Bangladesh J. Plant Taxon. **20**(1): 77-83, 2013 (June)

NUMERICAL TAXONOMY OF THE GENUS *SENNA* MILL. FROM BANGLADESH

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Keywords: Senna; Cluster analysis; Phenetic relationship; UPGMA.

Abstract

This study examines the patterns of morphological variation and phenetic relationships among 11 species of *Senna* Mill. from Bangladesh using 32 vegetative and floral characters. The highest similarity is found between *S. obtusifolia* and *S. tora*, while the highest variation is observed between *S. alata* and *S. hirsuta*. UPGMA tree derived from cluster analysis reveals three major clusters, the first of which consists of two species (*S. alata* and *S. auriculata*), the second cluster comprises four species (*S. hirsuta*, *S. obtusifolia*, *S. tora* and *S. occidentalis*) and the third one is composed of five species (*S. multiglandulosa, S. sophera, S. siamea, S. timoriensis* and *S. surattensis*). A close relationship is also found between *S. multiglandulosa* and *S. sophera*, and between *S. siamea* and *S. timoriensis*. Results obtained from the present study are found congruent with cytological and anatomical studies showing the significance of numerical analysis for taxonomic relationship in the genus *Senna*.

Introduction

Numerical taxonomy, also termed as morphometrics deals with grouping by numerical methods of taxonomic units into taxa on the basis of 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 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 and Rahman, 2012).

The genus *Senna* Mill. (Caesalpiniaceae) is represented by 350 species and is distributed throughout the world (Marazzi *et al*., 2006). Irwin and Barneby (1982) reports that about 80% of the *Senna* species are found in the American continent, while most of the remaining members occur in tropical Africa, Madagascar and Australia, with only a few species in southeastern Asia and the Pacific Island. *Senna* are characterized by the presence of cylindrical or flattened, irregularly dehiscent pods and longest filaments without sigmoidally curved towards the base and seed surfaces usually with areole. Economically *Senna* species are very important since their bark and oil extract are used for flavouring purposes and in soaps, candy and perfumery (Hill, 1952). Several *Senna* species are reported to have medicinal properties as laxative, expectorant, antimalarial, relaxant and anti-inflammatory (Sadique and Chandra, 1987; Ajagbonna and Mojiminiyi, 2001; Tona and Mesia, 2001).

Studies on the genus *Senna* are very much limited in Bangladesh. Baker (1879) described 18 species of *Cassia s.l.* of which 6 species now included in *Senna* are found in the area of Bangladesh. Prain (1903) listed 7 species of *Senna* from the then Bengal which falls under the

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territory of present Bangladesh. Although Khan *et al.* (1996) documented 6 species of the *Senna* from Bangladesh, recently Ahmed *et al*. (2008) reported 10 species of the genus from the country. The extensive field surveys through the present study revealed a total of 11 species of *Senna* are now found in Bangladesh. Despite few fragmentary studies are available on *Senna*, numerical approaches have never been tested in this genus to determine species relationships. Therefore, the present study aims at applying numerical method for examining morphological variation and inferring phenetic relationships among *Senna* species occurring in Bangladesh.

Materials and Methods

Plant materials:

Eleven species of *Senna* were used in the present study (Table 1). Both fresh materials collected from different areas of Bangladesh, and herbarium specimens housed at Dhaka University Salar Khan Herbarium (DUSH) and Bangladesh National Herbarium (DACB) were examined for numerical analysis.

Table 1. List of *Senna* species along with their vouchers used in the present study.

