ISSN 2394 - 7837

ARTICLE

Morphometric Analysis of a Few Species of Caesalpinia

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Received 19/02/2015 Accepted 28/05/2015

Abstract

The vegetative and floral characteristics of four species of Caesalpinia (*Caesalpinia pulcherrima* L., *Caesalpinia sappan* L., *Caesalpinia coriaria* (Jacq.)Willd. and *Caesalpinia mimosoides* Lamk.) were investigated during one complete flowering cycle (August to January). The vegetative features, pollination systems and reproductive systems of all the four species were studied during the peak of flowering. The vegetative characters like leaf, leaflet; reproductive characters like inflorescence, calyx, corolla, androecium, gynoecium, ovary, style, stigma, ovule, and aspects of floral biology like anthesis, pollen number per anther, pollen viability etc. were included in the study. The variations in these parameters were studied thoroughly and statistical analyses were conducted using SPSS software. All the four species were morphometrically analyzed with the help of PCA, Cluster Analysis and CD. Relationship between the four plants was traced and dendrogram was prepared using numerical taxonomic tools. The study revealed that *C. pulcherrima* L. is closely related with *C. sappan* and *C. coriaria* is closely related with *C. mimosoides*. The two clusters exhibited a considerable amount of morphological and ecological variations that throw light on the evolution and breeding system.

Keywords: Caesalpinia, Morphometrics, Principal Component Analysis, Cluster Analysis, Coefficient of Difference.

Introduction

The genus Caesalpinia (Caesalpiniaceae) has more than 500 species, many of which exhibit a wide range of pharmacological properties. (Zanin Joao *et al.*, 2012). It contains tropical or subtropical woody plants. Caesalpinia is a shrub typically reaching height 3m .The leaves are bipinnate, bearing 3-10 pairs of pinnae each with 6-10 leaflets. The flowers are born in racemes; flower colour may range from creamy yellow to red.

Morphometrics refers to the quantitative analysis of form, a concept that encompasses size and shape. Morphometrics is also used to precisely locate certain areas of organs and is used in describing the shapes of other things. A major objective of morphometrics is to statistically test hypotheses about the factors that affect shape. Morphometrics can be used to quantify a trait of evolutionary significance, and by detecting changes in the shape, deduce something of their ontogeny, function or evolutionary relationships. Principal component analysis (PCA) is a mathematical procedure that uses orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. Cluster analysis or clustering is the task of grouping a set of objects in such a way that objects in the same group (called cluster) are more similar to each other than to those in other groups. Identifying groups of individuals that are similar to each other but different from individuals in other groups can be phylogenetically important. Because the goal of this cluster analysis is to form similar groups of figure-skating judges, it has to be decided on the criterion to be used for measuring similarity or distance. Distance is a measure of how far apart two objects are, while similarity measures how similar two objects are. For cases that are alike, distance measures are small and similarity measures are large.

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Materials and Methods

Plant Specimens

Four species of Caesalpinia (*C. pulcherrima, C. sappan, C. coriaria, C. mimosoides*) were collected from various parts of Kozhikode during one complete flowering cycle (August-January) especially at the peak of flowering. *C. pulcherrima* is native to the tropics and sub tropics of America. It is cultivated as an ornamental. *C. sappan* is native of India and Malaya. It also produces a valued type of reddish dye called brazilin. *C. coriaria* is a native of South America and West Indies. *C. mimosoides* is a low growing thorny shrub usually seen in waste lands.

Morphological Analysis

Morphology of the vegetative parts like leaf and leaflet were analyzed to find out its correlation with other reproductive parts as well as to detect the relationship between different

species. Floral morphology of different floral parts like inflorescence, peduncle, pedicel, calyx, corolla, filament, anther, ovary, ovary, style, stigma, ovules, hypanthium, pollen etc. were observed thoroughly and measured to compare between plants.

