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Studies on variability in physico-chemical characters of Karonda (*Carissa carandas* L.) germplasm

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Abstract

Karonda (*Carissa carandas* L.) is one of the main underutilized fruits of Indian origin which is known for its wide adoptability and nutritional values. Twenty-nine accessions of karonda were evaluated at ICAR-IIHR-CHES, Chettalli to identify elite lines. The growth characteristic of 29 accessions of karonda revealed that the plant girth range from 17 to 93 cm it was the highest CHESK-V-9 (93 cm) and the lowest in CHESK-VIII-9 (17 cm). The height of the plant ranged from 1.75 to 3.70 m. It was the highest in CHESK-VI-9 (3.70 m). The accession CHESK-II-6, CHESK-II-7, CHESK-III-4, CHESK-VII-1 were found vigorous growth with plant height of more than 3 meter. The canopy spread was higher (> 7.5 m²) in CHESK-II-3 (8.10 m²), CHESK-II-6 (7.80 m²), CHESK-II-7 (8.61m²), CHESK-V-5 (7.78m²) and CHESK-VI-2 (9.65 m²). The higher plant volume was recorded in CHESK -VI-2 (23.37 m³), CHESK-V-9 (23.03 m³), CHEESK -II-7 (22.30 m³), CHESK-II-6 (20.55 m³). The number of fruits per plant were the highest in CHESK-III-4 (3145 fruits) and the lowest in CHESK II-5. The fruit yield was highest in CHESK-II-7 (21.18 kg/plant) followed by CHESK -V-6 (15.27 kg). The fruit weight ranged from 3.24 g to 3.81 g. The fruit colour of all the accession was dark purple at maturity. The pulp colour was varied from whitish pink, whitish red in most of the accessions but it was white colour in few accessions such as CHESK-II-VIII-7, CHESK-V-2, CHESK-II-5, CHESK-V-5, CHESK-V-10 and red in CHESK-IV-4 and CHESK-II-5. The fruit shape varied from round to oblong. The pulp content was the highest (91.03%) in CHESK-II-7. The seed content ranged from 2.05 to 12.81 percent. The total soluble solids ranged from 12.15⁰ Brix (CHESK -VIII-1) to 17.05 ⁰Brix (CHESK-V-4). The titrable acidity ranged from 0.67 to 3.29 percent. The ascorbic acid content range from 10.75mg/100g pulp (CHESK-VIII-1) to 50 mg /100g pulp in CHESK-VII-1. The reducing sugar ranged from 5.80 to 10.12 percent. The total sugar content ranged from 6.19 percent to 10.55 percent. The highest total sugar content was observed in CHESK-III-8 (10.55%). Over all the accessions, the accessions like K-II-7, K-V-6, K-VIII-1, K-VI-11, K-V-10 were found bigger in size coupled with sweetness with less seed content. These accessions may be used as table purpose while accessions like CHESK-II-6, CHESK III-8, CHESK V-2, CHESK VI-2 have smaller size fruit with higher number of fruits per plant. These identified accessions may be used for pickle making purpose.

Keywords: Karonda, variability, morphological and physico-chemical characters

Introduction

Karonda (*Carissa carandas* L.) belongs to family Apocynaceae. Karonda is an evergreen shrub, dichotomously branched, with short stem and strong thorns. It is a hardy, drought tolerant plant of the dry land, growing in a wide range of soil and climatic conditions. It grows naturally throughout the India except higher hills (> 1200 m) of Himalayas. Karonda is rich in vitamins and minerals. It is one of the richest sources of iron and has got fair amount of vitamin C. It is very useful for curing anaemia and has antiscorbutic properties. The fruits have antiscorbutic properties and are also useful in prevention of anaemia. Karonda is reportedly useful incurring stomach-ache and is anthelmintic (Das *et al.* 2013) [4]. Karonda fruits are sour and astringent, acidic too sweet in taste with a peculiar aroma and are not popular as a fresh due to its high pectin content. In Ayurveda, the unripe fruits are used as astringent, appetizer, antipyretic, antidiabetic (Itankar *et al.* 2011) [5]. In general, ripe fruits are used in the processing industry for the preparation of preserves (Bose *et al.* 1999) [3]. Karonda is hardy plant. It grows well in arid to very humid regions. Due to wide adoptability and origin of centre, India has lot of genetic diversity in Karonda with respect to tree height, thorniness, leaf characters, fruit size, fruit shape, fruit colour, sweetness and acidity etc. The wide variability of karonda in different parts of the country has been reported by Joshi *et al.* (1986) [18], Karale *et al.* (1990) [7], Kumar and Singh (1993) [17], Singh and Bajpai (2009) [13].

The Western Ghats regions has lot of variability of karonda with respect to fruit size, vigour and taste etc. The present study was conducted to identify big fruited, table purpose accessions with less astringent and more sweet taste.

