

NUMERICAL TAXONOMIC STUDIES OF THE GENUS *CLEOME* L. (CLEOMACEAE) FROM PAKISTAN

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Abstract

The genus *Cleome* L. was analysed numerically to find out the relationship of 11 species from Pakistan. Hierarchical clustering was performed by using Euclidean distance index and 214 characters from gross morphology, phenolic compounds, micromorphology of leaf, pollen, seeds and seed coat elements were taken into consideration. Results obtained by numerical data indicated the occurrence of two distinct groups. The group I comprised of 7 species viz., *C. karachiensis*, *C. scaposa*, *C. brachycarpa*, *C. fimbriata*, *C. rupicola*, *C. viscosa* and *C. oxypetala* and group II was represented by *C. ariana*, *C. dolichostyla*, *C. pakistanica* and *C. spinosa*. It was concluded that the group of species indicated the close affinity among them except that of the two morphologically allied species viz., *C. karachiensis* and *C. viscosa* which fell in separate groups. Which indicate that synthetic approach does not necessarily correlate with subjective findings.

Key words: *Cleome*, Cleomaceae, Numerical analysis, Pakistan.

Introduction

Numerical taxonomy is one of the most modern methods used in systematics. It was first conceptualized by Sokal & Sneath (1963). After them many workers like; Bremer (1987), Karis *et al.*, (1992), Walsh & Hoot (2001), Abid & Qaiser (2006), Sarwar & Qaiser (2012), Binzet *et al.*, (2018) used cladistics to study the phylogeny of various taxa.

Regarding to numerical approach to the genus *Cleome* L. few workers gave the attention. Such as, Sanchez-Acebao (2005) numerically analyzed the phylogeny of the new world *Cleome* by utilizing DNA profile, seed and pollen data. While, Inda *et al.*, (2008) worked on the phylogeny of *Cleome*, *Podandrogyne* and *polinisia* and concluded that they were paraphyletic genera. Fay & Christenhusz (2010) described the close relation between Cleomaceae and Brassicaceae based on numerical approach. Similarly, Kasem & Fathy (2013) also used the numerical method to study the correlation among *Cleome* species based on flavonoids and isoenzymes. While, Patchell *et al.*, (2014) used cladistics to study the phylogeny of *Cleome* and reconstruct its phylogeny by using data from genomes. Later on, Kasem (2016) numerically analyzed the *Cleome* species by using the data from anatomy, pollen and seed morphological studies to find out the phenetic relationship and it was concluded that the data obtained from pollen and seed exomorphic studies was found helpful for specific delimitation. While, Muhammad *et al.*, (2018) studied the intra-specific profiling of *C. viscosa* from Swat (Pakistan) where they found slight variations within the species.

From the above mentioned reports, it is evident that numerical data and cladistics have been used by various workers to study taxonomic correlation among the taxa of the family Cleomaceae and the genus *Cleome* but no

comprehensive reports are available on species of *Cleome* found in Pakistan.

The present study is carried out to enlighten the genus *Cleome* numerically from Pakistan. For this purpose morphological, micromorphological characters of seeds, pollen, phenolic compounds, seed coat elements and leaves were taken into consideration.

Materials and Method

Numerical analysis of c. 500 specimens from various geographical areas of Pakistan belonging to 11 species of the genus *Cleome* was carried out to study the phenetic relationship. Hierarchical clustering was performed using the Euclidean distance index with the computer package (IBM Corp., 2011). Each taxon was considered an operational taxonomic unit (OTU). Qualitative characters were recorded in binary state as 1, 2 and characters which were either absent or present were coded as 0 or 1 respectively. While, for quantitative characters average values were directly used (Tables 1 & 2).

Results and Discussion

Dendrogram obtained from numerical analysis of genus *Cleome* indicated the presence of two distinct clusters i.e., group-I and group-II (Fig. 1).

Group-I is represented by 7 species i.e., *C. karachiensis* S. Riaz, R. Abid & M. Qaiser, *C. scaposa* DC., *C. brachycarpa* Vahl. ex. DC., *C. fimbriata* Vicary, *C. rupicola* Vicary, *C. viscosa* L. and *C. oxypetala* Boiss. Their affinities might be due to average height of plants (up to 50cm). While, group-II attaining > 50cm plant height. Furthermore, group-II also had silicon and sodium in their seed coats, spiny stipules, cordate leaves, anisocytic stomata, irregular trichome head, hirsute hairs and truncate leaf base. While, these features were totally missing from group-I.