Morphometric Analyis

Specific characters were measured and analyzed using SPSS software to find out the correlation between the characters and relationship between taxa. Principal component analysis and cluster analysis were conducted and coefficient of difference and dissimilarity matrix between groups were calculated. Corresponding mean values of each quantitative character along with their Standard Deviation were obtained and processed for Principal Component Analysis and Cluster Analysis (Kovach, 1999). All the characters and the taxonomic units to be classified are arranged in a data matrix, and the similarities between all possible pairs of OTU's are then computed based on all the characters. Coefficient of Difference values for all the quantitative characters were calculated according to Mayr (1969). If the difference between two mean measurements of populations A and B exceeded the sum of the two standard deviations by 1.28, then about 90% of population A differed from about 90% of population B. Coefficient of difference was computed as: mb-ma/SDa + SDb where mb and ma are mean measurements of morphometric character for populations B and A respectively, SDa and SDb are standard deviations of measured character for population A and B respectively, and a and b being specific morphometric characters of the different Caesalpinia species respectively

Results

PCA results of fifteen quantitative characters based on similarity matrix reveals significantly the correlation between leaf & leaflet, leaf & peduncle, leaf & filament, peduncle & pedicel, peduncle & flower, peduncle & petal, peduncle & filament, peduncle & ovary, peduncle & style, peduncle & fruit, pedicel & flower, pedicel & petal, pedicel & filament, pedicel & ovary, pedicel & style, pedicel & fruit, flower & petal, flower & sepal, flower & filament, flower & style, flower & fruit, petal & sepal, petal & filament, petal & ovary, petal & style, petal & fruit, sepal & fruit, filament & ovary, filament & style and filament & fruit as shown in Tables 1-2. Cluster analysis and dendrogram based on farthest neigh-

Table 1. Quantitative Characters of Caesalpinia L. Species with Mean and Standard Deviation.

	C. pulcherrima Length (cm)		*C. sappan* Length (cm)		*C. coriaria* Length (cm)		*C. mimosoides* Length (cm)	
	x	sd	x	sd	x	sd	x	sd
Leaf	31.10	1.79	24.85	0.71	7.22	1.12	7.19	0.48
Leaflet	1.61	0.11	1.53	0.07	0.92	0.12	1.16	0.13
Inflorescence	27.10	1.52	25.17	0.67	6.32	1.12	24.49	1.37
Peduncle	11.86	0.25	5.60	0.40	3.19	0.17	4.73	0. 30
Pedicel	4.65	0.35	2.26	0.33	0.84	0.10	2.44	0.11
Flower	2.69	0.21	1.33	0.16	1.19	0.11	1.94	0.14
Petal	2.24	0.19	0.84	0.10	0.26	0.05	1.26	0.07
Sepal	1.39	0.10	0.21	0.02	0.46	0.08	1.14	0.08
Filament	12.40	0.21	3.37	0.21	0.52	0.06	1.28	0.08
Anther	0.46	0.05	0.90	0.23	1.17	0.11	2.27	0.16
Hypanthium	0.27	0.05	1.24	0.13	0.33	0.06	0.23	0.08
Ovary	0.87	0.13	0.37	0.08	0.34	0.05	0.33	0.08
Style	6.17	0.16	1.23	0.07	0.45	0.05	1.27	0.09
Stigma	0.21	0.02	0.21	0.06	0.12	0.04	0.26	0.04
Fruit	10.93	0.52	6.56	0.36	4.96	0.23	8.17	0.29

x : mean; sd : standard deviation

bor, mean character difference and constrained clustering strategy showed that the Caesalpinia species are distinctly divided into two groups; one group consisting of *C. pulcherrima* & *C. sappan* and a second group consisting of *C. coriaria* & *C. mimosoides.* (Fig. 1)

Coefficient of difference values were also calculated for all the quantitative parameters as shown in Table 3. The CD values reveal that the quantitative characters i.e., leaf length, peduncle length, pedicel length, flower size, sepal length, petal length, filament length, anther length, style length and fruit length have great contribution in separation of the taxa. CD values showed that *C. pulcherrima* & *C. sappan, C. pulcherrima* & *C. coriaria, C.pulcherrima* & *C. mimosoides, C. sappan* & *C. coriaria, C. coriaria* & *C. mimosoides* are significantly different from each other. Proximity Matrix also revealed the same results (Table 4).