Materials and Methods

The karonda collections were made from different parts of Western Ghats i.e. Hosur, Thiruvannamalai, Vengurla, Thakurwadi, Konkan and Kerala During 2005-06 through extensive surveys. The seedling plants were directly planted in the field whereas seeds were first sown in the nursery and the seedlings were transplanted in the field after one year. The planting was done at a distance of 3x3m at the Research Farm of ICAR-IIHR-Central Horticultural Experiment Station (IIHR), Chettalli, Kodagu, Karnataka during 2006-07. Central Horticultural Experiment Station (IIHR), Chettalli, Karnataka is located at 12°26' N latitude and 75°57' E longitude at 890 m above sea level. It has humid tropical climate with annual rainfall of 150 cm. The soil is a deep, dark brown, well drained sandy loam to sandy clay loam with 28.5% clay content and pH of 5.70. The plant started to fruiting in third year and yield stabilized from 5th year onwards. Twenty nine collections were evaluated for 3 years for vegetative growth, flowering, fruiting and fruit characteristics. Plant height and canopy diameter were converted into plant spread and tree volume. Plant spread (sq m) was estimated using formula (Plant spread (N-S) X Plant Spread (E-W))/2. The Tree volume (co.) was calculated using formula: (Tree spread X plant height) X 0.85). Twenty-five mature fruits were harvested randomly from each accession to record observation on physico-chemical parameters. The fruits were washed with distilled water and the surface water was removed using blotting paper. The cleaned air-dried samples were used. The fruit weight, fruit length, fruit diameter were recorded using electric balance and digital vernier callipers. The fruit shape and fruit colours were recorded per standard fruit shape and colour charts. The fruits were cut and pulp colour was recorded. The total soluble solids (TSS) were determined with Erma Hand Refractometer (0-32°Brix). The titratable acidity (%) and ascorbic acid content were determined by AOAC method. Total soluble solids (°Brix), acidity (%), ascorbic acid (mg/100g pulp), reducing sugars and total sugars were estimated using procedures described by Ranganna (1986) [19].

Data analysis: The data analysis was performed in R software. Hierarchical clustering was done the distance matrix required for hierarchical clustering was computed using the 'dist.' function which is based on Euclidean distances between the accessions. The hierarchical clustering of the

accessions was done using 'hclust' function based on complete linkage method. Principal component analysis was done using the 'pca' function (Team, 2019) [16].

Results and Discussion

Growth characteristics: The growth characteristics of the karonda collections revealed that there was lot of variation in the plant girth, plant height and canopy area. The growth characteristic of 29 accessions of karonda revealed that the plant girth range from 17 to 93 cm it was the highest CHESK-V-9 (93 cm) and the lowest in CHESK-VIII-9 (17 cm). The accession CHESK-II-7 also recorded higher plant girth. The height of the plant ranged from 1.75 to 3.70 m. It was the highest in CHESK-VI-9 (3.70 m). The accession CHESK-II-6, CHESK-II-7, CHESK-III-4, CHESK-VII-1 were found more vigorous with plant height noticed more than 3 m. Plant spread (East-West) ranged from 1.856 to 4.655 m. The plant spread (North-South) ranged from 1.7 to 4.5 m. and it was more than 4 m in accessions like CHESK-II-3, CHESK-II-7, CHESV-K-9, CHESK-VI-II and CHESK-IX-4. Similarly the canopy spread was higher (> 7.5 m²) in CHESK-II-3 (8.10 m²), CHESK-II-6 (7.80 m²), CHESK-II-7 (8.61 m²), CHESK-V-5 (7.78 m²) and CHESK-VI-2 (9.65 m²). The higher plant volume was recorded in CHESK-VI-2 (23.37 m³), CHESK-V-9 (23.03 m³), CHESK-II-7 (22.30 m³), CHESK-II-6 (20.55 m³). Lower plant value was recorded in accessions like CHESK-V-4 (59.3 m³), CHESK-VIII-11 (3.07 m³), CHESK-VII-9 (5.28 m³), CHESK-VII-9 (4.92 m³) and CHESK-V-4 (3.58 m³; Table 1). The growth of some of the karonda collections made from Western Ghats was higher than others collections. But in general, the growth was higher as compared to trial by under Jodhpur conditions (Meghwal, 2018) [9]. This may be due to the prevailing hot and humid climate and fertile soil conditions of Chettalli location which supported luxuriant growth. The flowering time of all the accessions was observed in the month of January and February in all three years. The initiation of flower bud opening was started in the month of January and flowering started almost after one week and continued up to March. The accessions like CHESK-II-1, CHESK-II-2, CHESK II-3, CHESK II-6, CHESK-II-8, CHESK-VI-8, CHESK-VI-9, CHESK-VI-11 were found early flowering whereas CHESK - V-6, CHESKVI-2, CHESK-VII-1, CHESK-VIII-9 were flowered late. The flowering continued for almost two months in all the accessions. The fruits started maturing in the month of May and continued up to in the month of June. The fruits did not mature at one time and several picking were done continuously as per maturity of the fruit. There was only 1-2 weeks difference in the flowering period of different collections.

Table 1: Growth characteristics of karonda collections

Accession no.	Plant girth (cm)	Plant Height (m)	Plant spread (N-S) m	Plant spread (E-W)m	Plant spread (m ²)	Plant volume (m ³)	Date of flower initiation of bud opening	Date of start of flowering
CHES-K-II-1	60.00	2.95	3.70	3.40	6.29	15.77	15 January	22 January
CHES-K-II-2	42.50	2.35	3.40	3.10	5.27	10.53	15 January	22 January
CHES-K-II-3	70.50	2.75	4.00	4.05	8.10	18.93	22 January	27 January
CHES-K-II-6	35.00	3.10	3.90	4.00	7.80	20.55	22 January	27 January
CHES-K-II-7	90.50	3.05	4.30	4.00	8.60	22.30	22 January	27 January
CHES-K-II-8	47.50	2.85	4.00	3.40	6.80	16.47	22 January	27 January
CHES-K-III-4	60.50	3.00	3.20	3.35	5.36	13.67	26 January	1 February
CHES-K-III-6	37.00	2.40	2.85	3.90	5.56	11.34	10 February	14 February
CHES-K-III-8	27.00	2.10	3.40	4.10	6.97	12.44	9 February	15 February
CHES-K-IV-2	38.50	2.85	3.40	3.00	5.10	12.35	9 February	15 February

