Morphometric Diversity of Date Palm (*Phoenix Dactylifera* L.) Cultivars from Gujarat Estimated by Fruit Characteristics

Minal Bambhaniya[1], Susy Albert[2]

[1]The Maharaja Sayajirao University of Baroda, Faculty of Science, Department of Botany, Vadodara – 390002, Gujarat, India
Corresponding Author Email: *minal.04bambhaniya[at]gmail.com*
Phone: +918160631202

[2]The Maharaja Sayajirao University of Baroda, Faculty of Science, Department of Botany, Vadodara – 390002, Gujarat, India
Email: *drsusyalbert[at]rediffmail.com*

Abstract: ***Date palm (Phoenix dactylifera L.) is a widely cultivated and highly valued crop in India due to its high energy content. Particularly, the districts of Kutch in Gujarat have extensive cultivation of date palms. Apart from their nutritional value, date palm fruits also hold significant medicinal importance as they contain numerous active constituents. This study aimed to assess the morphometric variations among different date palm cultivars, including five varieties from the local market and four elite varieties from Kutch. Fifteen qualitative and quantitative morphological traits were thoroughly examined in this research. These traits, such as fruit length, width, thickness, volume, density, firmness, and titratable acidity, were evaluated and compared. The results indicated that these traits played a substantial role in discriminating between the cultivars, suggesting their potential utilization in developing a morphological descriptor list specific to Indian date palms. Notably, significant variations were identified among the different cultivars, which provided compelling evidence for the taxonomic identity of the nine studied date palm cultivars. To analyze the collected data, the researchers employed principal component analysis (PCA), a statistical technique used to identify patterns and variability in multivariate data sets. The PCA analysis revealed a high degree of variability among the cultivars, further supporting the distinct morphological differences observed. Overall, this study enhances our understanding of the morphometric variations and taxonomic identity of different date palm cultivars in India. The findings suggest the potential application of these morphological traits as descriptors for future studies and the classification of Indian date palm varieties.***

Keywords: Physical properties, statistical analysis, PCA, *Phoenix dactylifera* L., Dimension, Fruit density

1. Introduction

Date palm (*Phoenix dactylifera* L.) has long been one of the most important fruit crops in the arid regions of the Arabian Peninsula, North Africa, and the Middle East (Chao & Krueger, 2007). In India, Dates growing and harvesting states include Rajasthan's districts of Jaisalmer, Bikaner, Jodhpur and Chandanwal, Punjab, and Gujarat. The primary product is the date fruit, which can be eaten fresh, dried, or in several processed varieties.

Phoenix the only member of the tribe Phoeniceae of Family Palmae is diploid (2n =2x =36) and perennial. *Phoenix* in Greek meaning ‘purple or red’ referring to the color of fruits and *dactylifera* means finger referring to the shape of the fruit.

There is a large number of Cultivars in date palm. There are 400 cultivars reported in Iran, 370 in Iraq, 250 in Tunisia, 244 in Morocco, and 400 in the Sudan (Osman & Awad, 1984). These date palm cultivars are identified commonly by a wide range of morphological features that describe trees and fruits (Nixon, 1951). India imports over 250000 mt of dates per year (Shah, 2014). The date fruit passes through four different maturation stages referred to in terms derived from Iraqi Arabic as 'Kimi', 'Khalal' (sometimes referred to as 'Bisri'), 'Rutab', and 'Tamar' to represent the immature green, the mature full-colored, the soft brown, and the hard raisin-like stages respectively (Reuveni et al., 1985). During the Kimri stage (19 weeks after pollination; unripe, green, and firm), fruit size and weight increased rapidly until the Khalal stage (29 weeks after pollination; partially ripe, colored yellow or red depending on the quality of cultivar). Fruit during the Rutab stage (30 weeks after pollination; fully ripe, light brown, and soft) is characterized by a darkening of the skin to amber, brown, or nearly black, accompanied by softening, decreasing astringency, and increasing insoluble The fruit loses much of its water during the Tamar stage (31 weeks after pollination; dark brown and soft, highly sweet and storable) its water. India produces and markets dates at the khalal stage because climatic conditions do not favor full ripening on the tree to produce Tamar dates (Chao & Krueger, 2007).

Morphology expresses an essential part of the phenotype, also an important indicator of the nature of selection pressures, including environmental constraints and anthropogenic factors. The use of morphological parameters is a common method to identify the date palm variation and diversity level. Commercial grading of date fruits is based principally on the physical characteristics and general appearance of the fruit. Therefore, it has been strongly assumed that traits related to the fruit parameters are useful for date palm characterization. In the present study characteristics of fruit traits, which are easily recognized have been studied to identify the variation and the diversity level in some of the date palm cultivars in Gujarat.

