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Multivariate Analysis of Morphological variation in Palmyrah (*Borassus flabellifer* L.) germplasm

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ABSTRACT: Determination of elite genotypes in crop improvement program is achieved by using the biometrical techniques that assess the crop performance. Up to now, no research work has been done on morphological characterization of palmyrah. This made us to select the present work as our study. In the present study, 21 Palmyrah germplasms were evaluated for 13 morphological traits through Principal Component analysis to evaluate the genetic divergence, pattern of variation present in the germplasms and relationship among the tested individuals and their correlation analysis. The study was conducted at Agricultural College & Research Institute, Killikulam in 2023. The first four principal components exhibited desired eigenvalues and explicated 72.97% of the total variability in the observed traits. From the Biplot, the traits *viz.*, stem girth at the ground level, girth of trunk at one meter height from ground level, crown length, number of Inflorescences per tree, number of leaf segments per tree, inflorescences length, plant height, petiole length, number of scars between 50cm in the trunk contributed maximum diversity. The genotypes ACC5EBKKM, ACC1ODKKM and ACC3ODKKM showed high positive values. The Cluster analysis displayed four major groups *viz.*, I, II, III and IV consisting of 8, 1, 9 and 3 accessions, respectively. The accessions from the diverse clusters can be exploited for breeding program in Palmyrah.

Keywords: Palmyrah, Principal Component analysis (PCA), genetic divergence, Biplot, Cluster analysis.

INTRODUCTION

Palmyrah palm is scientifically called as *Borassus flabellifer L.* belongs to the Arecaceae family and genus Borassus and the subfamily Borassoideae in the order Arecales. It belongs to tropical Africa and distributed in the drier parts of India, Sri Lanka, Thailand, Malaysia, Vietnam and Indonesia. It is a diecious crop, both male and female tree are separate. In Tamil Nadu, the palm tree is distributed over an area of about 24000 hectares (Krishnaveni *et al.*, 2020) in all districts except Nilgiris, and it serves as state tree of Tamil Nadu (Davis, 1985). Horticultural Research station, Pandirimamidi, East Godavari Dist., Andhra Pradesh (Dr. YSRHU Andra Pradesh) and Agricultural College & Research Institute, Killikulam in Tamil Nadu are the research centers under the All India Coordinated Research Project on Palms (AICRP) (Anon., 2004, 2005), where collection, conservation, and evaluation of existing germplasm in palmyra and hybridization for developing dwarf types are focused (Sankaralingam, 1999). The Palmyrah research station has released one variety in palmyrah, SVPR-1 in 1992. It is selection from Srivilliputhur local dwarf type and may be tapped for neera up to 95 days. Palmyrah featuring a sturdy trunk covered in thick, fibrous bark grow to a height of 30 meters, and sometimes even up to 90 meters. It is topped with a crown of large fan-shaped 20 to 30 big leaves grows of three meters in length. The edge of the leaf petiole is sclerotic serrated and grooved. Large, palmate leaf lamina measuring 1 to 5 metres long and composed of 60 to 80 compound segments. If the palm's sex could be established at the early seedling stage itself, breeding and crop enhancement activities would be greatly easier. This would aid palmyrah growers in the selection of seedlings as well as in maintaining an ideal sex ratio during plantation (Ponnuswami, 2010). The delicious sap from the male or female flower, which is obtained by tapping the top of the inflorescence, is historically gathered in hanging earthen pots and used to slake thirst among the many other uses for the palm. Palmyrah palm has rich sources of Vitamin C, Iron, Zinc, Calcium, Potassium, Phosphorous. It has cooling, laxative properties and enhances digestion. It is used to cure dry cough and sore throat. The immature seed endosperm of fresh seed nuts is eaten during the summer.

The genotypes of palmyrah found across India have a wide range of morphological variations (Kovoor *et al.*, 1983). There variations in plant morphological characteristics must be used to improve crops, and germplasm collections that are specific to certain regions of the country must be expanded to other parts of the nation to improve both adaptability and crop improvement in the palm (Sachin *et al.*, 2016). Therefore, choosing parents with a wide range of morphological characteristics would be very helpful for palm breeders in choosing parents for their future breeding plan (Ponnuswami and Chitra 2011).

MATERIALS AND METHODS

A. Experimental location

The experiment was conducted at Department of Horticulture, AC & RI, Killikulam located at 8º70′N latitude and 77º86′E longitude at the elevation of 41.73m above MSL. The weather prevailed at AC&RI, Killikulam, during the present study was hot summer from January-July. In open field condition, the maximum temperature various between 32ºC to 38ºC with an average of 35ºC. Minimum temperature various between 22ºC to 28ºC with an average of 25.4ºC. The annual rainfall was 668 mm and relative humidity various between 60 to 91 percentage with an average of 76 percentage and the palmyrah block consists of red soil.

