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RESEARCH ARTICLE

Morphometrics of genus *Senna* Mill from Gokak, Belagavi

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Abstract

The relationship among six species of the genus *Senna* is described using eight quantitative characters based on both fresh and herbarium specimens. The Principal Component Analysis results show that the number of leaflets, leaflet length, and leaflet breadth are the only three features that have a substantial impact on the taxonomic delimitation. Based on farthest neighbor, mean character difference, and constrained clustering strategy, cluster analysis and dendrogram reveal that there is a greater degree of dissimilarity between *Senna italica* and *S. sophera*, while there is a lower degree between *S. auriculata* and *S. italica*. These results suggest that the two species are closely related. Ultimately, this research has illustrated the value of numerical analysis in taxonomic work by combining several morphological characteristics to produce a large enough demarcation that has better implications for these species taxonomy.

Keywords: Cluster, Fabaceae, Morphology, *Senna*.

Introduction

Numerical taxonomy, often known as morphometrics, is the study of classifying taxonomic units into taxa using numerical techniques according to their character states (Sneath and Sokal, 1973). It is undeniable that morphological characteristic is still important in taxonomy, and that all proposed classification schemes are founded on morphological concepts, even in the modern world. Since plant characteristics are the primary means of identification, morphology serves as the fundamental instrument of taxonomy. Both in living plants and in specimens kept in herbariums, the physical characteristics are readily discernible. They have provided the basic information for a majority of the classification systems in plant taxonomy (Sneath and Sokal, 1973). The methodologies of numerical taxonomy encompass a multitude of underlying presumptions and philosophical perspectives of taxonomy. The modern taxonomist understands that knowledge of morphology, which is backed by knowledge of anatomy, cytology, embryology, breeding behavior, and chemistry, is essential to determining the final taxonomy of higher plants. Nonetheless, it has an impact on the integration of data from other fields, which are regarded as objective measures of the taxa's similarity and dissimilarity, and which were then utilized to organize the taxa in a hierarchical structure (Quike, 1993).

In other words, numerical taxonomy relies on the numerical comparison of a large number of uniformly weighted traits, scored uniformly for each group being examined, and sorts people based on observable commonalities (Subrahmanyam, 2006). Numerous plants have been classified using this strategy, which has also been used to evaluate taxonomic study results (Abu Zaida *et al*., 2008).

Many studies were carried out in different groups of Leguminosae, for example, morphological and agronomic characterization of *Indigofera* species using multivariate analysis (Hassan *et al*., 2006); leaf anatomy of eight species of *Indigofera* species (Nwachukwa and Edeoga, 2006); some novel reports of glands in Neotropical species of *Indigofera* by Marquiafavel *et al* (2008), Senna (Soladoye *et al*., 2010) Cassia (Deshmukh, 2011), Desmodium (Rahman and Rahman, 2012), Papilionoideae (El-Gazzar *et al*., 2013), Senna (Rahman *et al*., 2013), Onobrychis (Noori *et al*., 2014), trifoliolate group of *Indigofera* are recognized and analyzed (Chauhan and Pandey, 2015).

This present study thus examines the difference and similarities in macro morphological characters used in

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delimiting the six species of *Senna* in Gokak, Belagavi Karnataka. It is hoped that, the method of numerical taxonomy (Soladoye, 1982; Sonibare *et al*., 2004; Boratynski *et al*., 2008) which are employed in this study will give visual interpretation of taxonomic relationship existing between them. Therefore, the present study was undertaking to determine whether the measurements from leaves and flowers are sufficient to diagnose selected species of *Senna*, and to evaluate variation and inferring phenetic relationship among selected *Senna* species in Gokak, Belagavi Karnataka.

Materials and Methods

Plant collection and identification

The fresh specimens as well as herbarium specimens of *Senna auriculata* (L.) Roxb., *Senna italica* Mill., *Senna sophera* (L.) Roxb., *Senna surattensis* (Burm.f.) Irwin & Barneby, *Senna tora* (L.) Roxb. And *Senna uniflora* (Mill.) Irwin & Barne by collected from Gokak vicinity and identified with the aid of Singh (2001). The plant parts, leaves, flowers, fruits and stem were collected using secateurs. The fresh specimens were pressed using a plant press, which consist of a wooden frame (to maintain the rigidity), blotting paper (for absorbing moisture) and folded newspaper (to contain the plant material). The plant press was tightened using straps. The objective of pressing plants is to remove the moisture content from the plants so that it preserves the morphological integrity and then it can be mounted on standard herbarium sheet for permanent records.