CHES-K-V- 2	30.50	2.75	3.55	3.70	6.57	15.35	2 February	15 February
CHES-K-V- 4	70.50	1.95	2.65	2.70	3.58	5.93	2 February	15 February
CHES-K-V- 5	45.00	2.85	3.75	4.15	7.78	18.85	19 January	28 January
CHES-K-V- 6	50.00	2.70	3.30	2.95	4.87	11.17	2 February	15 February
CHES-K-V- 8	67.50	2.80	3.35	4.10	6.87	16.34	14 January	21 January
CHES-K-V- 9	93.00	2.65	4.15	4.50	9.34	21.03	2 February	15 February
CHES-K-V- 10	48.00	2.60	3.50	3.00	5.25	11.60	2 February	15 February
CHES-K-VI-2	51.00	2.85	4.15	4.65	9.65	23.37	2 January	7 January
CHES-K-VI-9	36.50	3.70	2.25	3.70	4.16	13.09	16 January	25 January
CHES-K-VI-11	56.50	2.50	3.25	3.50	5.69	12.09	16 January	25 January
CHES-K-VII-1	29.00	3.30	3.20	3.10	4.96	13.91	3 February	14 February
CHES-K-VII-3	48.00	2.80	3.10	4.00	6.20	14.76	3 February	14 February
CHES-K-VII-9	34.00	2.20	1.95	2.70	2.63	4.92	16 January	24 January
CHES-K-VII-11	44.00	1.75	3.15	3.35	5.28	7.85	16 January	24 January
CHES-K-VIII-1	51.00	2.35	3.45	3.40	5.87	11.72	16 January	24 January
CHES-K-VIII-9	17.00	2.70	2.30	2.35	2.70	6.20	10 February	21 February
CHES-K-VIII-11	18.50	2.30	1.70	1.85	1.57	3.07	12 February	18 February
CHES-K-IX-3	39.00	2.75	2.85	4.25	6.06	14.16	12 February	18 February
CHES-K-IX-4	64.00	2.85	4.00	3.50	7.00	16.96	15 January	21 January
Min	17	1.75	1.7	1.85	3.15	3.07	-	-
Max	93	3.7	4.3	4.65	9.65	23.37	-	-
Average	48.34	2.68	3.30	3.51	5.96	13.65	-	-
SD	20.18	0.46	0.71	0.72	2.21	5.51	-	-

Cluster analysis: Clustering of the all the 29 accessions was done based on the growth characters. As the dataset consisted of mixed data types *viz.* numeric and attribute, the distance between the accessions was computed using Gower’s distance measure. Hierarchical clustering of the accessions based on the complete agglomeration method was done for the above distance matrix and a dendrogram was generated (Fig 1). Two major clusters were observed, these were consisting of 7 and 22 accessions, respectively. The first cluster consisted of the seven accessions of karonda and cluster 2 consisted of 22 accessions. The minimum distance was found between the

accessions like CHES-K-IV-2 and CHES-K-II-8. While the maximum distance was observed between accessions like CHES-K-II-2 and CHES-K-II-1 (Fig 1).

Principal Component Analysis: The principal component analysis was done based on the numeric characters of growth chrematistics. The plant girth contributed 55.53 percent of the total variance while plant height contributed to 23.82 percent of total variance. These two components were contributed almost 79 percent of total variance (Fig 2 & Table 2).

Table 2: Summary of PCA components of growth characteristics

Components	Plant girth	Plant height	Plant Spread (N-S)	Plant Spread (E-W)
Standard deviation	1.4904	0.9761	0.7205	0.5539
Proportion of Variance	0.5553	0.2382	0.1298	0.0767
Cumulative Proportion	0.5553	0.7935	0.9233	1.0000

