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Fruit Morphology and Quality Parameter Studies of Global Custard Apple (*Annona squamosa*) Germplasms

Yashwant Kumar[1], Ajay Kumar Chandra[2*], Ashutosh Dubey[3] and H.P. Gajera[1]

[1]Department of Biochemistry, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat-362001, India
[2]Department of Molecular Biology and Genetic Engineering, [3]Department of Biochemistry, College of Basic Sciences & Humanities, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttrakhand-263145, India

**Corresponding author*

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A B S T R A C T

Since time immemorial custard apple is intimately associated with humans. It is popularly known for their delicious fleshy fruit and lesser for antioxidant and antidiabetic activities. Because of its unique nutraceutical properties custard apple is widely cultivated throughout the globe. In view of this the present investigation was undertaken to study the morphological and fruit quality traits to define the available wide variability within the global custard apple germplasms. Accordance to this, the experiment was laid out in completely randomized design (CRD) with 30 selected genotypes as the treatments with three replications for each defined traits. The results showed that the wide variability was present among custard apple genotypes for quantitative as well as qualitative traits. The fruit shape ranged from round to cordate, fruit weight varied from 98.8 to 170.1 gm, fruit length varied from 5.47 to 7.0 cm, fruit width varied from 5.57 to 7.13 cm, fruit volume varied from 77 to 178 cm^3 and pulp to seed ratio ranged from 3.69 to 32.87. Likewise, qualitative traits such as total soluble solids, total carbohydrate, free amino acids, dietary fiber, Ascorbic acid and total carotenoids were recorded and it also varied largely between the genotypes. Thus, results from the present study indicate that there is abundant natural genetic variability available within the custard apple genotypes which might offer suitable genetic material for future nutri-agricultural research.

Introduction

Custard apple (*Annona squamosa* L.) is one of the commercially grown fruit crop in India. It belongs to Annonaceae family and is a native of tropical region of West Indies (Porwal *et al.*, 2011). Custard apple is popularly called with numerous vernacular names such as sugar apple, sitaphal, sweet sop and Sharifa in the Indian subcontinents (Ghawade *et al.*, 2018). It is a crop of high nutritional value which harbours many important nutritional traits such as high amount of essential minerals (calcium, potassium and

phosphorous), calories, vitamin C, and carbohydrate contents (Bharad *et al.,* 2009). Because of its unique nutritional properties it is widely cultivated throughout the dry arid, semi-arid and tropical regions of the world. In India it is commercially grown on degraded lands having marginal soils mainly by subsistence farmers (Ghawade *et al.,* 2018). Custard apple is basically hardy in nature and being a cross pollinated fruit crop it is a home of large inter- and intra-specific variability in fruit qualities. As a result of this, it exhibits wide variability in form, colour, size, quality and fruit bearing tendency (Bharad *et al.,* 2009; Kad *et al.,* 2016). Morphological and fruit quality being a complex and polygenic trait and are highly influenced by several environmental factors or vary with various developmental stages of plants. Thus, because of abundant natural variability available within the custard apple global germplasm, it could be exploited to identify superior genotypes which might offer suitable genetic material for future nutri-agricultural research. In view of the above background the present study was conceptualized to study the available morphological and fruit quality trait variation in custard apple (*Annona squamosa*) genotypes.

Materials and Methods

Experimental materials and evaluation sites

The material comprises 30 diverse Custard apple accessions representing world collections were collected from Horticulture Research Station, Junagadh Agriculture University, Junagadh, Gujarat, India (Table: 01). The present study was conducted at research farm Madri Bag and Department of Biochemistry, Junagadh Agriculture University, Junagadh. The experiment was laid out in completely randomized design (CRD) with 30 selected genotypes as the treatments with three replications. Ripen fruits were randomly taken from healthy trees, washed in running water and were stored for further use (Figure: 1a and 1b). Similarly, five randomly selected fruits were used for pulp extraction and Fruit pulp after extraction in methanol kept in storage vial in -20°C for further use.

Fruit morphological characterization in custard apple genotype

Standard morphological characters from 30 custard apple genotypes were recorded.

Fruit shape, fruit weight and fruit volume: Randomly 5 fruits were selected from each landraces and their shape were noticed as round or oblong, along with weight in kg, were recorded and fruit volume were measured by water displacement (Bhatnagar *et al.,* 2012).

Fruit length: Randomly 5 fruits were selected from each landraces and length was measured by using vernier calliper and expressed in centimetres (Varasteh *et al.,* 2009).

Fruit width and pulp to seed ratio: Randomly 5 fruits were selected from each landraces and width was measured by using Vernier calliper and expressed in centimetres and pulp to seed ratio was calculated by method as followed by Akbarpour *et al.,* (2009) with minor modifications.

Fruit quality characterization in custard apple genotype

Total soluble solids (TSS): Total soluble solids in percentage brix of fruit were recorded by using an Erma refractometer (Ranganna, 1986).

Total carbohydrates: Total carbohydrate from pulp was estimated by phenol sulphuric acid method (Dubois *et al.,* 1956).

Free amino acid: Total free amino acid was estimated from fruit pulp as described by Lee and Takahasi (1996) using ninhydrin reagent.

Total dietary fiber: Total dietary fiber was estimated from fruit pulp as described by Prosky *et al.,* (1988).

Ascorbic acid (Vitamin C): Ascorbic acid content in fruit pulp was determined by the colorimeter method as described by Bhatnagar *et al.,* (2012).

Total carotenoids: The total carotenoid in fresh fruit pulp of each genotype was estimated as described by Jensen, (1978).

