

## Numerical Taxonomy of the Tribe Cassieae (Leguminosae: Caesalpinioideae) in Egypt

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### ABSTRACT

This study inspects the morphological variation and taxonomic relationships among 23 taxa of tribe Cassieae in Egypt, belonging to three genera *Ceratonia*, *Cassia* and *Senna*, using 59 morphological characters. The work is based on morphometric studies of fresh material and herbarium specimens as well as information from the literature. The purpose of the study was to get a better knowledge of the taxonomic status and conservation of Cassieae species in Egypt. The cluster analysis reveals three major clusters; the first contains the unique species *Ceratonia siliqua*, the second including *Cassia* species and the third including the *Senna* species. The data obtained from the cluster analysis are compared with the current taxonomic position of all studied taxa. Results attained from the present study showing the importance of numerical analysis for taxonomic relationships in the tribe Cassieae. Keys and phenogram are provided for all taxa studied.

**Key words:** *Ceratonia*, *Cassia*, *Senna*, Cassieae, Caesalpinioideae, Leguminosae, Cluster analysis, Numerical taxonomy and Morphological characters.

### Introduction

Tribe Cassieae (Leguminosae: Caesalpinioideae) was divided by (Irwin and Barneby, 1981) into five subtribes [Ceratoninae (monogeneric), Dialiinae (13 genera), Duparquetiinae (monogeneric), Cassiinae (3 genera) and Labicheinae (2 genera)]. The 20 genera of tribe Cassieae *sensu* (Irwin and Barneby, 1981) remained unchanged in (Polhill, 1994). In Egypt, the tribe Cassieae represented by 3 genera. Genus *Ceratonia* belonging to subtribe Ceratoninae and both of *Cassia* and *Senna* belonging to subtribe Cassiinae. The subtribe Cassiinae is the largest with 730-740 species. It includes *Cassia* L. *senso stricto*, *Senna* P. Mill. and *Chamaecrista* Moench. which were previously included in one genus *Cassia* L. *senso lato* but were separated into three genera by (Irwin and Barneby, 1981, 1982). This concept had found wide recognition (Randel, 1988, 1989,1990; Lock, 1988; Laxmikanta, *et al.*, 2011; George and Hussein, 2014).

The genus *Cassia* Linnaeus, Sp. Pl. 1: 376. 1753, nom. cons. consists of about 30 species in tropical regions (Wu *et al.*, 2010); five species were introduced as ornamental plants in Egypt. The genus *Senna* Miller, Gard. Dict. Abr., ed. 4. 1754 comprises of about 350 species and is distributed throughout the world (Marazzi *et al.*, 2006); 17 species; 4 wild and 13 introduced as ornamental plants in Egypt. Several species of *Cassia* and *Senna* are economically important and have medicinal properties as laxative, expectorant, antimalarial and anti-inflammatory (Ajagbonna and Mojiminiyi, 2001; Tona and Mesia, 2001). The genus *Ceratonia* Linnaeus, Sp. Pl. 2: 1026. 1753. was long considered monotypic, but a second species, *Ceratonia oreothauma*, was recorded in Oman and Somalia (Hillcoat, *et al.*, 1980). *Ceratonia siliqua* is native to the Mediterranean region and cultivated for its sweet fruits.

Numerical taxonomy is a classification system which deals with the grouping of taxonomic units by numerical technique based on their character states (Sneath and Sokal, 1973). Cluster analysis technique commonly used in numerical taxonomy to produce a hierarchical classification of entities based on the similarity matrix. It represents a logical means of expressing the relationships existing between taxonomic units. Numerical taxonomy received considerable attention for species relationships in different genera (Bolourian and Pakravan, 2011; Bello *et al.*, 2013). Many studies were carried out in different groups of Leguminosae, for example, *Cassia* (Deshmukh, 2011), *Desmodium* (Rahman and Rahman, 2012), Papilionoideae (El-Gazzar *et al.*, 2013), *Senna* (Rahman *et al.*, 2013), *Onobrychis* (Noori *et al.*, 2014). In this study, numeric taxonomic methods have been applied to classify 23 taxa belonging to tribe Cassieae, on the basis of morphological characters. The purpose was to get a wider understanding of the circumscription of the species that occur in the country.