Table 1. List of characters scored for cluster analysis for the species of genus *Cleome*.

S. No.	Characters description	S. No.	Characters description
	Habit		Capsule
1.	Herb (1) undershrub (2)		Size
	Stem	107.	Length (mm)
2.	Length (Cm)	108.	Breadth (mm)
3.	Suberect (1), erect (2)		Shape
4.	Unbranched (0), branched (1)	109.	Linear: Present (1), absent (0)
5.	Hairs: Present (1), absent (0)	110.	Oblong: Present (1), absent (0)
	Leaves	111.	Slightly curved: Present (1), absent (0)
6.	Simple (1), Compound (2)		Seeds
	Size		Size
7.	Length (mm)	112.	Length (mm)
8.	Breadth (mm)	113.	Breadth (mm)
9.	Spiny stipules at base: Present (1), absent (0)	114.	Nonangular (0), Angular (1)
	Shape		Colour
10.	Linear: Present (1), absent (0)	115.	Light brown: Present (1), absent (0)
11.	Lanceolate: Present (1), absent (0)	116.	Chocolate brown: Present (1), absent (0)
12.	Oblong: Present (1), absent (0)	117.	Rust brown: Present (1), absent (0)
13.	Ovate: Present (1), absent (0)	118.	Dark brown: Present (1), absent (0)
14.	Broadly ovate: Present (1), absent (0)	119.	Dust brown: Present (1), absent (0)
15.	Orbicular: Present (1), absent (0)	120.	Dull brown: Present (1), absent (0)
16.	Suborbicular: Present (1), absent (0)	121.	Golden brown: Present (1), absent (0)
17.	Elliptic: Present (1), absent (0)	122.	Mustard brown: Present (1), absent (0)
18.	Broad elliptic: Present (1), absent (0)	123.	Orange brown: Present (1), absent (0)
19.	Cordate: Present (1), absent (0)	124.	Metal green: Present (1), absent (0)
20.	Oblanceolate: Present (1), absent (0)	125.	Myrtle green: Present (1), absent (0)
21.	Obovate: Present (1), absent (0)	126.	Maroon: Present (1), absent (0)
22.	Linear-elliptic: Present (1), absent (0)	127.	Black: Present (1), absent (0)
23.	Broadly cordate: Present (1), absent (0)	128.	Blackish brown: Present (1), absent (0)
24.	Suborbicular-broadly ovate: Present (1), absent (0)		Shape
25.	Obovate-ob lanceolate: Present (1), absent (0)	129.	Ovoid: Present (1), absent (0)
26.	Elliptic-obovate: Present (1), absent (0)	130.	Ob-elliptic pyriform: Present (1), absent (0)
27.	Ovate-elliptic: Present (1), absent (0)	131.	Retortiform: Present (1), absent (0)
28.	Elliptic-lanceolate: Present (1), absent (0)	132.	Elliptic pyriform: Present (1), absent (0)
29.	Oblong-lanceolate: Present (1), absent (0)	133.	Reniform: Present (1), absent (0)
	Apex	134.	Obovate: Present (1), absent (0)
30.	Acuminate: Present (1), absent (0)		Surfaces
31.	Apiculate: Present (1), absent (0)	135.	Concentrically ridged: Present (1), absent (0)
32.	Obtuse: Present (1), absent (0)	136.	Appressedly reticulate: Present (1), absent (0)
	Base	137.	Reticulate: Present (1), absent (0)
33.	Cuneate: Present (1), absent (0)	138.	Faintly reticulate: Present (1), absent (0)
34.	Obtuse: Present (1), absent (0)	139.	Favulariate: Present (1), absent (0)
35.	Attenuate: Present (1), absent (0)	140.	Alveolate: Present (1), absent (0)
36.	Truncate: Present (1), absent (0)	141.	Foveate: Present (1), absent (0)
	Leaf Indumentum	142.	Pusticulate: Present (1), absent (0)