Statistical analysis of custard apple genotypes

The data collected on individual characters/traits were tabulated and subjected to statistical analysis by using completely randomized design (CRD) with 30 selected genotypes as the treatments with three replications. OPStat Excel Version software package was used for statistical analysis like coefficient variation, mean, standard deviation and range of individual characters/traits (Sheoran *et al.,* 1998) and Excel software of Microsoft was used for graphical representation.

Results and Discussion

Fruit morphological characterization in custard apple genotype

Fruit shape

Among thirty custard apple genotypes, 17 (K-1, K -2, H-1, Aml-1, Aml-2, Aml-3, Aml-4, Aml-5, Aml-6, Aml-7, Aml-9, Aml-10, Aml-11, Aml-12, DS-1, M-2 and Sindhan) were found round in shape while 13 genotypes (N-1, Lok-1, Lok-2, Aml-8, B-1, B-2, B-3, D-1, KT-1, S-1, S-2, S-3, M-1) were cordate in shape (Table: 02, Figure: 1b). Thakur and Singh (1967) reported that the shape of custard apple fruit may be irregular to spherical, cordate to conical depending upon the cultivar. *A. squamosa* fruit is rounded, heart shaped, ovate or conical, while *A. cherimoya* fruit is normally heart shaped, conical or oval in shape. *A. reticulata* fruits are commonly heart shaped, but may be conical, ovate or irregular in form (Anon, 2007). Mathakar (2005) grouped 24 hybrids on the basis of fruit shape into irregular, round and oval shape. Similar findings were reported by Jalikop, (2010) and Ghawade *et al.,* (2018). They reported that shape of *Annona squamosa* to be nearly round. Mathakar (2005) reported the shape of areole as round, square, mammal and hexagonal in *Annona* hybrids. Girwani *et al.,* (2011) observed that the shape of areole in *Annona* hybrids as round, flat, mammal, pointed, square and spiny which indicates presence of sufficient variability for fruit shape in custard apple genotypes.

Fruit weight

Among thirty genotypes of custard apple, fruit weight was varied in the range of 98.8 to 187.5 gm. The significantly highest fruit weight was obtained in Aml-11 (187.5 gm) while lowest fruit weight was observed in N-1 (98.8 gm) (Table: 02, Figure: 02). The fruit weight is a genetically controlled character and varied significantly in different landraces (Bhatnagar *et al.,* 2012). The fruit weight ranged from minimal 89.5 gm in germplasm collected from Chittorgarh to maximum 149.8 gm in those collected from Baran. P-36 recorded highest average fruit weight (515.0 gm) and pulp (82.03%). The fruits were round shaped and very attractive. Jalikop and Kumar (2007) reported that Arka Sahan, interspecific hybrid has fruits which are small and roundish in shape and the number of seeds was 9/100 gm fruit weight. Balanagar exhibited the

highest fruit weight (330 gm) (Abdualrahman *et al.,* 2016). Mathakar (2005) also evaluated that in 24 hybrids of *Annona spp.* the average fruit weight ranged from 187.7 to 672.5 gm. The average fruit weight of Annona Hy.2, at emoya, Balanagar and Island Gem was 888.33 gm, 353.33 gm, 236.0 gm and 625.0 gm, respectively (Anon., 2007). Similarly, Dikshit *et al.,* (2008) revealed average fruit weight in custard apple ranged 90.8 to 375 gm. Recently, Ghawade *et al.,* (2018) evaluated 29 custard apple genotypes and recorded fruit weight ranged from 167.33 to 428 gm which indicates presence of sufficient variability for fruit weight in custard apple genotypes.

Fruit volume

Fruit volume was significantly varied among thirty custard apple genotypes. The fruit volume was found in the ranges of 77 (Sindhan) to 178 cm^3 (Aml-7) among different genotypes (Table: 02, Figure: 02). Popular cultivar sindhan examined with lowest fruit volume. Jalikop, (2010) evaluated *Annona* hybrids and revealed great variability for morphological and biochemical characters. He reported significant variation in fruit length (5.53-10.15 cm), fruit breadth (6.30-9.73 cm) and pulp percentage (46.48- 58.96 %). Similar result was also reported by Kad *et al.,* (2016) and Ghawade *et al.,* (2018). They recorded fruit length ranged from 6.56 to 21.11 cm and fruit breadth ranged from 5.90 to 17.61 cm which indicates presence of sufficient variability for Fruit volume in custard apple genotypes.

Fruit length

Fruit length was examined among thirty custard apple genotypes. The fruit length varied non-significantly ranged from 5.77 to 7.00 cm among different genotypes (Table: 02, Figure: 03). Balanagar exhibited the fruit length of Custard apple are (8.3 cm) (Abdualrahman *et al.,* 2016). Jalikop, (2010) evaluated *Annona* hybrids exhibited various shape, colour, length and width. He reported significant variation in fruit length (5.53-10.15 cm). Similar result was also reported by Kad *et al.,* (2016) and Ghawade *et al.,* (2018). They recorded fruit length ranged from 6.56 to 21.11 cm which indicates presence of sufficient variability for Fruit length in custard apple genotypes.

Fruit width

The fruit width was also varied non-significantly ranged from 5.77 to 7.13 cm among different custard apple genotypes (Table: 02, Figure: 03). Ghosh *et al.,* (2001) found that Balanagar exhibited the highest fruit diameter (9.0 cm). Likewise, Jalikop, (2010) evaluated *Annona* hybrids leaves having various shape, colour, length, width and also reported significant variation in fruit breadth (6.30-9.73 cm). Similar result was also reported by Kad *et al.,* (2016) and Ghawade *et al.,* (2018). They recorded fruit width ranged from 5.90 to 17.61 cm which indicates presence of sufficient variability for Fruit width in custard apple genotypes.