### Materials and Methods

The present study was based on a sample of 23 taxa representing 3 genera of the tribe Cassieae in Egypt. The number of fresh and herbarium specimens of individual species being represented by five to ten specimens

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each. The specimens are collected from some of the local botanic gardens (Orman, Agricultural Museum, Zohria and Aswan Gardens) and the major local herbarium CAIM of the Flora & Phyto-taxonomy Researches Department, Agricultural Research Center, Giza, as well as information from the literatures. Nomenclature of all taxa was updated according to the two major online websites (www.tropicos.org; www.theplantlist.org). The herbarium vouchers and fresh materials subjected to more detailed studies of the variation in several morphological parameters. Observations were made using a dissecting microscope on selection of morphological characters, such as the variation in size, shape, hairiness and colour in selected organs, e.g., leaves, flowers, pods and seeds. Keys to genera and species were prepared primarily using easily assessed characters. Full valid names of all studied taxa with their taxonomic position, as reported by (Irwin and Barneby, 1982), are presented in Table 1.

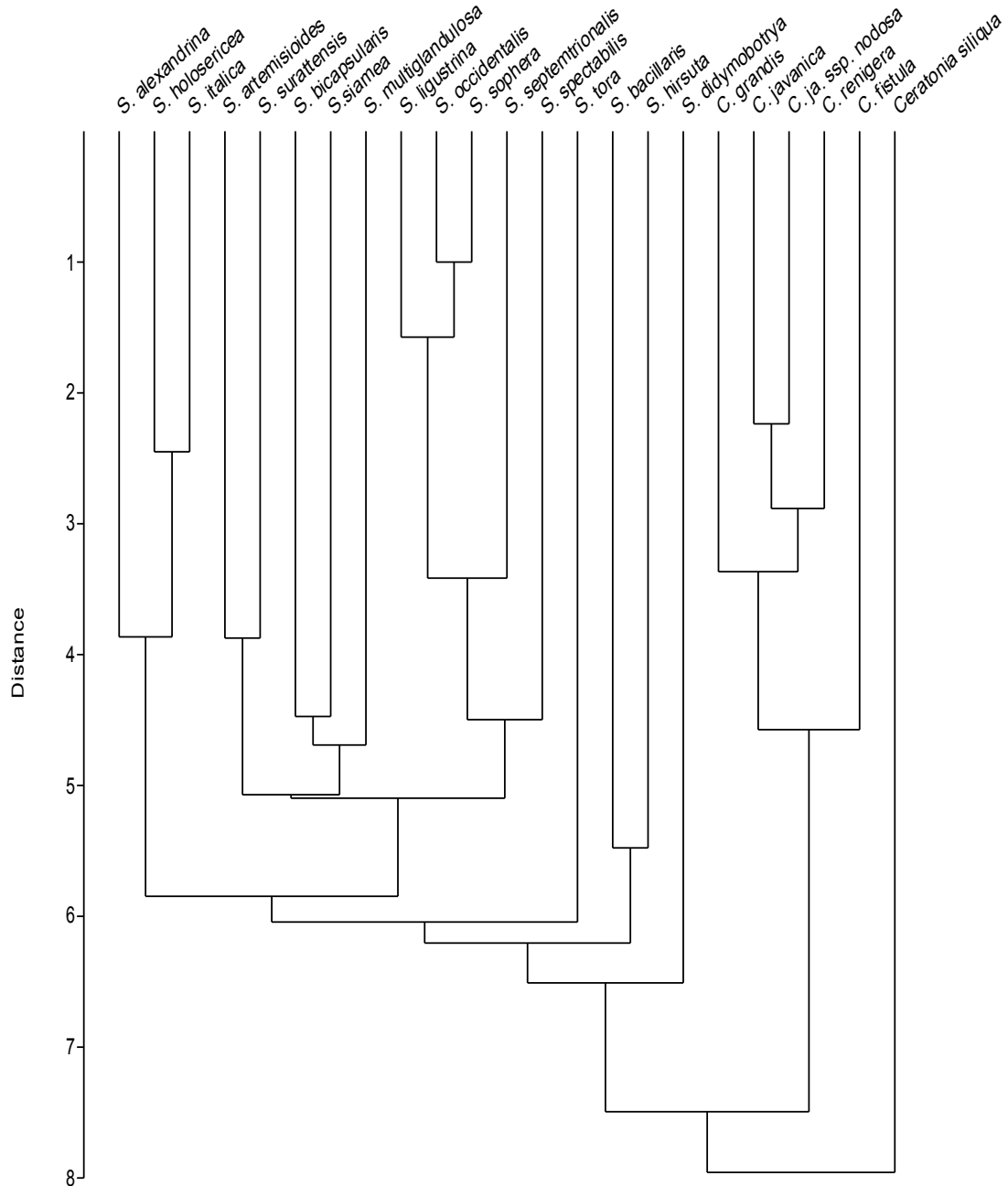
Fifty nine characters recorded comparatively for the studied taxa is given in Table 2. Characters and character states were determined through examination of both living and herbarium specimens and were coded as multistate characters. The data matrix was analysed using multistate matrix. The data matrix was subjected to cluster analysis using UPGMA (Unweighted pair group method with arithmetic mean) and a phenogram was constructed to show the relationship among the taxa. Morphological variation among the studied taxa based on squared euclidean distance was prepared in Table 3. All analyses were carried out using the program Past (Version 2.17c) (Hammer *et al.*, 2001).