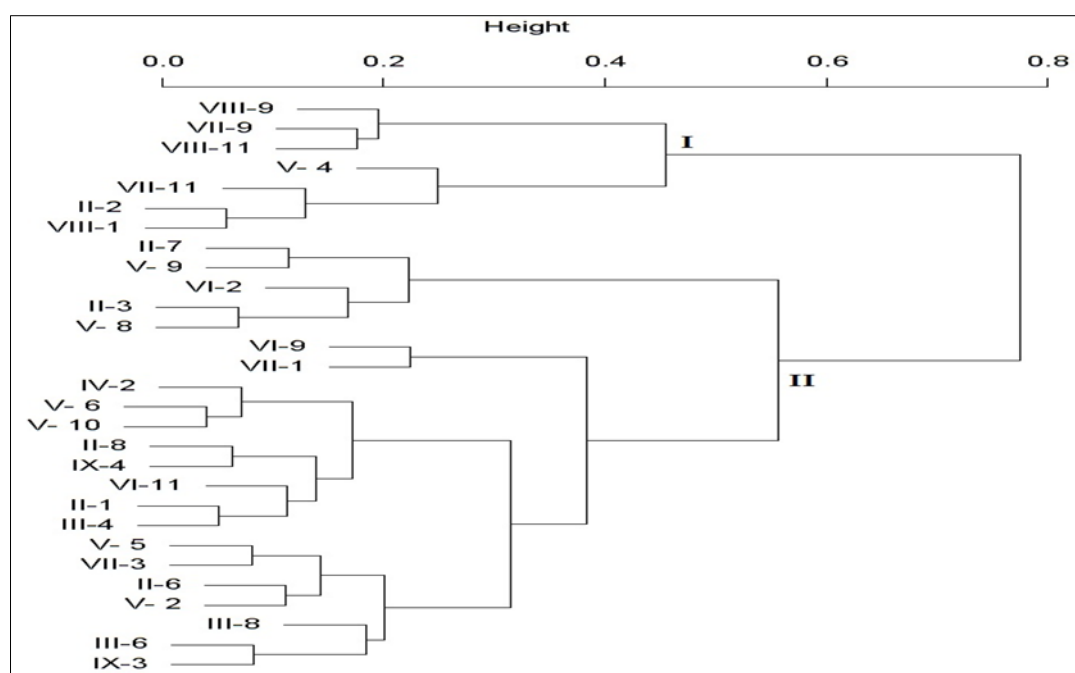


Fig 1: The grouping of karonda accessions on the basis of growth characters

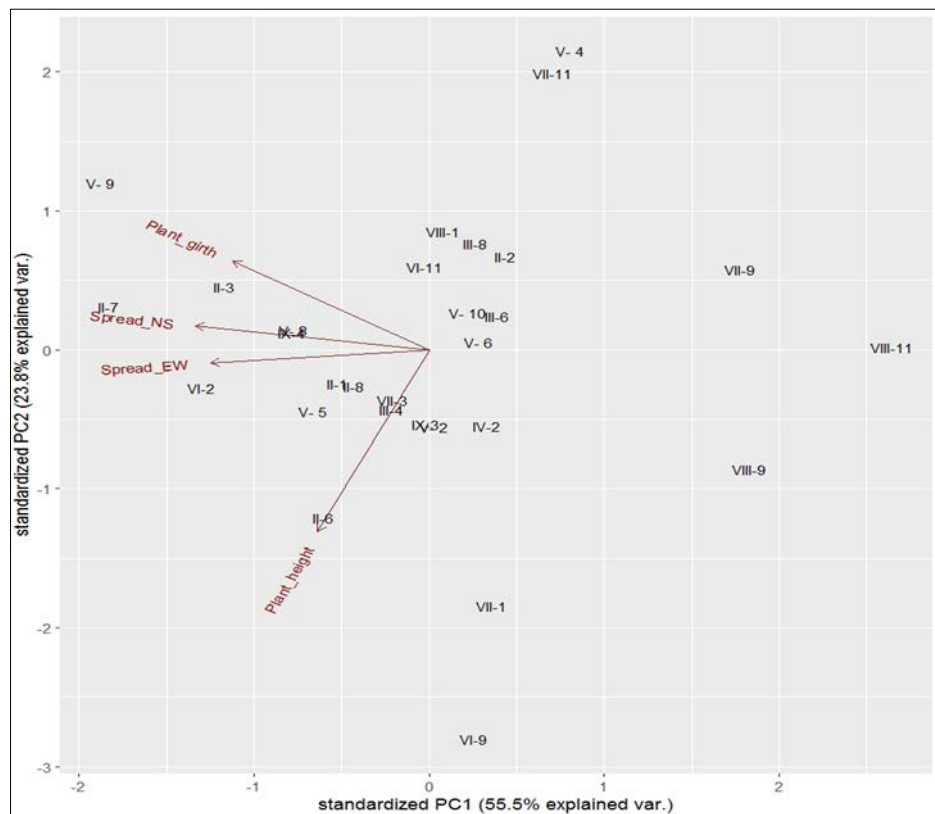


Fig 2: The Standardised PC2 of karonda accessions on the basis of growth characters

Characterisation for fruit traits and evaluation for yield:

The fruits started maturing in the month of May and continued up to month of June. The fruits did not mature at one time and several pickings were done. The number of fruits per plant were highest in CHESK-III-4 (3145 fruits). The accessions like CHESK-II-7 (1741 fruits), CHESK-III-6 (1863 fruits) and CHESK-VI-II (2600 fruits) produced higher number of fruits per plant. The lowest number of fruits were produced by CHESK II-5. The fruit yield was the highest in CHESK-II-7 (21.18 kg/plant) followed by CHESK -V-6 (15.27 kg), CHESK -III-4 (13.90 kg) and CHESK-VIII-1 (14.99 kg). The yield per unit plant volume was the highest in CHESK-V-6 (1.37 followed by CHESK-VIII-1 (1.28 kg). Some of the vigorously growing accession viz. CHESK- VI-2, CHESK -V-9 and CHESK-II-7 were produced less fruits for unit plant volume. It seems the vigorous accessions were utilized more photosynthates for their vegetative growth and failed to produce more number of fruits. Thus the conversion into fruits was lower. The average fruit weight ranged from 3.24 to 3.81 g. The fruit weight was the highest in accession CHESK-V-6. This accession produced higher yield despite of lower vegetative growth. The other accessions with higher fruit weight were CHESK-II-1 (12.63 g), CHESK-II-7 (12.14 g), CHESK-V-10 (10.97 g) and CHESK-VIII-1 (11.04 g) and CHESK-VIII-9 (10.3 g). There was no relationship between vigour of the plant and fruit weight. The fruit length and fruit diameter was to the tune of fruit weight of all the accessions.

