PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.4439

HORIZON
e-Publishing Group

RESEARCH ARTICLE

Genetic diversity and morphological characterization of different *Adenium* genotypes

S. Deepak[1], S. Padmapriya[2*], V. A. Sathiyamurthy[3], R. Renuka[4] & V. P. Santhanakrishnan[2]

[1] Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore-641 003, India

[2]Department of Medicinal and Aromatic crops, Tamil Nadu Agricultural University, Coimbatore-641 003, India

[3]Directorate of Research, Tamil Nadu Agricultural University, Coimbatore-641 003, India

[4]Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore-641 003, India

*Email: spadmapriyaa@yahoo.co.in

OPEN ACCESS

ARTICLE HISTORY

Received: 24 July 2024
Accepted: 21 August 2024

Available online
Version 1.0 : 05 September 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Deepak S, Padmapriya S, Sathiyamurthy VA, Renuka R, Santhanakrishnan VP. Genetic diversity and morphological characterization of different Adenium genotypes. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.4439

Abstract

The current study at Tamil Nadu Agricultural University in 2023–2024 aims to characterize the morphological features and genetic diversity of 20 *Adenium* genotypes. The research was performed with various vegetative and floral traits, revealing significant variations among genotypes. Notable differences were observed in plant height, branching habit, caudex circumference, leaf characteristics and floral features. Genetic analysis showed high genotypic and phenotypic coefficients of variation for traits like petal thickness, number of branches per plant and diameter of the corolla tube. These traits also exhibited high heritability and genetic advance, indicating potential for improvement through selective breeding. Other traits, such as plant height and leaf dimensions, showed moderate heritability and lower genetic advance, suggesting the influence of non-additive gene action and environmental factors. Principal component analysis identified seven principal components accounting for 85.178 % of the total variation. The first 2 components explained 40.59 % of the variability, with plant height, number of branches, flower diameter and length of anther appendages contributing significantly to PC_1, while leaf width, length of corolla tube and flower weight were major contributors to PC_2. This study provides valuable insight into the genetic architecture of *Adenium* traits, offering a foundation for future breeding efforts aimed at developing improved varieties for commercial and ornamental purposes. These findings highlight the potential for genetic improvement in *Adenium* through selective breeding, particularly for traits with high heritability and genetic advance.

Keywords

Adenium; ornamental traits; morphology; genotypes; principal component analysis

Introduction

Adenium obesum (Forssk.) Roem. & Schult, has surged in popularity as a potted plant, marking a notable shift in the ornamental plant industry's perspective towards it. Once deemed relatively novel, Adeniums have gained importance as a prioritized ornamental plant in landscaping, as evidenced by recent studies (1-4). Belonging to the Apocynaceae family, *A. obesum*, originates from various regions in Africa, including Ethiopia, Kenya, Senegal, Somalia, Sudan and Tanzania. Additionally, it is found in the wild in Oman, Saudi Arabia and Yemen. This plant has garnered attention for its striking sculptural caudex, robust branching habit and remarkable resilience to drought stress (5). *Adenium* is extensively cultivated as an ornamental species in numerous humid, tropical nations, including India, the Philippines and Thailand, where it holds significant relevance within the ornamental market (6). When different varieties are grown under identical conditions, the differences in their appearance are primarily due to their genetic makeup. Thus, the selection of varieties becomes a pivotal criterion for the prosperous cultivation of any ornamental plant. Within *Adenium*, variations in flower colour, petal doubling, flowering duration, branching compactness, dwarfism and other traits have been documented (7). Adeniums are cross-pollinated plants and are highly heterozygous in nature. There has been insufficient research in *Adenium* aimed at selecting or breeding superior horticultural varieties (8, 9). This research is aimed at the selection of superior genotypes in terms of flower colour, flower form, flowering habits and other traits.

Materials and Methods

The present study was carried out at the Department of Floriculture and Landscaping, Tamil Nadu Agricultural University, Coimbatore during 2023-24. The experiment was laid out in Completely Randomized Design (CRD) with 3 replications comprising of 20 genotypes *viz*., Pink Beauty, Golden Crown, Adenium Soft, Sudharsan, Mung Siam, Picotee, Harry Potter, Home Run, Buttons, Mor Lok Dork, Deang Siam, Miss India, My Country, Noble Queen, White Lucky, Nilakaan, Arrogant, Red Giant, Artic Snow and Triple Star. Observations encompassed various vegetative traits, including plant height (cm), caudex circumference (cm), number of branches per plant, plant spread (cm), leaf length (cm), number of leaves per plant, leaf width (cm), leaf area (cm^2 using a LAM-PB model portable leaf area meter) and leaf thickness (mm). Furthermore, flower traits such as flower diameter (cm), length of corolla tube (cm), diameter of corolla tube (cm), number of petals per flower and petal thickness (mm) were also recorded.

Data analysis

The morphological and flowering parameters were analysed using IBM-SPSS software. The coefficient of phenotypic and genotypic variations were calculated according to standard formulae (10). Broad sense heritability was computed to know the extent of variation due to genotype in the phenotypic variance and expressed in percentage (11). The expected genetic advance as expressed in percent of the mean was calculated (12). Statistical analysis was performed using the statistical package 'TNAUSTAT'. The breeding tool GRAPES 1.1.0 was used to conduct the correlation studies (13). The principal component analysis and basic descriptive statistics were carried out using the statistical program STAR 2.0.1.

