and adjoining main lands. , and exhibit fair amount of morphological and phytochemical diversity Anu *et al.*, 2016 [1], Parthasarathy *et al.*, 2014 [11] and Sivu *et al.*, 2017) [17]. The species *Garcinia indica* is endemic to Western Ghats of India is an important species of the genus *Garcinia* (Shameer *et al.*, 2016) [14]. *Garcinia* species in general and *Garcinia indica* in particular are known to have rich diversity in their phytochemical traits of food and nutritional importance to human (Jena *et al*. 2002) [6] (Anu *et al.*, 2016) [1]. Among the chemical compounds found in *Garcinia* species, the major compound is (-) - Hydroxycitric acid (HCA) which is used as an anti-obesity principle (Jayaprakasha 2002). It is a derivative of citric acid and a chiral compound (Jena *et al*. 2002) [6]. HCA has been found to have anti-obesity activity by inhibiting lipid synthesis in the body (Lewis and Neelakantan, 1965) [8]. The compound (-)- Hydroxycitric acid is chiral in nature and has an additional –OH group when compared to citric acid. Further, there are also two asymmetrical carbons rendering the compound to assume four isomer forms: all these confirmations possibly impart health benefit properties to the molecule (*Gogoi et al.*, 2014) [3]. Primarily the (-) -HCA has made the fruits of *Garcinia* species and their products popular in international market for anti-obesity properties in human.

Presence of two hydroxyl and three carboxyl groups makes (-) -HCA an unstable compound and therefore it easily tends to forms lactones with cations like Ca^{2+}, K^{+} *etc.* (Antony *et al.*, 1998). The Potential of weight loss property in human upon consuming (-) -HCA is aids by their ability of increasing lipid metabolism (Shrikanth *et al.*, 2014) [16]. ATP citrate oxaloacetate lyase (citrate lyase) is involved in catalyzing the cleavage reaction of citrate into oxaloacetate and acetyl CoA (Jena *et al.*, 2002) [6]. By inhibiting the activity of the citrate lyase enzyme and making Acetyl CoA unavailable for lipid synthesis, (-) -HCA acts as an anti-

obesity factor. However, the (-) -HCA content in the fruits of Garcinia indica vary from region to region and across the genotypes / ecotypes (Jayaprakasha 2002; Kureshi *et al*. 2019; Seethapathy *et al*. 2018) [4, 7, 13]. Assessment of genetic plasticity for (-) -HCA content among the natural populations of *G. indica* provides an insight into the natural sources of this valuable compound, its inheritance and distribution within and between the populations in its natural habitat. Estimation of (-) -HCA content is done from leaves and fruits, especially dried fruit rinds using various extraction procedures. The fruit rinds of *Garcinia* species contain higher amount of (-) -HCA compared to other parts of (-) -HCA (Jayaprakasha *et al.,* 2003) [5]. We report the nature and extent of variation for the (-) -HCA content in the ecotypes of the *Garcinia indica* prevailing in the Western Ghats covering Karnataka state in India.

Material and Methods

Fruits of *Garcinia indica* ecotypes from random locations covering Western Ghats of the Karnataka state of India were collected in the peak fruiting season of 2016-17 and the fruits were stored at 4 ºC until their actual use. The sampling locations are presented in Table 1. A set of 120 fruit samples each in replications were used for final analysis to estimate the (-) -HCA content. Chemicals used for the sample preparation were: 4N Sodium hydroxide, 50 per cent Calcium hydroxide, 10 per cent activated charcoal, 1N H_2SO_4 and 5 per cent Sodium metavanadate, Potassium hydroxycitrate bicarbonate (Standard for (-)- HCA).

Preparation of samples for extraction of (-) - HCA: The method described by Gogoi *et al.* (2014) [3] was followed for extraction of HCA with few minor modifications. About 5 g of chopped rinds of each fruit sample was dried to one third of their fresh weight (Figure 2 A and B). Powdered rinds were added to15 ml of double distilled water and autoclaved twice (121 °C, 15 PSI.). The liquid extract was separated and treated with 10 per cent activated charcoal. The thick concentrated liquid was filtered. The residue was washed with small portion of distilled water and combined with the filtrate. The filtrate was neutralized with 4N NaOH solution which was maintained at pH 7.5. Fifty per cent solution of $CaCl_2$, was added and stirred well. Precipitated residue was filtered through 125 mm pore size filter paper and dried (Figure 1 C). Weight of the dried pellets of HCA lactones was recorded. Accurately weighed 0.29 g of HCA lactone was dissolved in 5 ml of 1 N H_2SO_4 and diluted to 25 ml with distilled water. The sample solution was decolorized using 10 per cent activated charcoal. The solution was filtered into a 50 ml standard flask, washed the residue with small portion of distilled water and made up tothe volume. The standard Potassium hydroxycitrate bicarbonate salt equivalent to 0.0429 g of the free acid was weighed accurately and dissolved in 5 ml of 1 N H_2SO_4, and 25 ml of distilled water was added. It was filtered and transferred into a 50 ml volumetric flask and made up to the volume using distilled water. Linear working standards (0.5 ml, 1 ml, 1.5 ml and 2 ml) were prepared from the stock standard solution.

