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RESEARCH ARTICLE

Genetic diversity, correlation and path analysis in female palmyrah (*Borassus flabellifer* L.) germplasm- a research article

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Abstract

In this study, 16 female germplasm of palmyrah were analysed to assess diversity among the accessions. The experiments were laid in Randomized Block Design with 2 replications. Around 27 characters were observed during the research, and they were subjected to correlation analysis, path analysis and genetic divergence. The results of the statistical analysis revealed the characters such as the number of leaves per tree, petiole length, number of inflorescences per tree, number of branches per inflorescence, number of fruit bunches per tree and number of fruits per bunch showed significant and positive correlations with fruit yield per tree. The path analysis showed, the traits *viz.,* crown length (0.040), number of leaf segments per leaf (0.795), leaf length (0.845), inflorescence length (0.366), number of fruit bunches per tree (0.687), potassium (0.850), Total Soluble Solids (0.368), fruit length (0.230) and number of branches per inflorescence (0.170), petiole length (0.006), potassium content (0.850), phosphorous content (0.026) and calcium content (0.042) showed high positive direct effect with fruit yield per tree in female germplasm. In the genetic diversity analysis, the 16 germplasm were grouped into 12 clusters. The highest inter cluster distance was noticed between cluster VIII and cluster XI (959.377). The cluster VIII (Acc.11-KP-KKM) and cluster XI (Acc.2-OD-KKM) were showed high genetic divergence and utilized in the hybridization programme for developing superior genotypes with enhanced quality and improved yield. Among the various character studied, the maximum contribution to divergence was observed for zinc followed by number of fruits per bunch, fruit length, calcium and fruit weight.

Key words

correlation analysis; genetic divergence; germplasm; palmyrah; path analysis

Introduction

The Palmyrah palm, scientifically known as *Borassus flabellifer* L., belongs to the Arecaceae family and genus *Borassus* and the subfamily Borassoideae in the order Arecales. It originates to tropical Africa and is also distributed in the drier parts of India, Sri Lanka, Thailand, Malaysia, Vietnam and Indonesia. It is a dioecious crop, meaning that male and female trees are separate. Practically all of the parts of the tree components are valued economically, it is also known as **"**Kalpaka Vriksha**"**. The Palmyrah is said to be "Tree of life" and has served as the state tree of Tamil Nadu since 1978 (1). It is referred to as Lulu or Tadi in Telugu. In Malayalam, it is also known as "Karimpana". It is also known as the Tala palm, Toddy palm, Fan palm and Brab tree in English.

In Tamil Nadu, the palm tree is distributed across an area of about 24000 ha (2) in all districts, except Nilgiris, reaching a height of 30 m and sometimes even 90 m. No recognized variation exists in India. It is widely cultivated across the country, particularly in the coastal and dry/ sandy regions of Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Madhya Pradesh, Chattisgarh, Orissa and Rajasthan. In India, there are around 122 million palm trees (3), with 60 million of which are found in Tamil Nadu more than 50% of palms are concentrated in the southern district of Thoothukudi (4). This region has an arid climate, sandy soils and favorable growing conditions make it an ideal habitat for palm trees. Fresh palmyrah fruit endosperm, sap and tuber flour are all perishable and highly susceptible to post-harvest losses from spoiling. After being removed from the husk, the endosperm of the delicate palmyrah fruit begins to darken, lose its color. To minimize the post-harvest losses, preservation techniques such as canning, vacuum sealing, refrigeration and the use of natural antioxidants are being used. The wide variation in plant morphological characteristics that exist 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 (5). The present study aimed to achieve morphological characterization of growth and yield parameters in palmyrah germplasm, biochemical analysis of the fruit endosperm (nungu) and neera and assessment of the genetic relationships among germplasm accessions.

Materials and Methods

The germplasm materials consisted of accessions collected from the different parts of India such as Tamil Nadu, Andhra Pradesh and Odisha and maintained at college orchard, Department of Horticulture, AC and RI, Killikulam. The experiment was designed using a Randomized Block Design (RBD) with 16 accessions and 2 replications. Observations were recorded during the year 2023. This study utilized 16 female germplasm accessions, as only female trees were considered (Table 1).

Experimental location

The experiment was conducted at college orchard, Department of Horticulture, AC and RI, Killikulam located at latitude of 8° 7' N and a longitude of 77° 8' E, with the elevation of 41.73 m above mean sea level.

Characters observed

The characters observed for this study *viz.* morphological character like plant height (m), height of trunk (m), girth of trunk at one meter height (m), stem girth at the ground level (m), crown length, number of scars between 50 cm in the trunk from the ground level, number of leaves per tree, number of leaf segments per leaf, petiole length (cm), leaf length (m), leaf breadth (m), number of inflorescence per tree, inflorescence length (cm), number of branches per inflorescence, number of days taken from flowering to fruit set, fruit length (cm), number of fruit bunches per tree, number of fruits per bunch, fruit weight (kg), quality character like total soluble solids (°Brix) by using refractometer.