The dried specimens get exposed to 1 or 2% mercury chloride for preventing them from fungal and insect attack. Some of the specimens were poisoned by dipping the whole plants into a basin containing the poison and others were poisoned using a brush dipped in the mixture to brush both the adaxial and abaxial parts of plant according to the methodology of Bridson and Forman (1992). The poisoned specimens were then mounted on standard herbarium sheet using fevicol and kept in between newspaper for drying. Field note indicating location of collection, collector's name, habit, name of specimens and note were attached to mounting sheets along with the voucher number. The specimens were deposited in the Herbarium Department of Botany, J.S.S. Arts, Science and Commerce College, Gokak, Belagavi, Karnataka.

Morphometric Studies

Morphometric studies were carried on six living and six herbarium specimens of each *Senna* species. Length and width of the leaves are measured using a centimetre scale. The length of the leaf was obtained by spreading the middle leaflet on a flat surface on the laboratory bench, while for the width; the same median leaflet was chosen and measured to ensure uniformity, inflorescence length, fruit length, fruit width were also measured as the above and no of seeds and no of leaflets are also counted. In all, eight different characters were employed for each of the species and data collected were statistically analysed and recorded.

In order to study the morphometric characters the mean and Standard Deviation (SD) were obtained. Correlation between the morphometric characters were studied by using Karl-Pearson's Correlation Coefficient. Principal Component Analysis was used for reduction of dimensions in a data set by retaining those characteristics of the data set that contribute most to its variance, by keeping lower order principal components and ignoring higher order ones. The cluster analysis was used to Identifying groups of individuals or objects that are similar to each other but different from individuals in other groups can be intellectually satisfying, profitable, or sometimes both. Mayr's coefficient of difference (CD) (Mayr, 1969) was employed to test the equality of means of morphometric characters between the species. 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:

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 species respectively.

Results and Discussion

The Principal component analysis and cluster analysis are commonly used in the field of numerical taxonomy (Soladoye *et al*., 2010). The present study deals with the six different plant species widely distributed in Gokak taluka, these are *Senna auriculata* (L.) Roxb., *Senna italica* Mill., *Senna sophera* (L.) Roxb., *Senna surattensis* (Burm.f.) Irwin & Barneby, *Senna tora* (L.) Roxb., and *Senna uniflora* (Mill.) Irwin & Barneby. Comparative morphological parameters with their values of all the eight characters were presented in Table 1. Also, brief morpho-taxonomical detail of each taxon was presented in Table 2. The morphological characters employed for delimitation of the 6 plant species with their descriptive statistics are represented in Table 3. The results obtained from PCA shows that out of 8 three characters which are related with the leaf i.e. No. of leaflet, leaf length and leaf width are significant in delimitation of the plant species as their eigen value is greater than 1 represented in Table 4 and Fig. 1. The correlations between the morphological charters are given in Table 6. The results reveal the highly positive correlation between leaf length and leaf width, plant length and fruit length and leaf width and also fruit width and infl length.

Evaluation of Mayr's coefficient of difference values were shown in Table 5. The results reveal that S1S4 and S2

Table 1: Comparative morphological parameters with their values of all the characters (in cm)

	S1	*S2*	*S3*	*S4*	*S5*	*S6*
No of Lflt	8	4	5	4	4	3
Lf length	1.6	1.2	2.7	4.7	1.9	2.6
Lf width	0.7	0.8	1.1	2.6	1.1	1.3
Pt length	0.9	1.5	3.4	4	1.3	2.2
Infl length	5.5	7.0	3.3	9.3	2.6	2.1
Fr length	3.3	2.2	6.3	13.8	9.4	3.3
Fr width	1.4	1.1	1.1	2.6	1.2	0.5
No. of seeds	8	6.8	40	24	17	7

S1 *Senna auriculata* (L.) Roxb.
S2 *Senna italica* Mill.mnne
S3 *Senna sophera* (L.) Roxb.
S4 *Senna surattensis* (Burm.f.) Irwin & Barneby
S5 *Senna tora* (L.) Roxb.
S6 *Senna uniflora* (Mill.) Irwin & Barneby.