Quantification of HCA content by UV double- beamed spectrophotometer

One ml each of the prepared working standard solutions was added to 0.9 ml of 5 per cent Sodium metavanadate and 1ml double distilled water to estimate the HCA content present in the given sample (Figure 2 D). Absorbance value at 467 nm (Antony *et al.,* 1998) was noted for all the working standards and a linear graph was plotted with the absorbance values to obtain a standard curve (Figure 2). Similarly, absorbance values for samples were recorded and the HCA content in samples was estimated using the following formula;

$$\text{HCA content (per cent)} = \frac{\text{Absorbance value} \times \text{quantity of sample in the test solution} \times \text{factor}}{\text{Volume of the sample}} \times 100$$

Factor = Pellet quantity obtained after precipitation with Ca $(OH)_2$ /5 g of sample

Analysis of variance (ANOVA) and normal distribution of probability were worked out for the results obtained from HCA quantification.

Results

Relative levels of (-) - HCA content in the fruit samples on dry weight basis was estimated and analysed. The normal distribution of HCA content in ecotypes of *G. indica* species revealed a symmetrical bell-shaped curve (Figure 3). Per cent HCA content on dry weight basis in fruit samples of different ecotypes of *Garcinia indica* is presented in Table 2. The analysis of variance (ANOVA) revealed significant differences among the ecotypes of *Garcinia indica* for the (-) -HCA content in fruits (Table 3). The average mean per cent (-) -HCA content on dry weight basis was 17.90. The ecotype from Sirsi (Uttara Kannada) population recorded highest per cent (-) -HCA content of 25.46 and lowest per cent (-) -HCA content (10.53) was recorded in an ecotype from Mudigere (Chikmagalur) population.

The samples were divided into populations based on Districts as units. Descriptive statistics for HCA content among the samples of *Garcinia indica* representing different populations is presented in Table 4. The average mean for (-) -HCA content of populations of *G. indica* ecotypes based on geographical region was highest for the population from Uttara Kannada (20.60). The lowest average mean for (-) -HCA content was recorded in population from Belgaum (16.39). These results indicated that there is a fair amount of genetic plasticity for per cent (-) -HCA content among the ecotypes of *G. indica* in Western Ghats of Karnataka.

Discussion

The extraction of (-) - Hydroxycitric acid from the dried rinds of *Garcinia indica* by autoclaving the samples worked efficiently for better estimation of HCA content. Autoclaving the samples help in effective release of the target contents and enabling their detection (Gogoi *et al.*, 2014) [3]. The spectrophotometric estimation has some limitations such as inaccurate quantification due to reaction of other similar compounds and time dependence of the developed colour by the reaction. Nonetheless, a proper extraction of the target compound from the tissue into the solution, such as the process of autoclaving, evolved better capture and accounting in the final estimation. Similar results for (-) -HCA content estimation in fruit rinds of *Garcinia indica* (12 per cent) was reported by Pandey *et al.* (2015) [10]. The variation in (-) -HCA content among the ecotypes of *Garcinia indica* was significant across the samples of different natural populations of Western Ghats. The high HCA content of *Garcinia indica* in the sub-populations of Northern regions of Western Ghats of Karnataka such as Uttara Kannada and Udupi Districts pointed at the genetic diversity of *Garcinia indica.* The variation in (-) -HCA content across geographic populations may be due genotypic variation and adoption to different

regions where the environmental conditions have favoured maximum expression of the trait (Priyadevi *et al.*, 2012). The survey conducted by Parthasarathy *et al.* (2013) revealed that *Garcinia indica* and *Garcinia cambogia* were present throughout Western Ghats, extended from *Konkan* valley in North of Maharashtra to Malabar Coast in South of Kerala and ecotypes of *Garcinia indica* was predominant in *Konkan* region. The normal distribution of ecotypes with more number of ecotypes having the (-) -HCA content near to mean (-) -HCA content in ecotypes of *G. indica* also reveals that the content of HCA in fruits is symmetrically distributed in natural populations of the species in Western Ghats of Karnataka.