Results and Discussion

(a) Morphological parameters

Variation in different vegetative and floral traits was noticed among all genotypes, as detailed in Table 1. The genotype Sudharsan (Fig. 1) recorded maximum plant height (44.02 cm), increased number of branches per plant (5.07), plant spread (26.55 cm) and leaf area (39.45 cm^2). The minimum plant height (23.33 cm) was recorded in Home Run. These results are in agreement with the earlier observations in *Adenium* (7). In their natural setting, *Adenium* vary in size from small shrubs to trees (14). The variation in plant height among the different cultivars might be due to genotypic differences in phenotypic expression and their interaction. Similar variation in plant height was also observed in earlier findings (15). The genotype Soft recorded a minimum number of branches (1.47) and number of leaves (30.67), while the least plant spread (20.68 cm) was recorded in Red Giant and the leaf area was lowest in Triple Star (20.96 cm^2). Similarly, variations in the leaf length and leaf width was earlier recorded in 6 varieties of *Adenium obesum* (4). *Adenium* leaf shapes varied from narrow-linear to quite broad and sizes varied greatly between the species (15). Thus, the discernible variations in traits such as plant stature, branching patterns and leaf counts among diverse germplasm can be directly ascribed to genetic disparities. These findings corroborate with earlier studies in *Adenium* (3). The maximum caudex circumference was observed in the genotype Miss India (19.16 cm) (Fig. 2), followed by My Country (18.77 cm), while the minimum was recorded in Harry Potter (15.92 cm). Among the different varieties of *Adenium*, variability in caudex circumference was observed and reported (2). The comprehensive development of plant is intricately governed by the

Fig. 1. Sudharsan

Table 1. Variation in growth parameters of *Adenium* genotypes.

Name of the genotype	Plant height (cm)	Plant spread (cm)	Number of branches per plant	Number of leaves per plant	Caudex circumference (cm)	Leaf width (cm)	Leaf length (cm)	Leaf area (cm^2)	Leaf thickness (mm)
Pink Beauty	40.66	20.58	1.97	33.93	17.04	4.16	11.77	25.23	0.41
Golden Crown	39.21	22.23	2.53	35.20	17.26	2.83	13.56	24.79	0.35
Soft	29.06	22.40	1.47	30.67	17.00	4.68	10.83	32.00	0.24
Sudharsan	44.02	26.55	5.07	74.70	17.10	4.79	11.91	39.45	0.32
Mung Siam	39.00	21.36	2.30	34.83	16.98	5.55	8.90	32.03	0.33
Picottee	39.38	22.61	1.63	44.17	16.96	4.43	10.13	27.11	0.28
Harry Potter	36.32	22.61	1.97	49.97	15.92	4.53	9.05	21.44	0.30
Home Run	23.33	20.78	1.67	58.90	18.16	4.94	9.71	24.91	0.36
Buttons	30.82	23.30	1.70	44.60	18.33	3.84	9.48	21.82	0.30
Mor Lok Dork	37.80	25.63	2.53	48.07	18.30	4.29	7.50	24.79	0.33
Deang Siam	37.43	21.54	2.07	51.90	18.16	4.14	8.58	23.23	0.40
Miss India	36.32	23.24	2.13	48.73	19.16	4.31	11.27	33.31	0.36
My Country	34.90	22.78	2.00	43.70	18.77	3.88	10.90	22.88	0.32
Noble Queen	40.81	22.27	1.97	42.70	18.01	5.08	10.85	25.59	0.31
White Lucky	40.03	21.92	1.60	62.73	17.75	4.18	11.80	28.95	0.33
Nilakaan	42.04	23.20	3.70	80.01	17.45	3.74	10.04	24.42	0.38
Arrogant	39.31	25.63	2.13	66.73	16.97	4.88	10.77	24.47	0.34
Red Giant	40.61	20.68	1.53	60.90	16.98	4.91	10.11	25.18	0.39
Artic Snow	37.62	21.90	1.90	67.37	16.84	4.41	10.02	28.21	0.38
Triple Star	38.04	22.20	2.30	64.53	16.10	3.23	9.61	20.96	0.30
Mean	37.33	22.67	2.20	52.21	17.46	4.34	10.34	26.53	0.33
S. Ed Value	0.75	0.45	0.04	1.13	0.44	0.09	0.22	0.51	0.05
CD Value (5 %)	1.52	0.91	0.09	2.30	0.89	0.18	0.45	1.04	0.01

Fig. 2. Miss India

Fig. 3. Triple Star

interplay of their genetic constitution, management strategies and environmental circumstances. The inherent genetic makeup manifests observable morphological disparities when diverse germplasm collections are subjected to uniform environmental conditions and management protocols. Genotypic divergence or a broad spectrum of growth patterns are the major reasons for variations in floral characteristics as well (14).

The variation in flowering traits among different genotypes of *Adenium* is furnished in Table 2. The genotype Triple Star (Fig. 3) recorded the maximum flower diameter (9.69 cm), length of corolla tube (4.01 cm), diameter of corolla tube (2.29 cm), petal thickness (0.24 mm), flower weight (2.83 g) and length of anther appendages (4.91 cm). Hence, significant differences were observed in floral traits of *Adenium* varieties. These results are in line with the research findings in Tuberose (16). The long, equalling or exceeding the throat, anther appendages was earlier reported (17). The increase in flower diameter may be due to the organic substances

Table 2. Variation in floral parameters of *Adenium* genotypes.