Biochemical characters

Iron content

Iron nutrient was estimated by using atomic absorption spectrophotometry method (6). 5 g of fruit endosperm sample were taken and digested with triple acid extract. By using distilled water, the entire sample was made up to 100 mL. Iron analysis was done in SOTAC lab, Department of Soil Sciences and Agricultural Chemistry, TNAU, Coimbatore. The amount of iron was calculated and

Table 1. Details of palmyrah female accessions used in the present study

Sl. No.	Genotype	Type	Source
1.	Acc.1-EB-KKM	Female	Killikulam, Tamil Nadu
2.	Acc.2-EB-KKM	Female	Killikulam, Tamil Nadu
3.	Acc.8-EB-KKM	Female	Killikulam, Tamil Nadu
4.	Acc.12-EB-KKM	Female	Killikulam, Tamil Nadu
5.	Acc.17-EB-KKM	Female	Ananthanambikurchi, Tamil Nadu
6.	Acc.18-EB-KKM	Female	Ananthanambikurchi, Tamil Nadu
7.	Acc.22-EB-KKM	Female	Ananthanambikurchi, Tamil Nadu
8.	Acc.26-EB-KKM	Female	Ananthanambikurchi,Tamil Nadu
9.	Acc.1-KP-KKM	Female	Seerudiyarpuram, Tamil Nadu
10.	Acc.8-KP-KKM	Female	Anaikudi, Tamil Nadu
11.	Acc.11-KP-KKM	Female	Anaikudi, Tamil Nadu
12.	Acc.3-BI-KKM	Female	Pakkapatty, Tamil Nadu
13.	Acc.1-EL-KKM	Female	Kasimkotta, Andhra Pradesh
14.	Acc.1-OD-KKM	Female	Bhubaneswar, Odissa
15.	Acc.2-OD-KKM	Female	Bhubaneswar, Odissa
16.	SVPR1	Female	Srivilliputhur, Tamil Nadu

expressed in mg/100 mL.

Zinc content

Zinc nutrient was estimated by using atomic absorption spectrophotometry method (6). 5 g of fruit endosperm sample was taken and digested with triple acid extract. By using distilled water, the entire sample was made up to 100 mL. Zinc analysis was done in SOTAC lab, Department of Soil Sciences and Agricultural Chemistry, TNAU, Coimbatore. The amount of Zinc was calculated and expressed in mg/100 mL.

Potassium content

Potassium nutrient was estimated by using flame photometric method in fruit endosperm samples. 5 mL of triple acid sample extract added with 5 mL of ammonium hydroxide reagent and the intensity of color developed was measured at 470 nm. The amount of potassium was expressed in mg/100 mL (7).

Phosphorous content

Phosphorous nutrient was estimated by using flame photometric method in fruit endosperm samples. 5 mL of triple acid sample extract added with 5 mL of Barton's reagent and the intensity of color developed was measured at 470 nm. Amount of phosphorous expressed in mg/100 mL (8).

Calcium content

Calcium nutrient was estimated by using Ver senate method in fruit endosperm samples. 5 mL of triple acid sample extract added with 10% sodium hydroxide and titrated against 0.02 N EDTA. The amount of calcium was calculated and expressed in mg/100 mL (9).

Ascorbic acid (Vitamin C)

Ascorbic acid was estimated as per the method (10). 5 g of fruit endosperm extract added with 10 mL of 4% oxalic acid and titrated against dye solution (2, 6-dichlorophenol indophenol). The amount of ascorbic acid was calculated and expressed in mg/100 mL of sample.

Statistical analysis

The observed characters were subjected to various statistical analysis such as Correlation analysis, Path analysis and Genetic divergence. Correlation analysis among all the observed characters with yield was computed by adopting the method suggested (11). Path analysis which helps determine the direct and indirect relationships of variables with the independent variables was determined by referring to the method recommended (12, 13). Genetic divergence was assessed using the formula as mentioned in (14) D^2analysis.

Results and Discussion

In the present study, number of leaves per tree, petiole length, number of inflorescences per tree, number of branches per inflorescence, number of fruit bunches per tree and number of fruits per bunch showed significant and positive correlation values with fruit yield per tree. The number of inflorescences and fruit bunches per tree showed a strong association with fruit yield, while petiole length and the number of fruits per bunch were also highly correlated with fruit yield. The moderate correlation was observed for number of leaves per tree and number of branches per inflorescence with the fruit yield per tree. The traits such as number of leaf segments per leaf, leaf length, leaf breadth, fruit length, fruit weight and calcium content recorded weak association, while the traits such as plant height, height of trunk, stem girth at the ground level, number of days taken from flowering to fruit set, zinc content, potassium content, phosphorous content had very weak association with the fruit yield per tree. Therefore, breeding to achieve better yield performance based on the selection of germplasm, these traits will be effective because they are significant and positive correlated with the fruit yield per tree (Table 2 and Fig. 1). Similar results were reported for date palm (15), where plant height, leaf length, number of leaflets, whole nut weight, kernel weight and kernel thickness showed a positive but non-significant association with nut yield per palm in coconut (16) and for arecanut (17).

The correlation analysis provides the information about the degree of strength and direction of relationship between the 2 variables. To study the association between the characters expressed due to its own effect or indirect effect via other contributing characters, the information from the correlation studies alone may not be sufficient. For obtaining information about the direct and indirect effects of each character towards yield, path analysis was performed.

