Numerical analysis study on some taxa of Caesalpinoideae and Mimosoideae

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ABSTRACT

A traditional of eighty-nine characters recorded comparatively representing nineteen taxa of Fabaceae (Leguminosae); eleven taxa belong to three genera of Caesalpinoideae and eight taxa to four genera of Mimosoideae. The characters drawn from vegetative and floral features, in addition to description for the sculpture patterns of the pollen grains and seed coat by using scanning electron microscope (SEM) of the examined taxa. Data matrix subjected to numerical analysis using statistical programs PRIMER (software, version 6.0) and PC-ord version 5 for windows. The dendrograms obtained from this analysis split the examined taxa into two major clusters: the 1st cluster contains representative taxa of the Caesalpinoideae, while the 2nd one includes the representative taxa of the Mimosoideae. The results also agreed with the previous study, which gathered genus *Senna,* and *Cassia* within tribe Cassieae (subtribe Cassiinae); genus *Dichrostachys* and *Prsopis* within tribe Mimoseae and *Albizia lebbeck* and *Calliandra haematocephala* within tribe Ingeae. While separated genus *Ceratonia siliqua* in different group within tribe Cassieae (subtribe Ceratoniinae).

Keywords: Caesalpinoideae; Mimosoideae; Morphology; SEM; Numerical analysis.

INTRODUCTION

Numerical taxonomy, also termed as morphometries deals with grouping by numerical methods of taxonomic units into taxa based on their character state (Sneath and Sokal, 1973). Cluster analysis and principal component analysis are two techniques commonly used in numerical classification. Cluster analysis produces a hierarchical classification of entities (taxa) based on the distance and similarity matrix. It thus provides a logical means of expressing the relationship existing between taxa. Numerical taxonomic studies are important for discovering and documenting new morphological character and character states, and many attempts have been made in this regard for understanding phenetic relationships in different groups of plants (Pinheiro and de Barros, 2007; Mulumba and Kakudidi, 2010; Deshmukh, 2011; Rahman & Rahman, 2012, El-Gazzar *et al*., 2013 and ChenWen-qing 2020).

Caesalpinoideae and Mimosoideae belong to the family Fabaceae (Leguminosae) that is morphologically, physiologically and ecologically very diverse, representing one of the most amazing patterns of evolutionary variation in plants. All these characteristics have led to a continuous attraction with the diversity and evolution of the family in order to discover the relationships among the different lineages of the family.

Caesalpinoideae divided into seven to nine tribes based on number of characters, including leaves nature and flower characters, while separated into eight tribes according to Hutchinson (1967). Later Caesalpinoideae include only four tribes; Cassieae, Caesalpinieae, Detarieae and Cercideae as a result of phylogenetic studies by (Bruneau *et al.* 2008).

Brown (2008), classified Mimosoideae into four tribes; Acacieae, Ingeae, Mimoseae and Mimozygantheae, while Bentham (1875) and Elias (1981) into five tribes and Hutchinson (1964) into six tribes. Some recent morphological and molecular data sets by (Chappill 1995; Käss & Wink 1996; Dayanandan *et al.* 1997; Lavin *et al.* 2005) have supported the monophyly of the Mimosoideae characterized by regular actinomorphic flowers with valvate petals often fused at the base and compound pollen with porate apertures (Guinet 1981).

Brenan (1963) placed the Mimosoideae as the oldest taxon in legumes while, Hutchinson (1973) and Cornquist (1981) placed it between Caesalpinoideae and Papilionoideae. However, Elias (1981) suggested that the Mimosoideae more closely linked to the Caesalpinoideae than to the Papilionoideae based on seed morphology, which had supported by the findings of Corner (1951) and El-Gazzar & El-Fiki (1976).

The distinction between taxa in the Caesalpinoideae and Mimosoideae is not well define and further phylogenetic analysis is required to clarify this boundary (Luckow 2005).

Caesalpinoideae are tree, shrubs rarely herbs. Leaves pinnate, rarely bipinnate. Flowers irregular; sepals usually imbricate, free or less often partly united; petals 5 or fewer imbricate in bud free or some united; stamen usually 10, or fewer. It consists of about 180 genera and 2500-3000 species (Heywood, 1993) worldwide. This subfamily represented by three genera and six species only in Egypt according to Boulos (1999 & 2009).