Name of the genotype	Flower diameter (cm)	Length of corolla tube (cm)	Diameter of corolla tube (cm)	Petal thickness (mm)	Weight of flower (g)	Length of anther appendages (cm)
Pink Beauty	9.00	3.65	1.85	0.17	1.66	3.06
Golden Crown	8.07	3.54	2.06	0.14	2.68	3.23
Soft	6.85	3.41	1.30	0.15	1.39	2.38
Sudharsan	8.87	3.23	1.51	0.13	1.99	3.95
Mung Siam	8.14	4.02	1.86	0.16	2.33	3.07
Picottee	8.25	3.88	1.90	0.17	1.30	3.37
Harry Potter	7.34	3.12	1.54	0.14	1.16	3.09
Home Run	6.89	2.97	1.96	0.19	1.32	2.50
Buttons	7.95	3.06	1.64	0.20	1.27	2.96
Mor Lok Dork	9.02	3.30	1.92	0.14	1.49	3.42
Deang Siam	7.26	3.15	2.06	0.15	2.14	3.13
Miss India	7.85	3.20	1.81	0.13	1.04	2.66
My Country	8.58	3.08	1.80	0.16	1.29	3.57
Noble Queen	6.79	3.25	1.46	0.12	1.59	3.44
White Lucky	7.29	3.08	1.39	0.13	1.24	3.04
Nilakaan	8.13	3.86	1.65	0.13	1.65	4.47
Arrogant	7.87	3.30	1.40	0.11	1.14	4.03
Red Giant	8.99	3.54	1.41	0.21	1.18	3.13
Artic Snow	8.31	3.49	1.62	0.12	1.14	3.60
Triple Star	9.69	4.01	2.29	0.24	2.83	4.91
Mean	8.05	3.40	1.72	0.15	1.59	3.35
S. Ed Value	0.17	0.06	0.03	0.04	0.03	0.08
CD Value (5 %)	0.34	0.12	0.07	0.09	0.06	0.17

synthesized by the plants that encourage the growth and floral primordia development. The difference in the concentration of fructose and glucose levels at abaxial and adaxial epidermal cells might have increased the flower size of *Adenium*. This is in line with the earlier findings of *Ginkgo biloba* (18, 19). The genotype Noble Queen recorded minimum flower diameter (6.79 cm) and petal thickness (0.12 mm). Length of corolla tube was found to be the lowest in the genotype Home Run (2.97 cm). The genotype Soft exhibited the least diameter of corolla tube (1.30 cm) and length of anther appendages (2.38 cm). The variations observed in different floral traits could be attributed to the inherent divergence in the genotypes or the broad spectrum of growth tendencies, as proposed in earlier research findings in *Adenium* (3, 20). Similarly, the heritable changes observed in flowering and yield traits among genotypes are primarily attributed to their genetic makeup. In instances where agroclimatic conditions remain unaltered, the distinct varietal disparities in yield potential likely contribute to the notable differences observed. Comparable findings have previously been documented in *Adenium*, as noted (2).

(b) Genetic diversity studies

In order to understand the degree of variation among the cultivars, data on the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were represented in (Table 3 and Fig. 4). High estimates of GCV (>20 %) and PCV (>20 %) were noticed for leaf thickness (28.97, 40.66 respectively) and petal thickness (46.09, 68.46

Table 3. Genetic diversity of *Adenium* genotypes.

Sl. No.	Characters	Mean	GCV (%)	PCV (%)	H (%)	GAM (%)
1	**Plant height (cm)**	37.35	1.21	2.24	33.01	1.40
2	**Plant spread (cm)**	22.69	1.37	2.30	39.64	1.73
3	**Number of branches per plant**	2.22	6.78	9.25	52.50	10.51
4	**Number of leaves per plant**	52.22	1.11	2.30	29.01	1.18
5	**Caudex circumference (cm)**	17.46	1.70	2.81	40.10	2.17
6	**Leaf width (cm)**	4.32	2.87	4.06	51.81	4.25
7	**Leaf length (cm)**	10.35	1.51	2.51	39.68	1.94
8	**leaf area (cm^2)**	26.53	1.35	2.36	36.21	1.62
9	**Leaf thickness (mm)**	0.37	28.97	40.66	51.01	42.92
10	**Flower diameter (cm)**	8.04	2.01	3.10	44.14	2.71
11	**Length of corolla tube (cm)**	3.41	3.79	5.15	53.61	5.77
12	**Diameter of corolla tube (cm)**	1.74	7.22	9.91	54.29	11.01
13	**Petal thickness (mm)**	0.26	46.09	68.46	45.81	64.62
14	**Weight of flower (g)**	1.65	8.21	11.35	51.50	12.42
15	**Length of anther appendages (cm)**	3.41	3.68	5.42	49.22	5.29