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37. Hair: Present (1), absent (0)
38. Eglandular (1), glandular (2)
- Vesture type**
39. Pubescent: Present (1), absent (0)
40. Dense pubescent: Present (1), absent (0)
41. Hirsute: Present (1), absent (0)
42. Scabrous: Present (1), absent (0)
- Trichome head**
43. Peltate: Present (1), absent (0)
44. Capitate: Present (1), absent (0)
45. Globular: Present (1), absent (0)
46. Irregularly circular: Present (1), absent (0)
47. Pointed: Present (1), absent (0)
48. Irregular: Present (1), absent (0)
- Leaf stomata**
- Aperture**
49. Length (μm)
50. Breadth (μm)
- Type**
51. Anisocytic: Present (1), absent (0)
52. Paracytic: Present (1), absent (0)
53. Actinocytic: Present (1), absent (0)
54. Anomocytic: Present (1), absent (0)
- Position**
55. Sunken: Present (1), absent (0)
56. Slightly sunken: Present (1), absent (0)
57. At the level of epidermis: Present (1), absent (0)
- Apperture shape**
58. Oblong: Present (1), absent (0)
59. Elliptic: Present (1), absent (0)
60. Ovate: Present (1), absent (0)
- Flower**
61. Size (mm)
- Sepals**
- Size**
62. Length (mm)
63. Breadth (mm)
64. Indumentum: Present (1), absent (0)
- Shape**
65. Linear: Present (1), absent (0)
66. Lanceolate: Present (1), absent (0)
67. Oblong: Present (1), absent (0)
68. Ovate: Present (1), absent (0)
69. Elliptic: Present (1), absent (0)
143. Appressedly colliculate: Present (1), absent (0)
144. Densely pubescent: Present (1), absent (0)
145. Papillae: Present (1), absent (0)
146. Hair pillose: Present (1), absent (0)
147. Hair tomentose: Present (1), absent (0)
148. Hair lineate: Present (1), absent (0)
- Pollen grains**
- Size**
149. Length (μm)
150. Breadth (μm)
151. Colpus length (μm)
152. Mesocolpium (μm)
153. Apocolpium (μm)
154. Exine thickness (μm)
- Shape**
155. Prolate: Present (1), absent (0)
156. Sub-prolate: Present (1), absent (0)
157. Prolate-spheroidal: Present (1), absent (0)
- Colpal membrane surface**
158. Sub-psilate: Present (1), absent (0)
159. Scabrate: Present (1), absent (0)
160. Granulated: Present (1), absent (0)
161. Densely granulated: Present (1), absent (0)
162. Rugulate-reticulate: Present (1), absent (0)
163. Spinulose: Present (1), absent (0)
164. Verrucate: Present (1), absent (0)
- Tectum surface**
165. Rugulate-reticulate: Present (1), absent (0)
166. Reticulate: Present (1), absent (0)
167. Spinulose-verrucate: Present (1), absent (0)
168. Spinulose: Present (1), absent (0)
169. Rugulate-striate: Present (1), absent (0)
170. Verrucate: Present (1), absent (0)
171. Scrobiculous: Present (1), absent (0)
- Seed coat elements**
172. Carbon: Present (1), absent (0)
173. Oxygen: Present (1), absent (0)
174. Magnesium: Present (1), absent (0)
175. Potassium: Present (1), absent (0)
176. Copper: Present (1), absent (0)
177. Zinc: Present (1), absent (0)
178. Chlorine: Present (1), absent (0)
179. Calcium: Present (1), absent (0)
180. Sodium: Present (1), absent (0)
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70. Obovate: Present (1), absent (0)
71. Oblong-elliptic: Present (1), absent (0)
72. Oblong-obovate: Present (1), absent (0)