2. Materials and Method

Two sets of date palm fruit bunches were collected and analyzed in the present study. The samples selected were (1) Elite varieties and (2) Local varieties in the market. Date fruit samples designated as A, B, C, D, and E varieties were collected from the vendors in the local market in Vadodara. The elite varieties (KCL141, KCL143, KCL119, and KCL09.1) were procured from the orchard of Kutch Crop Services Limited, Kutch. The fruit samples were collected from 2015-to and 2016 at the khalal maturity stage.

50 fruits of each variety were cleaned to remove any foreign matter and packed in labelled polythene bags and stored in the refrigerator till analysis. Physical features were analyzed. The following data were recorded:

Fruits and seed dimensions: Length, width, and thickness were measured in centimeters using a Vernier calliper. The L, W, and T are perpendicular dimensions of date fruit, particularly length, width, and thickness, and P_L, P_W, and P_L are the projected areas taken along these three mutually perpendicular axes. Geometric mean diameter, Dg (g); sphericity index (ϕ); and surface areas, S (mm); were calculated using the following equations:

$$Dg = (LWT)^{-3} \quad (1)$$
$$\phi = Dg / L \quad (2)$$
$$S = \pi \times Dg^2 \quad (3)$$

As reported by (Kabas et al., 2006) and (Mohsenin, 1986).

Physical parameters: The mass of individual fruit and seed was determined using an electronic balance. Fruit samples were cleaned and seeds were removed. Date flesh was cut into pieces and dried at 60-70°C. The dry matter content % was calculated using the following equations:

Dry matter%= Avg. Dry weight * 100/ Avg. Fresh weight (4)

Fruit pulp % can be calculated by using the following equation
Fruit pulp%= Mesocarp weight * 100/ Total fruit weight (1)

Fruit volumes were measured by the method of water displacement. Fruit densities (g cm^{-3}) were calculated by using the following Equation (Mohsenin, 1986):

$$\rho_f = \frac{M_a}{M_a - M_w} \rho_W \quad (6)$$

Where: ρ_f = fruit density (g cm^{-3}), ρ_w = water density (g cm^{-3}), Ma = fruit mass in air (g), Mw = fruit mass in water (g).

Bulk density was determined using the following Equations (AOAC, 1984) & (Owolarafe et al., 2007):

$$\rho_b = \frac{M}{V} \quad (7)$$

Where: ρ_b = the bulk density (g cm^{-3}), M = bulk mass of fruit (g), V = the plastic container volume cm^3. This method was based on the work of (Owolarafe et al., 2007) & (Suthar & Das, 1996):

Porosity (ε) was calculated as the ratio of the differences in the fruit and bulk densities in the fruit density value and expressed in percentages: (Owolarafe et al., 2007), (Jain & Bal, 1997) & (Vursavuş et al., 2006).

$$\varepsilon = \frac{\rho_f - \rho_b}{\rho_f} \times 100 \quad (8)$$

Skin and flesh thickness was measured using a stereomicroscope and IS capturing software.

Fruit firmness (Kg cm^{-2}) was measured by using a fruit pressure tester penetrometer.

Statistical analysis: Fifteen quantitative designed parameters were used for morphological characterization (Table 6). Mean values for nine cultivars were subjected to principal components analysis (PCA) to discover the quantitative parameters that substantially make contributions to the variability among the cultivars. Cluster analysis, an approach for displaying variations or similarities among cultivars, was run for grouping cultivars that confirmed similarities in many characteristics. Clustering was performed on nine cultivars using fifteen vegetative parameters, using the Euclidean distance matrix.

3. Results

Depending on the variety, environmental conditions, and the technical care given (fertilization, pollination, tinning) fruit characteristics vary. The fruit stalks of all the studied cultivars were orange to yellow (Figure 1), short to medium in size, thick, and hard. The fruits were attached firmly to the stalk with the persistent calyx. Each fruit stalk had fruits varying from 20 to 38.

Fruit and seed dimensions: Among the 9 cultivars studied the fruits of Cultivar C and elite cultivar KCL143 were yellow (Figure.1 C and G). The other cultivars had light red to dark red colored fruits (Figure.1 A, B, D, E, F, H, I). Variety D and KCL143 mature fruits were spherical while the other varieties were oblong (Figure 1). Variety F was oblong and longer than the other fruits.

Figure 1: Fruit bunches of different cultivars
A- Cultivar A, B- Cultivar B, C- Cultivar C, D- Cultivar D, E- Cultivar E, F- Cultivar 09.1, G- Cultivar143, H- Cultivar119, I- Cultivar141

Length and width of the fruits were measured and significant differences in the fruit length and width in local and elite varieties could be prominently observed (Figure 2).