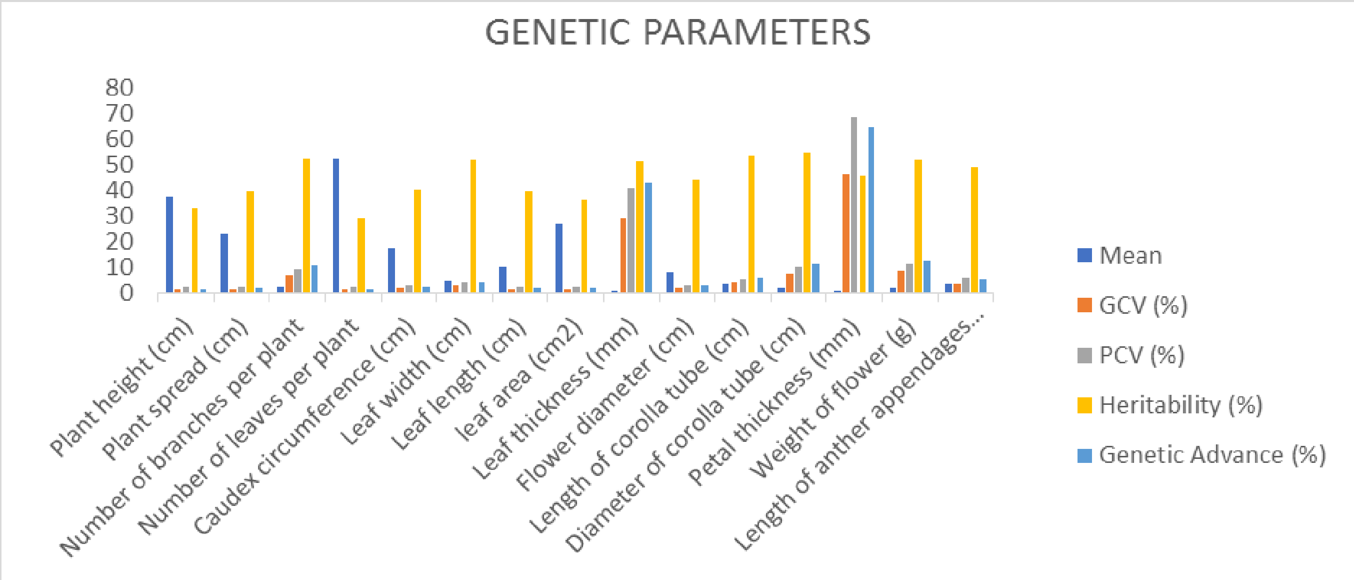

Fig. 4. Genetic diversity analysis of *Adenium* genotypes.

respectively). Moderate level of GCV and PCV were recorded for diameter of corolla tube (7.22 and 9.91 respectively) and weight of flower (8.21 and 11.35 respectively) and the lowest GCV and PCV were found for number of leaves per plant (1.11 and 2.30 respectively) and plant height (1.21 and 2.24 respectively). In general, PCV was slightly higher than GCV in most of the characters studied indicating little influence of environment. The results of the current investigation notified that all 15 traits of the 20 genotypes taken in study contributed to genetic variability. High value of PCV along with GCV indicated that there is more variability in the characters and closeness between PCV and GCV indicated that the phenotypic expression of all the cultivars is mostly under genetic control and environment has less influence on their expression (21). Similar findings were seen in Gladiolus (22, 23).

Heritability percentage and genetic advance as percent of mean was high in traits like number of branches per plant (52.50 % and 10.51 %), leaf width (51.81 % and 4.25 %), leaf thickness (51.01 % and 42.92 %), length of corolla tube (53.61 % and 5.77 %), diameter of corolla tube (54.29 % and 11.01 %) and weight of flower (51.50 % and 12.42 %) and these characters contributed more for the crop growth. In the present study, most of the characters exhibited moderate to high heritability, which indicated that the characters are less influenced by the environmental effects and are effectively transmitted to progeny. High heritability coupled with high genetic advance as per cent of mean suggested the role of additive gene action in the expression of these characters and could be considered as the reliable indicator for selection. The results obtained in the present study are in agreement with the findings in Gerbera (24).

(c) Correlation analysis

The genotypic correlation coefficients were generally higher than the phenotypic correlation coefficients suggesting significant inborn associations among the cultivars. The values in (Table 4 and 5) shows the correlation coefficients at the genotypic and phenotypic levels for the traits examined in relation to growth and reproductive parameters. In present investigation, genotypic correlation coefficient was found to be higher in magnitude than phenotypic correlation coefficient indicating a strong inherent association among various traits. Plant height exhibited positive significant correlation at genotypic level because of the increased photosynthesis leading to the availability of more photosynthates. This is in accordance with earlier studies in gladiolus (25). Plant height revealed a strong positive correlation with plant spread (0.65) and leaf area (0.71). At phenotypic level, plant height revealed a moderate positive correlation with plant spread (0.53) and leaf area (0.44). This suggests that taller plants tend to have wider spread and larger leaf, which could be beneficial for ornamental purposes. Number of branches exhibited strong positive correlation with number of leaves (0.52), caudex circumference (0.72) and leaf thickness (0.65). At phenotypic level, number of branches exhibited moderate to strong positive correlation with number of leaves (0.42), caudex circumference (0.60) and diameter of corolla tube (0.77). This indicates that plants with more branches tend to have more leaves, higher caudex circumference and thicker leaves, potentially leading to increased photosynthetic capacity. Similar study was done earlier with correlation of flower yield with morphological traits of chrysanthemum (26).

Leaf width obtained a strong negative correlation with number of leaves (-0.96) and leaf thickness (-0.68). At phenotypic level, leaf width showed a moderate negative correlation with number of leaves (-0.58) and leaf thickness (-0.43). This suggests a trade-off between leaf size and number, where plants with wider leaves tend to have fewer leaves overall.

Flower diameter is positively correlated with leaf length (0.73) and leaf area (0.63), indicating that plants with larger flowers tend to have longer and larger leaves. At phenotypic level, flower diameter is positively correlated with plant spread (0.45), caudex circumference (0.43) and leaf area (0.48), indicating that plants with larger flowers tend to have wider spread, higher caudex

Table 4. Genotypic correlation coefficient between characters of different *Adenium* genotypes.