**Table 1:** Full valid names of taxa with their taxonomic position, as reported by (Irwin and Barneby, 1982).

Subtribe	Genus	Section	Series	Taxa		
Cassiinae	<i>Cassia</i>		Cassia	<i>Cassia fistula</i> L., Sp. Pl. 1: 377–378 (1753). (= <i>Bactrylobium fistula</i> Willd.)		
			Grandes	<i>Cassia grandis</i> L.f., Suppl. Pl. 230 (1781 [1782]). (= <i>Cassia brasiliana</i> Lam.)		
						<i>Cassia javanica</i> L., Sp. Pl. 1: 379 (1753). (= <i>Cassia bacillus</i> Gaertn.)
						<i>Cassia javanica</i> L. subsp. <i>nodosa</i> (Roxb.) K. Larsen & S. S. Larsen, Nat. Hist. Bull. Siam Soc. 25(3–4): 205 (1974). (= <i>Cassia nodosa</i> Roxb.)
						<i>Cassia renigera</i> Benth., Trans. Linn. Soc. London 27: 518 (1871). (= <i>C. javanica</i> subsp. <i>renigera</i> (Wall. ex Benth.) K. Larsen
						<i>Senna surattensis</i> (Burm.f.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 81(1982). (= <i>Cassia galuca</i> Lam.; <i>C. surattensis</i> Burm.f., Fl.)
						<i>Senna artemisioides</i> (Gaudich. ex DC.) Isely ex DC., Native Natural. Legum. U.S. 44 (1998) subsp. <i>artemisioides</i> (= <i>Cassia artemisioides</i> Gaudich. ex DC.; <i>C. eremophila</i> Cunn. ex J. Vogel)
						<i>Senna bacillaris</i> (L.f.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 111 (1982). (= <i>Cassia bacillaris</i> L.f.)
						<i>Senna hirsuta</i> (L.) H.S.Irwin & Barneby, Phytologia 44(7): 499 (1979). (= <i>Cassia hirsuta</i> L.)
						<i>Senna ligustrina</i> (L.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 409 (1982). (= <i>Cassia ligustrina</i> L.)
						<i>Senna occidentalis</i> (L.) Link, Handbuch 2: 140 (1829). (= <i>Cassia occidentalis</i> L.; <i>C. planisiliqua</i> L.)
						<i>Senna sophera</i> (L.) Roxb., Fl. Ind. 2: 347 (1832). (= <i>Cassia sophera</i> L.)
						<i>Senna bicapsularis</i> (L.) Roxb., Fl. Ind. 2: 342 (1832). (= <i>Cassia bicapsularis</i> L.)
						<i>Senna multiglandulosa</i> (Jacq.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 357 (1982). (= <i>Cassia tomentosa</i> L.f.)
						<i>Senna septemtrionalis</i> (Viv.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 365 (1982). (= <i>Cassia laevigata</i> Willd.)
						<i>Senna siamea</i> (Lam.) H.S. Irwin & Barneby, Mem. New York Bot. Gard. 35: 98. 1982. (= <i>Cassia florida</i> Vahl; <i>C. siamea</i> Lam.)
						<i>Senna tora</i> (L.) Roxb., Fl. Ind. 2: 340 (1832). (= <i>Cassia tora</i> L.)
						<i>Senna didymobotrya</i> (Fresen.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 467 (1982). (= <i>Cassia didymobotrya</i> Fresen.)
						<i>Senna alexandrina</i> Mill., Gard. Dict. (ed. 8) no. 1 (1768). (= <i>Cassia acutifolia</i> Delile; <i>C. senna</i> L.)
						<i>Senna holosericea</i> (Fresen.) Greuter, Willdenowia 15(2): 429. 1986. (= <i>Cassia holosericea</i> Fresen.)
			<i>Senna italica</i> Miller, Gard. Dict. (ed. 8) no. 2 (1768). (= <i>Cassia italica</i> Mill; <i>C. obovata</i> Collad.)			
			<i>Senna spectabilis</i> (DC.) H.S.Irwin & Barneby, Mem. New York Bot. Gard. 35: 600 (1982). (= <i>Cassia spectabilis</i> Candolle)			
Ceratoniiinae	<i>Ceratonia</i>		Excelsae	<i>Ceratonia siliqua</i> L., Sp. Pl. 2: 1026 (1753).		