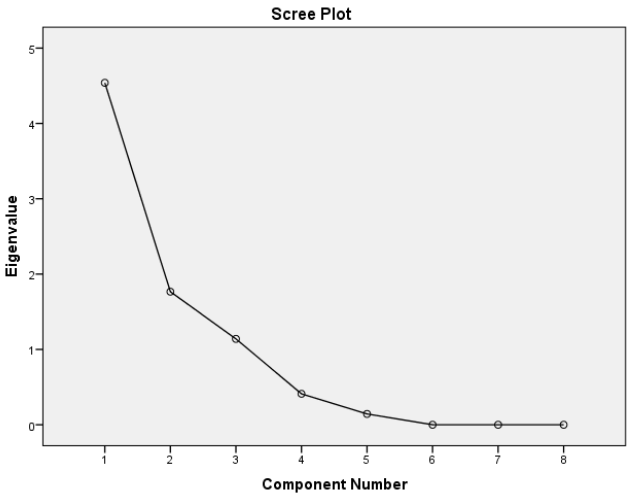

Fig. 1: Scree plot showing graphical representation of Eigen values and respective quantitative characters from Table 4.

Table 2: Short description of six species of *Senna*

S. No.	*Taxon*	*Brief description*
1	*Senna auriculata* (L.) Roxb.	Undershrubs. Leaflets elliptic-oblong; stipules auricled. Flowers in terminal and axillary racemes. Pods flat, thin papery, oblong, obtuse, mucronate, pale brown, deeply depressed between the seeds, having a crumpled appearance, pubescent. Seeds 8-10.
2	*S. italica* Mill.mnne	Herbs. Leaves rachis eglandular, leaflets 4-6 pairs, oblong, obtuse, mucronate apex. Flowers in axillary racemes. Sepals oblong, obtuse. Petals yellow, obovate-oblong, dark reticulate veined; antheriferous stamens 7, 2 larger. Pod flat, falcate, papery, rounded at both ends, crested longitudinally above seeds. Seeds 8-12.
3	*S. sophera* (L.) Roxb.	Undershrubs. Leaflets lanceolate, 5-10 pairs. Flowers in axillary, few flowered corymbose racemes. Stamens 10, of which 3 upper staminodes, remaining perfect. Pods linear, slightly turgid. Seeds 30-40.
4	*S. surattensis* (Burm.f.) Irwin & Barneby	Deciduous trees. Leaves pinnate; leaflets 4-9 pairs, one gland present between each lower pair, elliptic or oblong-elliptic. Flowers in racemes. Petals yellow-orange. Pods flat straight. Seeds 20-30, biseriate.
5	*S. tora* (L.) Roxb.	Foetid herbs. Leaflets obovate-oblong, 3 pairs. Flowers in subsessile pairs, in the axils of leaves, crowded upwards. Petals yellow, subequal. Pods subterete, often spreading. Seeds obliquely truncate at both ends, brown, smooth.
6	*S. uniflora* (Mill.) Irwin & Barneby.	Annual, herbs. Leaflets obovate-oblong, 3 pairs. Flowers in subsessile pairs, in the axils of leaves, crowded upwards. Petals yellow, subequal. Pods subterete, often spreading. Seeds obliquely truncate at both ends, brown, smooth.