Mimosoideae trees and shrubs, rarely herbs. Often prickly or spiny, erect branched stem and woody. Leaves evergreen or deciduous, alternate, simple, compound or absent. Flowers regular; sepals gamosepalous really free, valvate or imbricate; petal polypetalous or gamopetalous; androecium 10-∞. It comprised about 64 genera and 2950 species in the world. Represented by five genera and fourteen species in Egypt according to Boulos (1999 & 2009).

The objective of this study is to understanding the phenetic relationships between some taxa of Caesalpinoideae and Mimosoideae.

MATERIALS AND METHODS

Plant Materials

Fresh plant materials collected from different sites in Egypt, in addition to Herbarium specimens kept in the Faculty of Science Herbarium, Cairo University (CAIM), for the nineteen taxa; eleven related to three genera of Caesalpinoideae and eight to four genera of Mimosoideae (Table 1). Confirmed identification for the collecting plants based on (Tãckholm 1974, Davis 1975, Polhill & Raven 1981, Zohary 1987, Boulos 1999 & 2009, and APG IV 2016).

Characters investigation:

Appendix 1 shows the characters and character states scored for vegetative and floral features of the examined taxa using light microscopic; in addition to description for the sculpture patterns of the seeds coat and pollen grains using scanning electron microscopy (SEM).

Data Analysis:

A set of eighty-nine characters comprising three quantitative multistate characters and eighty-six qualitative characters (forty-five scored as binary and forty-one as multi-state characters) recorded comparatively for the nineteen taxa belonging to seven genera of the Caesalpinoideae and Mimosoideae as in data matrix (Appendix 1). The data matrix (Appendix1) was subjected to cluster analysis using statistical programs PRIMER software, version 6(used the Bray Curtis similarity) and PC-ord version 5(Sorensen's Bray Curtis distance)

RESULTS AND DISCUSSION

Three dendrograms (Fig.A, B and C) as a result of using statistical programs PRIMER software, version 6(used the Bray Curtis similarity) and PC-ord version 5(Sorensen's Bray Curtis distance) are similar to each other.

By using PRIMER version 6 (Bray Curtis with group average Clustering method measure similarity present), all taxa in (Fig. A) were split into two main clusters. The 1st cluster includes eleven taxa representative Caesalpinoideae and divided to three sub-clusters. The first one includes five taxa, *Cassia fistula* and *Cassia javanica* subsp. *nodosa* were the first two taxa linked together at similarity level (95). The next two taxa linked at similarity level (93) were *Senna didymobotrya* and *Senna occidentalis*, which both taxa linked with *Senna surattensis* at similarity, level (91). Finally, these three taxa of genus *Senna* linked with the first two taxa of genus *Cassia* at similarity level (86). The second sub-cluster includes also five taxa linked together at different levels of similarity. The first two taxa linked together at (95) similarity level were *Delonix elata* and *Delonix regia*, while both species *Caesalpinia sappan* and *Peltophorum pterocarpum* linked at (92) similarity level. Finally, the taxa *Caesalpinia gilliesii* linked with the previous four taxa at level (87). The third sub-cluster includes only one taxa; *Ceratonia siliqua* which linked with the previous ten taxa at similarity level (88).

The 2nd main cluster which representative taxa of the Mimosoideae split into two sub-clusters, the first one includes six taxa; *Acacia nilotica* subsp. *nilotica* and *Acacia farnesiana* were the first two taxa linked together at similarity level (94), then *Leucaena leucocephala* linked with them at (89), while *Acacia saligna* joined these three taxa at (86.5). On the hand, *Albizia lebbeck* and *Calliandra haematocephala* linked together first at similarity level (93). The second sub-cluster includes two taxa; *Dichrostachys cinerea* and *Prsopis juliflora*, which linked together at similarity level (86), then linked with the previous six taxa at similarity level (84).Finally, the two main clusters; the one with Caesalpinoideae taxa and the other with the Mimosoideae taxa were linked

together at (80) similarity level because all belongs to Fabaceae family. This indicates that these taxa were forcefully related on the bases of vegetative and floral morphological features, in addition to the pollen grains and seeds coat characters obtained from using scanning electron microscopy. In addition, the analysis agreed in the creation of two major groupings of taxa; one representative Caesalpinoideae and the other representative taxa of the Mimosoideae.