The fruit colour of all the accession was dark purple at the time of maturity. The pulp colour was whitish pink, whitish red in most of the accessions but it was observed white in colour in few accessions such as CHESK-II-VIII-7, CHESK-V-2, CHESK-II-5, CHESK-V-5, CHESK-V-10 and red in CHESK-IV-4 and CHESK-II-5. The fruit shape varied from round to oblong. The pulp content was higher in big fruited accessions. It was the highest (91.03%) in CHESK-II-7 followed by 89.04% in CHESK-V-6. The accession CHESK-II-1 had the highest peel content (12.93%) followed by CHESK-V-8 (14.77%) and CHESK-VII-1 (13.21%). These accessions had thicker rind which may be a good character suitable for distant transport and higher storage life. The seed content ranged from 2.05 to 12.81 percent. It was the lowest 2.05% in CHESK-V-6 which was almost seedless nature as compared to other accessions. Higher seed content was observed in accessions like CHESK-VIII-3 (12.81%) and CHESK-IV-2 (9.17%). In general small fruit accession had higher seed content (Table 3). Rich diversity in physico-chemical characteristics of the fruits of different accessions indicated the presence of genetic diversity in karonda accessions maintained at field gene bank in IIHR-CHES, Coorg. Variations in the germplasm of karonda with regard to physico-chemical characters and fruit yield corroborates the earlier findings of Bal, 2003 at Punjab and high degree of genotypic and phenotypic variability reported from Maharashtra by Sawant *et al.* (2003) [11].

Cluster analysis: Clustering of the 29 accessions was done based on the yield and yield contributing characteristics, the data set consisted of mixed data types viz. numeric and attribute, the distance between the accessions was computed using Gower's distance measure. Hierarchical clustering of the accessions based on the complete agglomeration method was done for the above distance matrix and a dendrogram was generated (Fig 3). Two major clusters were observed consisting of 16 and 13 accessions, respectively. The first cluster consisted of the sixteen accessions. Cluster 2 consisted of 13 accessions. Minimum distance was observed between

CHES-K-IV-2 and CHES-K-II-8 while maximum distance was found in between CHES-K-II-2 and CHES-K-II-1.

Principal Component Analysis: The principal component analysis was done based on the numeric characters of yield and yield contributing characteristics. The number of fruits per plant contributed 47.93 percent of total variance while yield per plant and fruit weight contributed 21.64 percent and 12.69 percent of total variance. These two components contributed 89.54 percent of total variance (Fig 4 & Table 4).

Table 4: Summary of PCA analysis of yield characteristics of karonda collections

components	No. of Fruits/plant	Yield (kg/plant)	Fruit Weight (g)	Fruit Length (cm)	Fruit Breadth (cm)	Pulp content (%)	Peel content (%)	Seed Content (%)
Standard deviation	1.9595	1.3157	1.0077	0.75994	0.68924	0.53202	0.25858	0.10699
Proportion of Variance	0.4799	0.2164	0.1269	0.07219	0.05938	0.03538	0.00836	0.00143
Cumulative Proportion	0.4799	0.6963	0.8233	0.89545	0.95483	0.99021	0.99857	1.00000

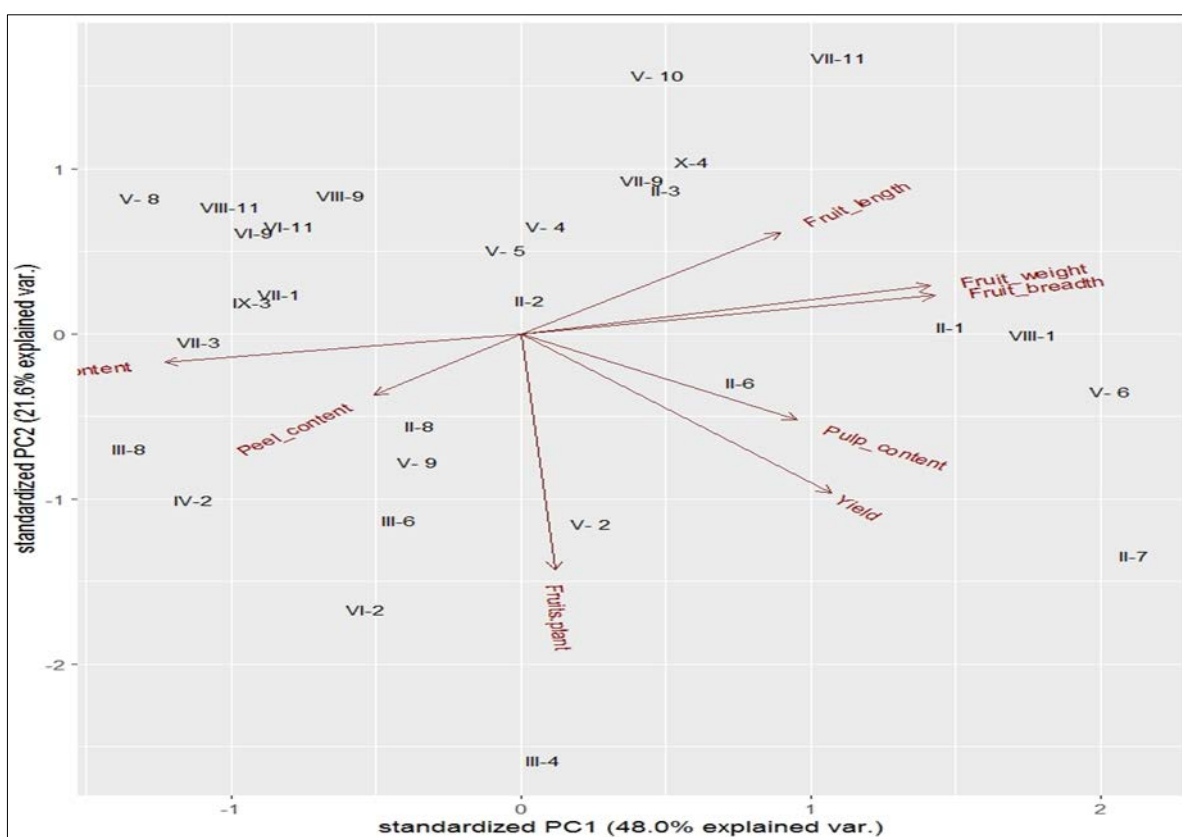


Fig 4: The Standardised PC2 of karonda accessions on the basis of yield and fruit characteristics