73. Linear-oblong: Present (1), absent (0)
74. Linear-lanceolate: Present (1), absent (0)
75. Oblong-lanceolate: Present (1), absent (0)
- Petals**
- Size**
76. Length (mm)
77. Breadth (mm)
- Colour**
78. White: Present (1), absent (0)
79. Yellow: Present (1), absent (0)
80. Pinkish: Present (1), absent (0)
- Shape**
81. Linear: Present (1), absent (0)
82. Oblong: Present (1), absent (0)
83. Lanceolate: Present (1), absent (0)
84. Ovate: Present (1), absent (0)
85. Broadly ovate: Present (1), absent (0)
86. Elliptic: Present (1), absent (0)
87. Obovate: Present (1), absent (0)
88. Oblanceolate: Present (1), absent (0)
89. Spathulate: Present (1), absent (0)
90. Linear-oblong: Present (1), absent (0)
91. Obovate-elliptic: Present (1), absent (0)
92. Lanceolate-oblong: Present (1), absent (0)
93. Oblanceolate-spathulate: Present (1), absent (0)
94. Oblong-elliptic: Present (1), absent (0)
- Apex**
95. Acute: Present (1), absent (0)
96. Acuminate: Present (1), absent (0)
97. Obtuse: Present (1), absent (0)
98. Clawed: Present (1), absent (0)
99. Acute-obtuse: Present (1), absent (0)
- Base**
100. Cuneate: Present (1), absent (0)
101. Attenuate: Present (1), absent (0)
102. Truncate: Present (1), absent (0)
- Gynoecium**
103. Gynophore: Present (1), absent (0)
104. Hairs: Present (1), absent (0)
105. Carpel length (mm)
- Androecium**
106. Number of stamens
181. Silicon: Present (1), absent (0)
182. Aluminium: Present (1), absent (0)
183. Sulphur: Present (1), absent (0)
- Phenolic acids**
184. Sinapic acid: Present (1), absent (0)
185. p-coumaric acid: Present (1), absent (0)
186. 3, 4, 5, Trimethoxy cinnamic acid: Present (1), absent (0)
187. Aesculin: Present (1), absent (0)
- Flavonols**
188. Kaempferol: Present (1), absent (0)
189. Quercetin: Present (1), absent (0)
190. Azaleatin: Present (1), absent (0)
191. Gossypetin: Present (1), absent (0)
- Flavones**
192. Apigenin: Present (1), absent (0)
193. Luteolin: Present (1), absent (0)
194. Chrysoeriol: Present (1), absent (0)
- Glycosylflavones**
195. Isovitexin: Present (1), absent (0)
- Biflavonyl**
196. Kayaflavone: Present (1), absent (0)
- Quercetin glycosides**
197. 3- Arabinoside: Present (1), absent (0)
198. 3- Xyloside: Present (1), absent (0)
199. 3- Glucoside: Present (1), absent (0)
200. 3- galactoside: Present (1), absent (0)
201. 3- Rhamnoside: Present (1), absent (0)
202. 3- Glucuronide: Present (1), absent (0)
203. 3- Rutinoside: Present (1), absent (0)
204. 7- Glucoside: Present (1), absent (0)
205. 4'- Glucoside: Present (1), absent (0)
- Chalcones**
206. Isoliquiritigenin: Present (1), absent (0)
207. Isoliquiritigenin 4'- glucoside: Present (1), absent (0)
- Aurones**
208. Aureusidin: Present (1), absent (0)
209. Aureusidin 4- glucoside: Present (1), absent (0)
210. Aureusidin 6- glucoside: Present (1), absent (0)
- Flavonones**
211. Hesperitin: Present (1), absent (0)
212. Hesperidin: Present (1), absent (0)
213. Naringin: Present (1), absent (0)
- Isoflavones**
214. Daidzein: Present (1), absent (0)
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Table 2. Data matrix of the genus *Cleome* L. for characters presented in table 1.