This result agreed with Irwin and Barneby (1982), Miller *et al*. (2003), Luckow (2005), Murphy (2008) and Fawzi *et al.* (2015) for gathered *Senna* and *Cassia* taxa within tribe Cassieae (subtribe Cassiinae), separation of *Ceratonia siliqua* in a separate group subtribe Ceratoniinae. *Dichrostachys* and *Prsopis* taxa gathered within tribe Mimoseae and also *Albizia lebbeck* and *Calliandra haematocephala* grouped within the tribe Ingeae.

CONCLUSION

The combined analysis of vegetative and floral features in addition to characters of pollen grains and seed coat by using of light (L.M) and scanning electron microscope (SEM) resulted in a higher degree of confirmation in the taxa of Caesalpinoideae and Mimosoideae.

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Table 1: Classification, Scientific names and collection data for the examined taxa of Caesalpinoideae according to Irwin and Barneby (1982) {*Cultivated - **Herbarium}

	Subfamily	Tribe	Subtribe	Taxa	Collection data
1	Caesalpinoideae	Cassieae	Cassiinae	**Cassia fistula* L.	Al- Azhar University, Cairo, 24/7/2019.
2				**Cassia javanica* L. subsp. *nodosa* (Roxb) K. & S. Larsen	Al- Azhar University Cairo, 22/5/2019
3				**Senna surattensis* (Burm.f.)	Al-Azhar University Cairo and Al-Orman garden, 5/7/2019
4				**Senna didymobotrya* (Fresen.)	Garden of Ain Shams, 24/3/2019.
5				**Senna occidentalis* (L.) Link.	Nasr City – Cairo, 24/4/2019.
6			Ceratoniinae	**Ceratonia siliqua* L.	Al- Azhar University Cairo, Garden faculty of Agriculture, 12/3/2019
7		Caesalpinieae		**Caesalpinia gilliesii* (Hook.)	EL-Shrouk City-Cairo,18/3/2019
8				**Caesalpinia sappan* L.	Garden of Ain Shams, 15/6/2019.
9				**Peltophorum pterocarpum* (DC.)	Nasr City – Cairo, 15/6/2019.
10				***Delonix elata* (L.) Gamble.	Cairo university Herbarium (CAI); Gabel Elba 20-5-1998 by Ibrahim EL-Garf.
11				**Delonix regia* (Bojer.) Raf.	Nasr City –Cairo, Al- Azhar University Cairo, 4/6/2019.

Classification, Scientific names and collection data for the examined taxa of Mimosoideae according to (Luckow 2005) {*Cultivated}.

	Subfamily	Tribe	Taxa	Collection data
1	Mimosoideae	Acacieae	**Leucaena leucocephala*	Nasr City –Cairo, 5/4/2019.
2			**Acacia farnesiana* (L.) Willd	Nasr City –Cairo, 20/5/2019 and AL- menoufia 15/8/2019.
3			**Acacia nilotica* (L.) Delile subsp. *nilotica*	Nasr City –Cairo, 9/8/2019 and AL- menoufia 15/5/2019.
4			**Acacia saligna* (Labill.) H. L. Wendl.	Al- Azhar University Cairo 22/4/219 and Cairo-Alexandria road, 100Km, 25/4/2019.
5		Ingeae	**Calliandra haematocephala* Hassk	Al-Azhar University, Cairo and AL-Orman garden, 20/7/2019.
6			**Albizia lebbeck* (L.) Benth.	Al-Azhar University, Cairo faculty of Agriculture Garden and AL-Menoufia, 15/8/2019.
7		Mimoseae	**Dichrostachys cinerea* (L.) Wight. & Arn.	AL-Orman garden, 22/3/2019.
8			**Prsopis juliflora* (Swartz.) DC.	Nasr City – Cairo, 15/7/2020.