B. Details of experiments

Design of experiment – RBD (Randomized Block Design)

Number of accessions – 21

Number of replications – 3

Year of observation – 2023

Palmyrah germplasm having 17-25 years old palm trees available at Department farm were used for the study. The germplasm materials were collected from the major parts of India such as Tamil Nadu, Andhra Pradesh, Odissa districts under AICRP- Palms project “Gen.9 Survey, Collection and Evaluation of Palmyrah Germplasm”.

The 21 accessions selected based on the duration were evaluated in the present study and the details are presented in Table 1.

C. Characters observed

a) Plant height(m): Height of the plant was measured from the base of the stem to the tip of the plant in the randomly selected palm and the value was expressed in meters.

b) Height of trunk(m): Height of the plant was measured from the base of the stem to the point of emergence of leaves and the value was expressed in meters.

c) Stem girth at the ground level (m): Circumference of stem at ground level was measured and the value was expressed in meters.

d) Girth of trunk at one meter height from the ground level(m): Circumference of trunk at the height of one meter above the ground, the girth of each selected palm was measured in centimeters and the value was expressed in meters

e) Crown length (cm): Length of the crown was measured from the point of emergence of leaves to the tip of the selected palm and the value was expressed in meters.

f) Number of scars between 50cm in the trunk: Counting the number of scars between fifty centimeters on the trunk and expressed in a number.

g) Number of leaves per tree: Total number of completely opened leaves presented on the tree was counted after excluding dried leaves and unopened one.

h) Number of leaf segments per leaves: All leaf segments are counted in the fifteenth leaf of selected palm and expressed as a number.

i) Petiole length (cm): Using measuring tape, the length of the petiole was determined from the base of the point at where the leaf segments emergence was measured in centimeters.

j) Leaf length (m): Length of leaf was measured in the fifteenth leaf of selected palms in meters from tip of leaf to the base.

k) Leaf breadth (m): Breadth of leaf was measured in the fifteenth leaf of selected palms in centimeters between the leaf segments left end to right end.

l) Total number of inflorescences per tree: In the selected palm, the number of inflorescences were counted in accordance with its growth right from the first one appeared to the last inflorescences and the total number produced was recorded.

m) Inflorescence length (cm): Length of inflorescence was measured from the tip of the inflorescence to base in the selected palm tree and expressed in centimeters.

D. Statistical analysis

Data was interpreted using Principal Component Analysis (PCA) to select the more significant set of variables from the largest original data having more variables. Eigenvalues were calculated from different Principal Components (PCs). Scoring of different germplasms to the corresponding PCs is used to determine the best germplasm showing diversity. The correlation between different variables and PCA biplots were used to explain the relationship between the PCs and various traits. Germplasm variables that had vectors with less than 90° (< 90°) are positively correlated and more than 90° (>90°) are negatively correlated and equal to 0 state of no correlation.

Agglomerative Cluster analysis was performed using STAR software for the various Palmyra germplasms.

The germplasms were grouped into different clusters based on interpretation; cluster means of different traits were calculated and used to find out diversity and significance in the population.

RESULTS AND DISCUSSION

From the Principal component analysis, various morphological characters like plant height, height of trunk, stem girth at the ground level, girth of trunk at one meter height from the ground level, crown length, number of scars between 50cm in the trunk, number of leaves per tree, number of leaf segments per leaves, petiole length, leaf length, leaf breadth, inflorescence length and total number of inflorescences per tree were studied.

PCA Analysis was carried out to find out the divergence between the germplasms of palmyrah by using STAR Software. The amount of variance explained by PCs defines number of PCs to be kept. PCs must explain at least 70% of the variation in accordance with the (Rencher and Christensen 2002).

The eigenvalues (λ), standard deviation, proportion of variance, cumulative proportion are given in the Table 2. Out of 13 PCs, four had shown the eigenvalue more than 1. The first four PCs explicated approximately 72.97% of all the variability in the observed traits (30.65% explicated by PC1, 17.52% by PC2, 15.24% by PC3 and 9.56% by PC4).

In Scree plot, the eigenvalues of principal components are plotted with the corresponding PCs that should be considered for the analysis. It indicated that the first four PCs (PC1, PC2, PC3 and PC4) showed maximum variability (Fig. 1).

The eigenvector values of different traits are shown in table 3. The PC1 exhibited positive value for two traits *viz*., SG, GT. PC2 showed positive values for 10 traits *viz*., PH, SG, GT, NS, CL, LS, PL, LB, IL, NI; PC3 showed positive values for eight traits *viz*., SG, GT, CL, LS, PL, LL, IL, NI and PC4 showed positive values for 7 traits *viz.*, PH, HT, NS, LS, PL, LL, IL. It explained that these are the important traits that having more variation and significance with corresponding PCs (Zhang *et al.*, 2021).