Pulp to seed ratio

The custard apple genotypes were subjected to fruit pulp to seed ratio and highly significant variation were observed among genotypes. The genotypes H-1 produced significantly highest (32.87gm) pulp to seed ratio with maximum yield of pulp and minimum of seeds in their fruit followed by N-1 (25.89 gm) with average pulp to seed ratio 10.26 gm observed among genotypes (Table: 02, Figure: 03). The minimum ratio was attained by K-2 (3.69 gm) which was no significant at 5%**.** Salvador *et al.,* (2006) carried out a trial to determine the relationships between fruit size and other fruit quality parameters in order to assess whether small size is correlated with poor fruit quality

in apples. Dikshit *et al.,* (2008) revealed fruit to pulp ratio (37-54.2) in custard apple. Later on, Bhatnagar *et al.,* (2012) studied the variations in shape (round and cordate), fruit colour (yellowish green, light green and pale green), pulp colour (pale white and creamy white) and areole shape (round, fused and mummiform) of custard apple fruits and observed maximum pulp weight of 47.0 gm in landrace collected from Baran site. Similarly, Aydin *et al.,* (2012) studied genetic diversity within Loquat (*Eriobotrya japonica*) and highest flesh ratio was obtained from 'Baffico' (90%) whereas 'Seedling 1' had the lowest flesh ratio (75%). Recently, pulp to seed ratio (8.18) was observed significantly in custard apple (Kad *et al.,* 2016). These observations indicate presence of sufficient variability for fruit to pulp ratio in custard apple genotypes.

Fruit quality characterization in custard apple genotype

Fruit pulp of thirty custard apple genotypes were analyzed for quality parameters and it was observed significant variability among custard apple genotypes for fruit quality parameters like total soluble solids, total carbohydrates, free amino acids, total dietary fibre, ascorbic acid and total carotenoids.

Total soluble solids (TSS)

The significantly highest TSS was observed in Aml-2 (25.74 brixº) which was at par with B-2 (25.73º Brix), Aml-1 (25.48º Brix), B3 (25.37º Brix), Lok-1 (25.37º Brix) whereas it was found lowest in Aml-12 (23.93º Brix) with average TSS was observed 24.72º Brix amongst genotypes (Table: 03, Figure: 04). Earlier, Dhumal *et al.,* (1997) reported the range of TSS of custard apple from 20.4 to 22.0º Brix. The total soluble solids ranged from 16.47 to 27.97º Brix in seventeen accessions of custard apple germplasm in Tamilnadu (Anon., 2007). Dikshit *et al.,* (2008) studied diversity in custard apple and the fruits revealed total soluble sugar (19-26º Brix). Girwani *et al.,* (2011) evaluated custard apple hybrids for quality attributing character and reported TSS ranged from 20 to 28.2º Brix. The TSS was highest in Hybrid-2 (28.2^0 Brix) followed by Hybrid-4 (25^0 Brix). Jalikop, (2010) reported a large variation in the total soluble solids of custard apple ranging from 19.3º to 28.0º Brix. Jalikop and Kumar (2007) observed that in Arka Sahan an interspecific hybrid had TSS more than 30º Brix. Shete *et al.,* (2009) screened 137 seedlings of custard apple for physicochemical character and observed that TSS varied from 17.75 to 27.30º Brix. These observations indicate presence of sufficient variability for Total soluble solids (TSS) in custard apple genotypes.

Total carbohydrates

Total carbohydrates were measured from fruit pulp of custard apple genotypes by colorimetric methods. The significantly highest carbohydrates (4.41 %) were observed in Lok-1, Lok-2, Aml-4, Aml-7, Aml-9, Aml-10 followed by Aml-3 (4.39 %) and DS-1 (4.31%). The Total carbohydrates content was found lowest (2.06 %) in B-1 genotypes. Average total carbohydrates content was measured amongst the genotypes are 3.39 % (Table: 03, Figure: 05). Similar result was also reported by Kad *et al.,* (2016) and Ghawade *et al.,* (2018). These observations indicate presence of sufficient variability for carbohydrates content in custard apple genotypes.

Free amino acid

In general fruit pulp are not considered good sources of protein. Protein contents (1.80 gm/100gm) found in the *A. crassiflora* pulp studied by Rao and Subramanyam (2010) were higher than in this study.

Table.1 List of custard apple genotypes used in present study

Sr. No.	Genotypes	Sr. No.	Genotypes
1	K-1	16	Aml-10
2	K-2	17	Aml-11
3	N-1	18	Aml-12
4	Lok-1	19	DS-1
5	Lok-2	20	B-1
6	H-1	21	B-2
7	Aml-1	22	B-3
8	Aml-2	23	D-1
9	Aml-3	24	KT-1
10	Aml-4	25	S-1
11	Aml-5	26	S-2
12	Aml-6	27	KH-1
13	Aml-7	28	M-1
14	Aml-8	29	M-2
15	Aml-9	30	Sindhan