KCL09.1 cultivar had the maximum fruit length (4.44 cm) compared to the other cultivars. The highest recorded diameters were 2.57, 2.77, and 2.37, 2.36 cm in KCL119, KCL143, KCL09.1, and B cultivars respectively. The maximum fruit length/fruit diameter ratio was 2.08 in the C cultivar giving it an elongated and thin fruit compared to the other varieties, while the lowest ratio was 1.16 in the KCL143 cultivar. C cultivar had a maximum seed length of 2.15 cm while KCL141 had a maximum diameter (0.98 cm) compared to the other cultivars. The maximum seed length/diameter ratio was 3.11 in the C cultivar, while the lowest ratio was 1.91 in the KCL09.1 cultivar.

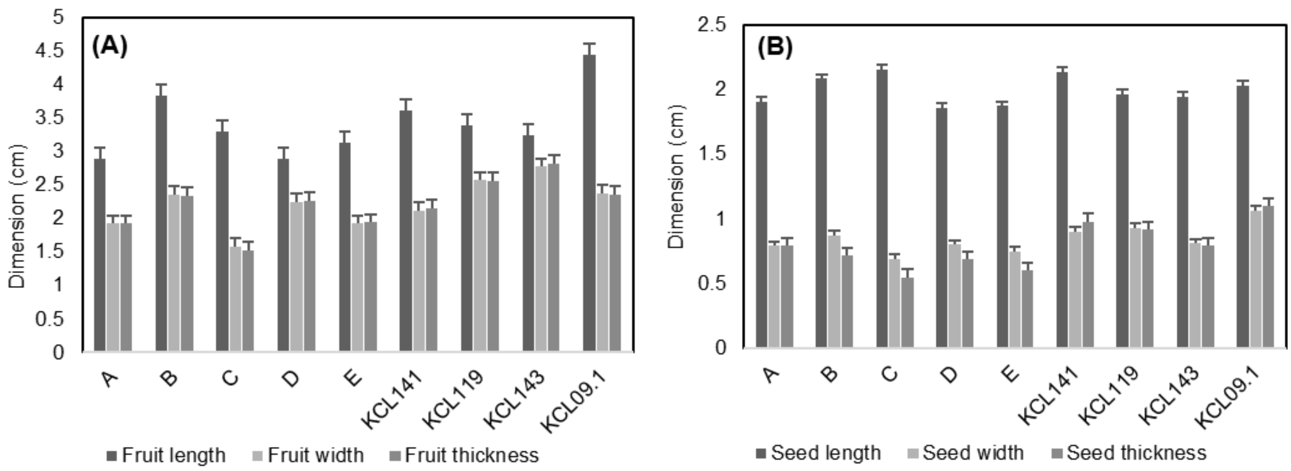

Figure 2: Difference in fruit and seed length, width, and thickness of different cultivars of date palm. (A) Fruit dimensions, (B) Seed dimensions. Letters indicate significant differences by Tukey's test ($P < 0.05$) and vertical bars indicate SE ($n = 5$).