From path coefficient analysis, the traits *viz.,* crown length (0.040), number of leaf segments per leaf (0.795), leaf length (0.845), inflorescence length (0.366), number of fruit bunches per tree (0.687), potassium (0.850), TSS (0.368), fruit length (0.230) and number of branches per inflorescence (0.170), petiole length (0.006), potassium content (0.850), phosphorous content (0.026) and calcium content (0.042) showed high positive direct effect with fruit yield per tree in female germplasm. It showed that for increasing the yield direct selection of these traits may be rewarding (Table 3). Similar findings were reported (18) in arecanut palm for plant height, leaf length, number of nuts per palm per year, fruit set, kernel length, husk thickness and kernel recovery towards dry kernel yield in arecanut palm.

The characters such as height of trunk (-0.234), girth of trunk at 1 m from the ground level (-0.361), stem girth at the ground level (-0.193), number of scars between 50 cm in the ground level (-0.139), number of leaves per tree (-0.553), leaf breadth (-0.344), number of inflorescence per tree (-0.437), number of days taken from flowering to fruit set (-0.232), number of fruits per bunch (-0.971), iron content (-0.973), zinc content (-0.073) and ascorbic acid content (-1.487) have shown that negative and direct effect with the fruit yield per tree. The negative relationships between these traits and fruit yield indicate that an imbalance between vegetative growth, nutrient allocation and reproductive processes can harm overall productivity.

Table 2. Correlation coefficient between various characters and fruit yield in Palmyrah germplasm of female trees

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	**1**	**0.93****	**0.50***	**0.72 ****	0.24	0.05	0.23	0.19	**0.69****	**0.50***	0.05	0.17	-0.01	0.24	-0.07	**0.51***	0.19	0.16	-0.08	-0.34	0.21	0.25	0.13	0.12	-0.10	0.36	0.12
2		**1**	0.15	**0.68****	0.06	-0.22	0.17	0.31	**0.71****	**0.69****	-0.17	0.23	0.11	0.22	-0.09	**0.60***	0.10	0.28	-0.04	-0.43	0.28	0.31	-0.02	0.05	-0.10	0.24	0.17
3			**1**	0.34	**0.50***	**0.65****	0.21	-0.21	0.19	-0.28	**0.52***	-0.06	-0.28	0.11	0.03	-0.04	0.27	-0.23	-0.13	0.08	-0.10	-0.06	0.38	0.19	-0.04	0.40	-0.08
4				**1**	**0.76 ****	-0.22	0.11	**0.58***	**0.50***	0.04	0.08	0.07	0.34	-0.14	**-0.56***	0.09	0.11	-0.15	-0.28	**-0.97****	-0.19	-0.10	-0.14	0.16	0.16	0.12	0.01
5					**1**	0.03	-0.39	0.15	-0.09	**-0.61***	0.15	-0.29	0.39	-0.33	-0.39	**-0.67****	-0.15	-0.32	**-0.58***	**-0.61***	-0.46	-0.46	0.15	-0.01	0.42	0.09	-0.31
6						**1**	-0.21	**-0.66****	**-0.52***	**-0.74****	0.41	-0.18	-0.19	0.02	0.11	-0.41	-0.03	**-0.51***	-0.07	0.33	-0.15	0.06	**0.78****	0.07	0.13	0.13	-0.35
7							**1**	0.12	**0.79****	0.44	0.44	**0.70****	-0.40	-0.24	0.24	**0.57***	**0.72****	0.19	0.04	0.05	-0.32	0.11	-0.38	0.21	-0.23	0.28	**0.59***
8								**1**	0.42	0.29	-0.24	0.08	0.41	**-0.52***	0.11	0.47	-0.01	0.05	0.10	**-0.65****	0.09	-0.22	-0.27	-0.10	0.17	0.05	0.22
9									**1**	**0.54***	0.30	**0.80****	-0.30	**0.51***	-0.02	0.45	**0.61***	**0.55***	0.05	-0.39	-0.26	0.09	-0.28	**0.50***	-0.37	0.21	**0.68****
10										**1**	-0.45	0.23	0.03	0.37	-0.07	**0.72****	0.05	0.47	0.08	-0.06	0.33	0.42	-0.50	0.13	-0.07	0.18	0.24
11											**1**	0.30	**-0.59***	-0.19	0.10	0.14	**0.55***	-0.19	**0.50***	-0.03	**-0.53***	-0.02	0.14	-0.11	**-0.58***	0.34	0.39
12												**1**	-0.43	**0.50***	0.19	0.11	**0.75****	**0.71****	0.12	-0.04	-0.25	-0.05	-0.05	0.38	**-0.57***	0.05	**0.89****
13													**1**	-0.45	-0.39	0.04	**-0.64****	-0.24	-0.16	-0.44	0.18	-0.34	0.14	-0.07	**0.59***	0.05	-0.44
14														**1**	-0.12	-0.04	0.40	**0.81****	0.19	0.38	0.08	0.27	0.29	0.42	-0.29	0.10	**0.56***
15															**1**	-0.04	0.13	-0.05	-0.20	0.27	-0.02	0.07	-0.03	-0.23	0.05	-0.19	0.05
16																**1**	0.10	0.10	**0.54***	-0.20	0.38	0.33	-0.27	-0.10	-0.28	0.45	0.26
17																	**1**	0.46	0.11	-0.17	-0.20	0.36	0.14	0.05	-0.47	0.25	**0.85****
18																		**1**	-0.03	0.03	0.12	0.04	-0.15	0.02	-0.38	0.24	**0.74****
19																			**1**	-0.05	0.26	0.14	0.13	0.15	**-0.61***	-0.04	0.30
20																				**1**	0.01	-0.12	-0.20	0.18	-0.09	-0.17	-0.25
21																					**1**	0.29	0.23	-0.38	-0.15	-0.16	-0.04
22																						**1**	0.19	-0.30	0.00	0.17	0.16
23																							**1**	-0.08	0.12	0.17	0.02
24																								**1**	0.05	-0.16	0.01
25																									**1**	0.11	**-0.6****
26																										**1**	0.24
27																											**1**