Table 1: Details of locations covered to collect *Garcinia indica* samples in Western Ghats of Karnataka

Sl. No.	District name	No. of locations	Location names
1	Uttara Kannada	10	Karasulli, Yana, Kumta, Dandeli, Sirsi, Siddapura, Yellapur, Honnawara, Ankola, Karwarand Ramnagar
2	Udupi	3	Mandarthi, and Kokkarne
3	Kodagu	6	Kodlipet, Chettalli, CHES-Chettalli, Madikeri, Valnoor and Coorg
4	Hassan	1	Sakleshpur
5	Chikmagalur	5	Koppa, Mudigere, Kadur, Sringeri, and Chattanahalli
6	Dakshina Kannada	5	Ullala, Koudichar, Puttur, Kaniyoor, Mudibidre and Machina Belthangadi
7	Belgaum	2	Belgaum and Anmod
8	Goa	1	Ela
9	Shivamogga	1	Aagumbe
10	Dharwad	1	Dharwad
11	Kasargod (Kerala)	1	Kasargod

Table 2: Relative content of (-) – HCA (per cent on dry weight basis) in fruit rinds of different ecotypes of *Garcinia indica* estimated by spectrophotometer method

Sl. No.	Sample ID	Mean (%)	SD
1	GI_KAR1	22.37	0.18
2	GI_KAR2	21.66	0.21
3	GI_KAR3	11.50	0.50
4	GI_KAR4	13.69	0.11
5	GI_KAR5	12.28	0.50
6	GI_KAR6	13.47	0.14
7	GI_KAR7	17.59	0.15
8	GI_KAR8	15.18	0.30
9	GI_KAR9	17.29	0.10
10	GI_KAR10	11.41	0.14
11	GI_KAR11	10.57	0.09
12	GI_KAR12	17.11	0.20
13	GI_KAR13	11.42	0.11
14	GI_KAR14	12.67	0.15
15	GI_KAR15	14.02	0.09
16	GI_MAN2	17.54	0.53
17	GI_MAN3	14.82	0.31
18	GI_MAN8	14.54	0.76
19	GI_KAD1	14.34	0.56
20	GI_KAD2	12.48	0.14
21	GI_KAD3	14.64	0.27
22	GI_KAD4	14.41	0.16
23	GI_KAD5	17.11	0.92
24	GI_KOK1	13.55	0.10
25	GI_KOD1	17.57	0.75
26	GI_MAC	17.48	0.16
27	GI_CHE1	12.02	0.28
28	GI_KOP1	17.50	0.51
29	GI_MDB	17.43	0.61
30	GI_SKP	20.13	0.07
31	GI_MDG1	20.04	0.14
32	GI_YAN1	20.02	0.94
33	GI_KOK2	21.33	0.85
34	GI_KOD2	20.58	0.35
35	GI_GOA4	13.21	0.25
36	GI_DAN1	11.65	0.31
37	GI_KAN1	13.29	0.56
38	GI_KAN2	14.98	0.63
39	GI_KAN3	15.44	0.13
40	GI_KAN4	16.03	0.42
41	GI_KAN5	12.72	0.38
42	GI_KAN6	14.35	0.16
43	GI_KAN7	12.33	0.37
44	GI_KAN8	13.28	0. 53

45	GI_KAN9	13.09	0.52
46	GI_KAN10	21.54	0.21
47	GI_KAN11	23.04	0.15
48	GI_KAN12	13.40	0.45
49	GI_KAN13	17.50	0.16
50	GI_KAN14	20.78	0.86
51	GI_KAN15	23.06	0.57
52	GI_KAN16	16.07	0.48
53	GI_KAN17	19.62	0.15
54	GI_KAN18	19.39	0.68
55	GI_KAN19	18.66	0.67
56	GI_KAN20	19.76	0.23
57	GI_YAN2	18.39	0.10
58	GI_CHE2	19.61	0.87
59	GI_CHE3	19.74	0.25
60	GI_CHE4	14.45	0.32
61	GI_CHE5	14.87	0.64
62	GI_CHE6	15.67	0.26
63	GI_YAN3	17.67	0.32
64	GI_YAN4	16.68	0.20
65	GI_KOP2	14.67	0.27
66	GI_BEL1	13.79	0.42
67	GI_KUM1	15.42	0.15
68	GI_KUM2	12.61	0.23
69	GI_KOU1	14.06	0.21
70	GI_KOU2	17.06	0.14
71	GI_KOU3	16.79	0.17
72	GI_KOU4	15.65	0.61
73	GI_KOU5	12.59	0.26
74	GI_SAK2	13.61	0.62
75	GI_SID1	14.05	0.24
76	GI_SID2	12.90	0.15
77	GI_SID3	11.80	0.43
78	GI_MDG1	10.53	0.71
79	GI_BEL3	15.41	0.98
80	GI_BEL4	15.25	0.22
81	GI_BEL5	12.23	0.61
82	GI_BEL6	15.91	0.46
83	GI_BEL7	17.41	0.26
84	GI_MDG7	17.05	0.32
85	GI_MDG8	13.76	0.31
86	GI_GOA1	13.52	0.22
87	GI_GOA2	12.98	0.18
88	GI_GOA3	23.68	0.31
89	GI_KOP3	22.63	0.36
90	GI_PUT-1	24.06	0.09
91	GI_PUT-2	22.43	0.25
92	GI_PUT-3	23.78	0.87
93	GI_PUT-4	24.45	0.42
94	GI_PUT-5	24.72	0.30
95	GI_PUT-6	22.74	0.16
96	GI_ULL3	23.40	0.32
97	GI_ULL4	24.03	0.42
98	GI_ULL5	24.37	0.46
99	GI_BEL2	24.70	0.63
100	GI_GOA5	23.91	0.34
101	GI_GOA6	23.16	0.42
102	GI_MDG3	23.50	0.93
103	GI_MDG4	24.09	0.22
104	GI_MDG5	24.41	0.31
105	GI_MDG6	24.86	0.76
106	GI_SIR1	20.66	0.38
107	GI_SIR2	22.61	0.25
108	GI_SIR3	21.41	0.82
109	GI_SIR4	21.76	0.25
110	GI_SIR5	23.60	0.32
111	GI_SIR6	25.46	0.24
112	GI_DAN2	24.54	0.37
113	GI_DAN3	24.93	0.45
114	GI_DAN4	22.66	0.27
115	GI_DAN5	24.57	0.67
116	GI_ULL1	25.27	0.45
117	GI_ULL2	21.68	0.71