Appendix 1 : List of characters for numerical analysis of the studied taxa of Caesalpinoideae and Mimosoideae.			
Habit			1-Tree [1] / shrub [2] / subshrub [3]
Plant			2- Dioecious [1] / monecious [2].
Leaf	Type		3- Simple [1]/ compound [2].
	Base		4- Ex stipulate [1]/ pulvinus [2].
	Petiole	Nature	5- Sessile [1] / petiolate [2].
		Texture	6- Glabrous [1] / / hairy [2] / absent [3].
		Inter petiolar gland	7 - Present [1] / absent [2].
	Blade	Type	8- Simple [1]/ paripinnate [2]/ Bipinnate [3].
		Shape	9- Oblong [1] / oblong rhomboid [2] / ovate [3] / elliptic [4] / cordate [5]/ lanceolate [6].
		Apex	10- Obtuse [1] / acute [2]/ acuminate [3]/ mucronate [4]/ emarginated [5]/ retuse [6].
		Margin	11- Entire [1] / undulate [2].
		Nature	12- Coriaceous [1] / papery [2].
		Black glands	13- Present [1]/ absent [2].
		Gland shape	14- Papillae [1] / discoid [2] / absent [3].
Rachis		Stipuleus	15- Present [1] / absent [2].
		Pinna arrangement	16- Alternate [1]/ opposite [2].
		Inter foliar glands	17- Present [1] / absent [2].
Inflorescence			18- Terminal[1]/ axillary racemes[2]
			19- Head [1]/ spike [2]/ corymb [3]/ catkin [4]/ simple raceme [5].
Flower		Flower	20- Complete [1]/ incomplete [2].
		Nature	21- Sessile [1]/ Pedicellate [2] / the central one is sessile and external one is pedicellate (mixed) [3].
		Type	22- Unisexual [1] / hermaphrodite [2]/ upper part of spike with hermaphrodite (yellow) flower and the lower sterile (muve) flower [3].
		Hypanthium	23- Present [1] / absent [2].
Bract			24- Bracteates [1] / ebracteate [2].
Calyx	Sepals	Sepals	25- Polysepalous [1]/ gamosepalous [2].
		Texture	26- Glabrous [1]/ sparsely hairy [2]/ hairy [3]/ hairy with conspicuous gland [4].
		Shape	27- Obovate [1] / ovate [2]/ oblong to elliptic [3]/ oblong [4] /elliptic [5].
		Apex	28- Obtuse [1]/ acute [2]/ acuminate [3]/ praemorse [4]
		Aestivation	29-Valvate [1]/ imbricate [2]
Corolla		Petal	30- Present [1] / absent [2].
		Color	31- Monochrome [1]/ dichrome [2]/ polychrome [3]/ absent [4].
			32- Yellow[1]/ pink [2]/ red [3]/ light green [4]/ off white[5]/ absent [6].
		Petal	33- Gamopetalous [1] /polypetalous [2] / absent [3].
		Aestivation	34- Valvate [1]/ascending imbricate [2]/ absent [3].
		Petal claw	35- with claw [1] / without claw [2]/ absent [3]
		Texture	36- Glabrous [1] /hairy [2]/ absent [3].
Androecium		Androecium	37- Homogenous [1]/ heterogeneous [2].
		Cohesion	38- Monadelphous [1]/ polyandrous [2].
		Number of Stamen	39- Five [1]/ ten [2]/ numerous(α) stamens [3]
		Length of stamen	40- Inserted [1] / exerted [2]
		Staminode	41- Present [1] / absent [2].