* Significant at 5% level, ** Significant at 1% level where,
[1]Plant height (m), [2]Height of trunk (m), [3]crown length (m), [4]Girth of trunk at 1 m height from the ground level (m), [5]Stem girth at the ground level (m), [6]Number of scars between 50 cm in the trunk from the ground level, [7]Number of leaves per tree, [8]Number of leaf segments per leaf, [9]Petiole length (m), [10]Leaf length (m), [11]Leaf breadth (m), [12]Number of inflorescence per tree, [13]Inflorescence length (m), [14]Number of branches per inflorescence, [15]Number of days taken from flowering to fruit set, [16]Fruit length (cm), [17]Number of fruit bunches per tree, [18]Number of fruits per bunch, [19]Fruit weight (kg), [20]Total Soluble solids (°Brix), [21]Iron Content (mg/100 mL), [22]Zinc Content (mg/100 mL), [23]Potassium (mg/100 mL), [24]Phosphorous (mg/100 mL), [25]Ascorbic acid (mg/100 mL), [26]Calcium (mg/100 mL), [27]Fruit yield per tree (kg/tree).

Table 3. Path analysis showing direct and indirect effect of various characters in palmyrah germplasm of female trees

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	**-0.234**	0.006	-0.248	-0.012	0.031	-0.097	0.243	0.004	0.589	0.058	-0.099	0.041	0.038	0.021	0.139	0.065	-0.269	-0.158	-0.273	-0.023	-0.014	0.001	0.142	0.010
2	-0.034	**0.041**	-0.122	-0.098	-0.092	-0.115	-0.163	0.001	-0.238	-0.180	0.027	-0.102	0.018	-0.007	-0.010	0.188	0.219	0.030	0.102	0.004	0.322	0.005	0.054	0.017
3	-0.161	0.014	**-0.362**	-0.148	0.031	-0.060	0.467	0.003	0.032	-0.027	-0.031	0.124	-0.023	0.131	0.020	0.074	0.148	-0.361	0.186	0.008	-0.121	0.004	-0.233	0.005
4	-0.015	0.021	-0.277	**-0.193**	-0.005	0.217	0.121	-0.001	-0.519	-0.051	0.128	0.143	-0.055	0.092	-0.155	-0.106	0.309	-0.228	0.452	0.033	0.129	0.000	-0.627	0.004
5	0.052	0.027	0.081	-0.006	**-0.140**	0.118	-0.531	-0.003	-0.630	-0.142	0.077	-0.070	0.003	-0.026	-0.094	-0.022	0.498	0.121	0.149	-0.005	0.664	0.002	-0.200	0.005
6	-0.041	0.008	-0.039	0.076	0.030	**-0.553**	0.092	0.005	0.369	-0.151	-0.307	-0.146	-0.041	-0.055	0.133	0.498	-0.188	0.018	0.310	-0.008	-0.321	0.005	0.335	0.012
7	-0.072	-0.008	-0.213	-0.030	0.093	-0.064	**0.795**	0.003	0.249	0.083	-0.034	0.151	-0.090	-0.025	0.109	-0.006	-0.050	-0.240	-0.092	0.016	-0.227	-0.003	-0.248	0.002
8	-0.168	0.008	-0.182	0.017	0.073	-0.437	0.331	**0.006**	0.462	-0.103	-0.354	-0.111	0.087	0.005	0.103	0.425	-0.539	-0.144	0.257	-0.007	-0.241	0.013	0.543	0.009
9	-0.164	-0.012	-0.014	0.119	0.104	-0.241	0.234	0.003	**0.845**	0.155	-0.099	0.011	0.062	0.016	0.167	0.037	-0.457	-0.023	-0.324	-0.031	-0.422	0.003	0.103	0.008
10	0.040	0.021	-0.028	-0.029	-0.058	-0.243	-0.191	0.002	-0.381	**-0.345**	-0.131	-0.219	-0.032	-0.024	0.032	0.380	0.189	-0.010	0.522	0.002	0.121	-0.003	0.878	0.014
11	-0.053	-0.003	-0.025	0.057	0.025	-0.388	0.062	0.005	0.192	-0.103	**-0.437**	-0.156	0.086	-0.044	0.026	0.516	-0.696	-0.015	0.241	0.004	-0.040	0.010	0.858	0.002
12	-0.026	-0.011	-0.123	-0.076	0.027	0.220	0.328	-0.002	0.026	0.206	0.186	**0.366**	-0.076	0.090	0.009	-0.445	0.229	-0.163	-0.179	0.025	0.119	-0.002	-0.887	0.002