118	GI_MAN1	23.26	0.24
119	GI_KOU6	24.26	0.26
120	GI_SIR7	23.22	0.53

Table 3: Analysis of variance (ANOVA) of (-) –HCA content among ecotypes of *Garcinia indica*

Source of Variation	Df	MS	F-cal	F-critical
Treatments	119	59.25	848.01	1.43**
Replications	240	0.07		
Total	359			
Standard error				0.22
t tab 0.01 (240)				2.34
Critical Difference				0.51
Co- efficient of Variance (CV)				0.25

**- significant at 1%

Table 4: Mean, range and standard deviation for (-) - HCA content in different sub populations (regions) of *Garcinia indica*

Sub populations	Regions	Mean (%)	Minimum (%)	Maximum (%)	Standard Deviation
POP 1	Uttara Kannada	19.11	12.05	23.22	4.25
POP 2	Udupi	15.97	9.07	23.96	4.83
POP 3	Kodagu	15.32	10.53	19.08	3.04
POP 4	Dakshina Kannada	15.38	12.11	18.64	4.62
POP 5	Chikmagalur	16.91	11.48	22.41	5.67
POP 6	Hassan	16.45	10.83	23.78	4.07
POP 7	Belgaum	16.38	9.03	23.36	4.73

A. B. C. D

Fig 1: Steps in preperation of samples for HCA content estimation; A) Dried rinds of *Garcinia indica*, B) Powdered dried rinds, C) HCA lactone pellets and D) Colour development after Sodium meta vanadate reaction with HCA in the sample