Anther	Shape	42- Oblong [1] / linear [2] / elliptic [3]
	Anther lobes	43- Equal [1] / unequal [2].
	Attachment.	44- Basifixed [1] / dorsifixed [2] / versatile [3]/ adnate [4].
	Apical gland	45- Present [1] /absent [2].
Pollen	Shape	46- Prolate [1]/ (sub prolate) [2]/ per-prolate [3]/ suboblate [4].
	Class	47- Tricolporate [1]/ tetracoloporate [2]/ polyade [3].
	Pollen size	48- Small (0.8-1.1um) [1]/ medium (1.2-1.5um) [2]/ large (1.6-1.8)[3]/ very large (2-4.2um) [4].
	Pollen units	49- 3 units[1] / 4 units[2]/ 10 units[3]/ 16 units[4]/ 32 units[5].
	Out line in polar view (amb)	50- Circular [1]/ convex triangular [2]/ straight triangular [3]/ spheroidal quadrangular[4]/ ovoid [5]
		51-1- Angulaperturate[1]/ planaperturate[2].
	Outline in equatorial view	52- Elliptic [1]/ oblong [2]/ circular [3].
	Aperture type (colpi)	53- Zonocolpate [1]/ syncolpate [2]/ absent [3].
	Colpus shape	54- Linear [1]/ elliptic [2]/infolded [3]/ rectangular [4]/ absent [5].
	Margo	55- Present [1]/ absent [2].
	Bervicolporus	56- Present [1]/ absent [2].
	Costae	57-Present [1]/ absent [2].
	Ornamentation	58- Psilate[1]/ psilate- foveolate [2]/ perforate [3]/ reticulate[4]/ fossulate[5].
Gynoecium	Shape	59- Straight [1]/ curved [2]
	Gynophore	60- Present[1]/ absent [2]
Ovary	Shape	61- Ovate [1] / elliptic [2] / oblong [3]/ reniform [4]
	Texture	62- Glabrous [1] hairy [2].
Fruit	Type	63- Lomentum [1] / pod [2].
	Pod	64- Single [1] / cluster [2].
	Openness	65- Dehiscent [1] / indehiscent [2].
	Color	66- Yellowish brown [1] / black [2] / brown [3] / dark brown [4].
	Beak	67- Present [1] / absent [2].
	Shape	68- Straight [1]/ curved [2].
		69- Rhombic [1] / oblanceolate [2]/moniliform [3]/falcate [4]/fusiform [5].
	Transection:	70- Flattened [1] / cylindrical [2].
	Seed arrangement	71- Horizontal [1] / vertical [2].
	Septa	72- Papery [1] / gelatinous substance [2] / not so [3].
	Number of seeds	73- (1-2 seeds) [1] / (5-10 seeds) [2] / (11-30 seeds) [3] / more than 30 seeds [4].
	Fleshy sweet portion between the seed	74- Present [1] / absent [2].
Seed (LM)	Color	75-Monochrome [1]/dichrome (mottled) [2].
	Color	76- Brown [1]/dark brown [2]/ yellowish [3].
	Shape	77- Ovate [1]/ globose [2]/ obovate [3]/ oblong [4].
	Surface	78- Glossy [1] / dull [2].
	Hilum position	79-Terminal [1] / sub terminal [2].

	Line	80- Present [1]/ absent [2].
	Seed areolate	81- Present [1]/ absent [2].
	Pleurogram shape	82- U-shaped [1]/ horseshoe shaped [2]/ oblong [3]/ elliptic [4]/ absent [5].
	Pleurogram openness	83- Opened [1]/ closed [2]/ absent [3].
	Funicle	84- Present [1]/ absent [2].
Seed (SEM)	Fracture line	85-Present [1]/ absent [2].
		86- Thin [1]/ thick [2]/ very thick [3]/ absent [4].
		87- Regular [1]/ irregular [2]/ absent [3].
		88- Continuous [1]/ discontinuous [2]/ absent [3].
	Ornamentation	89-Reticulate [1]/reticulate-foveate [2]/ favulariate [3]/ rugose [4]/ ruminate [5]/ psilate [6]/ fossulate [7]/ scalariform [8].

Appendix 2 : Data matrix of morphological characters listed in Appendix 1.