The scores of germplasms in relation to the four principal components (PC1, PC2, PC3, PC4) are given in Table 4. It was observed that out of 21 genotypes, only three accessions *viz.*, (ACC5EBKKM, ACC1ODKKM and ACC3ODKKM) showed high positive score for all the four principal components (PC1, PC2, PC3 and PC4).

PC1 and PC2 were plotted against each other in Biplot to record the relationship between the germplasms and different traits studied (Fig. 2). In this Biplot the positive values for both PC 1 and PC2 are grouped in right top corner of Biplot. The accessions having positive values are (ACC5EBKKM, ACC8EBKKM, ACC12EBKKM, ACC18EBKKM, ACC22EBKKM, ACC1ODKKM, ACC2ODKKM and ACCODKKM) and the traits *viz*., stem girth at the ground level, girth of trunk at one meter height from the ground level are located in same quadrant that exhibits maximum diversity.

PC1 and PC3 were plotted against each other in Biplot to record the relationship between the accessions and different traits studied (Fig. 3). The genotypes having positive values ACC5EBKKM, ACC3BIKKM, ACC1ODKKM, ACC3ODKKM are grouped in right top corner and the traits *viz.*, stem girth at the ground level, girth of trunk at one meter height from the ground level are also located in same quadrant exhibiting maximum diversity.

PC1 and PC4 were plotted against each other in Biplot to record the relationship between the germplasms and different traits studied (Fig. 4). In this Biplot the positive values for both PC1 & PC4 are grouped in right top corner of Biplot. The germplasms having positive values are ACC5EBKKM, ACC18EBKKM, ACC22EBKKM, ACC26EBKKM, ACC1ODKKM, ACC2ODKKM and ACC3ODKKM and there are no positive traits observed in this relation.

PC2 and PC3 were plotted against each other in biplot to record the relationship between the genotypes and different traits studied (Fig. 5). In this Biplot, the positive values for both PC2 & PC3 are grouped in right top corner of biplot. The germplasms having positive values are ACC3EBKKM, ACC5EBKKM, ACC1KPKKM, ACC1ODKKM and ACC3ODKKM and the traits *viz.*, stem girth at the ground level, girth of trunk at one meter height from the ground level, crown length, total number of inflorescences per tree, number of leaf segments per leaves, inflorescences length are located in same quadrant that exhibits maximum diversity.

PC2 and PC4 were plotted against each other in biplot to record the relationship between the accessions and different traits studied (Fig. 6). In this Biplot, the positive values for both PC2 & PC4 are grouped in right top corner of biplot. These include the genotypes ACC5EBKKM, ACC18EBKKM, ACC22EBKKM, ACC12KPKKM, ACC18KPKKM, ACC27KPKKM, ACC1ODKKM, ACC2ODKKM, ACC3ODKKM and the traits *viz.*, inflorescences length, number of leaf segments per leaves, plant height, petiole length, number of scars between 50cm in the trunk in same quadrant that exhibits maximum diversity.

PC3 and PC4 were plotted against each other in Biplot to record the relationship between the germplasms and different traits studied (Fig. 7). In this Biplot the positive values for both PC3 & PC4 are grouped in right top corner of Biplot. The germplasms having positive values are ACC5EBKKM, ACC1ODKKM and ACC3ODKKM and the traits *viz.*, inflorescences length, number of leaf segments per leaves are located in same quadrant exhibiting maximum diversity.

In the present study, 21 palmyrah accessions were grouped into 4 clusters based on the Euclidean distance method of agglomerative cluster analysis as shown in the diagram (Fig. 8, Table 5). Four major groups were formed as clusters *viz*., I, II, III, IV consisting of 8, 1, 9 and 3 genotypes respectively. Cluster means of different traits in palmyrah accessions are given in Table 6. Cluster I had the highest mean value for the traits *viz.*, plant height (10.30 m), height of trunk (6.87 m), crown length (4.63 m), number of leaf segments

(86.00), petiole length (1.66 m), leaf breadth (152.33 cm), number of inflorescences (9). Cluster II had the highest mean value for the traits *viz.*, girth of trunk at one meter height from the ground level (2.64 m), inflorescences length (175.50 cm). Cluster III had the highest mean value for the traits *viz.*, stem girth at the ground level (2.20 m), number of scars between 50 cm (28). Cluster IV had the highest mean value for the traits *viz.*, number of leaves (27.33), leaf length (358.00 cm). Here, the value of cophenetic correlation coefficient was 0.634 that showed the high efficiency of the clustering pattern. Hence, the genotypes of respective clusters can be utilized for crop improvement that showed higher mean value (Sarkar *et al*., 2012).