Name of species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cleome ariana</i>	1	58.5	2	1	1	2	14.5	3	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	
<i>C. brachycarpa</i>	1	22.5	1	1	1	2	13	5	0	0	0	1	0	0	1	0	1	0	0	1	1	0	0	0	
<i>C. dolichostyla</i>	1	55	2	1	1	1	18.5	16	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	
<i>C. fimbriata</i>	1	30.5	2	1	1	1	12.5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
<i>C. karachiensis</i>	1	10.5	2	0	1	2	11	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>C. oxypetala</i>	1	50	2	1	0	1	20.5	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
<i>C. pakistanica</i>	2	90	2	1	1	1	4	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
<i>C. rupicola</i>	1	20	1	1	1	1	16	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>C. scaposa</i>	1	22.5	2	1	1	1	10.5	13	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	
<i>C. spinosa</i>	1	90	2	1	1	2	55.5	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>C. viscosa</i>	1	50	2	1	1	2	23	10	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	0	
Name of species	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	
<i>Cleome ariana</i>	0	0	0	0	0	0	0	1	1	1	0	0	1	2	1	0	0	0	1	0	0	0	0	0	0
<i>C. brachycarpa</i>	0	0	0	0	0	0	0	1	1	0	0	0	1	2	1	0	0	0	1	0	0	0	0	0	0
<i>C. dolichostyla</i>	0	0	0	0	0	1	1	0	0	0	0	1	1	2	0	0	1	0	0	0	1	0	0	0	0
<i>C. fimbriata</i>	0	0	0	0	0	0	0	1	1	1	0	0	1	2	0	0	0	1	0	0	0	1	0	0	0
<i>C. karachiensis</i>	1	0	0	0	0	0	0	0	1	0	0	0	1	2	1	0	0	0	0	1	0	0	0	0	0
<i>C. oxypetala</i>	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. pakistanica</i>	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0
<i>C. rupicola</i>	0	0	1	1	0	0	0	0	1	0	0	0	1	2	1	0	0	0	1	0	0	0	0	0	0
<i>C. scaposa</i>	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0
<i>C. spinosa</i>	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1
<i>C. viscosa</i>	0	0	0	0	0	0	0	1	1	0	1	0	1	2	0	1	0	0	0	1	0	0	0	0	0
Name of species	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	
<i>Cleome ariana</i>	7.6	3.01	1	0	0	0	0	1	0	0	0	1	4	1.5	0.4	0	0	0	0	1	1	0	1	0	
<i>C. brachycarpa</i>	20	8.43	0	1	0	0	0	1	0	0	0	1	10	2.8	1.3	1	1	0	1	0	1	0	1	0	
<i>C. dolichostyla</i>	18	10.1	0	0	1	0	0	0	1	0	1	0	6.5	4	1.3	1	0	0	0	0	0	0	1	0	
<i>C. fimbriata</i>	8.3	4.15	0	0	1	0	0	0	1	1	0	0	6	3.5	1.8	1	1	1	0	0	0	0	0	0	
<i>C. karachiensis</i>	6.9	1.42	0	0	1	0	0	0	1	1	0	0	6.5	3	0.8	1	0	0	0	0	0	0	0	1	
<i>C. oxypetala</i>	13	5.87	0	0	1	0	0	1	0	0	1	0	10	1.5	0.5	1	1	0	0	0	0	0	0	0	
<i>C. pakistanica</i>	6.7	3.88	0	0	1	0	1	0	0	0	1	0	5	1.5	0.5	0	1	0	0	0	0	0	0	0	
<i>C. rupicola</i>	15	8.05	0	0	0	1	0	0	1	0	1	0	6.5	1.5	0.5	1	0	0	0	0	0	0	0	0	
<i>C. scaposa</i>	14	4.47	0	0	0	1	0	0	1	0	1	0	3.5	1.8	0.5	1	0	1	0	0	0	0	0	0	
<i>C. spinosa</i>	11	4.4	0	0	0	1	0	0	1	0	1	0	25	6	3	1	0	0	0	0	0	0	0	0	
<i>C. viscosa</i>	8.1	2.34	0	0	0	1	0	0	1	1	0	0	11	5	1.5	1	0	0	1	0	0	0	0	0	