13	-0.053	0.004	0.050	0.063	-0.003	0.134	-0.420	0.003	0.311	0.065	-0.221	-0.165	**0.170**	0.029	-0.010	0.277	-0.787	0.141	-0.073	-0.020	0.249	0.011	0.427	0.004
14	0.021	0.001	0.204	0.076	-0.016	-0.132	0.084	0.000	-0.060	-0.036	-0.082	-0.142	-0.021	**-0.233**	-0.010	0.091	0.050	0.100	0.019	-0.005	-0.028	-0.006	-0.070	-0.008
15	-0.141	-0.002	-0.032	0.130	0.057	-0.319	0.377	0.003	0.615	-0.048	-0.049	0.014	-0.007	0.010	**0.230**	0.067	-0.101	-0.072	-0.370	-0.024	-0.231	-0.003	0.419	0.019
16	-0.022	0.011	-0.039	0.030	0.004	-0.401	-0.007	0.004	0.045	-0.190	-0.328	-0.237	0.068	-0.031	0.023	**0.687**	-0.443	-0.061	0.193	-0.027	0.117	0.001	0.705	0.011
17	-0.065	-0.009	0.055	0.062	0.071	-0.107	0.041	0.003	0.398	0.067	-0.313	-0.086	0.137	0.012	0.024	0.313	**-0.972**	0.009	-0.121	-0.003	-0.126	0.000	0.566	0.010
18	0.100	0.003	0.354	0.119	-0.046	-0.026	-0.518	-0.002	-0.053	0.009	0.017	-0.162	0.065	-0.063	-0.045	-0.115	-0.024	**0.368**	-0.009	0.009	-0.169	0.005	0.140	-0.007
19	-0.066	-0.004	0.069	0.090	0.021	0.176	0.075	-0.002	0.281	0.185	0.108	0.067	0.013	0.005	0.087	-0.136	-0.121	0.003	**-0.974**	-0.021	0.193	-0.010	0.227	-0.007
20	-0.072	-0.002	0.038	0.088	-0.009	-0.062	-0.178	0.001	0.358	0.008	0.022	-0.123	0.046	-0.017	0.075	0.249	-0.042	-0.045	-0.278	**-0.073**	0.161	-0.008	-0.005	0.007
21	0.004	0.016	0.051	-0.029	-0.109	0.209	-0.212	-0.002	-0.420	-0.049	0.020	0.051	0.050	0.008	-0.062	0.094	0.144	-0.073	-0.222	-0.014	**0.850**	-0.002	-0.177	0.007
22	-0.013	0.008	-0.060	0.002	-0.010	-0.114	-0.080	0.003	0.113	0.040	-0.164	-0.025	0.072	0.054	-0.023	0.033	-0.015	0.066	0.368	0.022	-0.069	**0.026**	-0.071	-0.007
23	0.022	-0.001	-0.057	-0.082	-0.019	0.125	0.133	-0.002	-0.059	0.203	0.252	0.218	-0.049	-0.011	-0.065	-0.326	0.370	-0.035	0.149	0.000	0.101	0.001	**-1.487**	0.005
24	-0.057	0.016	-0.045	-0.018	-0.018	-0.156	0.036	0.001	0.150	-0.115	-0.022	0.019	0.017	0.045	0.104	0.172	-0.230	-0.062	0.155	-0.012	0.144	-0.004	-0.163	**0.043**

Diagonal value indicates direct effects while off-diagonal value indicates indirect effects, where

[1]Height of trunk (m), [2]Crown length (m), [3]Girth of trunk at 1 m from the ground level (m), [4]Stem girth at the ground level (m), [5]Number of scars at fifty centimetres in the trunk from the ground level, [6]Number of leaves per tree, [7]Number of leaf segments per leaf, [8]Petiole length (m), [9]Leaf length (m), [10]Leaf breadth (m), [11]Number of inflorescence per tree, [12]Inflorescence length (m), [13]Number of branches per inflorescence, [14]Number of days taken from flowering to fruit set, [15]Fruit length (cm), [16]Number of fruit bunches per tree, [17]Number of fruits per bunch, [18]TSS(°Brix), [19]Iron content (mg/ 100 mL), [20]Zinc content (mg/ 100 mL), [21]Potassium content (mg/ 100 mL), [22]Phosphorous content (mg/ 100 mL), [23]Ascorbic acid content (mg/ 100 mL), [24]Calcium content (mg/ 100 mL)