**Results and Discussion**

Numerical taxonomic studies are significant for documenting and discovering new morphological characters and character states, and many studies have been made in this regard for understanding taxonomic relationships in different groups of plants (Soladoye *et al.*, 2010; Deshmukh, 2011; Rahman and Rahman, 2012; El-Gazzar *et al.*, 2013). In the present study, 23 taxa were evaluated on the basis of data matrix generated from 59 characters by using numerical analysis. The complete data matrix for studied taxa including the characters and character states as well as its value for each taxa are listed in (Table 2). Numerical taxonomy of the studied taxa were determined according to the phenogram resulting from the UPGMA clustering (Fig. 1). The data obtained from the phenogram compared with the taxonomic position of all studied taxa as reported by (Irwin and Barneby, 1982) (Table 1).



**Fig. 1:** Phenogram showing the relationships within the tribe Cassieae in Egypt.

The resulted phenogram separated the studied taxa into three major groups; the first contains *Ceratonia siliqua*, the second includes *Cassia* species and the third includes the *Senna* species. The delimitation of

*Ceratonia siliqua* L. in a separate group from all studied taxa agrees with the exclusion of genus *Ceratonia* in the monogeneric subtribe Ceratoniinae. Moreover *Ceratonia siliqua* showed high morphological variation (6.6-9.5) with *Cassia* and *Senna* species.

The separation of *Cassia* and *Senna* species into two different clusters verify the segregation of the genus *Cassia* L. *sensu lato* into three distinct genera namely *Senna* P. Mill., *Cassia* L. *sensu stricto* and *Chamaecrista* Moench. This findings are significant and support the results obtained on the basis of the molecular data by (Ghareeb *et al.*, 1999; Laxmikanta, *et al.* 2011; Tripathi and Goswami, 2011; George and Hussein, 2014).

Within *Cassia* group; *C. fistula* separated firstly and followed by *C. grandis*, the other three taxa *C. javanica*, *C. javanica* ssp. *nodosa* and *C. renigera* linked together. This extremely agrees with the series level by (Irwin and Barneby, 1982). They involved *C. fistula* within series *Cassia*, *C. grandis* within series *Grandes* and the other three within series *Obolospermae*. *C. fistula* varies from the other *Cassia* species by pendulous inflorescence, yellow flowers, leaflet relatively large, lanceolate and number of leaflets 3-8 pairs.

Within *Senna* group; *S. alexandrina*, *S. holosericea* and *S. italic* linked together indicating that they are closely allied. They showed low morphological variation (2.4-4.1). The three species placed together in series *Senna* (Table 1). Similar results has been attained by (Ghareeb *et al.*, 1999). Also phenogram appeared a close relationships between *S. ligustrina*, *S. occidentalis* and *S. sophera*. While *S. hirsuta* separated from them, although (Irwin and Barneby, 1982) keep the four species together in series *Basiglandulosae*. This is evidenced by the presence of specific characters in *S. hirsuta*; young branches, petioles, and rachises, leaflets and sepals are densely villous. Legume long up to 20 cm, densely hirsute, seeds exareolate. The grouping of *S. artemisioides* with *S. surattensis* agree with including them belonging to section *Psilorhegma*, within two series *Subverrucosae* and *Interglandulosae*, respectively as shown in (Table 1).

*S. bicapsularis*, *S. multiglandulosa* and *S. siamea* are clustered together. (Irwin and Barneby, 1982) arranged them in section *Chamaefistula*; *S. siamea* in series *Floridae* and both *S. bicapsularis* and *S. multiglandulosa* in series *Coluteoideae* with *S. septentrionalis*. Also the phenogram showed *S. siamea* has more affinity to *S. bicapsularis* than *S. multiglandulosa*. Moreover *S. septentrionalis* and *S. spectabilis* appeared has more attraction to both of *S. ligustrina*, *S. occidentalis* and *S. sophera*. *S. didymobotrya* delimited early from all *Senna* species and showed less affinity to *S. alexandrina*, *S. holosericea* and *S. italica*, although all of them placed belonging the same section but in different series. *S. tora* recorded the lowest morphological variation (4.8) with *S. bicapsularis* both of them belonging to section *Chamaefistula*, in separate series; *Trigonellokkae* and *Coluteoideae*, respectively. Additionally *S. bacillaris* in series *Bacillares* and *S. hirsuta* in series *Basiglandulosae* belonging to section *Chamaefistula* grouped together with morphological variation (5.5). Finally the arrangement of the studied taxa in the phenogram congruent, to a great extent, with (Irwin and Barneby, 1982). Keys are provided for subtribes, genera and species to facilitate the identification of the studied taxa.