Table 1: The 21 accessions selected based on the duration were evaluated in the present study and the details are presented.

Sr. No.	Genotype	Place of collection and maintained at Killikulam
1.	ACC1EBKKM	Killikulam, Tamil Nadu
2.	ACC2EBKKM	Killikulam, Tamil Nadu
3.	ACC3EBKKM	Killikulam, Tamil Nadu
4.	ACC5EBKKM	Killikulam, Tamil Nadu
5.	ACC8EBKKM	Killikulam, Tamil Nadu
6.	ACC12EBKKM	Killikulam, Tamil Nadu
7.	ACC17EBKKM	Ananthanambikurchi, Tamil Nadu
8.	ACC18EBKKM	Ananthanambikurchi, Tamil Nadu
9.	ACC22EBKKM	Ananthanambikurchi, Tamil Nadu
10.	ACC26EBKKM	Ananthanambikurchi, Tamil Nadu
11.	ACC1KPKKM	Seerudiyarpuram, Tamil Nadu
12.	ACC8KPKKM	Anaikudi, Tamil Nadu
13.	ACC11KPKKM	Anaikudi, Tamil Nadu
14.	ACC12KPKKM	Anaikudi, Tamil Nadu
15.	ACC18KPKKM	Thisayanvilai, Tamil Nadu
16	ACC27KPKKM	Ampalacherry, Tamil Nadu
17.	ACC3BIKKM	Pakkapatty, Tamil Nadu
18.	ACC1ELKKM	Kasimkotta, Andhra Pradesh
19.	ACC1ODKKM	Odissa-1
20.	ACC2ODKKM	Odissa-2
21.	ACC3ODKKM	Odissa-3

Table 2: Principle component analysis, standard deviation, proportion of variance, cumulative proportion, eigenvalues.

Principal components	Standard deviation	Proportion of variance	Cumulative proportion	Eigenvalues
PC1	1.9962	0.3065	0.3065	3.9850
PC2	1.5091	0.1752	0.4817	2.2774
PC3	1.4075	0.1524	0.6341	1.9810
PC4	1.1146	0.0956	0.7297	1.2422
PC5	0.9811	0.0740	0.8037	0.9625
PC6	0.8406	0.0544	0.8581	0.7067
PC7	0.7856	0.0475	0.9055	0.6172
PC8	0.6359	0.0311	0.9366	0.4043
PC9	0.5330	0.0219	0.9585	0.2841
PC10	0.4647	0.0166	0.9751	0.2160
PC11	0.4182	0.0134	0.9886	0.1749
PC12	0.2913	0.0065	0.9951	0.0848
PC13	0.2528	0.0049	1.0000	0.0639

Table 3: Contribution of different traits for total variance in palmyrah accessions.

Principal components	PH	HT	SG	GT	NS	CL	NL	LS	PL	LL	LB	IL	NI
PC1	-0.4032	-0.4323	0.1103	0.0779	-0.08	-0.3651	-0.1918	-0.1562	-0.4549	-0.2696	-0.2399	-0.0408	-0.3043
PC2	0.1854	-0.0292	0.5218	0.1596	0.3151	0.1048	-0.2568	0.0152	0.0023	-0.4766	0.3974	0.3231	0.0333
PC3	-0.2499	-0.0848	0.1483	0.4867	-0.5281	0.2454	-0.007	0.4755	0.0318	0.0296	-0.1065	0.2154	0.216
PC4	0.0912	0.2589	-0.3123	-0.1043	0.0175	-0.2877	-0.4617	0.1837	0.0591	0.0773	-0.2249	0.634	-0.1557
PC5	-0.1592	-0.167	0.1987	-0.5032	-0.2581	0.0001	-0.2714	0.3288	0.137	0.2517	0.4577	-0.1365	-0.3088
PC6	0.0966	0.1795	-0.1043	0.2781	-0.301	0.2888	-0.6016	-0.4978	-0.0338	0.1037	0.1103	-0.2372	-0.0789
PC7	-0.2025	-0.0915	-0.0424	-0.3237	0.0798	-0.0713	-0.3844	0.0353	-0.0143	-0.1084	-0.0922	-0.1543	0.7996
PC8	0.3024	0.1641	-0.1759	0.0505	0.1774	0.1572	-0.1632	0.5595	-0.5174	-0.1353	-0.0622	-0.3877	-0.1099
PC9	-0.022	0.0136	0.1336	-0.4802	-0.11	0.6454	0.0416	-0.1114	-0.0712	-0.2319	-0.4399	0.1861	-0.1454
PC10	-0.1777	-0.2981	-0.6768	-0.0077	0.0202	0.2769	0.1031	-0.0335	-0.1147	-0.2392	0.4577	0.2291	0.0181
PC11	0.0979	-0.5241	0.0648	0.1359	0.4324	0.2667	-0.1542	0.0026	-0.0919	0.6034	-0.1315	0.1442	0.0225
PC12	-0.4574	0.4972	0.159	-0.0433	0.1383	0.08	0.1197	-0.1038	-0.5196	0.3159	0.2259	0.1944	0.0846
PC13	0.5606	-0.1778	0.0868	-0.1783	-0.4489	-0.1697	0.1536	-0.1453	-0.4518	0.1193	0.1314	0.2256	0.2308