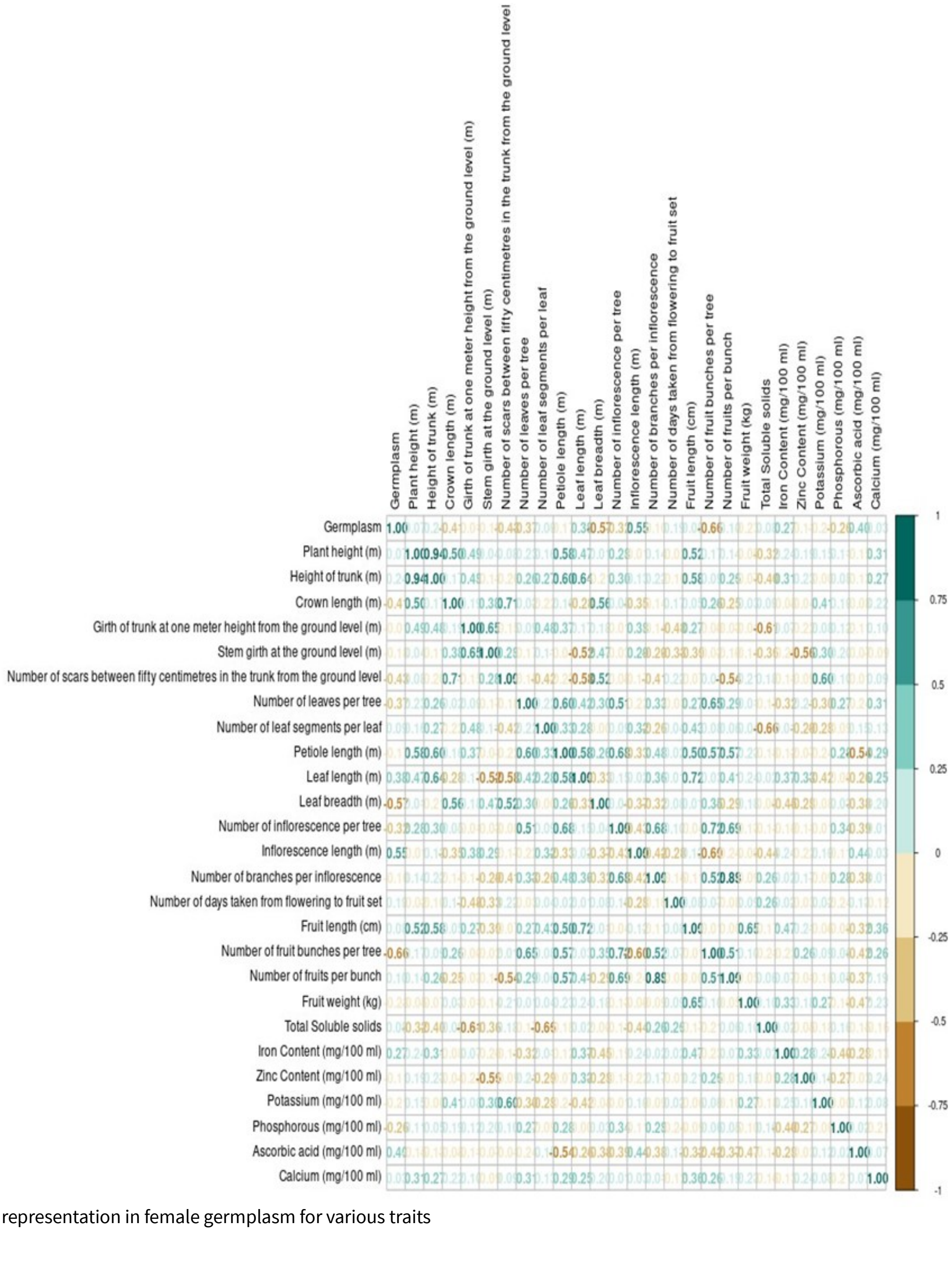


Fig. 1. Correlogram representation in female germplasm for various traits

Similar results were observed (19) in coconut and (20) in arecanut; (21) in coconut in arecanut.

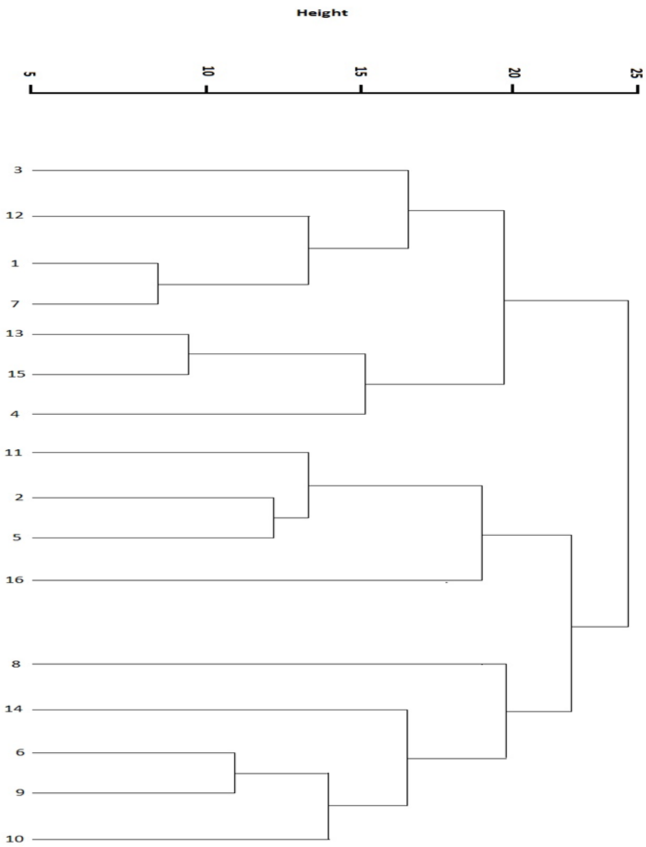
The selection based on the traits such as number of leaf segments per leaf, leaf length, inflorescence length, number of fruit bunches per tree, potassium content, TSS, fruit length and number of branches per inflorescence would yield better performance because they possess high positive direct effect with the fruit yield per tree.