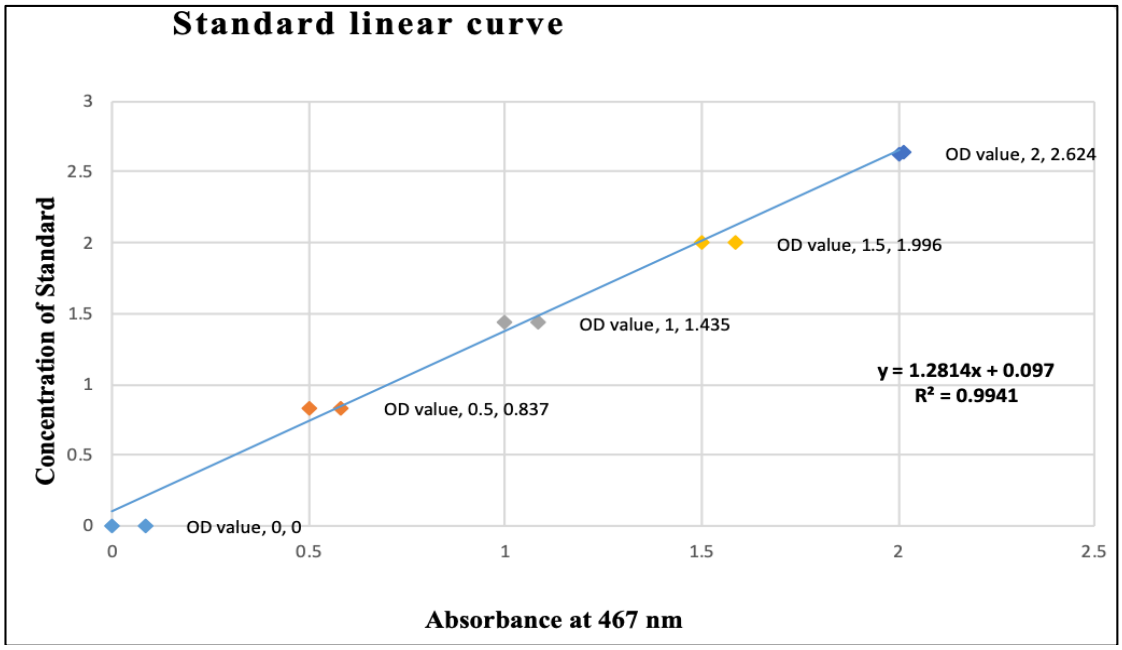

Fig 2: Standard linear curve plotted for the linear working standard solutions (0.5 ml, 1.0 ml, 1.5 ml and 2.0 ml) of Potassium hydroxycitrate bicarbonate at 467 nm absorbance in UV double-beamed spectrophotometer. The R^2 value above 0.8 (0.9941) confirms the linearity of the standard curve plotted for the estimation of HCA content

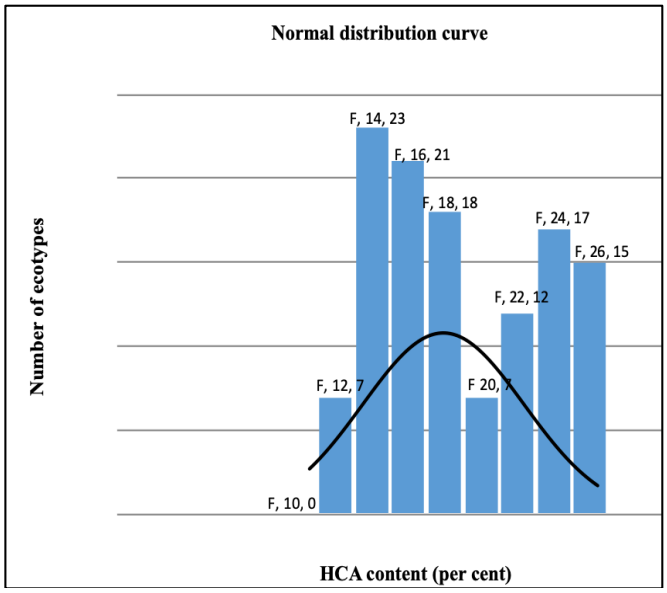

Fig 3: Normal distribution of HCA content among *G. indica* ecotypes

Supplementary materials

Table 1: Details of *Garcinia indica* samples collected from different regions of Karnataka