	PH	PS	NB	NL	CC	LW	LL	LA	LT	FD	LCT	DCT	PT	WF	LAP
PH	1														
PS	0.656**	1													
NB	0.033 NS	0.318 NS	1												
NL	0.415**	0.331 NS	0.523**	1											
CC	0.271	-0.223	0.722**	0.651	1										
LW	-0.006	0.007 NS	-0.503	-0.961	-0.070	1									
LL	0.078**	0.250 NS	0.538**	0.472**	0.251**	-0.524	1								
LA	0.710**	0.557 NS	0.324**	0.397**	0.005**	0.060 NS	0.347**	1							
LT	0.127**	0.036 NS	0.653**	-0.368	0.322**	-0.682	0.001**	0.292**	1						
FD	0.221 NS	0.551**	0.418**	0.221 NS	0.434**	0.037 NS	0.735**	0.636**	0.054**	1					
LCT	0.257 NS	0.833**	0.585**	0.429 NS	0.516**	0.254 NS	0.444**	0.365**	0.037**	0.420**	1				
DCT	0.327 NS	0.307 NS	0.847**	0.470 NS	0.618 NS	-0.387	0.326**	0.284**	0.567**	0.346**	0.436**	1			
PT	0.178	0.221**	0.411	0.143 NS	-0.255	0.012**	-0.626	-0.341	-0.324	-0.173	-0.059	-0.037	1		
WF	0.359	0.755**	-0.457	-0.526	-0.327	-0.260	-0.657	-0.148	-0.013	0.124 NS	0.878 NS	-0.557	0.164**	1	
LAP	0.022 NS	0.365**	0.802**	0.159 NS	-0.752	-0.350	-0.324	-0.117	-0.581	-0.046	-0.693	-0.824	0.208**	0.468**	1

PH: Plant height (cm), PS: Plant spread (cm), NB: Number of branches per plan, NL: Number of leaves per plant, CC: Caudex circumference (cm), LW: Leaf width (cm), LL: Leaf length (cm), LA: leaf area (cm^2), LT: Leaf thickness (mm), FD: Flower diameter (cm), LCT: Length of corolla tube (cm), DCT: Diameter of corolla tube (cm), PT: Petal thickness (mm), WF: Weight of flower (g), LAP: Length of anther appendages (cm).

Table 5. Phenotypic correlation coefficient between characters of different *Adenium* genotypes.

	PH	PS	NB	NL	CC	LW	LL	LA	LT	FD	LCT	DCT	PT	WF	LAP
PH	1														
PS	0.531**	1													
NB	0.016 NS	0.240 NS	1												
NL	0.310 NS	0.251 NS	0.420**	1											
CC	-0.341	0.155 NS	0.606**	0.416	1										
LW	-0.074	-0.119	0.283	-0.581	-0.021	1									
LL	0.024**	0.310	0.416**	0.408**	0.216**	-0.367	1								
LA	0.443**	0.345 NS	0.162**	0.278**	0.005**	0.020 NS	0.357**	1							
LT	0.083**	0.034 NS	0.434**	-0.159	0.160**	-0.434	0.012**	0.219**	1						
FD	0.158 NS	0.451**	0.278**	0.208 NS	0.433**	0.010 NS	0.081**	0.486**	0.029**	1					
LCT	0.209 NS	0.602**	0.345**	0.334	0.514**	0.205	0.350**	0.211**	0.046**	0.376**	1				
DCT	0.242 NS	0.220 NS	0.777**	0.321 NS	0.455 NS	-0.250	0.179**	0.078**	0.410**	0.136**	0.407**	1			
PT	-0.168	0.188**	0.266	0.132 NS	-0.246	0.027**	-0.461	-0.196	-0.300	-0.114	-0.081	-0.076	1		
WF	0.304 NS	0.522**	0.323 NS	0.355 NS	-0.317	-0.217	-0.450	0.214 NS	0.103 NS	0.035 NS	0.326 NS	-0.187	0.164**	1	
LAP	0.028 NS	0.146**	0.527**	-0.001	-0.519	-0.130	-0.232	-0.023	-0.420	-0.034	-0.3532	-0.547	0.245**	0.316**	1

PH: Plant height (cm), PS: Plant spread (cm), NB: Number of branches per plan, NL: Number of leaves per plant, CC: Caudex circumference (cm), LW: Leaf width (cm), LL: Leaf length (cm), LA: Leaf area (cm^2), LT: Leaf thickness (mm), FD: Flower diameter (cm), LCT: Length of corolla tube (cm), DCT: Diameter of corolla tube (cm), PT: Petal thickness (mm), WF: Weight of flower (g), LAP: Length of anther appendages (cm).

circumference and larger leaf. The relationship between genotypic, phenotypic and environmental correlations have been discussed which emphasizes the characters having high heritability. Positive correlation between pairs of characters suggests that enhancing one trait will also enhance the other, enabling breeders to choose characters that respond well to selection. The present study also clearly proved the importance of the positive link between these traits (27).

(d) Principal component analysis

Principal component analysis (PCA) is used to determine the extent of genetic diversity among the genotypes. It is also used to ascertain plant attributes which account for the majority of the observed variation among the genotypes. It was done to reduce the dimensionality of the parameter dataset and to identify the new underlying variables (28).

Eigen values, percentage of variation and percentage contribution of each variable

In the current investigation, the mean of fifteen quantitative characteristics was subjected to principal component analysis in order to identify the characters that significantly contributed to the variation. To determine the agro-morphological variability of the genotypes, only PCs with Eigen values greater than one were included. Eigen values of more than 1 was observed in 6 principal components (PC_1 to PC_6), *viz.,*3.78, 2.30, 1.73, 1.58, 1.42 and 1.11 respectively, that contributed 79.68 % of the total divergence in this study (Table 6). The percentage of variation in relation with each principal component could be demonstrated by a scree plot, obtained by a graph between Eigen values and principal component numbers (Table 7 and Fig. 5, 6). Among the 15 variables taken for the analysis, majority of them were contributed for explaining the total variation within the *Adenium* genotypes. Similar findings were reported in Korean chrysanthemum (29).

Table 6. Eigen values of *Adenium* genotypes.