Figure 1. Dendrogram using Average Linkage (Between Groups) Rescaled Distance Cluster Combine

Table 2. Principal Component Analysis of Caesalpinia Species - Correlation Matrix

Correlation	Leaf	Leaflet	Inflorescence	Peduncle	Pedicel	Flower	Petal	Sepal	Filament	Anther	Hypanthium	Ovary	Style	Stigma	Fruit
Leaf	1.00														
Leaflet	.888	1.00													
Inflores.	.631	.773	1.00												
Peduncle	.838	.752	.632	1.00											
Pedicel	.761	.761	.771	.954	1.00										
Flower	.519	.536	.629	.859	.887	1.00									
petal	.656	.666	.760	.916	.962	.948	1.00								
Sepal	.178	.234	.451	.650	.721	.894	.819	1.00							
Filament	.856	.737	.564	.990	.918	.822	.876	.606	1.00						
Anther	-.790	-.540	-.061	-.610	-.408	-.202	-.279	.093	-.684	1.00					
Hypanthium	.374	.390	.223	-.145	-.150	-.485	-.290	-.734	-.134	-.307	1.00				
Ovary	.723	.572	.414	.915	.834	.786	.825	.620	.922	-.623	-.253	1.00			
Style	.767	.664	.554	.986	.933	.889	.919	.720	.985	-.578	-.280	.928	1.00		
Stigma	.150	.385	.673	.247	.458	.384	.431	.376	.162	.301	.027	.073	.193	1.00	
Fruit	.614	.642	.754	.896	.950	.947	.980	.849	.853	-.238	-.336	.783	.903	.471	1.00

Discussion

Numerical taxonomy is the grouping of taxonomic units by numerical methods into taxa on the basis of their character states. It includes the drawing of phylogenetic inferences from the data by statistical or other mathematical methods collectively called cluster analysis (Sokall & Sneath, 1963). Estimation of resemblance is the most important and fundamental step in numerical taxonomy. It commences with the collection of information about characters in the taxonomic group to be studied. Overall phenetic similarity is based on all available characters without any differential weighting of some characters over others. Conventional taxonomy usually employs only a few characters in classification and weights these in terms of their presumed evolutionary importance. Numerical taxonomy contends that

Table 3. Coefficient of Difference in between all the Species Groups of Caesalpinia

Sl. No.	Morphometric character	C1 & C2	C1 & C3	C1 & C4	C2 & C3	C2 & C4	C3 & C4	Total
1	Leaf	*	*	*	*	*		5
2	Leaflet		*	*	*	*		4
3	Inflorescence		*		*		*	3
4	Peduncle	*	*	*	*		*	5
5	Pedicel	*	*	*	*		*	5
6	Flower	*	*	*		*	*	5
7	Petal	*	*	*	*	*	*	6
8	Sepal	*	*		*	*	*	5
9	Filament	*	*	*	*	*	*	6
10	Anther	*	*	*		*	*	5
11	Hypanthium	*			*	*		3
12	Ovary	*	*	*				3
13	Style	*	*	*	*		*	5
14	Stigma		*				*	2
15	Fruit	*	*	*	*	*	*	6
Total		12	14	11	11	9	11	

Table 4. Proximity Matrix (Dissimilarity matrix)

	Squared Euclidean Distance			
	Cl *C. pulcherrima*	C2 *C. sappan*	C3 *C. coriaria*	C4 *C. mimosoides*
C1: C. pulcherrima	0.000	97.066	1.142E3	651.545
C2: C. sappan	97.066	0.000	707.794	351.742
C3: C. coriaria	1.142E3	707.794	0.000	426.230
C4: C. mimosoides	651.545	351.742	426.230	0.000

evolutionary importance is indefinable and generally unknown and that no consistent scheme for weighting characters before undertaking a classification has yet been proposed (Sokall, 1966). In the present study a few vegetative and reproductive morphological characters of Caesalpinia were analyzed using numerical taxonomic tools and the relationship between the taxa was traced.

Conclusion

Similarities and differences among the four species of Caesalpinia were analyzed and closely related taxa were identified. The study revealed that *C. pulcherrima* L. is closely related with *C. sappan* and *C. coriaria* is closely related with *C. mimosoides*. The two clusters exhibited a considerable amount of morphological variations that throw light on the evolution and breeding system within the Genus.

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