Table 2. (Cont'd.).

Name of species	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	
<i>Cleome ariana</i>	0	0	0	2.25	0.35	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
<i>C. brachycarpa</i>	0	0	0	5	2	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
<i>C. dolichostyla</i>	0	0	0	7	1.5	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
<i>C. fimbriata</i>	0	0	0	7	2	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. karachiensis</i>	0	0	0	4.25	1.75	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>C. oxypetala</i>	0	0	0	7	1.5	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>C. pakistanica</i>	0	0	0	2.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>C. rupicola</i>	1	0	0	4.5	2.25	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>C. scaposa</i>	0	0	0	4	1.5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>C. spinosa</i>	0	1	0	1.5	10	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>C. viscosa</i>	1	0	1	8	2	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0
Name of species	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
<i>Cleome ariana</i>	1	0	0	0	1	0	1	0	1.25	6	14.5	1	1	0	0	1.2	1	0	1	1	0	0	0	0	
<i>C. brachycarpa</i>	1	0	0	1	0	0	0	1	2.5	6	7.5	1.75	0	1	0	0.82	0.82	0	0	0	1	0	0	0	0
<i>C. dolichostyla</i>	0	0	0	0	0	1	0	1	10	4	22	3.5	1	1	0	0.93	0.88	1	1	0	0	0	0	0	0
<i>C. fimbriata</i>	1	0	0	0	1	0	0	1	-	4	21	2.5	0	1	0	0.8	0.5	0	0	0	0	0	0	0	0
<i>C. karachiensis</i>	1	0	0	1	1	0	0	1	4.0	7	19.5	1.5	1	0	0	1.16	1.05	0	1	0	0	0	0	0	0
<i>C. oxypetala</i>	0	0	0	0	1	0	0	0	4.0	6	62.5	4	1	0	0	2.33	2.17	0	0	0	0	0	0	0	1
<i>C. pakistanica</i>	1	0	0	0	0	1	0	1	5.0	6	30	1.5	1	0	0	1.5	1	1	0	0	0	0	0	0	0
<i>C. rupicola</i>	1	0	0	0	1	0	0	0	4.0	6	50	5	0	1	0	2.36	2.22	0	0	0	0	0	0	1	0
<i>C. scaposa</i>	1	0	1	0	1	0	0	0	2.5	6	21	1	1	0	0	0.73	0.71	0	0	0	0	0	0	0	0
<i>C. spinosa</i>	0	1	0	1	0	0	1	0	7.0	6	22.5	2.25	1	0	0	0.99	0.95	1	0	0	0	0	0	0	0
<i>C. viscosa</i>	0	0	0	0	1	0	0	1	5.5	16	58.5	3	1	0	1	1.6	1.2	0	0	0	1	1	0	0	0
Name of species	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	
<i>Cleome ariana</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. brachycarpa</i>	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0
<i>C. dolichostyla</i>	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
<i>C. fimbriata</i>	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0
<i>C. karachiensis</i>	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	0
<i>C. oxypetala</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>C. pakistanica</i>	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>C. rupicola</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. scaposa</i>	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
<i>C. spinosa</i>	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>C. viscosa</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0

Table 2. (Cont'd.).

Name of species	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	
<i>Cleome ariana</i>	1	0	0	1	14.5	14.05	12.9	10.4	2.64	2.05	0	0	1	0	0	0	0	1	0	0	1	0	0	0	
<i>C. brachycarpa</i>	0	0	0	0	25.7	17.15	21.9	8.55	5.71	2.21	1	0	0	0	0	0	0	0	1	0	0	0	0	1	
<i>C. dolichostyla</i>	0	0	0	0	28.1	20.15	25.5	13.2	6.82	2.81	1	0	0	0	0	0	1	0	0	0	0	1	0	0	
<i>C. fimbriata</i>	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>C. karachiensis</i>	0	0	0	0	15.6	12.07	12.5	6.76	4.13	1.95	0	1	0	0	0	1	0	0	0	0	0	0	0	0	
<i>C. oxypetala</i>	0	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>C. pakistanica</i>	0	0	0	1	19.5	17	16.6	13.3	4.13	2.8	1	0	0	1	0	0	0	0	0	0	1	0	0	0	
<i>C. rupicola</i>	0	1	0	0	15.3	9.57	12.9	5.28	2.45	1.59	1	0	0	1	0	0	0	0	0	0	0	0	0	0	
<i>C. scaposa</i>	0	0	0	0	13.4	10.39	11.42	7.11	4.25	1.94	0	1	0	0	1	0	0	0	0	1	0	0	1	0	
<i>C. spinosa</i>	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>C. viscosa</i>	0	0	0	0	22.5	19.1	19.6	15.33	6.37	2.66	0	1	0	0	0	0	0	0	0	1	1	0	0	0	
Name of species	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	
<i>Cleome ariana</i>	0	0	0	1	1	1	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
<i>C. brachycarpa</i>	0	0	0	1	1	1	1	0	0	0	1	0	0	0	1	1	1	0	0	1	0	0	0	0	0
<i>C. dolichostyla</i>	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
<i>C. fimbriata</i>	-	-	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. karachiensis</i>	0	1	0	1	1	1	1	1	0	0	1	0	0	1	0	0	0	0	0	0	1	1	1	1	1
<i>C. oxypetala</i>	-	-	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. pakistanica</i>	0	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. rupicola</i>	1	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
<i>C. scaposa</i>	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. spinosa</i>	-	-	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. viscosa</i>	0	0	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0
Name of species	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214			
<i>Cleome ariana</i>	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	
<i>C. brachycarpa</i>	0	0	1	0	1	0	1	0	1	0	1	1	1	1	1	1	0	1	1	0	1	0	1	0	0
<i>C. dolichostyla</i>	0	0	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>C. fimbriata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. karachiensis</i>	0	0	0	1	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. oxypetala</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. pakistanica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. rupicola</i>	0	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>C. scaposa</i>	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. spinosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>C. viscosa</i>	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0