**Key to the subtribes of tribe Cassieae:**

- 1a. Flowers polygamo-dioecious, apetalous, with a fleshy hypogynous disc wider than the calyx ..... **subtribe Ceratoniinae (*Ceratonia siliqua*)**
- 1b. Flowers hermaphrodite, petaliferous, lacking hypogynous disc ..... **subtribe Cassiinae**

**Key to the genera of subtribe Cassiinae:**

- 1a. Filaments of 3 abaxial antesepalous stamens sigmoidally curved and many times longer than their anther; pod indehiscent, up to 60 cm length, with woody valves ..... ***Cassia***
- 1b. Filaments of all stamens straight or simply incurved and either shorter than or not over twice as long as their anther; pod dehiscent ..... ***Senna***

**Key to the species of genus Cassia:**

- 1a. Inflorescence pendulous with yellow flowers ..... ***C. fistula***
- 1b. Inflorescence erect with pink or dark red flowers, fading to white ..... **(2)**
- 2a. All stamens pink to purple, all filaments not swollen in the middle, fertile anthers woolly pilosulous ..... ***C. grandis***
- 2b. All stamens yellow, 3 long stamens having filaments swollen in the middle into a globose or ellipsoid nodule, anthers of fertile stamens glabrous or thinly hairy ..... **(3)**
- 3a. Ovary glabrous ..... ***C. renigera***
- 3b. Ovary hairy ..... **(4)**
- 4a. Stipules 5 mm long, linear, leaflets acute, glabrous or with scattered hairs beneath..... ***Cassia javanica* subsp. *nodosa***
- 4b. Stipules 12-15 mm long, leafy, leaflets usually obtuse, silky beneath ..... ***C. javanica***

**Table 2:** Morphological characters and character states used in the numerical analysis.

Characters	Taxa																						
Sepals: glabrous 1/ hairy 2/ densely velvety 3/ villous 4	3	2	1	1	2	3	2	2	1	1	2	1	2	2	2	2	2	2	2	2	2	2	2
Sepals length in mm: (1-2) 1/ (5-7) 2/ (8-10) 3	3	2	1	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sepals colour: green or yellowish-green 1/ reddish 2/dark brown to blackish green 3	1	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sepals shape: ovate 1/ lanceolate 2/ orbicular 3	1	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bract shape : linear to lanceolate 1/ ovate 2/ leafy 3	2	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Flowers pedicellate 1/ flowers sessile or nearly so 2	1	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Inflorescence length in cm: (less than 10) 1/ (10-15) 2/ (20-25) 3/ (more than 25) 4	4	1	1	1	3	1	1	1	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Inflorescence: many-flowered 1/ 1-3-flowered 2	1	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stipules shape: linear to lanceolate 1/deltoid to ovate 2/ kidney shaped 3	2	2	2	2	3	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stipule: persistent 1/ caducous 2	2	2	2	2	3	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Petiole glands: present 1/ absent 2	1	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rachis teret 1/ channelled 2	1	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rachis have glands between some or all pairs of leaflets 1/ rachis eglandular 2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet width in cm: (less than 1) 1/ (1-2) 2/ (2.5-3.5) 3/ (more than 6) 4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet length in cm: Long (10-14) 1/ medium (5-9 cm) 2/short (2-4) 3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lower surface of leaflet: glabrous 1/ hairy or sparingly hairy 2/ villous 3/ tomentose 4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Upper surface of leaflet: glabrous 1/ hairy or sparingly hairy 2/ villous 3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet thick and leathery 1/ not so 2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet margin: entire 1/ undulate 2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet base: obtuse 1/cuneate 2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet apex: obtuse 1/ acute 2/ acuminate 3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet apex: emarginate 1/ not emarginate 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflets shape: obovate 1/ oblong 2/ ovate 3/ lanceolate 4/ linear 5	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaflet pairs number: numerous (15-20) 1/ many (6-12) 2/ few (2-4) 3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Leaves length in cm: Long (30-40) 1/ medium (20-30 cm) 2/short (less than 20 cm) 3	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stem: glabrous 1/ hairy 2/ villous 3/ tomentose 4	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dioecious 1/ Hermaphrodite 2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plant: herb 1/ shrub 2/ tree 3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Table 2: Cont.