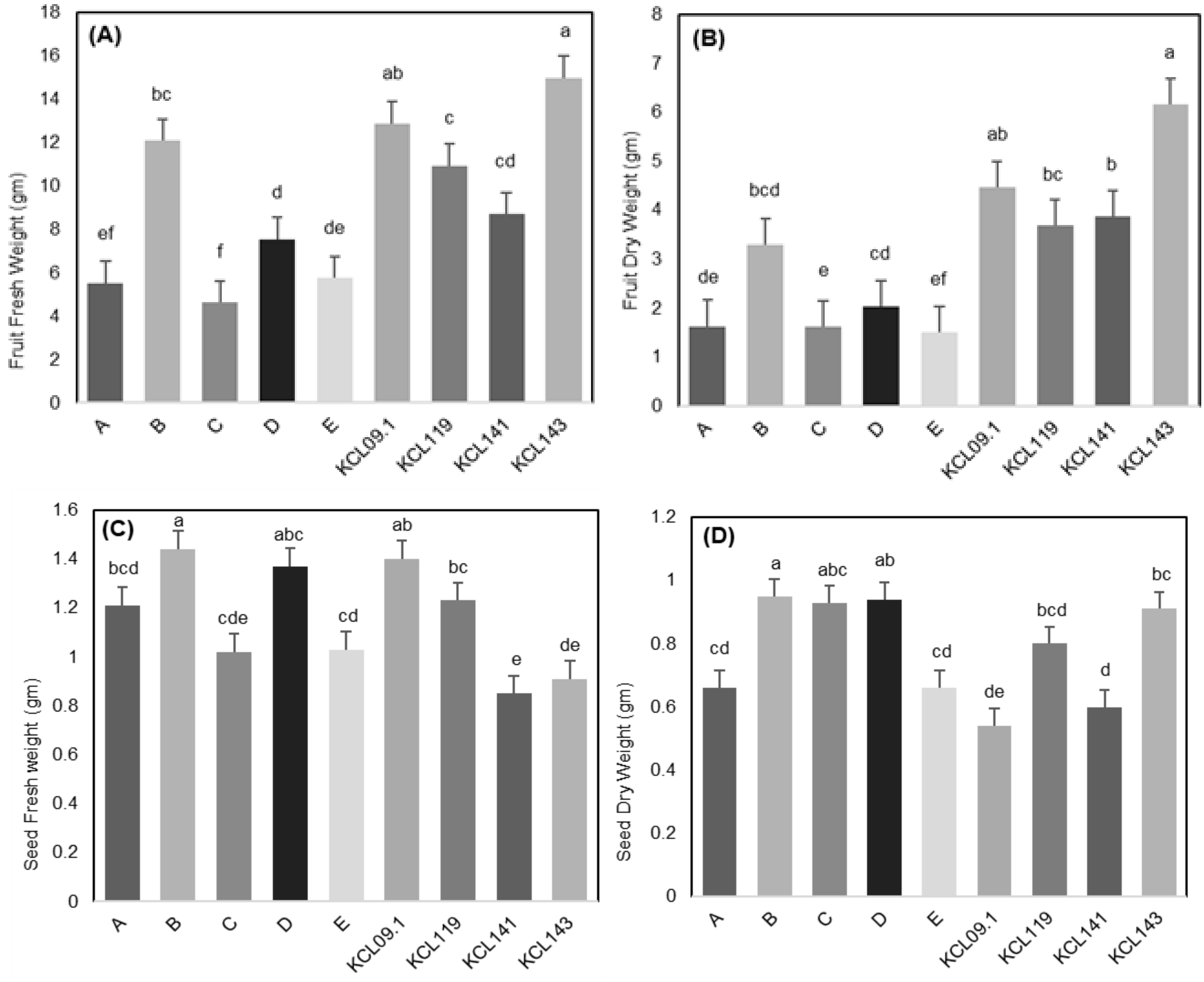

Figure 3: Difference in fruit and seed fresh and dry weight different cultivars of date palm (A) Fruit fresh weight, (B) Fruit dry weight, (C) Seed fresh weight, (D) Seed dry weight. Letters indicate significant differences by Tukey's test ($P < 0.05$) and vertical bars indicate SE ($n = 5$).

Fruit weight was also found to be varying significantly. The maximum fruit fresh weight was observed in KCL143 and KCL09.1 with 15.70 and 13.89 gm respectively, while the lowest fruit weight was in the C cultivar 5.41 gm. Seed weight was maximum in B and KCL09.1 cultivar 1.4 gm (Figure 3).

Length and width in KCL09.1 were maxima indicating that the fruit is elongated in shape. But in KCL143, KCL119, and D cultivars, there is no considerable distinction in length and width of fruit determining fruit shape round while in the B cultivar, the fruit is oblong.

Fruit and seed physical properties: Elite varieties had significantly higher fruit volume and fruit pulp compared to the local varieties A, C, D, and E. Local varieties B had a volume and weight similar to the elite varieties. Environment and care play a major role in these parameters.

Table 1: Fruit and Seed morphometric characteristics of different cultivars

Fruit Parameters	A	B	C	D	E	KCL141	KCL119	KCL143	KCL09.1
Fruit Volume (cm^3)	2.19 ± 0.04	7.08 ± 0.19	1.54 ± 0.26	4.33 ± 0.12	3.35 ± 0.27	5.05 ± 1.39	8.4 ± 1.62	9.4 ± 1.14	8.9 ± 1.09
Fruit density	2.87	1.84	3.51	1.91	1.93	1.90	1.42	1.67	1.56
Bulk density	0.50	0.81	0.54	0.61	0.48	0.70	0.82	0.87	0.82
Porosity %	82.57	55.97	84.61	68.39	75.12	62.15	42.25	47.90	47.43
Geometric M Diameter	2.20	2.76	1.99	2.44	2.26	2.42	2.80	2.93	2.91
Sphericity Index	0.76	0.73	0.60	0.84	0.72	0.67	0.83	0.90	0.65
Fruit Surface area	6.90	8.66	6.26	7.69	7.11	7.97	8.81	9.20	9.14
Fruit L/D	1.50	1.62	2.08	1.28	1.62	1.70	1.31	1.16	1.87
Fruit pulp weight%	74.4	85.11	73.75	77.49	79.44	85.99	94.74	91.01	86.32
Fruit colour	Red-yellow	Red	Red	Dark red	Yellow	Dark red	Red	Yellow	Red
Fruit shape	Elliptical	Ovate	Elongated	Round	Elongated	Elongated	Round	Round	Ovate
Skin Thickness(mm)	0.36 ± 0.13	0.34 ± 0.4	0.28 ± 0.6	0.31 ± 0.8	0.26 ± 0.5	0.21 ± 0.4	0.34 ± 0.15	0.37 ± 0.4	0.32 ± 0.6