No.	Species	Specimens examined
1	*Senna alata* (L.) Roxb.	Bandarban: Chimbuk hills, Mirzapara, 27.11.1983, Khan, Huq, Rahman & Mia K. 6494 (DACB); Dhaka: Dhaka University campus, 23.12.2011, Ayesa 65 (DUSH).
2	*S. auriculata* L.	Dhaka: Shere-e-Bangla Agricultural University compound, 26.1.2011, Ayesa 07 (DUSH); Sangshad Bhaban, 27.1.2011, Ayesa 08 (DUSH).
3	*S. hirsuta* (L.) Irwin & Barneby	Bandarban: Lama, 6.12.2007, Bushra, Halib & Mafiz B 609 (DACB); Cox's Bazar: Bamiachara near Chakaria, 2.12.1999, Khan, Mia, Rashid & Islam K. 10177 (DACB); Gazipur: Gazipur, 30.6.2011, Ayesa 40 (DACB).
4	*S. multiglandulosa* (Jacq.) Irwin & Barneby	No fresh or herbarium specimens available.
5	*S. obtusifolia* (L.) Irwin & Barneby	Bandarban: Chimbuk hills, 26.11.1983, Khan, Huq, Rahman & Mia K. 6472 (DACB); Cox's Bazar: Teknaf, Mouchuni, 24.4.2011, Ayesa 32 (DUSH); Patuakhali: Islampur, 6.2.2011, Ayesa 17 (DUSH).
6	*S. occidentalis* Roxb.	Bogra: Mohasthangarh, 22.8.1989, Mia, Rahman, Mahbuba & Rezia M 2117 (DACB); Dhaka: Dhaka University campus, 26.12.2010, Ayesa 02 (DUSH); Gazipur: Rajendrapur forest, 22.12.2011, Ayesa 63 (DUSH).
7	*S. siamea* (Lamk.) Irwin & Barneby	Chittagong: Chunati range, 10.6.1979, Khan, Huq & Rahman K 5515 (DACB); Dhaka: Tejgaon, Old Airport, 27.12.2011, Ayesa 74 (DUSH). Panchagarh: Fakirhat, 30.6.1998, Mia *et al*. M 3883 (DACB).
8	*S. sophera* (L.) Roxb.	Chittagong: Sandwip, Rahmatpur 12.2.1988, Mia and Mahfuz M 1590 (DACB); Cox's Bazar: Teknaf, Shilkhali, 30.2. 2011, Ayesa 25 (DUSH); Dhaka: Dhaka University Campus, 30.4.11, Aeysa 33 (DUSH).
9	*S. surattensis* (Burm. f) Irwin & Barneby	Dhaka: Dhaka University campus, 20.12.2011, Ayesa 47 (DUSH); Div 22, 19.10.1977, M. Naskar 3955 (DUSH).
10	*S. timoriensis* (DC.) Irwin & Barneby	Bandarban: Ruma bazar, 28.10.1984, Khan, Huq, Rahman & Mia K 6724 (DACB); Chittagong Hill Tracts: Ruma P.S., Changnakra, 25.1.1965, M. S. Khan 1166 (DUSH).
11	*S. tora* (L.) Roxb.	Dhaka: Dhaka University Botanical garden, 26.12.2011, Ayesa 69 (DUSH); Khulna: Jatrapur Railways line side, 16.6.1982, A. M. Huq 5542 (DACB).

Characters:

Thirty two characters were investigated and used in this analysis. Characters and character states were determined through examination of both living and herbarium specimens housed at DUSH and DACB. Both qualitative and quantitative characters were coded as binary-state. The characters and their binary states used for numerical taxonomic studies are listed in Table 2. Neither herbarium nor living specimens of *Senna multiglandulosa* were available; therefore character states for this species were determined from the relevant literature (Ahmed *et al.*, 2008).

Statistical analysis:

The data matrix was scored using binary matrix. Dissimilarity matrix was prepared based on the data matrix. Cluster analysis was performed using UPGMA (unweighted pair group method with arithmetic mean) and a dendrogram was constructed to show the relationship among the species (Sneath and Sokal, 1973). All analyses were carried out using the program STATISTICA (Version 3.0).

Result and Discussion

Thirty two vegetative and reproductive characters have been identified for numerical analysis of *Senna* species (Table 2).

Table 2. Morphological characters and their state used in the numerical analysis.