In the D^2 analysis, the 16 female germplasms were grouped into 12 clusters. The clusters I, II, V and X contained two germplasms each and the remaining clusters had only one germplasm each (Table 4). The highest intra cluster distance expressed in cluster X (33.026), indicated that the germplasm present in this cluster exhibit greater diversity than others. The next best cluster after X with higher intra cluster distance was cluster I (26.917) which contains one genotype and followed by cluster II (13.305) which possess 2 accessions. The range of inter cluster distance ranged from 42.941 (between I and IV) to 959.377 (between VIII and XI) as expressed by cluster distance. The highest inter cluster distance was noticed between cluster VIII and cluster XI, followed by cluster II and cluster XI, cluster VI and cluster XI. The distance between two clusters is a measure of diversification. Therefore, the greater diversity was observed between cluster VIII and cluster XI, followed by cluster II and cluster XI and cluster VI and cluster XI. Hence, the germplasms under the cluster XI can be utilized as parent for breeding programme followed by the germplasm in cluster VIII, cluster II and cluster VI respectively to create maximum segregating population which can exhibit more variability (Table 5). Similar results reported (22) in coconut.

Table 4. Composition of D^2 clusters for palmyrah germplasm based on various characters in female trees

Clusters	Genotypes
Cluster I	Acc.22-EB-KKM, Acc.1-EB-KKM
Cluster II	Acc.2-EB-KKM, Acc.17-EB-KKM
Cluster III	Acc.8-EB-KKM
Cluster IV	Acc.12-EB-KKM
Cluster V	Acc.18-EB-KKM, Acc.1-KP-KKM
Cluster VI	Acc.26-EB-KKM
Cluster VII	Acc.8-KP-KKM
Cluster VIII	Acc.11-KP-KKM
Cluster IX	Acc.3-BI-KKM
Cluster X	Acc.1-EL-KKM, Acc.1-OD-KKM
Cluster XI	Acc.2-OD-KKM
Cluster XII	SVPR1

From the obtained clusters, the highest cluster mean value were observed for the traits *viz.,* height of trunk in cluster II, number of branches per inflorescence in cluster III, number of leaf segments per leaf in cluster IV, phosphorous content in cluster V, total soluble solids in cluster VI and VIII calcium content in cluster VII, inflorescence length in cluster IX, plant height in cluster X, stem girth at the ground level in cluster XI and number of leaves per tree in cluster XII. Among the various character studied, the maximum contribution to divergence was observed for zinc followed by number of fruits per bunch, fruit length, calcium and fruit weight (Table 6 and Fig. 2). The number of days taken from flowering to fruit set contributed very less towards the divergence. Similar results were reported in oil palm (23).



1 - ACC1EBKKM 2 - ACC2EBKKM 3 - ACC8EBKKM 4 - ACC12EBKKM 5 - ACC17EBKKM 6 - ACC18EBKKM 7 - ACC22EBKKM 8 - ACC26EBKKM 9 - ACC1KPKKM 10 - ACC8KPKKM 11 - ACC11KPKKM 12 - ACC3BIKKM 13 - ACC1ELKKM 14 - ACC1ODKKM 15 - ACC2ODKKM 16 - SVPR 1

Fig. 2. Dendrogram of female palmyrah germplasm

Table 5. Intra and Inter Cluster Distance (D2 values) in female Palmyrah germplasm
* Diagonal values indicate intra cluster distance

	1	2	3	4	5	6	7	8	9	10	11	12
1	26.917	374.653	190.991	42.941	212.827	330.550	109.238	405.728	203.727	260.454	339.831	203.754
2		13.305	377.199	385.609	347.639	87.254	444.912	63.974	692.135	788.136	917.313	682.618
3			0	182.568	110.505	308.108	201.612	371.860	217.858	286.236	382.021	252.527
4				0	208.619	342.909	52.301	421.518	171.368	222.173	294.917	166.020
5					9.781	285.398	236.770	340.697	303.559	387.202	495.345	338.496
6						0	401.042	56.352	623.666	709.699	832.677	612.321
7							0	483.960	151.725	207.346	280.734	159.296
8								0	730.422	825.710	959.377	724.269
9									0	280.702	693.374	271.573
10										33.026	135.343	130.326
11											0	293.303
12												0

Table 6. Cluster mean for various characters in palmyrah germplasm of female trees