Sl. No.	Sample	Sample ID	Location	District/State	GPS Coordinates
1	*G. indica*	GI_KAR1	Karasulli	Uttara Kannada	14° 34' 30.8316" N 74° 48' 33.1992" E
2	*G. indica*	GI_KAR2	Karasulli	Uttara Kannada	14° 34' 30.8388" N 74° 48' 33.1632" E
3	*G. indica*	GI_KAR3	Karasulli	Uttara Kannada	14° 34' 30.828" N 74° 48' 33.1524" E
4	*G. indica*	GI_KAR4	Karasulli	Uttara Kannada	14° 34' 30.8172" N 74° 48' 33.174" E
5	*G. indica*	GI_KAR5	Karasulli	Uttara Kannada	14° 34' 30.8244" N 74° 48' 33.1488" E
6	*G. indica*	GI_KAR6	Karasulli	Uttara Kannada	14° 34' 30.8136" N 74° 48' 33.1236" E
7	*G. indica*	GI_KAR7	Karasulli	Uttara Kannada	14° 34' 30.8028" N 74° 48' 33.1668" E
8	*G. indica*	GI_KAR8	Karasulli	Uttara Kannada	14° 34' 30.7956" N 74° 48' 33.1344" E
9	*G. indica*	GI_KAR9	Karasulli	Uttara Kannada	14° 34' 30.8532" N 74° 48' 33.1056" E
10	*G. indica*	GI_KAR10	Karasulli	Uttara Kannada	14° 34' 30.846" N 74° 48' 33.138" E
11	*G. indica*	GI_KAR11	Karasulli	Uttara Kannada	14° 34' 30.846" N 74° 48' 33.1524" E
12	*G. indica*	GI_KAR12	Karasulli	Uttara Kannada	14° 34' 30.846" N 74° 48' 33.1524" E
13	*G. indica*	GI_KAR13	Karasulli	Uttara Kannada	14° 34' 30.8244" N 74° 48' 33.1668" E
14	*G. indica*	GI_KAR14	Karasulli	Uttara Kannada	14° 34' 30.8064" N 74° 48' 33.1344" E
15	*G. indica*	GI_KAR15	Karasulli	Uttara Kannada	14° 34' 30.8028" N 74° 48' 33.1812" E
16	*G. indica*	GI_MAN2	Mandarthi	Udupi	13° 29' 48.4476" N 74° 48' 35.172" E
17	*G. indica*	GI_MAN3	Mandarthi	Udupi	13° 29' 47.7852" N 74° 48' 36.5256" E
18	*G. indica*	GI_MAN8	Mandarthi	Udupi	13° 29' 46.9572" N 74° 48' 35.136" E
19	*G. indica*	GI_KAD1	Kadur	Chikmagalur	13° 33' 12.0528" N 76° 0' 40.0248" E
20	*G. indica*	GI_KAD2	Kadur	Chikmagalur	13° 33' 9.6588" N 76° 0' 39.9852" E
21	*G. indica*	GI_KAD3	Kadur	Chikmagalur	13° 33' 12.438" N 76° 0' 38.1312" E
22	*G. indica*	GI_KAD4	Kadur	Chikmagalur	13° 33' 12.2868" N 76° 0' 36.432" E
23	*G. indica*	GI_KAD5	Kadur	Chikmagalur	13° 33' 10.5624" N 76° 0' 35.9676" E
24	*G. indica*	GI_KOK1	Kokkarne	Udupi	13° 26' 37.1796" N 74° 48' 55.6848" E
25	*G. indica*	GI_KOD1	Kodlipet	Kodagu	12° 47' 48.588" N 75° 53' 22.9308" E
26	*G. indica*	GI_MAC	MachinaBelthangadi	Dakshin Kannada	12° 57' 35.946" N 75° 12' 26.046" E
27	*G. indica*	GI_CHE1	Chettalli	Kodagu	12° 22' 12.0144" N 75° 49' 50.4336" E
28	*G. indica*	GI_KOP1	Koppa	Chikmagalur	13° 31' 57.5688" N 75° 21' 20.8548" E
29	*G. indica*	GI_MDB	Mudibidre	Dakshin Kannada	13° 4' 7.6764" N 74° 59' 36.96" E
30	*G. indica*	GISKP	Sakleshpur	Hassan	12° 56' 33.1188" N 75° 47' 32.7228" E
31	*G. indica*	GI_MDG1	Mudigere	Chikmagalur	13° 8' 9.3336" N 75° 38' 23.1216" E
32	*G. indica*	GI_YAN1	Yana	Uttara Kannada	14° 34' 10.6788" N 74° 33' 28.962" E
33	*G. indica*	GI_KOK2	Kokkarne	Udupi	13° 26' 38.7456" N 74° 48' 56.8044" E
34	*G. indica*	GI_KOD2	Kodlipet	Kodagu	12° 47' 45.51" N 75° 53' 27.4488" E
35	*G. indica*	GI_GOA4	Ela	Goa	15° 17' 57.5736" N 74° 7' 26.3856" E
36	*G. indica*	GI_DAN1	Dandeli	Uttara Kannada	15° 14' 58.8408" N 74° 37' 2.5464" E
37	*G. indica*	GI_KAN1	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 0.8976" N 75° 22' 5.448" E
38	*G. indica*	GI_KAN2	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 0.0048" N 75° 22' 1.704" E
39	*G. indica*	GI_KAN3	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 59.9292" N 75° 22' 5.4084" E
40	*G. indica*	GI_KAN4	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 59.9292" N 75° 22' 8.886" E
41	*G. indica*	GI_KAN5	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 55.7856" N 75° 22' 3.4788" E
42	*G. indica*	GI_KAN6	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 51.5664" N 75° 22' 3.5544" E