Characters	Taxa																			
seed with emarginate end 1/ obtuse-truncate 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Seeds narrowed at hilum end and obviously protrude 1/ not so 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
seeds areolate 1/exareolate 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Seed surface: smooth 1/ rough 2/ wrinkled 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
seeds arranged transversely 1/ not so 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seeds separated by transverse papery septa 1/ not so 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed color: yellowish 1/ brown 2/ dark brown 3/ olivaceous 4	3	2	2	3	2	1	1	1	3	2	1	1	1	3	2	1	1	1	3	2
Seed: length in cm: (less than 0.6) 1/ (0.6-0.8) 2/ (less than 0.6)	2	1	1	3	2	1	1	1	3	2	1	1	1	3	2	1	1	1	3	2
Seed shape: obovate-elliptic 1/obovate-oblong 2/ rhomboid 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed number: numerous (more than 30) 1/ many (from 10 to 30) 2/ few (less than 10) 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seeds embedded in black, glutinous substance 1/ not so 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Seed enveloped by a finally detached suberous disc 1/ not so 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pod: dehiscent 1/ indehiscent 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pod valves: papery 1/ woody 2/ thick and fleshy 3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pod: terete 1/sub-terete 2/ flattened 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pod apex: rounded 1/ acute 2/ acuminate 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pod: glabrous 1/hairy or sparsely hairy 2/ hirsute 3/ densely granular-papillate 4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pod: slightly curved or curved 1/ straight 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pod colour: brown 1/ dark brown 2/golden brown 3/ blackish 4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pod width in cm: (less than 1) 1/(1-1.5) 2/ (1.6-2) 3/(up to 2.5) 4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pod length in cm: (up to 50 or more) 1/(20-30) 2/(10-15) 3/(4-6) 4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ovary: glabrous 1/ hairy 2/ hirsute 3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3 abaxial stamens up to 3-4 cm long 1/ not so 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3 abaxial stamens, having filaments swollen in the middle 1/ not so 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Intra-staminal disk present 1/ absent 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stamens colour: yellow 1/ pink to purple 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stamens numbers: (5) 1 /Stamens (10) 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Petals length in cm: (less than 1.5) 1/(1.5 - 2) 2/(up to 3.5) 3	3	2	2	3	2	1	1	1	3	2	1	1	1	3	2	1	1	1	3	2
Petals: pink 1/ yellow 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Petals shape: obovate 1/ oblong-obovate 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Petals absent 1/ present 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
<i>Cassia fistula</i>	2	1	2	3	2	1	2	2	1	2	1	4	2	2	1	1	1	3	2	2
<i>Cassia grandis</i>	2	1	1	3	2	2	2	1	2	1	4	2	2	2	1	1	2	2	1	2
<i>Cassia javanica</i>	2	1	1	3	2	1	2	1	2	1	4	2	2	2	2	2	3	2	1	2
<i>Cassia ja. ssp. nodosa</i>	2	1	1	3	2	1	2	1	2	1	4	2	2	2	2	1	1	3	2	2
<i>Cassia renigera</i>	2	1	1	3	2	1	2	1	1	1	4	2	2	2	1	1	1	3	2	2
<i>Ceratonia siliqua</i>	1	0	0	0	1	1	1	2	2	2	4	2	1	1	1	3	3	2	1	2
<i>Senna alexandrina</i>	2	2	2	2	2	1	2	2	2	2	4	3	1	1	3	1	1	1	2	3
<i>Senna artemisioides</i>	2	2	2	2	2	1	2	2	2	2	3	2	2	2	1	3	2	2	2	2
<i>Senna bacillaris</i>	2	2	2	2	2	1	2	2	2	2	3	1	1	1	4	2	2	1	1	2
<i>Senna bicapsularis</i>	2	1	2	2	2	1	2	2	2	1	3	2	1	1	1	2	1	1	2	2
<i>Senna didymobotrya</i>	2	1	2	2	2	1	2	2	2	2	3	3	4	1	2	3	1	1	2	2
<i>Senna hirsuta</i>	2	1	2	2	2	1	2	2	2	3	2	1	1	2	3	2	2	1	1	2
<i>Senna holosericea</i>	2	2	2	1	2	1	2	2	2	2	4	3	1	1	2	1	3	1	2	3
<i>Senna italica</i>	2	2	2	1	2	1	2	2	2	2	4	3	2	1	2	1	3	2	2	3
<i>Senna ligustrina</i>	2	1	2	1	2	1	2	2	2	2	3	2	1	1	1	2	1	1	2	2
<i>Senna multiglandulosa</i>	2	1	2	2	2	1	2	2	2	2	3	2	1	1	1	2	2	1	1	2
<i>Senna occidentalis</i>	2	1	2	1	2	1	2	2	2	2	3	2	1	1	1	2	2	1	1	2
<i>Senna septemtrionalis</i>	2	1	2	2	2	1	2	2	2	1	3	2	1	1	1	2	1	1	2	2
<i>Senna siamea</i>	2	1	2	2	2	1	2	2	2	2	2	2	1	1	2	3	2	1	1	2
<i>Senna sophora</i>	2	1	2	1	2	1	2	2	2	2	3	2	1	1	1	2	2	1	1	2
<i>Senna spectabilis</i>	2	1	2	2	2	1	2	2	2	1	2	2	2	1	1	2	2	1	1	2
<i>Senna surattensis</i>	2	1	2	2	2	1	2	2	2	2	3	2	2	2	1	3	1	1	2	2
<i>Senna tora</i>	2	2	2	2	2	1	2	2	2	2	3	1	1	1	2	3	2	1	1	2