No. of character / Taxa	*Cassia fistula*	*Cassia javanica* subsp. *Nodosa*	*Caesalpinia gilliesii*	*Caesalpinia sappan*	*Ceratonia siliqua*	*Delonix elata*	*Delonix regia*	*Peltophorum pterocarpum*	*Senna didymobotrya*	*Senna occidentalis*	*Senna surattensis*	*Leucaena leucocephala*	*Acacia farnesiana*	*Acacia nilotica* subsp. *nilotica*	*Acacia saligna*	*Calliandra haematocephala*	*Albizia lebbeck*	*Dichrostachys cinerea*	*Prosopis juliflora*
1	1	1	2	2	1	1	1	1	2	3	2	1	1	1	1	2	1	2	1
2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2	1
5	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
6	1	1	2	1	1	1	1	2	2	1	2	1	2	2	3	1	1	2	2
7	2	2	2	2	2	2	2	2	2	1	2	1	1	1	2	2	1	2	2
8	2	3	2	3	2	3	3	3	2	2	2	3	3	3	1	3	3	3	3
9	3	4	1	2	5	1	1	2	4	4	1	4	1	1	6	4	1	4	1
10	2	2	1	6	5	2	1	1	4	3	6	3	1	1	1	2	2	3	6
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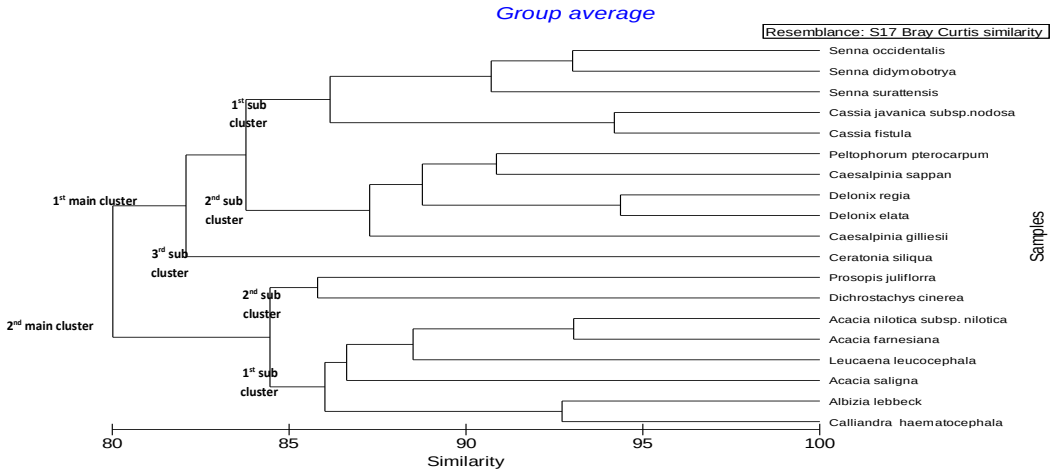

Figure A: Dendrogram using Bray Curtis with group average Clustering method measure similarity. (Primer program)

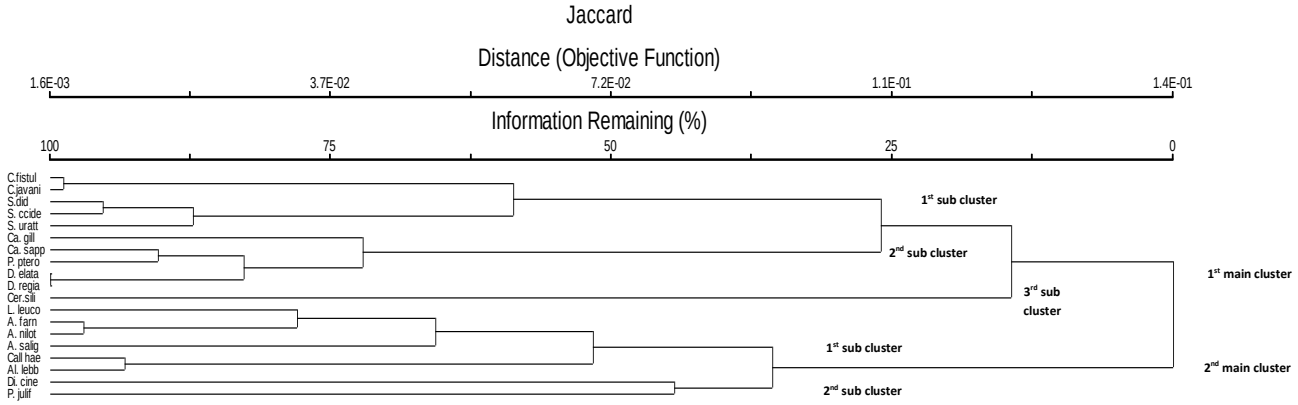

Figure B: Dendrogram illustrating the hierarchical classification of 19 taxa of Caesalpinoideae and Mimosoideae based on 89 characters listed in (Appendix1) and analyzed under Jaccard distance as measure of similarity and group average method of clustering; the % chaining is 9.35. (PC-ord program)