44	*G. indica*	GI_KAN8	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 56.7648" N 75° 22' 4.3284" E
45	*G. indica*	GI_KAN9	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 51.5664" N75° 22' 1.47" E
46	*G. indica*	GI_KAN10	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 53.676" N 75° 22' 13.7532" E
47	*G. indica*	GI_KAN11	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 6.1104" N 75° 21' 59.2308" E
48	*G. indica*	GI_KAN12	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 4.7532" N 75° 22' 9.8148" E
49	*G. indica*	GI_KAN13	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 58.7268" N 75° 21' 58.3812" E
50	*G. indica*	GI_KAN14	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 4.7532" N 75° 22' 12.9036" E
51	*G. indica*	GI_KAN15	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 49.608" N 75° 22' 9.1956" E
52	*G. indica*	GI_KAN16	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 2.4924" N 75° 22' 20.9352" E
53	*G. indica*	GI_KAN17	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 58.2732" N 75° 21' 52.434" E
54	*G. indica*	GI_KAN18	Kaniyoor, Puttur	Dakshin Kannada	12° 43' 10.0272" N 75° 22' 0.4656" E
55	*G. indica*	GI_KAN19	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 53.7624" N 75° 21' 55.6776" E
56	*G. indica*	GI_KAN20	Kaniyoor, Puttur	Dakshin Kannada	12° 42' 48.4128" N 75° 22' 11.5896" E
57	*G. indica*	GI_YAN2	Yana	Uttara Kannada	14° 34' 10.6788" N 74° 33' 28.962" E
58	*G. indica*	GI_CHE2	CHES, Chettalli	Kodagu	12° 23' 20.2524" N 75° 50' 43.26" E
59	*G. indica*	GI_CHE3	CHES, Chettalli	Kodagu	12° 23' 19.284" N 75° 50' 44.5344" E
60	*G. indica*	GI_CHE4	CHES, Chettalli	Kodagu	12° 23' 20.868" N 75° 50' 50.6364" E
61	*G. indica*	GI_CHE5	CHES, Chettalli	Kodagu	12° 23' 19.284" N 75° 50' 47.7024" E
62	*G. indica*	GI_CHE6	CHES, Chettalli	Kodagu	12° 23' 24.414" N 75° 50' 47.0076" E
63	*G. indica*	GI_YAN3	Yana	Uttara Kannada	14° 34' 10.6788" N 74° 33' 28.962" E
64	*G. indica*	GI_YAN4	Yana	Uttara Kannada	14° 34' 9.8688" N 74° 33' 27.2268" E
65	*G. indica*	GI_KOP2	Koppa	Chikmagalur	13° 32' 24.4356" N 75° 21' 5.688" E
66	*G. indica*	GI_BEL1	Belgaum	Belgaum	15°50’58.902”N 74°29’51.62”E
67	*G. indica*	GI_KUM1	Kumpta	Uttara Kannada	14° 25' 35.5944" N 74° 25' 6.8412" E
68	*G. indica*	GI_KUM2	Kumpta	Uttara Kannada	14° 25' 34.1724" N 74° 25' 1.668" E
69	*G. indica*	GI_KOU1	Koudichar	Dakshin Kannada	12° 33' 29.0664" N 75° 23' 26.7612" E
70	*G. indica*	GI_KOU2	Koudichar	Dakshin Kannada	12° 33' 24.7788" N 75° 23' 19.0752" E
71	*G. indica*	GI_KOU3	Koudichar	Dakshin Kannada	12° 33' 20.1024" N 75° 23' 24.1728" E
72	*G. indica*	GI_KOU4	Koudichar	Dakshin Kannada	12° 33' 32.2416" N 75° 23' 13.3584" E
73	*G. indica*	GI_KOU5	Koudichar	Dakshin Kannada	12° 33' 37.0692" N 75° 23' 10.3452" E
74	*G. indica*	GI_SAK2	Sakleshpur	Hassan	12° 56' 38.202" N 75° 47' 14.8416" E
75	*G. indica*	GI_SID1	Siddapura	Uttara Kannada	15° 17' 20.436" N 74° 45' 43.6284" E
76	*G. indica*	GI_SID2	Siddapura	Uttara Kannada	15° 17' 20.1372" N 74° 45' 48.5748" E
77	*G. indica*	GI_SID3	Siddapura	Uttara Kannada	15° 17' 12.6888" N 74° 45' 43.6284" E
78	*G. indica*	GI_MDG1	Mudigere, ZHRS	Chikmagalur	13° 7' 58.5012" N 75° 38' 41.2728" E
79	*G. indica*	GI_BEL3	Anmod	Belgaum	15° 26' 11.148" N 74° 18' 37.278" E
80	*G. indica*	GI_BEL4	Anmod	Belgaum	15° 26' 8.9988" N 74° 18' 36.3096" E
81	*G. indica*	GI_BEL5	Anmod	Belgaum	15° 26' 9.672" N 74° 18' 38.1636" E
82	*G. indica*	GI_BEL6	Anmod	Belgaum	15° 26' 12.948" N 74° 18' 40.2516" E
83	*G. indica*	GI_BEL7	Anmod	Belgaum	15° 26' 10.5648" N 74° 18' 40.0176" E
84	*G. indica*	GI_MDG7	ZHRS, Mudigere	Chikmagalur	13° 1' 57.3564" N 75° 36' 29.8584" E
85	*G. indica*	GI_MDG8	ZHRS, Mudigere	Chikmagalur	13° 1' 56.6148" N 75° 36' 34.0668" E
86	*G. indica*	GI_GOA1	Ela	Goa	15° 29' 51.8964" N 73° 55' 2.5608" E
87	*G. indica*	GI_GOA2	Ela	Goa	15° 29' 55.77" N 73° 55' 2.2512" E
88	*G. indica*	GI_GOA3	Ela	Goa	15° 29' 55.6188" N 73° 54' 58.6188" E
89	*G. indica*	GI_KOP3	Koppa	Chikmagalur	13° 32' 24.4356" N 75° 21' 5.688" E
90	*G. indica*	GI_PUT-1	DCR-Puttur	Udupi	12° 44' 25.2096" N 75° 13' 42.2328" E
91	*G. indica*	GI_PUT-2	DCR-Puttur	Udupi	12° 44' 28.2372" N 75° 13' 40.3392" E
92	*G. indica*	GI_PUT-3	DCR-Puttur	Udupi	12° 44' 31.326" N 75° 13' 38.1792" E
93	*G. indica*	GI_PUT-4	DCR-Puttur	Udupi	12° 44' 25.0728" N 75° 13' 32.772" E
94	*G. indica*	GI_PUT-5	DCR-Puttur	Udupi	12° 44' 23.1864" N 75° 13' 40.4184" E
95	*G. indica*	GI_PUT-6	DCR-Puttur	Udupi	12° 44' 24.9108" N 75° 13' 44.6124" E
96	*G. indica*	GI_ULL3	AHRS, Ullala	Dakshin Kannada	12° 48' 21.3408" N 74° 50' 45.8196" E
97	*G. indica*	GI_ULL4	AHRS, Ullala	Dakshin Kannada	12° 48' 20.6604" N 74° 50' 46.7484" E
98	*G. indica*	GI_ULL5	AHRS, Ullala	Dakshin Kannada	12° 48' 19.7568" N 74° 50' 45.6648" E
99	*G. indica*	GI_BEL2	Belgaum	Belgaum	15°50’55.2732” N 74°30’9.7416” E
100	*G. indica*	GI_GOA5	Ela	Goa	15° 29' 46.9824" N 73° 49' 6.978" E
101	*G. indica*	GI_GOA6	Ela	Goa	15° 29' 52.4904" N 73° 49' 15.8628" E
102	*G. indica*	GI_MDG3	Mudigere	Chikmagalur	13° 8' 13.92" N 75° 38' 33.0648" E
103	*G. indica*	GI_MDG4	Mudigere	Chikmagalur	13° 1' 58.5732" N 75° 36' 35.6904" E
104	*G. indica*	GI_MDG5	Mudigere	Chikmagalur	13° 1' 53.004" N 75° 36' 24.0264" E
105	*G. indica*	GI_MDG6	Mudigere	Chikmagalur	13° 1' 51.6468" N 75° 36' 33.606" E
106	*G. indica*	GI_SIR1	Sirsi	Uttara Kannada	14° 36' 59.382" N 74° 50' 46.7268" E
107	*G. indica*	GI_SIR2	Sirsi	Uttara Kannada	14° 37' 0.0552" N 74° 50' 43.1736" E
108	*G. indica*	GI_SIR3	Sirsi	Uttara Kannada	14° 37' 7.0068" N 74° 50' 32.6688" E
109	*G. indica*	GI_SIR4	Sirsi	Uttara Kannada	14° 37' 4.5408" N 74° 50' 47.7312" E
110	*G. indica*	GI_SIR5	Sirsi	Uttara Kannada	14° 37' 10.146" N 74° 50' 20.7708" E
111	*G. indica*	GI_SIR6	Sirsi	Uttara Kannada	14° 37' 7.9896" N 4° 50' 53.7576" E
112	*G. indica*	GI_DAN2	Dandeli	Uttara Kannada	15° 14' 50.0568" N 74° 37' 15.9492" E