Principal component	Eigen value	Percentage of variance	Cumulative percentage of variance
PC_1	3.78	25.22	25.22
PC_2	2.30	15.36	40.59
PC_3	1.73	11.57	52.16
PC_4	1.58	10.59	62.75
PC_5	1.42	9.47	72.22
PC_6	1.11	7.46	79.68

From the graph, it could be observed that the first principal component PC_1 had Eigen value of 3.78 with 25.22 percentage of variance. The graph gradually decreased with decreasing Eigen value with increasing principal components. The maximum contribution to the variance was due to PC_1 (25.22 %) followed by PC_2 (15.36 %), PC_3 (11.57 %), PC_4 (10.59 %), PC_5 (9.47 %) and PC_6 (7.46 %). These results are in accordance with the principal component analyses of anatomical attributes of leaves of 8 Apocynaceae taxa (30). The first 4 principal component analysis showed highest amount of variation. These findings were in accordance with the 43 cultivars of *Heliconia* with 3 principal components (31).

The PC_1 showed maximum contribution of variables on principal components with traits *viz.*, plant height, plant spread, number of branches per plant, number of leaves per plant, caudex circumference, leaf width, leaf length, leaf area, leaf thickness, flower diameter, length of corolla tube, diameter of corolla tube, petal thickness, weight of flower and length of anther appendages as given in the Table 1 and 2. It is effective for the genetic improvement of critical traits with larger contributions to variability rather of focusing on all the aspects under research (32). PCA has been successfully used in multiple cases to generate novel concepts, to simplify large data sets or to understand how complex features respond to interventions or evolutionary processes (33, 34).

Table 7. Percent contribution of variables on principal components of *Adenium* genotypes.

Variables	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6
Plant height (cm)	14.11	0.05	0.72	1.87	8.82	0.93
Plant spread (cm)	9.02	10.41	5.59	2.56	2.83	1.50
Number of branches per plant	15.76	1.50	8	0.24	7.92	0.96
Number of leaves per plant	9.37	7.26	3.44	8.75	0.09	2.65
Caudex circumference (cm)	4.01	2.64	20.98	9.30	2.81	0.79
Leaf width (cm)	1.15	16.80	5.57	5.15	1.31	19.70
Leaf length (cm)	1.04	0.08	13.81	19.79	0.05	25.62
Leaf area (cm^2)	1.52	8.81	5.91	23.65	1.80	13.17
Leaf thickness (mm)	1.94	0.88	1.11	7.59	46.52	1.68
Flower diameter (cm)	10.84	6.59	0.98	2.54	1.87	5.49
Length of corolla tube (cm)	3.14	18.23	8.89	3.46	0.91	9.15
Diameter of corolla tube (cm)	1.50	10.64	16.22	7.92	0.02	11.21
Petal thickness (mm)	5.62	0.10	0.76	1.81	19.86	4.15
Weight of flower (g)	3.43	15.17	6.81	1.63	4.38	0.01
Length of anther appendages (cm)	17.49	0.76	1.15	3.68	0.86	2.93

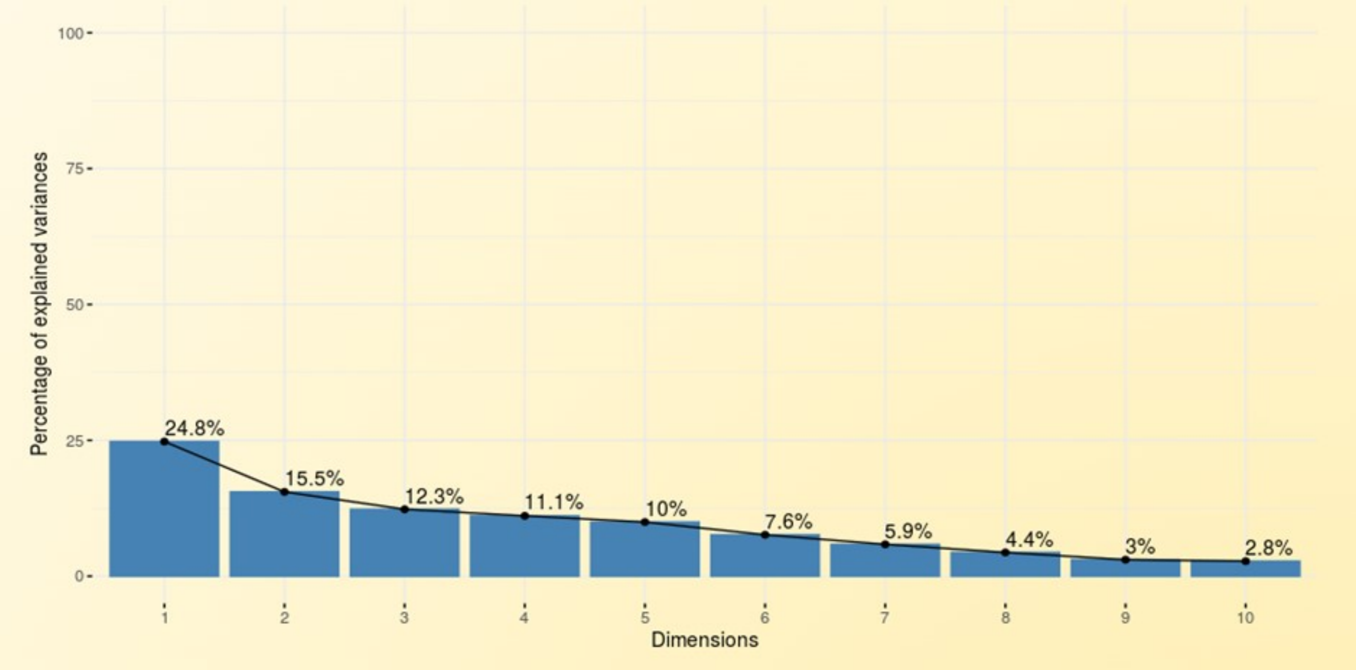

Fig. 5. Scree plot of variables of *Adenium* genotypes.