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	8.01	8.13	4.97	4.63	2.47	8.65	13.32	40.30	12.86	30.35	3.73	5.62	1.94	3.38	5.05	13.12	16.67	38.22	7.10	7.23	4.72	4.77	2.55	8.01	13.54	40.90
2	12.75	37.16	11.41	29.50	4.09	4.34	2.45	2.50	5.15	13.73	15.50	35.06	6.81	4.85	5.22	3.18	3.03	10.34	12.08	36.59	11.29	27.38	4.21	4.14	2.63	3.20
3	2.23	2.17	5.10	14.69	15.67	28.30	7.03	5.24	4.68	3.15	2.50	9.78	12.38	35.30	12.78	26.77	3.55	3.70	2.12	3.83	4.79	13.47	15.00	29.43	6.09	6.07
4	5.70	7.13	4.98	5.00	2.57	9.23	14.10	35.98	11.52	28.48	3.75	5.20	2.18	2.51	5.80	12.98	14.00	31.48	5.94	6.68	4.96	4.00	2.63	9.56	12.76	35.90
5	2.15	3.65	5.45	12.82	15.83	37.22	6.76	8.86	4.86	4.47	2.35	9.60	13.62	36.06	12.70	32.61	3.89	5.24	2.04	3.80	5.57	12.31	16.33	38.44	6.67	9.17
6	14.01	36.78	9.81	27.85	3.70	3.79	1.93	2.85	6.46	13.73	13.33	32.20	5.51	9.89	4.37	3.61	2.27	8.80	15.05	37.78	9.44	26.74	3.48	4.10	1.80	3.15
7	3.63	4.54	3.62	3.15	2.59	8.46	12.03	37.40	8.39	28.31	2.91	2.91	1.95	2.55	5.28	12.17	13.00	32.90	4.20	5.89	3.59	3.02	2.94	8.84	11.81	38.06
8	13.86	36.53	10.02	31.32	6.10	6.17	2.36	2.57	6.19	12.53	14.33	35.63	5.51	7.69	6.90	6.24	2.91	9.97	12.86	37.80	10.35	32.32	6.09	6.07	2.45	2.63
9	0.71	2.17	12.61	5.68	13.92	6.12	2.37	0.79	2.33	3.08	5.06	2.41	23.00	0.91	13.10	0.91	2.44	3.76	5.12	1.95	22.28	0.79	13.69	0.91	2.44	3.76
10	21.45	2.33	18.27	2.18	13.69	4.07	13.36	4.17	21.02	2.61	18.10	2.35	13.92	3.96	13.36	4.22	21.17	2.80	17.71	2.19	14.00	3.44	12.74	3.55	20.71	3.54
11	7.51	2.57	17.45	3.78	22.46	1.02	18.90	2.26	7.51	2.57	17.45	3.75	22.36	1.12	18.85	2.16	12.88	2.33	16.58	2.46	19.53	1.59	17.28	1.81	13.13	2.34
12	14.54	4.74	8.11	3.55	12.89	1.92	23.05	1.36	13.79	3.18	7.52	4.86	18.80	3.61	15.73	1.16	12.97	3.32	7.69	5.05	18.70	3.40	15.68	1.22	12.75	3.32

[1]Height of trunk (m), [2]Crown length (m), [3]Girth of trunk at 1 m from the ground level (m), [4]Stem girth at the ground level (m), [5]Number of scars at fifty centimetres in the trunk from the ground level, [6]Number of leaves per tree, [7]Number of leaf segments per leaf, [8]Petiole length (m), [9]Leaf length (m), [10]Leaf breadth (m), [11]Number of inflorescence per tree, [12]Inflorescence length (m), [13]Number of branches per inflorescence, [14]Number of days taken from flowering to fruit set, [15]Fruit length (cm), [16]Number of fruit bunches per tree, [17]Number of fruits per bunch, [18]TSS(°Brix), [19]Iron content (mg/100 mL), [20]Zinc content (mg/ 100 mL), [21]Potassium content (mg/ 100 mL), [22]Phosphorous content (mg/ 100 mL), [23]Ascorbic acid content (mg/ 100 mL), [24]Calcium content (mg/ 100 mL)

Conclusion

From the study, it was concluded that with regard to association analysis in female germplasm, the yield character has positive correlation. In path coefficient analysis, the traits *viz.,* number of leaf segments per leaf, leaf length, inflorescence length, number of fruit bunches per tree, potassium content, total soluble solids, fruit length and number of branches per inflorescence exhibited high positive direct effect with fruit yield per tree in female germplasm. The cluster VIII (Acc.11-KP-KKM) and cluster XI (Acc.2-OD-KKM) demonstrated high genetic divergence and utilized in the hybridization programme for developing superior genotypes with enhanced quality and improved yield. The demand for palmyrah products is increasing worldwide. There is a huge scope in the palmyrah research around the globe. For the efficient palmyrah improvement program, the identification of desirable genes which control various yield and quality traits, quantitative trait loci (QTL) and molecular characterization are necessary. This will facilitate the identification and selection of elite germplasm.

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Authors' Contribution

All the authors contributed equally to executing the research idea, designing the experiment, providing laboratory facilities for analysis, supervising the study and interpreting the data. They also revised and corrected the final manuscript.

Compliance with ethical standards

Conflict of Interest: The authors have no conflict of interest.

Ethical issues: None

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