PH - Plant height (m) , HT - Height of trunk(m), ST - Stem girth at the ground level(m), GT - Girth of trunk at one meter height from the ground level(m), CL - Crown length(cm), NS - Number of scars between 50cm in the trunk, NL - Number of leaves per tree, NLS - Number of leaf segments per leaves, PL - Petiole length (cm), LL - Leaf length (m), LB - Leaf breadth (m), IL - Inflorescence length (cm) and NI - Total number of Inflorescence per tree.

Table 4: Scores for germplasm in relation to the four principal components (PC1, PC2, PC3, PC4).

germplasm	PC1	PC2	PC3	PC4
ACC1EBKKM	-2.73281	-0.16661	2.704118	-0.5039
ACC2EBKKM	-2.52302	-0.30785	-1.53556	-0.97729
ACC3EBKKM	-1.5207	1.12722	1.702042	-0.49536
ACC5EBKKM	**1.521668**	**0.60785**	**3.69135**	**0.319217**
ACC8EBKKM	0.533365	0.555951	-0.77952	-1.8763
ACC12EBKKM	1.889028	0.249604	-1.12544	-1.4807
ACC17EBKKM	-0.01537	0.119583	-1.25569	-2.00425
ACC18EBKKM	1.101357	0.821932	-0.73596	0.086486
ACC22EBKKM	0.824544	1.900908	-1.67254	1.496045
ACC26EBKKM	0.661484	-0.17837	-1.75116	1.156272
ACC1KPKKM	-2.92837	1.810209	0.462417	-1.29763
ACC8KPKKM	-0.64313	-3.96995	-0.36885	0.02719
ACC11KPKKM	-0.47771	0.141589	-0.60822	-0.23393
ACC12KPKKM	-1.56446	1.251897	-0.46104	0.900959
ACC18KPKKM	-1.34231	0.267649	-0.00658	1.524654
ACC27KPKKM	-2.9084	0.554193	-0.38358	2.151321
ACC3BIKKM	0.691368	-2.32793	1.117277	-0.00632
ACC1ELKKM	-0.4157	-3.45759	-0.2633	0.410412
ACC1ODKKM	**3.464636**	**0.043161**	**0.954654**	**0.377548**
ACC2ODKKM	2.975784	0.130909	-0.16819	0.400589
ACC3ODKKM	**3.408758**	**0.825647**	**0.483763**	**0.024987**

Table 5: Clustering in palmyrah germplasm.

Cluster	Frequency	Cluster Membership
I.	8	ACC1EBKKM, ACC2EBKKM, ACC3EBKKM ACC1KPKKM, ACC11KPKKM, ACC12KPKKM ACC18KPKKM, ACC27KPKKM
II.	1	ACC5EBKKM
III.	9	ACC8EBKKM, ACC12EBKKM, ACC17EBKKM, ACC18EBKKM, ACC22EBKKM, ACC26EBKKM ACC1ODKKM, ACC2ODKKM, ACC3ODKKM
IV.	3	ACC8KPKKM, ACC3BIKKM, ACC1ELKKM

Table 6: Cluster means of different traits in palmyrah germplasm.