Flesh Thickness (mm)	7.59 ± 0.59	7.59 ± 1.64	0.28 ± 0.6	7.39 ± 0.5	6.50 ± 0.9	7.36 ± 1.42	6.21 ± 0.69	8.20 ± 2.32	7.36 ± 2.36
Fruit Firmness (kg cm^{-2})	4.92	3.90	5.29	4.95	3.70	3.59	3.81	3.73	5.34
Seed volume	1.30	2.18	0.80	1.23	1.70	1.54	3.32	3.47	2.22
Seed density	3.54	2.87	4.16	3.72	2.98	3.51	1.94	1.77	2.42
Seed L/D	2.43	2.39	3.11	2.16	2.49	2.36	2.10	2.39	1.91
Seed surface Area (cm)	3.46	3.73	2.71	3.14	2.77	4.75	4.37	3.59	5.55
Geometric mean diameter	1.05	1.09	0.93	1.00	0.94	1.23	1.18	1.07	1.33

Significant differences in these parameters were recorded for the nine different cultivars studied. Table 1 depicts the value of the different parameters studied. Fruit volume (cm^3) was high (9.4 and 8.9 respectively) in KCL143 and KCL09.1 cultivars, followed by 8.40 and 7.08 in KCL119 and B cultivars. The lowest value was recorded in the C cultivar (1.54 cm^3). Fruit density was also highest in C cultivar, (3.51 gm cm^{-3}) while the minimum was recorded in the KCL09.1 cultivar (1.56 gm cm^{-3}). Seed volume (cm^3) was maximum in KCL143 and KCL119 cultivars (3.47 and 3.32), followed by 2.22 and 2.18 in KCL09.1 and B cultivars. Seed density was maximum in C cultivars with 4.16. The lowest value was recorded in the KCL143 cultivar (1.77). The fruit pulp weight % was highest in KCL119 at 94.74% and maximum in the C cultivar (73.75%), there was no significant variation in B, KCL141, or KCL09.1. The cultivar used and the firmness/ maturity of the fruit are also of great importance. The fruit firmness was maximum in KCL09.1 and C cultivars by 5.34 and 5.29 kg/cm respectively. Fruit skin and flesh thickness were maximum in KCL143 (0.37 and 8.20 mm, respectively) while the skin thickness and flesh thickness were lowest in KCL141 (0.21 mm) and KCL119 (6.21 mm) respectively.

Table 2: Measured parameters

Parameters	Labels	Parameters	Labels
ruit length	FL	Fruit density	FD
Fruit width	FW	Seed density	SD
Fruit thickness	FT	Fruit surface area	FSA
Seed length	SL	Seed surface area	SSA
Seed width	SW	Fruit firmness	FF
Seed thickness	ST	Fruit weight	FWT
Fruit volume	FV	Seed weight	SWT
Seed volume	SV	Bulk density	BD

The surface area of fruit was maximum in KCl143 and KCL09.1 (9.20 and 9.14 respectively) but the surface area of seed was maximum in KCL09.1 (5.55) and minimum in C cultivar by 2.71. Bulk density is highest in KCL143 by 0.87 and lowest in E cultivar by 0.48 while no significant difference was noted in KCL119 and KCL09.1 (0.82). Porosity is highest in the C cultivar at 84.61%, while lowest in KCL119 at 42.25%. The sphericity index is highest in KCL143 by 0.90 and lowest in C cultivar by 0.60.

Principal component analysis: The mean values of quantitative (Table 3) characteristics confirmed variability in the studied date palm cultivars and this was confirmed through the results of the principal component analysis (PCA) for quantitative parameters, which explained 78.6% of variability via the first and second component (Table 4). The first component explaining 60.3% of the variability was correlated to the following traits: FW, FT, ST, FV, SV, FWT, FSA, and SSA. The second component explaining 18.3% of the variability was influenced using the FF and SL traits.