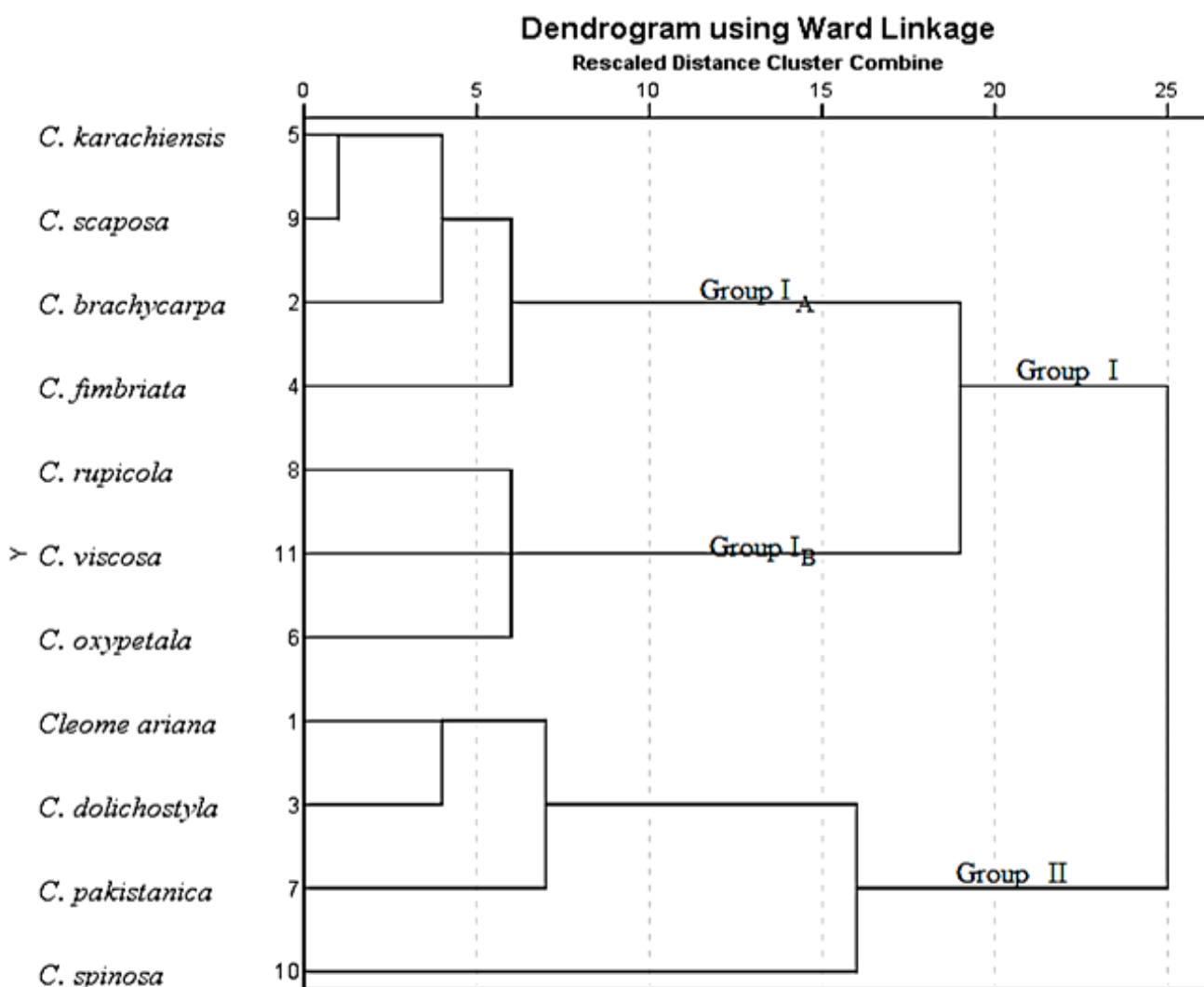


Fig. 1. Dendrogram showing the relationship of the species of the genus *Cleome* L.

Group-I is further splitted into two distinct clads viz., I_A and I_B. In clad I_A, *C. karachiensis*, *C. scaposa*, *C. brachycarpa* and *C. fimbriata* are grouped together due to comparatively smaller size of capsules and seeds. Amongst these taxa, *C. fimbriata* remained separate from other species by having 4 stamens (Jafri, 1973), mustard brown and pusticulate seeds, and absence of magnesium and potassium in seed coat (Riaz & Abid, 2018). While, *C. karachiensis*, *C. brachycarpa* and *C. scaposa* formed a common cluster due to the presence of 6 or more stamens and also having magnesium and potassium in seed coat. Furthermore, *C. karachiensis* and *C. scaposa* were coupled together by having subprolate pollen and more or less similar size of pollen grains, colpus, apocolpium, exine thickness and presence of azaleatin in leaves (Sana, 2018). Although *C. karachiensis* had morphological affinities with *C. viscosa* and *C. brachycarpa* but *C. karachiensis* remained distinct from *C. scaposa* due to compound leaves, actinocytic stomata, retortiform, concentrically ridged, foveate with appressedly colliculate seeds. *C. scaposa* is characterized by simple leaves (Hedge & Lamond, 1970), anomocytic stomata, reniform and alveolate seeds. On the other hand, *C. brachycarpa* fell separately and remained distinct from *C. karachiensis* and *C. scaposa* probably due to the presence of prolate

pollen, with larger colpus, apocolpium and absence of azaleatin in the leaves.