113	*G. indica*	GI_DAN3	Dandeli	Uttara Kannada	15° 14' 50.1324" N 74° 37' 13.8612" E
114	*G. indica*	GI_DAN4	Dandeli	Uttara Kannada	15° 14' 46.7016" N 74° 37' 16.2588" E
115	*G. indica*	GI_DAN5	Dandeli	Uttara Kannada	15° 14' 44.9124" N 74° 37' 18.498" E
116	*G. indica*	GI_ULL1	Ullala	Dakshin Kannada	12° 51' 9.936" N 74° 50' 14.568" E
117	*G. indica*	GI_ULL2	Ullala	Dakshin Kannada	12° 51' 0.7488" N 74° 50' 30.5556" E
118	*G. indica*	GI_MAN1	Mandarthi	Udupi	13° 29' 46.9572" N 74° 48' 27.486" E
119	*G. indica*	GI_KOU6	Koudichar	Dakshin Kannada	12° 33' 17.3124" N 75° 22' 55.4376" E
120	*G. indica*	GI_SIR7	Sirsi	Uttara Kannada	14° 36' 58.1112" N 74° 50' 38.7708" E

Source: Dept. of ITBTS & T, KBITS, Project- 'CBR', Dept. of BCI, COH, Bengaluru

Conclusion

The plasticity for HCA content in fruit rinds of ecotypes of *Garcinia indica* in the present study suggested that there is a significant amount of diversity with respect to (-) -HCA content in ecotypes of *G. indica* in Western Ghats of Karnataka. The diversity for (-) -HCA content in fruits of ecotypes of *G. indica* is normally distributed across the geographical region of Western Ghats of Karnataka. These results can serve as basis for selection of ecotypes for a detailed estimation of (-) -HCA content using more robust methods and select the superior ecotypes for further evaluation.

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