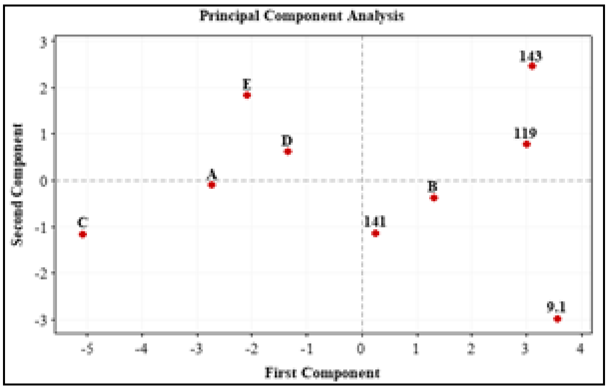

Figure 4: Principal Component Analysis plot of 9 cultivars based on the 15 quantitative morphological traits

Table 3: Mean values of measured characters of date palm cultivars

Parameters	FL	FW	FT	SL	SW	ST	FV	SV	FD	SD	FSA	SSA	FF	FWT	SWT
A	2.89	1.92	1.92	1.9	0.79	0.79	2.19	1.3	2.87	3.54	6.9	3.46	4.92	6.3	1.21
B	3.83	2.36	2.33	2.08	0.87	0.72	7.08	2.18	1.84	2.87	8.66	3.73	3.9	13.03	1.44
C	3.29	1.58	1.53	2.15	0.69	0.55	1.54	0.8	3.51	4.16	6.26	2.71	5.29	5.41	1.03
D	2.89	2.25	2.26	1.86	0.8	0.69	4.33	1.23	1.91	3.72	7.69	3.14	4.95	8.31	1.37
E	3.12	1.92	1.94	1.87	0.75	0.6	3.35	1.7	1.93	2.98	7.11	2.77	3.37	6.47	1.03
141	3.61	2.12	2.15	2.13	0.9	0.98	5.05	1.54	1.9	3.51	7.97	4.75	3.59	9.64	0.85
119	3.38	2.57	2.55	1.96	0.93	0.92	8.4	3.32	1.42	1.94	8.81	4.37	3.81	11.99	1.23
143	3.24	2.77	2.81	1.94	0.81	0.79	9.4	3.47	1.67	1.77	9.2	3.59	3.73	15.7	0.91
9.1	4.44	2.37	2.35	2.03	1.06	1.1	8.9	2.22	1.56	2.42	9.14	5.55	5.34	13.89	1.4

Table 4: Similarity level of different cultivar

Number of Clusters	Similarity level	Clusters joined	
8	85.89	A	C
7	82.62	B	KCL119
6	81.78	A	E
5	81.76	A	D
4	81.39	B	KCL09.1
3	79.67	A	KCL141
2	79.13	B	KCL143
1	58.60	A	B

Cluster analysis: Grouping of cultivars was also illustrated in a dendrogram based totally on cluster analysis for fifteen vegetative quantitative traits (Table 5).

Table 5: Proportion of the quantitative variance for the three-principal component

Principal Component	Characters	PC1	PC2	PC3
Eigenvectors	FL	0.196	-0.421	-0.138
	FW	0.307	0.183	0.090
	FT	0.303	0.204	0.072
	SL	-0.011	-0.384	-0.527
	SW	0.271	-0.311	0.077
	ST	0.246	-0.291	-0.062
	FV	0.326	0.028	-0.007
	SV	0.286	0.239	-0.078
	FD	-0.292	-0.119	-0.072
	SD	-0.292	-0.200	0.018
	FSA	0.329	0.011	0.024
	SSA	0.248	-0.354	-0.091
	FF	-0.103	-0.371	0.435
	FWT	0.313	0.017	-0.041
	SWT	0.069	-0.207	0.685
Eigenvalue	9.0407		2.7430	1.4301
Variance Proportion				
Individual (%)	60.3%		18.3%	9.5%
Cumulative (%)	60.3%		78.6%	88.1%

They were generally two main groupings: the first one for A, C, E, D, and KCL141 cultivars and the second for B, KCL119, KCL143, and KCL09.1 cultivars. The first cluster is composed of two sub-clusters, one with A, C, and E and the second with D and KCL141The second cluster is composed of B, KCL119, and KCL09.1 together with KCL143 cultivars with a significant divergence of KCL143 from the others (Figure 5).

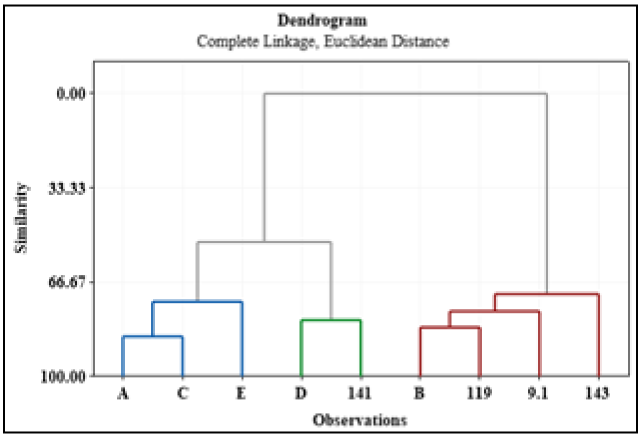

Figure 5: Dendrogram of 9 cultivars based on the 15 quantitative morphological traits

Correlation matrix: In addition, the correlation matrix between the studied quantitative characteristics (Table 6) showed a strong correlation mainly between FW and FT; FW and FV; FW and FSA; FW and FWT; FT and FV; SW and ST; ST and SSA; FV, FSA, and FWT; FSA and FWT. This finding highlighted some strong relationships between some cultivars, particularly between KCL143 and KCL09.1, KCL119 and KCL141, as well as between A, C, D, and E cultivars about some quantitative fruit characteristics.