Table.2 Fruit morphological characterizations of custard apple genotypes

Sr. No.	Genotypes	Fruit shape	Fruit weight (g)	Fruit volume (cm^3)	Fruit length (cm)	Fruit width (cm)	Pulp to seed ratio
1.	**K-1**	Round	142.8	114.5	5.87	5.70	3.71
2.	**K-2**	Round	170.1	133.5	6.45	5.93	3.69
3.	**N-1**	Cordate	98.8	91.0	5.55	6.27	25.89
4.	**Lok-1**	Cordate	140.8	91.0	5.77	5.77	13.65
5.	**Lok-2**	Cordate	138.9	86.75	5.47	6.23	15.75
6.	**H-1**	Round	106.7	110.5	6.07	6.43	32.87
7.	**Aml-1**	Round	150.1	149.5	6.57	6.27	8.74
8.	**Aml-2**	Round	132.9	121.0	6.27	6.33	16.64
9.	**Aml-3**	Round	135.4	121.5	6.10	6.37	15.58
10.	**Aml-4**	Round	155.8	110.0	5.67	6.73	3.92
11.	**Aml-5**	Round	109.0	111.5	5.62	6.73	6.20
12.	**Aml-6**	Round	104.0	106.5	5.77	6.67	8.52
13.	**Aml-7**	Round	163.8	178.0	7.00	6.47	6.38
14.	**Aml-8**	Cordate	126.2	156.2	6.65	7.13	8.31
15.	**Aml-9**	Round	156.2	128.5	5.95	7.07	9.09
16.	**Aml-10**	Round	133.3	122.5	6.50	6.67	4.90
17.	**Aml-11**	Round	187.5	142.5	6.70	6.80	11.27
18.	**Aml-12**	Round	142.2	138.0	6.47	7.13	14.10
19.	**DS-1**	Round	125.3	127.7	6.45	6.73	8.59
20.	**B-1**	Cordate	160.0	148.7	6.52	6.90	4.87
21.	**B-2**	Cordate	152.6	120.0	6.52	6.93	8.32
22.	**B-3**	Cordate	131.1	115.5	6.15	6.47	7.32
23.	**D-1**	Cordate	106.4	96.20	6.05	7.13	7.34
24.	**KT-1**	Cordate	142.6	103.7	6.42	6.43	5.17
25.	**S-1**	Cordate	119.7	160.5	5.87	6.37	13.37
26.	**S-2**	Cordate	122.8	104.0	5.80	6.13	5.95
27.	**S-3**	Cordate	110.7	133.5	6.27	5.67	7.69
28.	**M-1**	Cordate	104.4	95.50	6.30	6.57	17.77
29.	**M-2**	Round	121.3	98.50	6.10	6.80	5.36
30.	**Sindhan**	Round	99.7	77.0	6.27	5.57	6.79
	Mean	-	133.05	119.8	6.18	6.48	10.26
	S.E± m	-	14.59	15.12	0.33	0.34	1.08
	C.D at 5%	-	41.28	42.57	NS	NS	3.07
	C.V. %	-	19.0	25.26	10.69	9.26	18.38

Note: Values representing mean of three independent replications and each replication consisted of five fruit observations per one tree.

Table.3 Fruit quality parameters study from fruit pulp of custard apple genotypes

Sr. No.	Genotypes	Total soluble solids (% Brix°)	Total carbohydrates (%)	Free amino acids (mg %)	Total dietary fiber (%)	Ascorbic acids content (%)	Total carotenoids (mg.g^{-1})
1.	K-1	24.61	4.26	0.54	7.14	2.11	0.33
2.	K-2	24.45	4.41	0.81	7.48	1.48	0.03
3.	N-1	24.17	4.40	0.57	9.86	2.96	0.02
4.	Lok-1	25.37	4.41	0.83	9.23	2.39	0.03
5.	Lok-2	24.73	4.41	1.72	7.76	2.51	0.01
6.	H-1	24.26	3.89	1.29	10.00	1.82	0.02
7.	Aml-1	25.48	3.64	0.74	10.24	1.31	0.02
8.	Aml-2	25.74	4.23	0.93	4.44	2.91	0.01
9.	Aml-3	25.00	4.39	0.74	10.50	2.68	0.01
10.	Aml-4	24.77	4.41	0.72	9.51	2.11	0.03
11.	Aml-5	24.27	4.35	0.44	6.12	2.22	0.02
12.	Aml-6	24.38	4.30	0.64	10.37	2.11	0.03
13.	Aml-7	24.96	4.41	0.36	5.84	1.77	0.02
14.	Aml-8	25.30	3.36	0.58	7.41	4.39	0.02
15.	Aml-9	24.76	4.41	0.88	11.28	2.74	0.02
16.	Aml-10	24.89	4.41	1.31	8.66	3.19	0.05
17.	Aml-11	24.74	3.53	0.40	11.66	2.39	0.03
18.	Aml-12	23.93	4.25	0.38	7.22	2.57	0.27
19.	DS-1	24.49	4.31	0.44	10.57	2.05	0.88
20.	B-1	25.32	2.06	0.97	13.03	1.65	0.01
21.	B-2	25.73	3.27	1.07	7.17	2.39	0.03
22.	B-3	25.37	3.62	0.90	6.85	1.48	0.04
23.	D-1	24.32	3.91	1.20	5.45	2.39	0.11
24.	KT-1	24.22	3.76	1.41	8.54	1.71	0.05
25.	S-1	24.15	3.46	1.03	7.75	2.17	0.02
26.	S-2	24.12	4.15	0.48	9.76	1.65	0.15
27.	S-3	24.90	2.66	0.69	9.74	1.88	0.04
28.	M-1	24.33	3.30	0.38	8.78	1.77	0.64
29.	M-2	24.16	4.28	0.15	7.55	1.71	0.03
30.	Sindhan	24.85	3.51	2.05	11.31	3.19	0.02
	Mean	24.74	3.93	0.82	8.71	2.26	0.10
	S.E±m	0.029	0.09	0.02	0.04	0.11	0.04
	C.D at 5%	0.085	0.27	0.06	0.11	0.32	0.01
	C.V. %	0.17	4.24	4.76	7.14	8.92	7.29

Note: Values representing mean of three independent replications and each replication consisted of five fruit observations per one tree.