Traits	Cluster	Minimum	Maximum	Mean	Std. Dev.
Plant height (m)	1	8.63	10.30	9.39	0.66
	2	7.87	7.87	7.87	-
	3	6.63	9.60	8.14	1.17
	4	7.40	8.50	8.03	0.57
Height of trunk(m)	1	4.20	6.87	5.38	0.84
	2	4.20	4.20	4.20	-
	3	1.97	4.73	3.75	0.90
	4	4.10	5.10	4.70	0.53
Stem girth at the ground level (m)	1	1.93	2.33	2.10	0.13
	2	2.10	2.10	2.10	-
	3	2.00	2.20	2.15	0.07
	4	1.80	2.03	1.90	0.12
Girth of trunk at one meter height from the ground level	1	1.35	1.63	1.48	0.11
	2	2.64	2.64	2.64	-
	3	1.32	1.57	1.49	0.08
	4	1.37	1.45	1.41	0.04
Number of scars between 50 cm	1	23.00	25.67	24.42	0.94
	2	21.67	21.67	21.67	-
	3	22.67	28.00	24.85	1.60
	4	21.00	23.00	22.22	1.07
Crown length	1	3.43	4.63	3.92	0.48
	2	3.67	3.67	3.67	-
	3	2.67	3.40	3.00	0.22
	4	3.10	3.40	3.27	0.15
Number of leaves per tree	1	18.33	26.33	22.46	2.60
	2	21.67	21.67	21.67	-
	3	19.00	25.33	22.04	2.02
	4	21.67	27.33	23.67	3.18
Number of leaf segments per leaves	1	70.67	86.00	76.50	4.45
	2	76.00	76.00	76.00	-
	3	66.67	76.67	72.52	3.65
	4	74.00	75.33	74.44	0.77
Petiole length (m)	1	1.41	1.66	1.55	0.10
	2	1.28	1.28	1.28	-
	3	1.16	1.42	1.30	0.09
	4	1.41	1.47	1.43	0.03
Leaf length (cm)	1	235.00	276.33	262.21	13.31
	2	209.00	209.00	209.00	-
	3	193.67	230.00	216.85	11.87

	4	293.00	358.00	333.44	35.29
Leaf breadth (cm)	1 2 3 4	125.00 116.67 115.67 111.67	152.33 116.67 141.67 120.00	139.33 116.67 128.15 115.00	9.09 - 8.52 4.41
Inflorescences length (cm)	1 2 3 4	129.00 175.50 112.00 118.50	186.00 175.50 176.40 136.00	158.61 175.50 148.17 129.50	17.65 - 21.67 9.58
Number of inflorescences	1 2 3 4	5.00 6.00 3.00 4.50	9.00 6.00 7.50 6.00	6.66 6.00 4.87 5.37	1.36 - 1.38 0.78

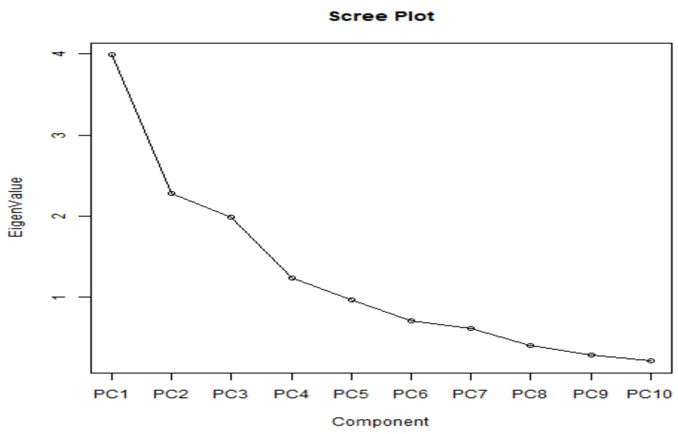

Fig. 1. Scree plot of eigenvalues (Principal components).

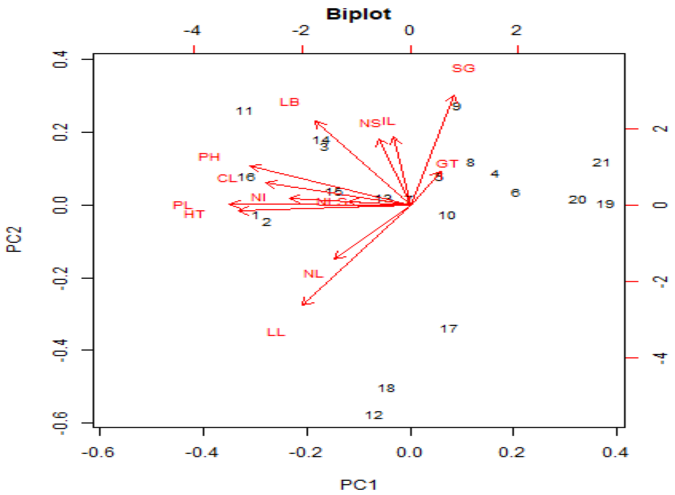

Fig. 2. Biplot displaying eigenvectors and scores for principal components 1 and principal components 2.

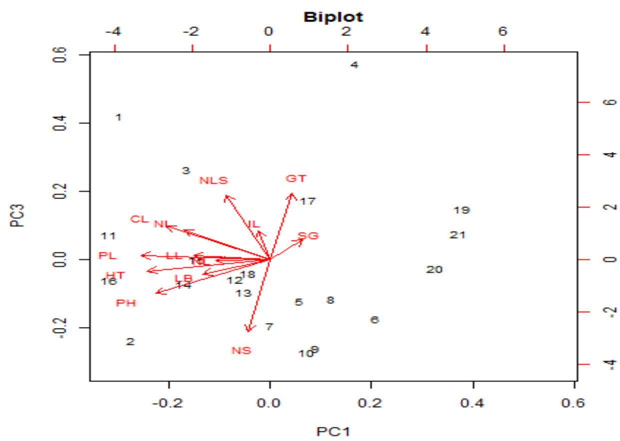

Fig. 3. Biplot displaying eigenvectors and scores for principal components 1 and principal components 3.