No.	Characters	Character states
1	Habit	Herb or undershrub (1), Shrub or tree (0).
2	Stem	Hairy (1), Glabrous (0).
3	Leaves	6-20 pairs (1), 2-5 pairs (0)
4	Stipules	Persistent (1), Cauducous or subpersistent (0).
5	Shape of stipules	Deltoid or ovate (1), Linear or cordate (0).
6	Size of stipules	1-5 mm (1), 8-20 mm (0).
7	Leaf attachment	Alternate (1), Opposite (0).
8	Petiole length	0.1-0.3 cm (1), > 0.4 cm (0).
9	Gland	Present (1), Absent (0).
10	Laminar shape	Oblong or elliptic (1), Ovate or cordate (0).
11	Base angle	Obtuse (1), Acute (0).
12	Apex angle	Acute (1), Acumminate or obtuse (0).
13	Base shape	Rounded or obtuse (1), Oblique or unequal (0).
14	Apex shape	Rounded or obtuse (1), Acute or acumminate
15	Margin type	Entire (1), Serrulate (0).
16	Lobation of vein	Present (1), Absent (0).
17	Inflorescence	Axillary and terminal (1), Terminal (0).
18	Sepal	Free (1), United (0).
19	Bract	Present (1), Absent (0).
20	Shape of bract	Ovate (1), Linear to lanceolate (0).
21	Bracteole	Present (1), Absent (0).
22	Corolla	Free (1), United (0).
23	Anther	Bilobed (1), Not bilobed (0).

Table 2 Contd.

No.	Characters	Character states
24	Anther opening	Apical pore (1), Lateral (0).
25	Ovary	Glabrous (1), Hairy (0).
26	Stigma	Truncate (1), Punctiform or others (0).
27	Shape of pod	Linear to curved (1); Oblong (0).
28	Surface of pod	Pubescent (1), Glabrous (0).
29	Number of seeds per pod	> 30 (1), 6-12 (0).
30	Dehiscence of pod	Dehiscent (1), Indehiscent (0).
31	Areole	Present (1), Absent (0).
32	Seed shape	Ovoid or oblong (1), Rhomboidal (0).

The present study reveals that the lowest morphological variation is observed between *S. obtusifolia* and *S. tora* indicating that they are most closely related among all species studied. *S. occidentalis* is also very close to *S. obtusifolia*. The highest variation is found between *S. alata* and *S. hirsuta* (Table 3). A high variation has also been detected between *S. alata* and *S. tora*; and *S. alata* and *S. obtusifolia*.

Table 3. Morphological variation among 11 species of *Senna* based on Squared Euclidean distance.

Species	alat	auri	hirs	mult	obtu	occi	siam	soph	sura	timo	tora
alat	0										
auri	9	0									
hirs	18	13	0								
mult	10	9	14	0							
obtu	15	10	9	13	0						
occi	12	13	8	10	5	0					
siam	12	13	12	8	13	10	0				
soph	12	13	12	6	9	6	10	0			
sura	14	11	12	10	9	12	10	10	0		
timo	11	10	11	11	12	13	7	13	9	0	
tora	16	9	8	12	3	6	12	8	6	11	0

alat = *Senna alata*, auri = *S. auriculata*, hirs = *S. hirsuta*, mult = *S. multiglandulosa*, obtu = *S. obtusifolia*, occi = *S. occidentalis*, siam = *S. siamea*, soph = *S. sophera*, sura = *S. surattensis*, timo = *S. timoriensis*, tora = *S. tora*

The numerical analysis presents the phenetic relationships among 11 *Senna* species. The UPGMA dendrogram based on cluster analysis reveals three clusters. The first cluster consists of two species, *viz. S. alata* and *S. auriculata*; the second one comprises four species, namely *S. hirsuta*, *S. obtusifolia*, *S. tora* and *S. occidentalis*; while the third cluster includes five species, *viz.*, *S. multiglandulosa*, *S. sophera*, *S. siamea*, *S. timoriensis* and *S. surattensis* (Fig. 1).

In the first cluster *S. alata* is grouped with *S. auriculata* indicating that they are closely allied, and this is evidenced by the presence of their puberulent stem, persistent stipule and linear to oblong pod. A close association between *S. hirsuta*, *S. obtusifolia*, *S. tora* and *S. occidentalis* is evident in the second cluster. The common characters shared by these four species include linear

stipule, racemose inflorescence, orbicular to rhomboidal seeds and presence of glands on the rachis. In this cluster the highest similarity has been observed between *S. obtusifolia* and *S. tora* showing that they are most closely related among all the species studied, and this highest affinity is supported by the following shared characters: leaflets obovate, stipules linear, falcate, inflorescence short-racemose, axillary, ovary ribbed, style glabrous, stigma truncate, pod linear or subtetragonous and seeds are 4-5 mm long, with an areole on each face.