Fig.2 Morphological characterizations of custard apple genotypes for fruit weight and fruit volume

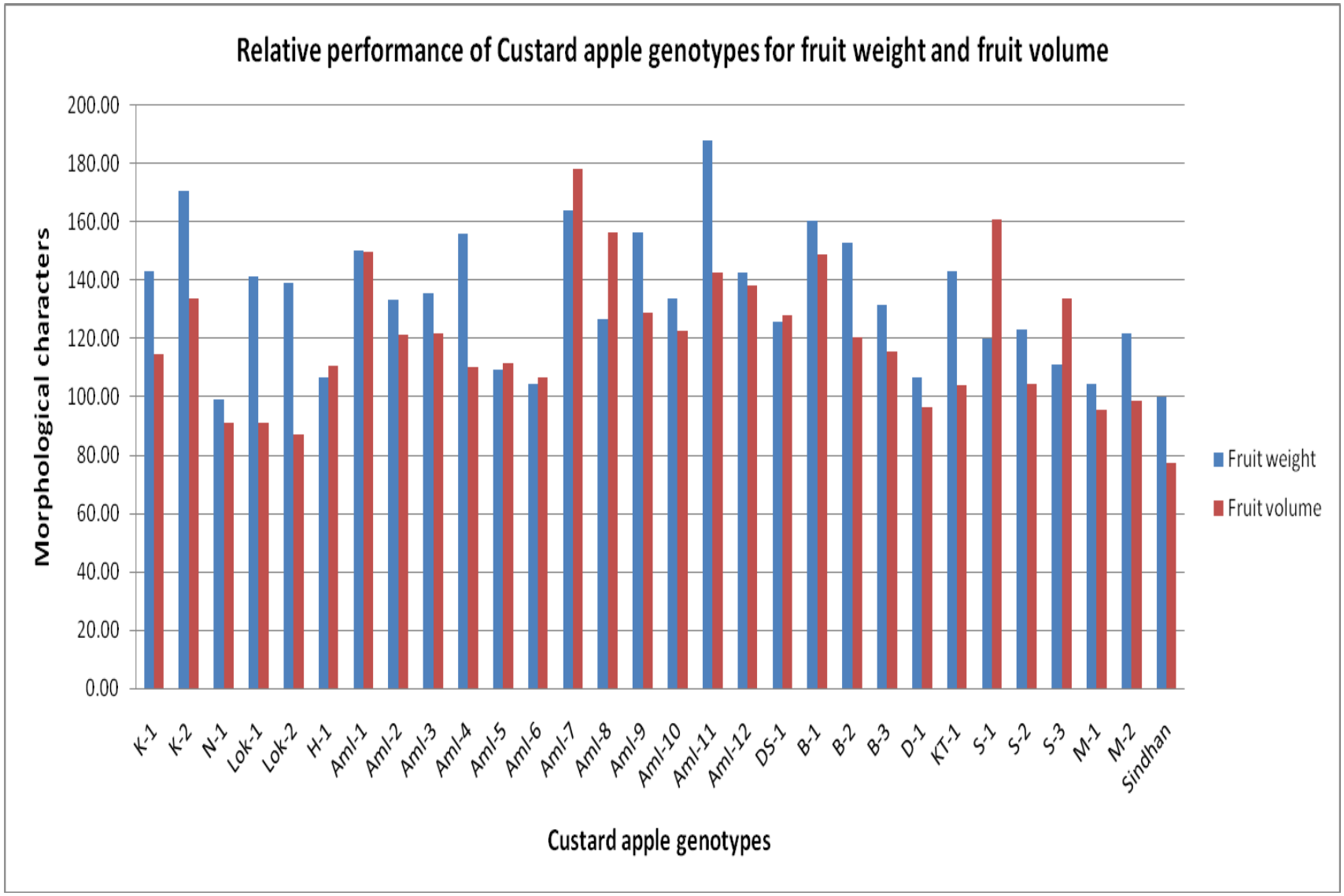

Fig.3 Morphological characterizations of custard apple genotypes for fruit length, fruit width and pulp to seed ratio