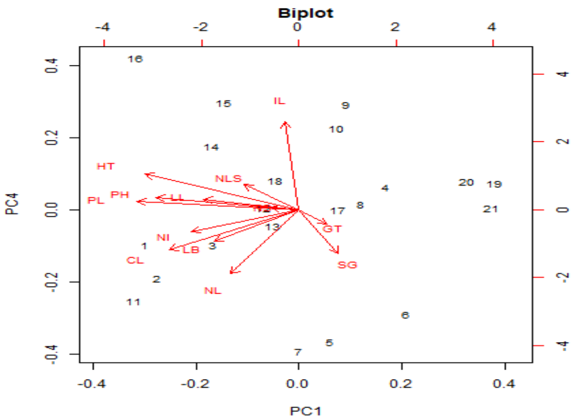

Fig. 4. Biplot displaying eigenvectors and scores for principal components 1 and principal components 4.

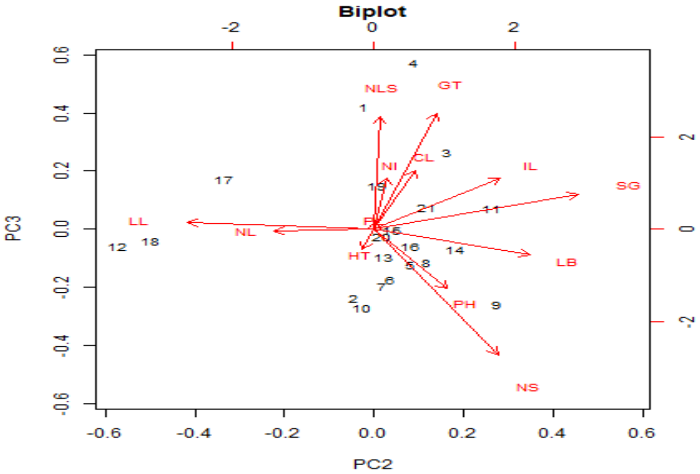

Fig. 5. Biplot displaying eigenvectors and scores for principal components 2 and principal components 3.

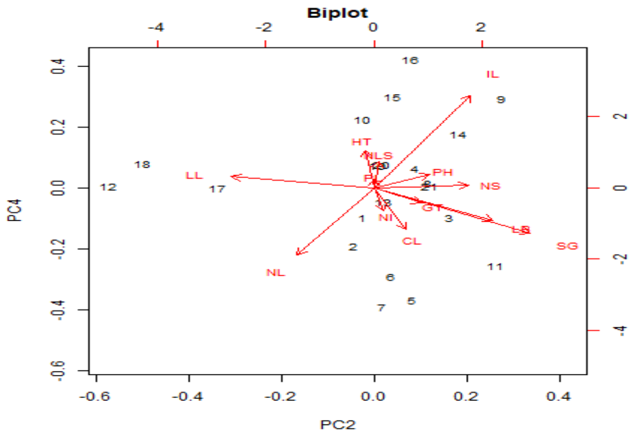

Fig. 6. Biplot displaying eigenvectors and scores for principal components 2 and principal components 4.

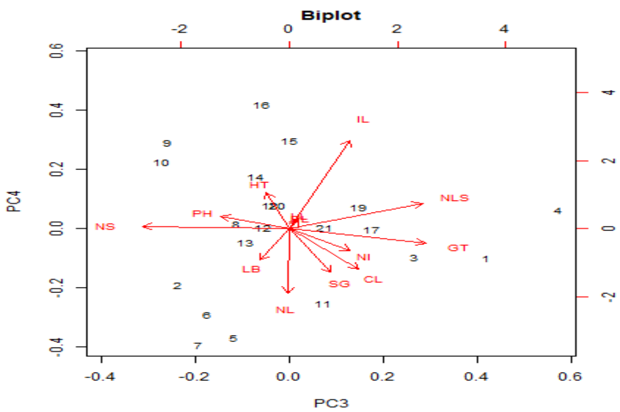

Fig. 7. Biplot displaying eigenvectors and scores for principal components 3 and principal components 4.