**Table 3:** Morphological variation among 23 studied taxa based on squared euclidean distance.

Taxa	<i>Cassia fistula</i>	<i>Cassia grandis</i>	<i>Cassia javanica</i>	<i>Cassia j. ssp. nodosa</i>	<i>Cassia renigera</i>	<i>Ceratonia siliqua</i>	<i>Senna alexandrina</i>	<i>Senna artemisioides</i>	<i>Senna bacillaris</i>	<i>Senna bicapsularis</i>	<i>Senna didymobotrya</i>	<i>Senna hirsuta</i>	<i>Senna holosericea</i>	<i>Senna italica</i>	<i>Senna ligustrina</i>	<i>Senna multiglandulosa</i>	<i>Senna occidentalis</i>	<i>Senna septentrionalis</i>	<i>Senna siamea</i>	<i>Senna sophera</i>	<i>Senna spectabilis</i>	<i>Senna surattensis</i>	<i>Senna tora</i>	
<i>Cassia fistula</i>	0.0																							
<i>Cassia grandis</i>	4.7	0.0																						
<i>Cassia javanica</i>	4.4	3.3	0.0																					
<i>Cassia j. ssp. nodosa</i>	4.2	3.5	2.2	0.0																				
<i>Cassia renigera</i>	5.0	3.3	2.4	3.3	0.0																			
<i>Ceratonia siliqua</i>	7.8	7.5	7.7	7.5	8.2	0.0																		
<i>Senna alexandrina</i>	8.2	8.3	8.4	8.1	8.7	8.8	0.0																	
<i>Senna artemisioides</i>	7.9	7.9	7.9	7.7	8.6	8.2	5.1	0.0																
<i>Senna bacillaris</i>	7.3	8.5	8.3	8.0	8.5	9.0	6.2	6.4	0.0															
<i>Senna bicapsularis</i>	7.3	7.1	7.2	7.0	7.6	7.2	5.8	5.8	6.1	0.0														
<i>Senna didymobotrya</i>	7.1	6.6	6.5	6.4	6.9	8.1	6.8	6.5	7.0	6.8	0.0													
<i>Senna hirsuta</i>	7.3	7.2	7.4	6.9	7.7	9.5	7.0	6.9	5.5	7.0	7.3	0.0												
<i>Senna holosericea</i>	8.5	8.1	8.2	8.0	8.5	7.8	3.6	6.2	6.6	4.8	6.7	7.9	0.0											
<i>Senna italica</i>	8.6	8.2	8.3	8.1	8.7	7.7	4.1	5.9	6.5	5.0	5.7	8.0	2.4	0.0										
<i>Senna ligustrina</i>	7.1	7.9	7.7	7.2	8.4	7.9	5.2	4.6	5.7	5.0	6.7	5.7	6.2	6.3	0.0									
<i>Senna multiglandulosa</i>	7.7	6.6	7.2	6.9	7.2	8.0	5.8	6.3	6.2	4.7	6.5	5.4	5.7	5.9	5.0	0.0								
<i>Senna occidentalis</i>	6.7	7.9	7.7	7.3	8.5	7.9	5.5	5.1	5.6	5.1	6.8	5.9	6.4	6.6	1.7	5.5	0.0							
<i>Senna septentrionalis</i>	6.3	7.7	7.5	7.1	8.2	7.7	5.9	5.7	5.3	4.1	7.3	6.5	6.3	6.6	3.5	5.7	3.3	0.0						
<i>Senna siamea</i>	6.1	5.7	6.0	5.7	6.6	6.6	5.8	5.5	5.6	4.5	5.7	5.6	5.4	5.7	4.8	4.7	5.1	5.0	0.0					
<i>Senna sophera</i>	6.9	7.9	7.7	7.2	8.4	7.9	5.4	4.8	5.8	5.0	6.7	6.0	6.3	6.5	1.4	5.4	1.0	3.5	5.0	0.0				
<i>Senna spectabilis</i>	5.6	6.1	6.0	5.4	6.3	8.1	6.2	5.8	6.1	5.8	5.7	5.4	7.0	7.1	4.4	5.3	4.5	4.8	4.5	4.4	0.0			
<i>Senna surattensis</i>	7.1	6.6	6.9	6.6	7.4	6.9	5.2	3.9	5.3	4.1	5.4	6.2	4.9	4.5	4.7	4.8	5.0	4.9	3.9	4.9	5.6	0.0		
<i>Senna tora</i>	8.9	8.6	8.7	8.5	9.1	8.7	6.9	6.2	5.8	4.8	6.7	7.2	6.2	5.5	6.3	5.7	6.2	6.5	5.7	6.2	7.4	4.9	0.0	