Table 6: Correlation matrix between the different vegetative traits of date palm cultivar

	FL	FW	FT	SL	SW	ST	FV	SV	FD	SD	FSA	SSA	FF	FWT
FW	0.27													
FT	0.24	1												
SL	0.57	-0.24	-0.27											
SW	0.8	0.57	0.55	0.16										
ST	0.65	0.52	0.51	0.17	0.93									
FV	0.58	0.93	0.92	0	0.73	0.64								
SV	0.25	0.9	0.89	-0.18	0.46	0.43	0.89							
FD	-0.39	-0.84	-0.85	0.28	-0.69	-0.58	-0.83	-0.73						
SD	-0.34	-0.87	-0.86	0.24	-0.54	-0.47	-0.89	-0.98	0.76					
FSA	0.58	0.94	0.93	-0.02	0.77	0.68	0.99	0.84	-0.86	-0.85				
SSA	0.79	0.48	0.47	0.31	0.96	0.98	0.65	0.39	-0.57	-0.45	0.69			
FF	0.12	-0.36	-0.39	0.11	0.04	0.02	-0.28	-0.49	0.51	0.44	-0.29	0.04		
FWT	0.58	0.91	0.9	0.08	0.67	0.58	0.97	0.84	-0.74	-0.83	0.97	0.61	-0.25	
SWT	0.3	0.17	0.12	-0.18	0.4	0.13	0.19	-0.02	-0.2	-0.05	0.24	0.19	0.46	0.17

4. Discussion

A morphometric study of the fruits and seeds was carried out, to evaluate the potentiality of fruit and seed size and shape in distinguishing the elite and local varieties. The shape varied from round to ovate to elongated and oblong. The significance of the dimensions is in identifying the aperture dimension of machines, specifically in the separation of materials (Mohsenin, 1986). These dimensions can be used in designing machine components and other parameters for separating fruits of the same size, an important factor in maintaining quality. Date seeds also called pits/ stones/ kernels represent about 10-15% of the weight of the fruit depending upon the variety.

In E, KCL119 and KCL143 seed size is small compared to the fruit of other cultivars which indicates that there is more flesh compared to other cultivars. KCL141 cultivar takes more time to dry so it can be stored long time compare to another cultivar.

Physical properties of the fruit, i.e. Mass (gm), Volume (cm^3), Length (mm), Thickness (mm), Fruit density (g cm^{-3}), Geometric mean diameter (mm), Sphericity (%), Bulk density (g cm^3) and Porosity (%) help in determining the separation process and transportation of fruits. It will facilitate boost suitable technologies for its processing size, shape, and physical dimensions are essential in sorting and sizing fruits and determining how many fruits can be positioned in transporting containers or plastic baggage of a given size. Porosity, the percentage of air space in particulate solids, influences airflow resistance through bulk solids.

Flesh and skin thickness are maximum in KCL143 so it can be used as table variety, but firmness is less so it cannot be stored for a long time. In the D cultivar, it is a local variety, but its firmness is more so it can be stored for a long time. The fruit pulp weight percentage is highest in KCL119 indicating that this cultivar is economically important. The fruit L/D ratio is important for determining fruit shape. L/D ratio is lower in the D cultivar depicting its round shape. Quality differences can be often detected by a difference in density.

The implication of the studied quantitative traits on the plot was defined by using the two first principal components PC1 and PC2 (Figure 4), displaying a substantial relation between KCL143 and KCL09.1, KCL119 and KCL141 on the PC1 associated positively with the following traits: FW, FT, ST, FV, SV, FWT, FSA, and SSA. The PC2 recorded grouping between A, C, D, and E cultivars associated with SL, SW, SSA, and FF traits.

Grouping of cultivars was also demonstrated in a dendrogram based on cluster analysis for fifteen vegetative quantitative traits (Figure 5). In the first sub-cluster, A and C cultivars associate themselves in the centre of the dendrogram proposing that it shares some traits with another group. In the second sub-cluster B and KCL119 cultivar associates itself in the centre of the dendrogram proposing that it shares some characteristics with the other group.