Table 3: Descriptive Statistics and Standard deviation of Morphometric Characters (in Cm)

Plant species	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*
No of Lflt	8.40 ± 1.65	4.40 ± 0.52	5.10 ± 0.74	4.90 ± 0.88	4.00 ± 1.41	3.40 ± 0.52
Lf length	1.61 ± 0.41	1.22 ± 0.32	2.79 ± 1.02	4.73 ± 0.87	1.95 ± 0.33	2.6 ± 0.72
Lf width	0.74 ± 0.12	0.83 ± 0.22	1.17 ± 0.61	2.63 ± 0.39	1.15 ± 0.15	1.35 ± 0.23
Pt length	0.92 ± 0.21	1.52 ± 0.39	3.46 ± 0.78	4.08 ± 0.37	1.33 ± 0.16	2.27 ± 0.85
Infl length	5.52 ± 1.58	7.03 ± 0.91	3.31 ± 0.50	9.33 ± 0.91	2.6 ± 0.52	2.13 ± 0.13
Fr length	3.38 ± 1.68	2.24 ± 0.19	6.36 ± 2.03	13.80 ± 2.20	9.48 ± 1.93	3.33 ± 0.41
Fr width	1.44 ± 0.22	1.11 ± 0.34	1.11 ± 0.53	2.69 ± 0.31	1.22 ± 0.55	0.53 ± 0.12
No. of seeds	8.70 ± 3.06	6.80 ± 0.79	40.80 ± 6.29	24.00 ± 4.74	17.00 ± 0.94	7.90 ± 0.88

S1 *Senna auriculata* (L.) Roxb.
S2 *Senna italica* Mill.mnne
S3 *Senna sophera* (L.) Roxb.
S4 *Senna surattensis* (Burm.f.) Irwin & Barneby
S5 *Senna tora* (L.) Roxb.
S6 *Senna uniflora* (Mill.) Irwin & Barneby.

Table 4: Variance in studied quantitative characters

Component	*Initial Eigenvalues*			*Extraction Sums of Squared Loadings*		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
No of Lflt	4.54	56.74	56.74	4.54	56.74	56.74
Lf length	1.77	22.08	78.82	1.77	22.08	78.82
Lf width	1.14	14.25	93.07	1.14	14.25	93.07
Pt length	0.41	5.13	98.21			
Infl length	0.14	1.79	100.00			
Fr length	0.00	0.00	100.00			
Fr width	0.00	0.00	100.00			
No. of seeds	0.00	0.00	100.00			

Table 5: Coefficient of difference in between all the plant groups

	No of Lflt	*Lf length*	*Lf width*	*Pt length*	*Infl length*	*Fr length*	*Fr width*	*No. of seeds*
s1s2	-0.46	-0.53	0.27	1.00	0.61	-0.61	-0.59	-0.49
s1s3	-0.13	0.83	0.59	2.57*	-1.06	0.80	-0.44	3.44*
s1s4	-0.20	2.43*	3.75*	5.45*	1.53	2.69*	2.37*	1.96*
s1s5	-0.46	0.46	1.53*	1.10	-1.39	1.69*	-0.29	2.08*
s1s6	-0.92	0.88	1.77*	1.27	-1.98	-0.02	-2.66	-0.20
s2s3	0.56	1.18	0.41	1.66*	-2.65	1.86*	0.00	4.81*
s2s4	0.36	2.95*	2.96*	3.36*	1.27	4.84*	2.45*	3.11*
s2s5	-0.21	1.13	0.86	-0.34	-3.12	3.41*	0.12	5.89*
s2s6	-0.97	1.33*	1.16	0.60	-4.71	1.81*	-1.26	0.66
s3s4	-0.12	1.03	1.46*	0.54	4.28*	1.76*	1.88*	-1.52
s3s5	-0.51	-0.62	-0.03	-2.26	-0.70	0.79	0.10	-3.29
s3s6	-1.36	-0.11	0.21	-0.73	-1.86	-1.24	-0.88	-4.59
s4s5	-0.39	-2.32	-2.76	-5.15	-4.73	-1.04	-1.72	-1.23
s4s6	-1.08	-1.34	-2.09	-1.48	-6.92	-4.00	-5.08	-2.87
s5s6	-0.31	0.62	0.53	0.93	-0.72	-2.62	-1.03	-5.00

Table 6: Principal components analysis of *Senna* L. species using quantitative characters (Tolerance of eigen analysis set at 1E-010)