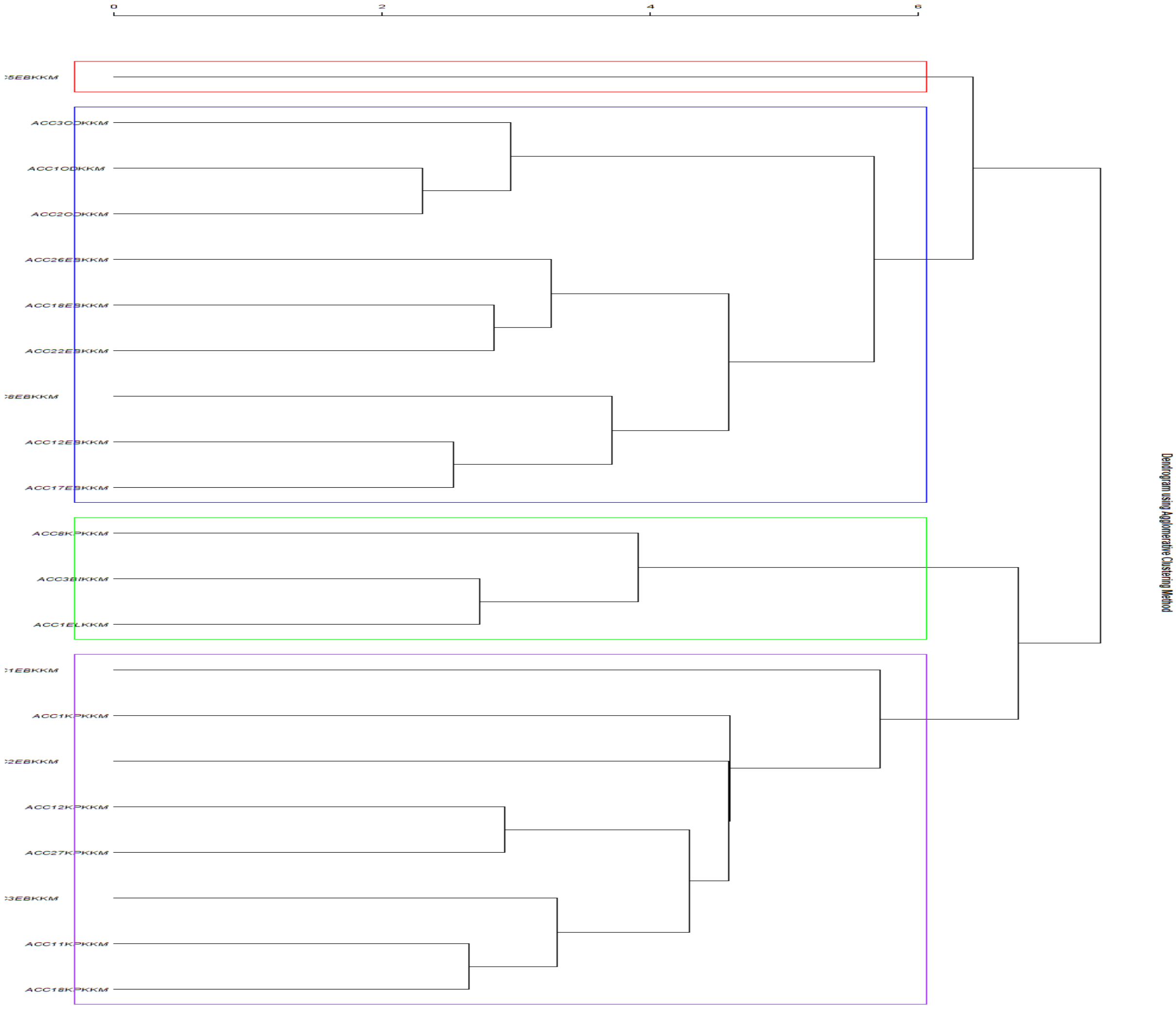

Fig. 8. Dendrogram based on agglomerative cluster analysis for morphological traits.

CONCLUSIONS

Multivariate analysis was performed in Palmyrah germplasms to study the morphological variation among them to find out the best genotypes. The STAR (Computer software) software was used for this analysis. Totally 21 germplasms were evaluated in this analysis. From the results, out of 21 germplasms three accessions *viz.*, ACC5EBKKM, ACC1ODKKM and ACC3ODKKM had more diversity. Among the morphological traits, stem girth at the ground level, girth of trunk at one meter height from the ground level, inflorescences length, crown length, plant height, number of scars between 50cm in the trunk, number of leaf segments per leaves showed significant variations. In cluster analysis, there are four clusters. Here, the value of cophenetic correlation coefficient was 0.634 that showed the high efficiency of the clustering pattern.

FUTURE SCOPE

This study will provide the morphological traits in multivariate analysis to utilized for more crop improvement in palmyrah genotypes for future use.

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