The present morphological characteristics concentrated on to survey of the phenotypic variability in a group of date palm cultivars demonstrated strongly helpful. The grouping of the cultivars in the PCA plot as well as in cluster analysis supported the possibility that the researched cultivars are demonstrated by a high level of genetic diversity. Hence, this study highlighted the relationship between vegetative and fruit characteristics which may be genetically related. This method of taxonomy cannot resolve definitively the cultivar identification problem. Many different populations may have the same aspect, despite their different genotypes. On the other hand, the strong correlation between the parameters used suggests that the tree architecture is well arranged. In addition, the derived dendrogram has permitted the clustering of cultivars into two main groups supported by tree branching made according to fruit characteristics. These results revealed that the cultivars are very close to each other and joined together firstly because they had the same needs for growth habitat and environmental conditions. The dendrogram concluded that the A and C, B, and KCL119 were taxonomically closer to each other than to the cluster of the other cultivars.

5. Conclusion

Morphometric dimensions determined of the fruits will help in separating fruits of equal size and shape which would help in quality control (marketing). Physical properties determined by the fruit will also help in sorting and separating the fruits of the same size. Flesh and skin thickness are highest in KCL143 so it can be used as table food, but firmness is less so it cannot be stored for a long time. Overall cultivar KCL09.1 was considered to be the best cultivar in terms of quality based on the different parameters studied. Cluster analysis and dendrogram obtained indicated that cultivars A and C both local varieties and local variety B and elite variety KCL119 were taxonomically closer to each other than to the cluster of the other cultivars.

Acknowledgments

The authors are highly indebted to Prof J.J. Shah for initiating this topic in a morphometric study on the date palm cultivars in Gujarat. This is the first study in Gujarat. The authors are thankful to the Kutch crop limited to, providing elite varieties of fruits.

References

[1] AOAC, 1984. Official Methods of Analysis. AOAC Press, Washington, D.C.
[2] Chao, C.T. and Krueger, R.R., 2007. The Date Palm (Phoenix dactylifera L.): Overview of Biology, Uses, and Cultivation. *HortScience*, 42(5): 1077–1082. https://doi.org/10.21273/hortsci.42.5.1077
[3] Jain, R.K. and Bal, S., 1997. Properties of Pearl Millet. *J. Agric. Eng. Res*., 66(2): 85–91. https://doi.org/10.1006/jaer.1996.0119
[4] Kabas, O., Ozmerzi, A., and Akinci, I., 2006. Physical properties of cactus pear (Opuntia ficus india L.) grown wild in Turkey. *J. Food Eng.*, 73(2): 198-202. https://doi.org/10.1016/j.jfoodeng.2005.01.016
[5] Mohsenin, N.N., 2020. Physical Properties of Plant and Animal Materials. Structure, Physical Characteristics and Mechanical Properties. Routledge. https://doi.org/10.1002/food.19870310724
[6] Nixon, R.W., 1951. The date palm— "Tree of Life" in the subtropical deserts. *Econ. Bot*., 5(3): 274-301. https://doi.org/10.1007/bf02985151
[7] Osman and Awad M.A., 1984. The performance of date palms in Sudan. *Acta Hortic*, 143, 231-238. https://doi.org/10.17660/actahortic.1984.143.25
[8] Owolarafe, O.K., Olabige, T.M., and Faborode, M.O., 2007. Macro-structural characterization of palm fruit at different processing conditions. *J. Food Eng*., 79(1), 31-36. https://doi.org/10.1016/j.jfoodeng.2006.01.024
[9] Reuveni, O., Abu, S., and Golobovitz, S., 1985, May. Date palm pollen germination and tube elongation on pistillate flowers cultured at different temperatures. In Symposium on *Physiology of Productivity of*

ISSN: 2319-7064
SJIF (2022): 7.942

Subtropical and Tropical Tree Fruits 175, p. 91-96. https://doi.org/10.17660/actahortic.1986.175.13

[10] Shah, J.J., 2014. Date palm cultivation in India: An overview of activities. *Emirates Journal of Food and Agriculture*, 987-999. https://doi.org/10.9755/ejfa.v26i11.18986

[11] Suthar, S.H., and Das, S.K., 1996. Some physical properties of karingda [Citrullus lanatus (Thumb) Mansf] seeds. *J. Agric. Eng. Res*., 65(1); 15-22. https://doi.org/10.1006/jaer.1996.0075

[12] Vursavuş, K., Kelebek, H., and Selli, S., 2006. A study on some chemical and physico mechanic properties of three sweet cherry varieties (Prunus avium L.) in Turkey. *J. Food Eng.*, 74(4): 568-575. https://doi.org/10.1016/j.jfoodeng.2005.03.059

Author Profile

Minal D. Bambhaniya, Research scholar (CSIR JRF), Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara. Email: minal.04bambhaniya@gmail.com , Phone: +918160631202

Prof. Susy Albert, Seed anatomy Lab, Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara. Email: drsusyalbert@rediffmail.com