Fruit biochemical analysis: It was observed that the fruit of all the accessions of karonda had latex at the time of harvesting. The total soluble solids ranged from 12.15⁰ Brix (CHESK -VIII-1) to 17.05⁰Brix (CHESK-V-4). Higher TSS was recorded in accessions like CHESK-II-3 (15.32⁰Brix), CHESK-II-7 (15.61⁰Brix), CHESK-III-4 (15.58⁰Brix), CHESK-III-6 (15.33⁰Brix), CHESK-V-6 (15.15⁰Brix), CHESK-V-8 (15.37⁰Brix) and CHESK-V-9 (15.58⁰Brix). There was no relation observed between Total Soluble solids and fruit size. The titrable acidity ranged from 0.67 to 3.29 percent. In general, the small fruited accessions had more acidity than large fruited karonda accessions. The TSS: Acid ratio was higher in accession CHESK-II-3. Some of the large fruited accessions such as CHESK-V-10 had also higher

acidity. The ascorbic acid content ranged from 10.75mg/100g pulp (CHESK-VIII-1) to 50 mg /100g pulp in CHESK-VII-1. In general ascorbic was higher in small fruited accessions. The reducing sugar ranged from 5.80 to 10.12 percent. It was the highest in CHESK-III-8. Higher reducing sugar content was observed in CHESK-II-3 (9.07%), CHESK-II-6 (8.37%), CHESK-III-6 (8.34%), CHESK-VI-9 (8.17%), CHESK-VII-9 (8.40%) and CHESK-VIII-9 (8.87%).The total sugar content ranged from 6.19 to 10.55 percent. It was the highest in CHESK-III-8 (10.55%) (Table 5). This variation in quality parameters in the present investigation was may be due to genetic makeup of genotypes and the prevailing climatic conditions as reported by many earlier workers (Joshi *et al.*, 1986 and Singh and Uppal 2015) [6, 15].

Table 5: Biochemical characteristics of karonda accessions

Accessions	TSS (°Brix)	Acidity (%)	TSS: Acidity	Ascorbic acid (mg/100g)	Reducing sugar (%)	Total sugar (%)
CHES-K-II-1	13.22	0.78	16.95	29.50	6.22	6.39
CHES-K-II-2	13.27	1.13	11.74	28.25	7.14	7.41
CHES-K-II-3	15.32	0.67	22.87	22.75	9.07	9.43
CHES-K-II-6	13.48	1.13	11.93	23.25	8.73	9.94
CHES-K-II-7	15.61	1.07	14.59	27.25	7.73	7.90
CHES-K-II-8	14.03	1.33	10.55	50.00	7.43	7.49
CHES-K-III-4	15.58	1.63	9.56	30.00	7.31	7.35
CHES-K-III-6	15.33	2.83	5.42	26.00	8.34	8.67
CHES-K-III-8	14.14	2.10	6.73	25.50	10.12	10.55
CHES-K-IV-2	13.40	2.87	4.67	13.75	7.29	7.94
CHES-K-V- 2	14.53	2.07	7.02	15.00	5.80	6.31
CHES-K-V- 4	17.05	1.28	13.32	21.00	6.90	7.01
CHES-K-V- 5	14.83	2.02	7.34	16.25	7.01	7.38
CHES-K-V- 6	16.15	1.18	13.69	20.25	6.95	8.27
CHES-K-V- 8	15.37	2.43	6.33	16.50	7.08	7.98
CHES-K-V- 9	15.58	2.14	7.28	20.00	7.39	8.71
CHES-K-V- 10	14.53	2.15	6.76	11.25	6.22	8.25
CHES-K-VI-2	13.31	2.70	4.93	19.25	7.01	8.47
CHES-K-VI-9	13.13	3.07	4.28	33.50	7.58	8.58
CHES-K-VI-11	14.86	2.85	5.21	42.25	6.94	7.77
CHES-K-VII-1	13.63	2.47	5.52	50.00	7.34	7.89
CHES-K-VII-3	14.95	2.52	5.93	24.00	5.96	8.11
CHES-K-VII-9	13.85	1.35	10.26	19.25	8.17	8.45
CHES-K-VII-11	14.45	1.07	13.50	10.75	8.40	8.89
CHES-K-VIII-1	12.15	2.08	5.84	14.75	6.68	7.67
CHES-K-VIII-9	14.70	2.83	5.19	24.50	8.87	9.47
CHES-K-VIII-11	14.70	3.29	4.47	33.75	6.27	6.94
CHES-K-IX-3	15.26	2.73	5.59	23.25	6.73	8.01
CHES-K-X-4	13.88	1.62	8.57	21.00	7.68	7.77
Min.	12.15	0.67	4.28	10.75	5.80	6.19
Max.	17.05	3.29	22.87	50.00	10.12	10.55
Average	14.49	1.98	8.83	24.58	7.42	8.07
SD	1.07	0.76	4.99	9.97	1.00	0.99