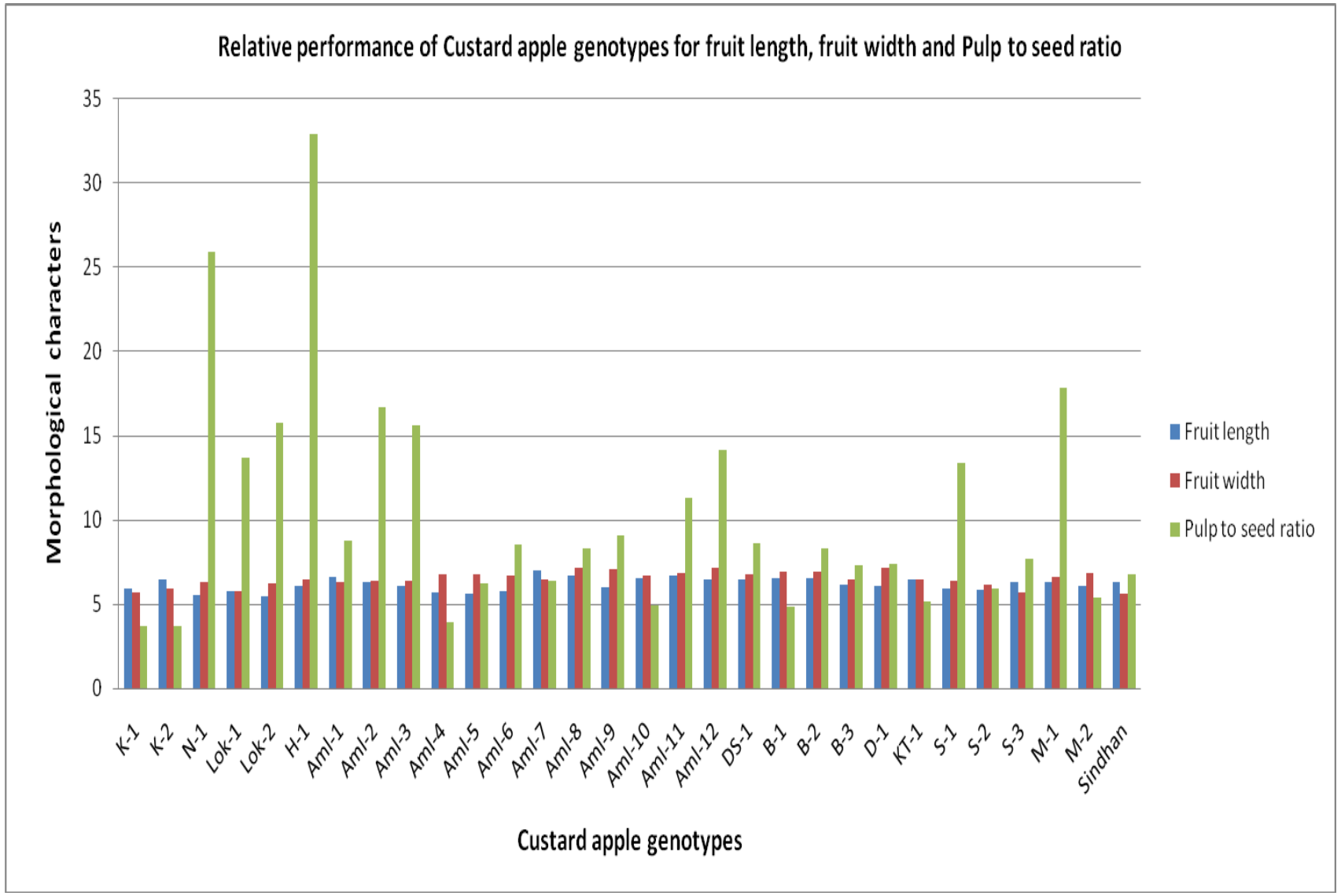

Fig.4 Fruit quality parameters study from fruit pulp of custard apple genotypes for TSS and Dietary fibers