**Key to the species of genus *Senna*:**

- 1a. Pod thin, flattened compressed, All seeds lying with broad areolate faces toward the valves..... (2)  
 1b. Pod turgid, subterete, seeds mostly lying with broad faces to the septa ..... (8)  
 2a. Petiole and rachis of leaves without glands ..... (3)  
 2b. Petiole or rachis of leaves with glands ..... (4)  
 3a. Tree, 10-15 m tall, leaflets 6-10 pairs, bracts green ..... *S. siamea*  
 3b. Shrub, 2.5-3 m tall, leaflets 8-16 pairs, bracts dark brown or black ..... *S. didymobotrya*  
 4a. Leaflets linear ..... *S. artemisioides* ssp. *artemisioides*  
 4b. Leaflets not so ..... (5)  
 5a. A shrub to small tree, 2 -3 m tall, pod 10-20 cm long, seeds 20-30 ..... *S. surattensis*  
 5b. Suffruticose, 20-120 cm tall, pod less than 10 cm long, seeds less than 10 ..... (6)  
 6a. Pod on both sides with a crest of elevated projections along the middle..... *S. italica*  
 6b. Pod not longitudinally crested ..... (7)  
 7a. Leaflets apex obtuse ..... *S. holosericea*  
 7b. Leaflets apex acute ..... *S. alexandrina*  
 8a. Petiole and rachis of leaves without glands ..... *S. spectabilis*  
 8b. Petiole or rachis of leaves with glands..... (9)  
 9a. Glands present on petiole only..... (10)  
 9b. Glands present on rachis only..... (13)  
 10a. Young branchlets, leaflets, petiole and rachis of leaves densely villous; legume densely hirsute on surfaces of valves ..... *S. hirsuta*  
 10b. Young branchlets, leaflets, petiole and rachis of leaves glabrous or subglabrous; legume glabrous..... (11)  
 11a. Petiolar glands slenderly ovate or lance-attenuate in profile, acute or subacute, including stipe (not always present) 1.7-3.5 x 0.4-1 m m ; racemes mostly 5-30-fld..... *S. ligustrina*  
 11b. Petiolar glands (sessile or almost so) obovoid, depressed-hemispherical or globose, obtuse, 0.5-1.5 m m; racemes 1-5-fld..... (12)  
 12a. Leaflets 4-6 pairs, petiolar gland globose or ovoid, at basal joint; pod somewhat flattened ... *S. occidentalis*  
 12b. Leaflets up to 12 pairs, petiolar gland clavate to subulate, above basal joint; pod turgid ..... *S. sophera*  
 13a. Seed areolate..... (14)  
 13b. Seed exareolate..... (16)  
 14a. Leaflets 6-8 pairs..... *S. multiglandulosa*  
 14b. Leaflets 2-4 pairs ..... (15)  
 15a. Leaflets relatively small, 2-6 × 1.5–2.5 cm, obovate, apex broadly rounded, seeds rhomboid..... *S. tora*  
 15b. Leaflets relatively large, 8-15 x 3-9 cm, ovate, seeds obovate ..... *S. bacillaris*  
 16a. Rachis of leaves with a gland between lowest pair of leaflets ..... *S. bicapsularis*  
 16b. Rachis of leaves with a gland between each pair of leaflets ..... *S. septemtrionalis*

In conclusion, our study shows the importance of numerical analysis for detecting variation and taxonomic relationships among studied taxa. Additionally the obtained results consent with giving more weight to the numerous characters differences than to a single character with delimitation of species, series or sections.

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