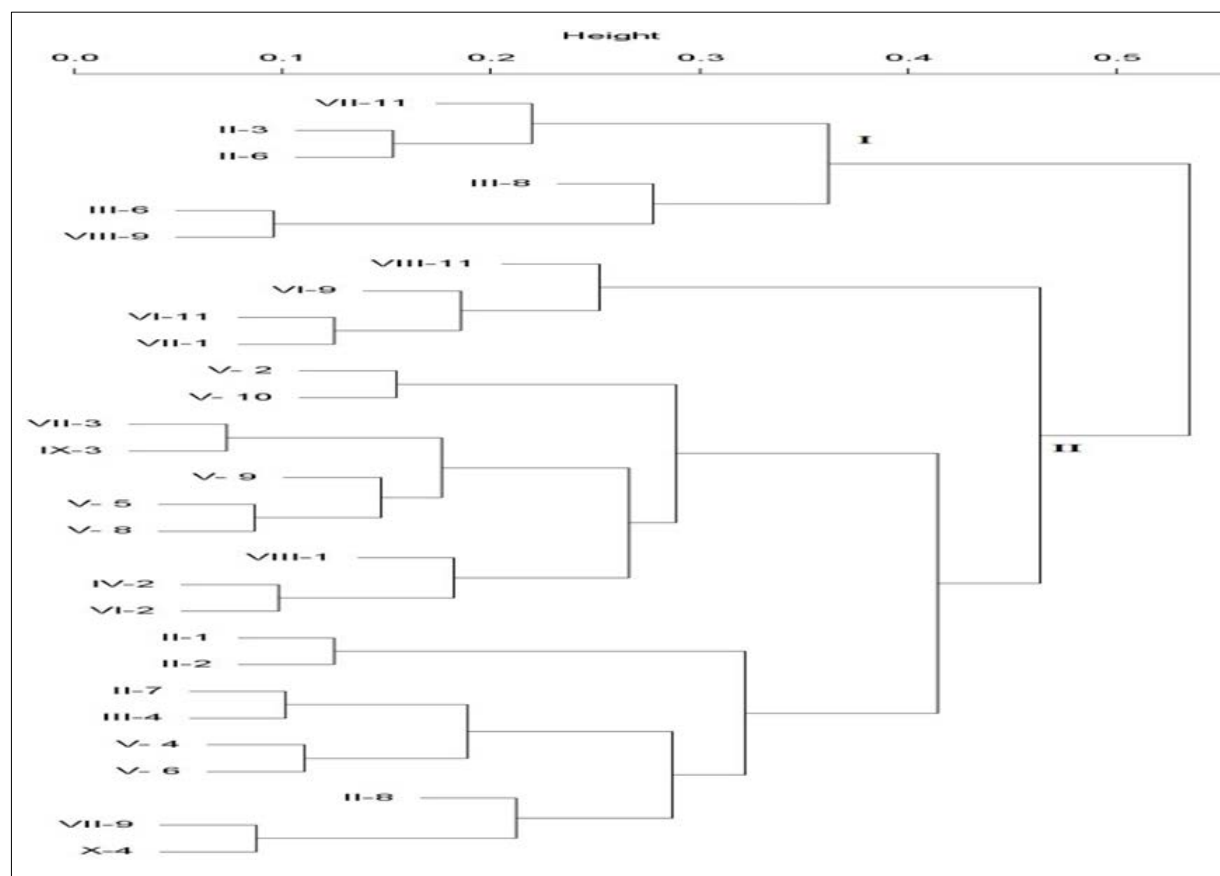


Fig 5: Grouping of karonda accessions on the basis of biochemical characteristics

Cluster analysis: Clustering of the 29 accessions was done based on the yield and yield contributing characteristics of the karonda dataset consisted of mixed data types viz. numeric and attribute, the distance between the accessions was computed using Gower's distance measure. Hierarchical clustering of the accessions based on the complete agglomeration method was done for the above distance matrix and a dendrogram was generated (Fig 5). Two major clusters were observed consisting of 6 and 23 accessions, respectively. The first cluster consisted of the six karonda accessions.

Cluster 2 consisted of 23 karonda accessions. Minimum distance was observed in between CHES-K-IV-2 and CHES-K-II-8 while maximum distance was found between CHES-K-II-2 and CHES-K-II-1.

Principal Component Analysis: The analysis of PCA for biochemical characteristics showed that 79.7% of the total variation was explained by the first three principal components (37% by PC1 (TSS), 23.72% by PC2 (acidity) and 18.78% by PC3 (Ascorbic Acid), (Fig 6 & Table 6).

Table 6: Summary of PCA for biochemical characteristics of karonda collections

Components	TSS	Acidity	Ascorbic acid	Reducing sugar	Total sugar
Standard deviation	1.364	1.0890	0.9690	0.9468	0.34429
Proportion of Variance	0.372	0.2372	0.1878	0.1793	0.02371
Cumulative Proportion	0.372	0.6092	0.7970	0.9763	1.00000