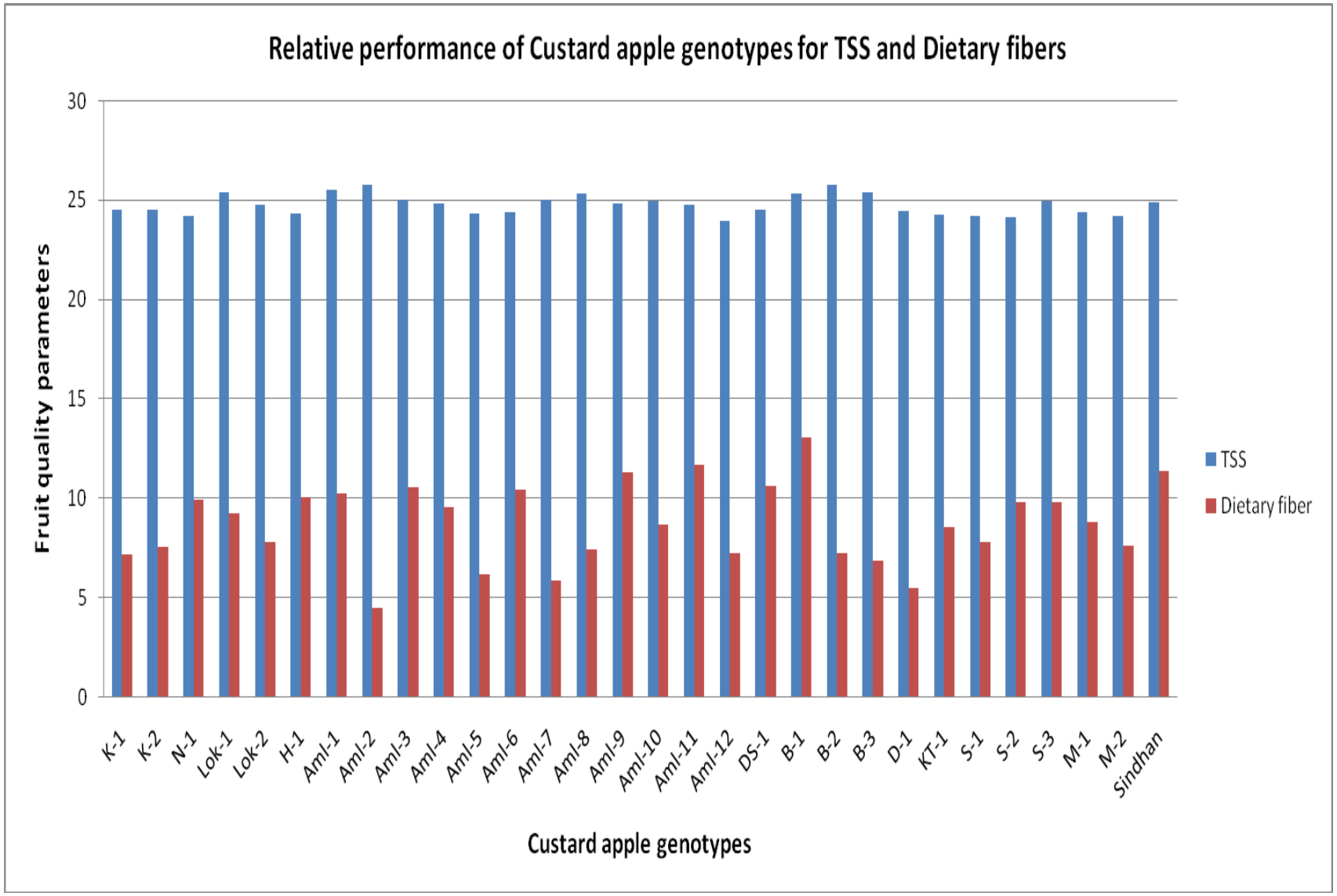

Fig.5 Fruit quality parameters study from fruit pulp of custard apple genotypes for total carbohydrate, free amino acid, ascorbic acid and carotenoids

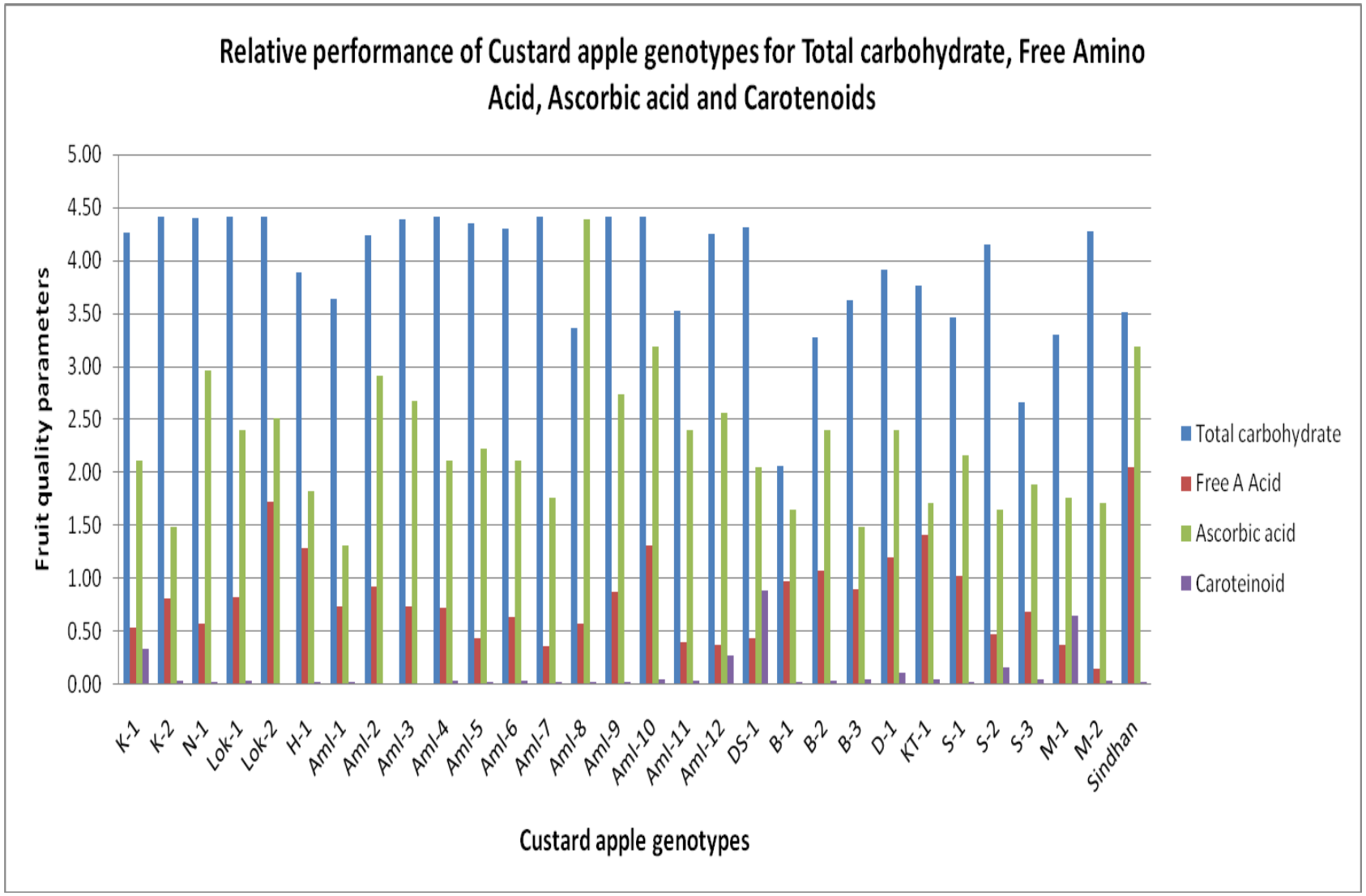

Fig.1 a) Custard apple fruits collected from 30 genotypes from field, and b) randomly selected custard apple fruits for fruit morphology and fruit quality study