Group-I_B comprised of three species viz., *C. rupicola*, *C. viscosa* and *C. oxypetala*. These three species are linked together due to comparatively larger size of capsules and seeds. While, the close affinities of *C. rupicola* with *C. oxypetala* were earlier reported by Jafri (1973) on the basis of similar flower and capsule. The remaining species i.e., *C. viscosa* stands distinct from both of the species by having capitate trichome head all over the leaf surface (Riaz *et al.*, 2019), distinct petals and seed shapes.

Group-II comprised of *C. ariana* Hedge & Lamond, *C. dolichostyla* Jafri, *C. pakistanica* (Jafri) S. Khatoun & A. Perveen and *C. spinosa* Jacq. Amongst them *C. spinosa* fell separately and characterized by the presence of spiny stipules at the base of leaves, larger leaves and flowers (Gleason & Cronquist, 1963). While the remaining taxa viz., *C. ariana*, *C. dolichostyla* and *C. pakistanica* formed common cluster due to the presence of smaller leaves and flowers and absence of spiny stipules. Among these three species *C. pakistanica* could be separated from rest of the two species due to taller height, undershrub habit and presence of silicon in seed coats (Riaz & Abid, 2018). While, *C. ariana* and *C.*

dolichostyla were coupled together by having more or less similar plant height, herbaceous habit and absence of silicon in seed coats. While, both the species could be separated by having compound leaves and 6 stamens in *C. ariana* (Hedge & Lamond, 1970; Raghavan, 1993) and *C. dolichostyla* is characterized by the presence of simple leaves and 4 stamens (Jafri, 1957).

It is noteworthy that the conclusions obtained by numerical data did not support the close affiliation of species based on gross morphological data and the present findings could be supported with the suggestion of Stearn (1968) and Cronquist (1964) that numerical analysis represented the synthetic approach which could not always be correlated with subjective findings.

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