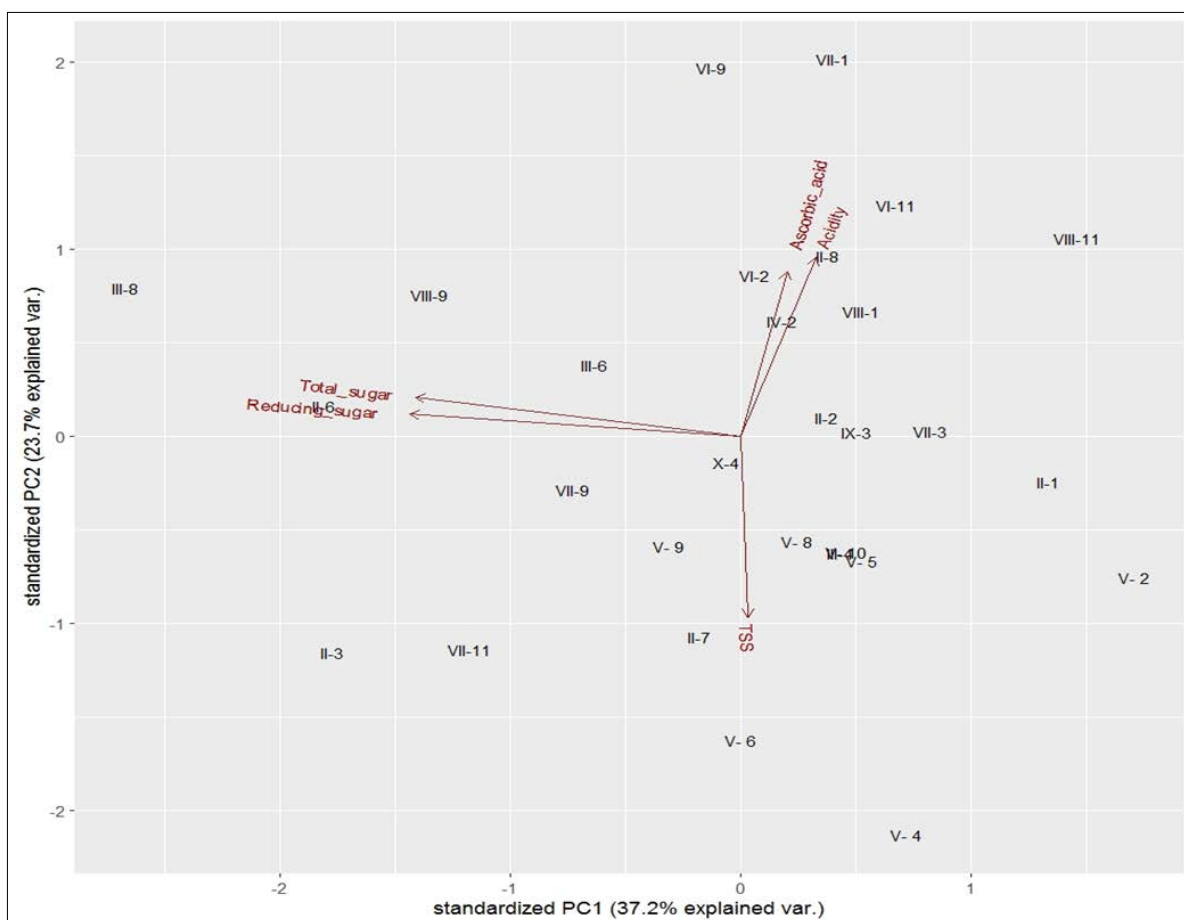


Fig 6: The Standardised PC2 of karonda accessions on the basis of biochemical characteristics

Table 7: Correlation coefficient matrix of fruit characters of karonda collections

Characters	No. of Fruits / plant	Fruit Weight	Fruit Length	Fruit Breadth	Pulp content	Peel content	Seed content	TSS	Acidity	Ascorbic acid	Reducing sugar	Total sugar	Yield/ tree
No. of Fruits/ plant	1.00												
Fruit Weight	-0.12	1.00											
Fruit Length	-0.22	0.57	1.00										
Fruit Breadth	-0.09	0.98	0.56	1.00									
Pulp content	0.26	0.43	0.18	0.49	1.00								
Peel content	0.18	-0.27	-0.14	-0.28	-0.31	1.00							
Seed content	0.04	-0.78	-0.41	-0.76	-0.38	0.14	1.00						
TSS	0.01	-0.03	-0.30	-0.04	0.01	-0.25	-0.12	1.00					
Acidity	0.01	-0.71	-0.30	-0.76	-0.54	0.20	0.64	-0.10	1.00				
Ascorbic acid	0.00	-0.35	-0.31	-0.33	0.15	-0.18	0.36	-0.08	0.11	1.00			
Reducing sugar	0.02	-0.09	-0.05	-0.02	0.02	0.23	-0.14	0.01	-0.22	0.04	1.00		
Total sugar	-0.07	-0.10	-0.06	-0.07	-0.24	0.05	0.01	0.00	0.00	-0.10	0.80	1.00	
Yield/ tree	0.67	0.57	0.20	0.58	0.56	-0.08	-0.46	0.07	-0.41	-0.12	-0.07	-0.16	1.00

Correlation analysis between growth and yield characters:

The yield per plant was highly corrected correlated with number of fruits/plant (0.67), fruit weight (0.57), fruit length (0.58) and fruit diameter (0.56). The fruit weight was highly corrected correlated with fruit length (0.57) and fruit breadth (0.98). The fruit length was highly correlated with fruit breadth but negatively correlated with number of fruits per plant. The pulp content, peel content and seed content were not found significantly correlated with fruit weight, fruit length and fruit breadth. Moreover, it was observed that the titrable acidity was positively correlated with fruit seed content (0.64). Ascorbic acid and total sugar content were not found significantly correlated with number of fruit/plant and fruit size (Table 7).

Conclusion

It was observed that based on the performance of the Karonda accessions over a period of three years for growth, fruit yield and other desirable attributes studied, accessions like K-II-7, K-V-6, K-VIII-1, K-VI-11 and K-V-10 were found bigger fruit size combined with sweetness and less seed content. These karonda accessions may be used as table purpose while karonda accessions like CHESK-II-6, CHESK III-8, CHESK V-2 and CHESK VI-2 have noticed smaller size with higher number of fruits. These karonda accessions may be used for pickle purpose.

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