However, Almeida *et al.*, (2008) found lower values (1.28 gm/100gm). The significantly highest free amino acids (2.05 mg %) were observed in popular cultivars sindhan. The content was found lowest (0.38 gm/100gm) in Aml-12 and M-1 genotypes (Table: 03, Figure: 05). The total yield of free amino acids in pulp of crop *Annona* species ranged from 5.57 ± 1.06 mg/g dry matter to 25.66 ± 1.75 mg/g dry matter. *The A. cherimola* presented the highest concentration (25.66 ± 1.75 mg/g dry matter), followed by *A. cherimola* ×*A. squamosa* cv. Gefner (23.15 ± 2.78 mg/g dry matter). *A. cherimola* × *A. squamosa* cv. Pink' Mamonth presented the lowest quantity of free amino acids (5.57 ± 1.06 mg/g dry matter). Previous data for *A. cherimola* showed a total free amino acid amount (1.6 mg/g dry matter) much lower than that obtained at this study (Maldonado *et al.*, 2002). Egydio *et al.*, (2013) studied the free amino acid profiles of two cultivars of *Aemoya* (*Annona cherimola M.* ×*Annona squamosa L.*) and one of cherimoya (*A. cherimola Mill.*) were investigated by reverse HPLC-F. The total yield of free amino acids in these three samples ranged from 5.57 mg/g to 25.66 mg/g dry matter. These observations indicate presence of sufficient variability for free amino acids in protein content trait in custard apple genotypes.

Total dietary fiber

The content of total dietary fiber in the present study was estimated as reported by Silva *et al.*, (2008). The significantly high dietary fiber (13.03 %) were observed in B-1 genotypes followed by Aml-11 (11.66 %), sindhan (11.31 %), Aml-9 (11.28 %), DS-1 (10.57 %), Aml-1 (10.24 %), H-1 (10.0 %). The content was found lowest (5.84 %) in Aml-7 followed by Aml-5 (6.12 %) genotypes and average total dietary fiber was measured amongst the genotypes are 8.71 % (Table: 03, Figure: 04). However, compared with conventional flours, the ACF showed high values of total dietary fibers (Padovani, 2007). Adam *et al.*, (2001) revealed that custard apple flours with high insoluble fiber contents were effective in lowering LDL-cholesterol in experimental animals. The dietary fibers are important component for regulation of human nutrition assimilation and deposition. These observations indicate presence of sufficient variability for total dietary fiber content in custard apple genotypes.

Ascorbic acid

The ascorbic acid (Vitamin C) acts as antioxidant and potential for free radical scavenging activity. The significantly highest ascorbic acids (4.39 %) were observed in Aml-8 genotypes followed by Sindhan and Aml-10 with 3.19 %. The content was found lowest (1.31 %) in Aml-1 followed by K-2 (1.48 %) genotypes. The percent content of ascorbic acid in fruit pulp varies from 1.31 to 4.39 % with an average of 2.26 % across the genotypes (Table: 03, Figure: 05). Recently, Abdualrahman *et al.*, (2016) reported that fruit pulp of the *A. squamosa* contain 17.65-31.22 mg/100ml of ascorbic acid. They also revealed that Ascorbic acid content was found to be lower in all the products prepared compared to the stored fruit pulp. The reduction in ascorbic acid may be attributed to its destruction by oxidation or heat during processing. It is readily oxidized to dehydro-l-ascorbic acid by the enzyme ascorbic acid oxidase found in fruits (Abdualrahman *et al.*, 2016). Later on, Pareek *et al.*, (2011) reported that the percent content of ascorbic acid in fruit pulp varies from 9.22 to 60 mg/100 g across the indigenous custard apple genotypes. These observations indicate presence of sufficient variability for ascorbic acid content in custard apple genotypes.

Total carotenoids

The Carotenoids are important component of Vitamin A and act as antioxidants to scavenge free radicals associated with many chronic degenerative diseases. In present study, the significant level of carotenoids content was found in DS-1 (0.88 $mg.g^{-1}$) followed by M-1 (0.64 $mg.g^{-1}$), K-1 (0.33 $mg.g^{-1}$) to Aml-12 (0.27 $mg.g^{-1}$). Thus, Carotenoids content in fruit pulp varies from 0.01 to 0.88 $mg.g^{-1}$ with an average value of 0.10 $mg.g^{-1}$ across the genotypes (Table: 03, Figure: 05). The *A. crassiflora* pulp studied by Almeida *et al.*, (2008) showed 0.84 mg/100g carotenoids. Marquez *et al.*, (2012) studied the chemical composition in the *Annona muricata* L. and reported that fruit pulp provide essential nutrients, phytochemicals and antioxidants which are vital to human health as well as bioactive compounds such as anthocyanins and carotenoids among others. These observations indicate presence of sufficient variability for Carotenoids content trait in custard apple genotypes.

In essence, the present study is conceptualized for morphological and fruit quality parameter study of custard apple genotypes to identify possible genetic variability among them. Custard apple is a delicious fruit crop. It has many medicinal applications and a good source of nutritional and phytochemical compounds. According to the observations, there is significant variability in custard apple genotypes under the studied traits. The desirable fruit morphological characters *viz.* weight, volume, length, width and pulp to seed ratio were recorded significant in genotypes Aml-11, Aml-7, Aml-7, Aml-8 and H-1, respectively. Total soluble solids, total carbohydrates, free amino acids, total dietary fiber, ascorbic acid, and total carotenoids measured as fruit quality parameters and found to be better in Aml-2, K-2, Sindham, B-1, Aml-8 and DS-1 genotypes showing good fruit quality among 30 custard apple genotypes. Thus based on these observations, these identified genotypes may be good in future for developing new varieties of custard apple.

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