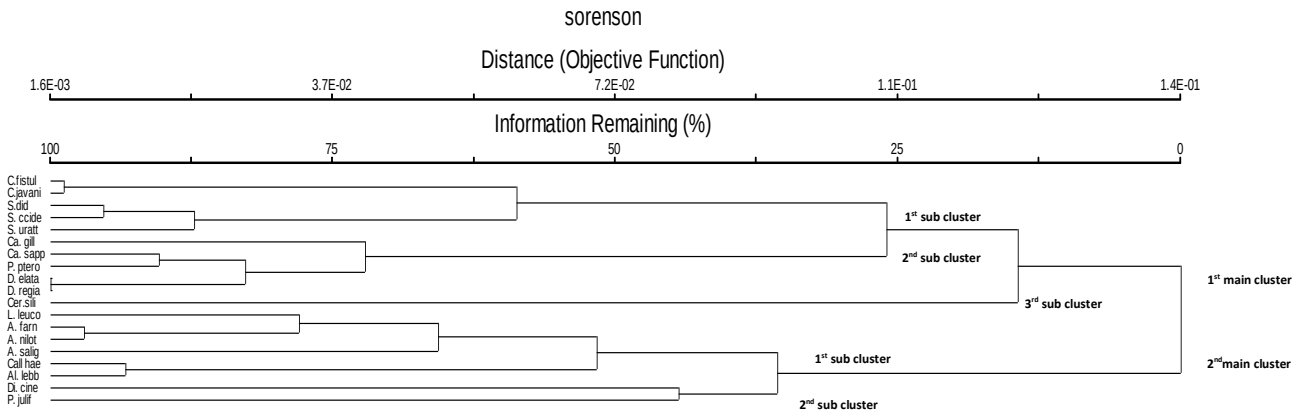

Figure C: Dendrogram illustrating the hierarchical classification of 19 taxa of Caesalpinoideae and Mimosoideae based on 89 characters listed in (Appendix 1) and analyzed under Sorensen (Bray Curtis) distance measure and group average method of clustering; the % chaining is 9.35

(PC-ord program)

دراسة التحليل العددي لبعض وحدات المنتمية للبقمية والطلحية

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الملخص العـربي

اشتمل هذا البحث على دراسة تصنيفية لعدد تسعة عشر وحدة تصنيفية لتحت الفصيلة البقمية والطلحية التابعة للفصيلة القرنية بواسطة استخدام التحليل العددي معتمدا على ٨٩ صفة مورفولوجية، احدى عشر وحدة تصنيفية تنتمي لثلاثة اجناس من تحت الفصيلة البقمية وثمان وحدات تنتمي الى أربعة اجناس من تحت الفصيلة الطلحية. هذا وقد استخلصت النتائج من الصفات الخضرية والزهرية بالإضافة الى فحص أنماط الزخرفة السطحية لكل من حبوب اللقاح والبذور وذلك باستخدام الميكروسكوب الإلكتروني الماسح. وأخضعت هذه الصفات للتحليل العددي بواسطة استخدام برمجيات الحاسب الآلي للبرنامجين [Pc-ord version 0.5 and Primer version 0.6] لتقيم نسبة التشابه والحصول على شجرة العلاقات dendrogramللأنواع قيد الدراسة. وقد رصدت نتائج التحليل العددي وشجرة العلاقات dendrogram قسمت الانواع المدروسة الى قسمين رئيسين: القسم الأول اشتمل على انواع تحت الفصيلة البقمية واشتمل القسم الثاني على انواع تحت الفصيلة الطلحية وقد اتفقت نتائج الدراسة مع نتائج الدراسات السابقة حيث جمعت كل من جنس *Cassia* and *Senna*, ضمن رتبة; (Cassieae (subtribe Cassiinae ..Mimoseae ضمن رتبة *Dichrostachys* and *Prsopis*وكذلك .Ingeae رتبة ضمن*Albizia lebbeck* and *Calliandra haematocephala* وأيضا بينما فصلت *Ceratonia siliqua* في مجموعة مختلفة ضمن رتبة Cassieae (Ceratoniinae).

الكلمات الاسترشادية: البقمية,الطلحيه,مورفولوجي,الميكروسكوب الماسح الالكتروني, التحليل العددي.