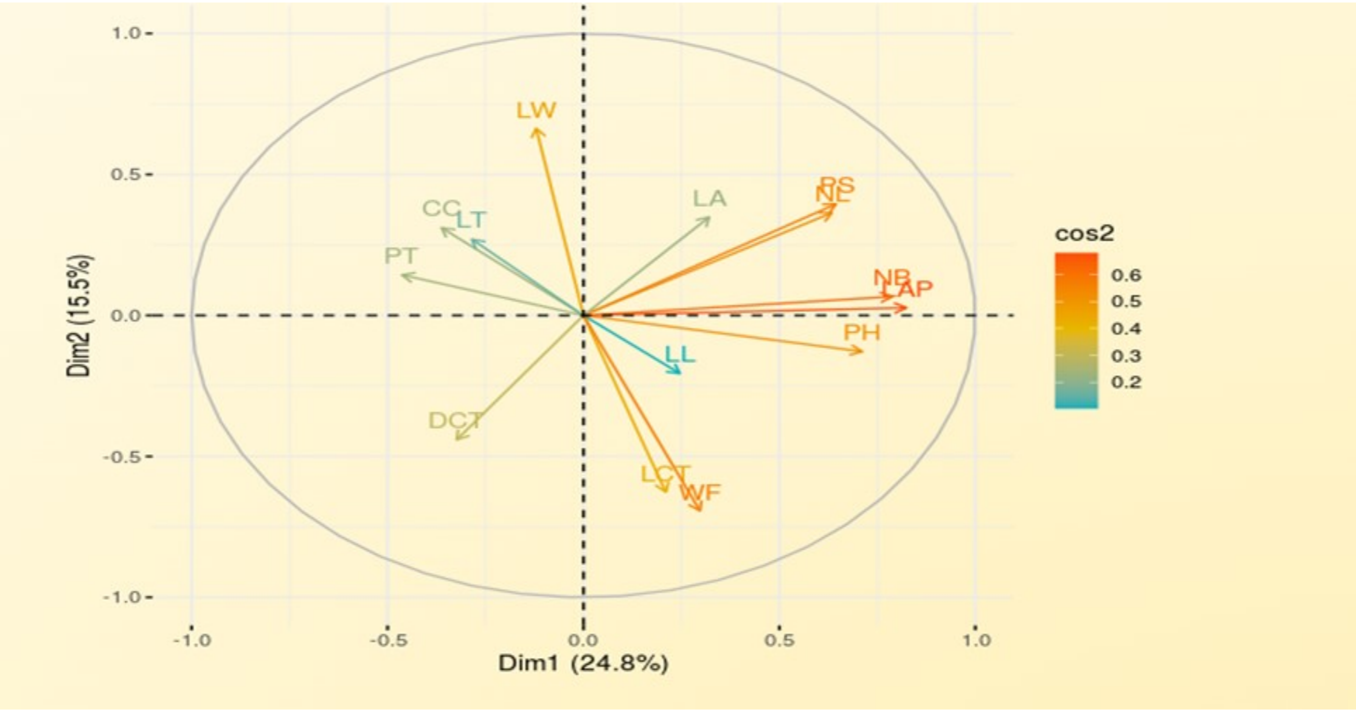

Fig. 6. Contribution of variables on principal component of *Adenium* genotypes.

Conclusion

From the evaluation of 20 *Adenium* genotypes, Sudharsan exhibited superior growth, Triple Star excelled in flowering and Miss India showed the best caudex development making them suitable for ornamental use and as potted plants in landscaping. These findings could be employed in the future to create significantly improved *Adenium* varieties with high heritability and genetic advancement.

References

1. Sindhuja M, Singh A, Kapadiya C, Bhandari A, et al. Evaluation of *Adenium* genotypes for physio-chemical and flowering characters. International Journal of Chemical Studies. 2020;8 (4):3840-44.https://doi.org/10.22271/chemi.2020.v8.i4aw.10246
2. Singh A, Bhandari A, Chavan S, Patel N, et al. Evaluation of *Adenium obesum* for potted ornamentals under soilless growing system. International Journal of Current Microbiology and Applied Sciences. 2017;6(12):2141-46. https://doi.org/10.20546/ijcmas.2017.612.246
3. Singh A, Chavan S, Bhandari A, Parekh V, et al. New multipetalous variety G. Ad. 1 of *Adenium obesum*. International Journal of Current Microbiology and Applied Science. 2019;8 (2):197-203. https://doi.org/10.20546/ijcmas.2019.807.025
4. Hastuti D, Suranto S, Setyono P. Variation of morphology, karyotype and protein band pattern of Adenium (*Adenium obesum*) varieties. Nusantara Bioscience. 2009;1(2). https://doi.org/10.13057/nusbiosci/n010205
5. Paul D, Biswas K, Sinha SN. Biological activities of *Adenium obesum* (Forssk.) Roem. & Schult.: a concise review. Malaya Journal of Biosciences. 2015;2(4):214-21. https://doi.org/10.5958/0974-0112.2022.00040.8

6. Versiani MA, Ahmed SK, Ambreen Ikram AI, Ali ST, et al. Chemical constituents and biological activities of *Adenium obesum* (Forsk.) Roem. et Schult. Chemistry and Biodiversity. 2014;11 (2):171-80. https://doi.org/10.1002/cbdv.201200254

7. Dimmitt M. Adenium culture: producing large specimens quickly. Cactus and Succulent Journal. 1998;70(2):59-64.

8. Chavan S, Singh A, Barkule S. Genetic variability studies on *Adenium obesum* forsskroem and schult. Asian Jr of Microbiol Biotech Env Sc. 2018;20(3):965-69.