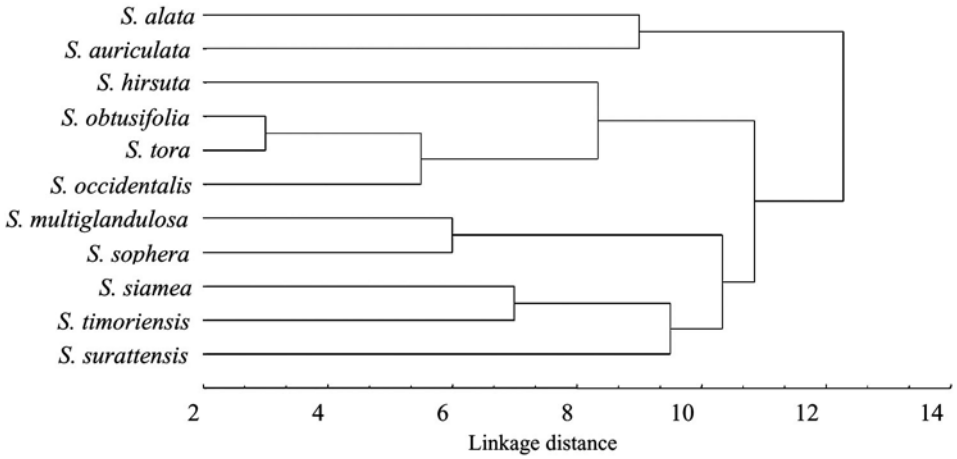

Fig.1. UPGMA dendrogram showing species relationship in *Senna*.

In the third cluster two distinct subclusters are found. The first one consists of *S. multiglandulosa* and *S. sophera*, and they are in the same line by presence of glandular leaves, ovate bracts, caducous stipule, pubescent ovary, and compressed, pointed seeds. The second subcluster contains *S. siamea, S. timoriesnsis* and *S. surattensis*. In this subcluster *S. siamea* and *S. timoriensis* are found to be more close to each other than they are to *S. surattensis*. *Senna siamea* and *S. timoriensis* both are evergreen trees and the close affinity between them is supported by their eglandular leaves, linear bracts, puberulent sepals, glossy brown seeds and presence of areoles.

Morphometric studies received considerable attention for species relatedness in different genera (Gomez-Campo *et al*., 2001; Henderson and Ferreira, 2002; Sonibare *et al.* 2004; Bolourian and Pakravan, 2011). Although such studies were carried out in different legume genera, for example, *Cassia* (Boonkerd *et al*., 2005), *Indigofera* (Soladoye *et al*., 2010a), *Daniellia* (de La Estrella *et al.* 2009), however very little is known about the morphometrics in the genus *Senna*. Recently Soladoye *et al*. (2010b) made a morphometric study of eight species of *Senna* from south-western Nigeria and using 13 morphological characters they showed that *S. sophera* is closely related to *S. hirsuta*. Our results suggest that *S. sophera* is closely allied to *S. multiglandulosa* which is incongruent with that of Soladoye *et al*. (2010b). The present study reveals a close association between *S. hirsuta, S. obtusifolia, S. tora* and *S. occidentalis* as they grouped together. Ogundipe *et al*. (2009) have shown that paracytic and anomocytic types of stomata are found both in *S. hirsuta* and *S. occidentalis*. The anticlinal walls are straight and undulate in both these species indicating a close relationship between them. Our result is supported by Ogundipe *et al.* (2009) since a close affinity has been observed between *S. hirsuta, S. obtusifolia, S. tora* and *S. occidentalis*. The close affinity among these species is also evidenced by

cytological investigation where the somatic chromosome number 2n=28 was reported for these four species (Irwin and Turner, 1960; Bir and Kumari, 1980). In conclusion, our study shows the significance of numerical analysis for detecting variation and taxonomic relationships among *Senna* species available in Bangladesh as it is attested by previous studies based on cytological and anatomical characters.

Acknowledgement

The authors are thankful to the Director, Bangladesh National Herbarium, Dhaka for allowing to use herbarium facilities. Thanks are also due to Prof. Md. Abul Hassan and Prof. Momtaz Begum, Department of Botany, University of Dhaka for their help and cooperation during this study.

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(Manuscript received on 15 November 2012; 24 February 2013)