9. Singh A, Chavan S, Bhandari A, Parekh V, Shah H, Patel A, et al. New multipetalous variety G. Ad. 2 of *Adenium obesum.* Electronic Journal of Plant Breeding. 2020;11(02):346-50. https://doi.org/10.37992/2020.1102.062

10. Pawadashetti DV, Kumari RV, Shanthala J, Thimmarayappa M. Effect of gamma irradiation on vegetative and floral traits in Gladiolus (*Gladiolus hybrida* L.). Mysore J Agric Sci. 2022;56 (4):148-54.

11. Choudhary R, Kumar A, Kanwar J, Kachouli B, Yadav BR. Effect of gamma irradiation on growth and corm yield of gladiolus (*Gladiolus grandiflorus*) varieties. The Indian Journal of Agricultural Sciences. 2023;93(11):1266. https://doi.org/10.56093/ijas.v93i11.141492

12. Burton GW. Quantitative inheritance in grasses. Proceedings of the Sixth International Grassland Congress, Pennsylvania; 1952.1(2):277-83.

13. Hanson C, Robinson H, Comstock R. Biometrical studies of yield in segregating populations of Korean lespedeza 1. Agronomy Journal. 1956;48(6):268-72. https://doi.org/10.2134/agronj1956.00021962004800060008x

14. Dimmitt M, Joseph G, Palzkill D. Adenium: Sculptural elegance, floral extravagance: Scathingly Brilliant Idea; 2009.

15. Sidhu G, Arora J, editors. Evaluation of gladiolus varieties for summer flower production. Proceeding of the National Conference on Gladiolus; January 2000.

16. Dimmitt M, Hanson C. The genus *Adenium* in cultivation. Part 1: *A. obesum* and *A. multiflorum.* Cactus and Succulent Journal. 1991;63(5):223-25.

17. Lalthawmliana A, Keditsu R, Buchem YA, Bagang L. Evaluation of tuberose (*Polianthes tuberosa* L.) cultivars under the foothill conditions of Nagaland. Journal of Ornamental Horticulture. 2017;20(1 and 2):69-74.

18. Patil J, Warke D, Paul V, Gunjkar S. Studies on epicotyl grafting in mango. Indian Journal of Horticulture. 1984;41(1 and 2):69-72.

19. Lu Z, Zhu L, Lu J, Shen N, Wang L, Liu S, et al. Rejuvenation increases leaf biomass and flavonoid accumulation in *Ginkgo biloba*. Horticulture Research. 2022;9:uhab018. https://doi.org/10.1093/hr/uhab018

20. Varella TL, Silva GM, Cruz K, Mikovski AI, Nunes JdS, Carvalho IF, et al. *In vitro* germination of desert rose varieties. Ornamental Horticulture. 2015;21(2):227-34. https://doi.org/10.14295/aohl.v21i2.676

21. Singh B, Singh M. Studies on variability and genetic advance parameters in gladiolus. Progressive Horticulture. 1990;19(3-4):271-75.

22. Mahanta P, Paswan L. Studies on variability and heritability of some quantitative characters in *Gladiolus*. South Indian Horticulture. 1993;41(3):166-68.

23. Mishra H, Jha P. Variability study in gladiolus. Haryana Journal of Horticultural Sciences. 2005;34(1/2):70.

24. Kannan M, Seemanthani Rammdas SR. Variability and heritability studies in gerbera (*Gerbera jamesonii* L.). Progressive Horticulture. 1990;22(1-4):72-76.

25. Raj R, Misra H, Dohare S. Coerelation and path-coefficient studies in gladiolus over different environments. Journal of Ornamental Horticulture. 1998;1(1):26-31.

26. Raghava S, Negi S, Nancharaiah D. Genetic variability, correlation and path analysis in chrysanthemum. Indian Journal of Horticulture. 1992;49(2):200-04.

27. Falconer DS. Introduction to quantitative genetics: Pearson Education India; 1996.

28. Bruna EM, Kress WJ. Habitat fragmentation and the demographic structure of an Amazonian understory herb (*Heliconia acuminata*). Conservation Biology. 2002;16(5):1256-66. https://doi.org/10.1046/j.1523-1739.2002.99494.x

29. Priyanka Bhareti PB, Singh D, Khulbe R. Genetic variability and association analysis of advanced lines and cultivars following intervarietal and interspecific crosses in blackgram. Crop Improvement. 2011;38(1):67-70

30. Kim SJ, Lee CH, Kim J, Kim KS. Phylogenetic analysis of Korean native Chrysanthemum species based on morphological characteristics. Scientia Horticulturae. 2014;175:278-89. https://doi.org/10.1016/j.scienta.2014.06.018

31. El-Taher AM, Gendy AE-NGE, Alkahtani J, Elshamy AI, Abd-ElGawad AM. Taxonomic implication of integrated chemical, morphological and anatomical attributes of leaves of eight Apocynaceae taxa. Diversity. 2020;12(9):334. https://doi.org/10.3390/d12090334

32. Avendaño-Arrazate CH, Arrazate-Argueta JA, Ortíz-Curiel S, Moreno-Pérez E, Iracheta-Donjuan L, Reyes-López D, et al. Morphological characterization in wild species of Heliconias (*Heliconia* spp) in Mexico. American Journal of Plant Sciences. 2017;8(06):1210. https://doi.org/10.4236/ajps.2017.86080

33. Das S, Das SS, Chakraborty I, Roy N, Nath MK, Sarma D. Principal component analysis in plant breeding. Biomolecule Reports. 2017;3:1-3.

34. Mustafa HSB, Farooq J, Bibi T, Mahmood T. Cluster and principle component analyses of maize accessions under normal and water stress conditions. Journal of Agricultural Sciences, Belgrade. 2015;60(1):33-48. https://doi.org/10.2298/JAS1501033M4