	No of Lflt	*Lf length*	*Lf width*	*Pt length*	*Infl length*	*Fr length*	*Fr width*	*No. of seeds*
No of Lflt	1.000							
Lf length	0.120	1.000						
Lf width	0.006	.963**	1.000					
Pt length	0.163	.896*	0.811	1.000				
Infl length	0.505	0.404	0.511	0.328	1.000			
Fr length	0.147	0.806	.841*	0.625	0.372	1.000		
Fr width	0.702	0.528	0.518	0.467	.888*	0.322	1.000	
No. of seeds	0.417	0.511	0.336	0.720	-0.047	0.496	0.145	1.000

and S4 shows more significant CD and S1S2, S3S5, S3S6, S4S5, S4S6, S5S6 are with less CD than the other ones; as well as quantitative characters fruit length, no. of seeds and leaf length has vital contribution in differentiation of the taxa respectively. Cluster analysis and dendrogram (Table 7 and Fig. 2) on the basis of farthest neighbor, mean character difference and constrained clustering strategy shows that the dissimilarities in between S2 and S3. is greater i.e.1193.657 while that in between S1 and S2 is minimum i.e. 8.800 indicating both the species are closely related.

Based on the present results, the observations from this work have also shown that there are differences in the

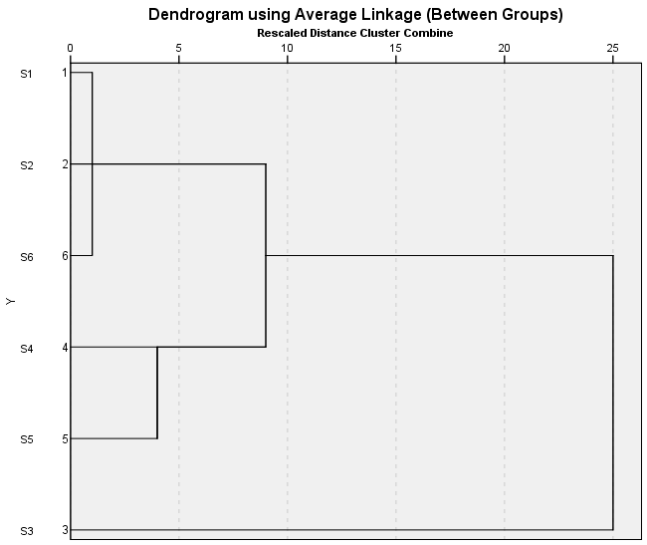

Fig. 2: Dendrogram on the basis of mean character difference observed in quantitative characters

Table 7: Cluster analysis revealing relationship between six *Senna* species

	S1	*S2*	*S3*	*S4*	*S5*	*S6*
S1	0.000					
S2	8.800	0.000				
S3	1052.453	1193.657	0.000			
S4	380.975	457.767	380.964	0.000		
S5	118.248	177.554	583.621	133.807	0.000	
S6	19.949	30.395	1097.518	434.062	122.650	0.000

quantitative character of the same species measured at various locations particularly, the leaflet length, number of seeds. This variation within species may be due to the following; age of plant, location and place of collection and genetic factor (Jongebloed *et al.,* 2004) which mostly occur as a result of mutation. Sunlight also causes variation in plant. This is because sunlight aids manufacturing of food during photosynthesis (Aborg, 1943).

Leaf shapes and sizes have been shown by the work of previous authors to vary within the same plant due to the action of light intensity on the leaves, thereby affecting the carbohydrate balance which in turn affects the length of the cells in the direction of the long axis which in turn gives rise to differences in shapes, length and width of the leaves (Campey *et al*., 2000). Also, variation in the morphology of plant may be due to the fact that some of the species are growing naturally in their habitat while some are cultivated with care and proper management. Some of the species of Senna seen growing in their natural habitat are, *S. auriculata, S. italic, S. sophera, S. tora, S. uniflora*, while those cultivated in an undisturbed environment is *S. surattensis*.

With the help of morphometry used in this study, it is possible to distinguish between the six species of *Senna* studied even when they are not in their fruiting period. This work has helped in bringing out the characters that contributed greatly in differentiating individual species from each other and those characters that made the species of *Senna* studied to be grouped together as one genus. However, with all the shortcomings of numerical methods (as in all other forms of taxonomic methods) one should not be led to believe that "numerical taxonomy is an excursion to futility" as claimed by Soladoye *et al*. (2010).

Conclusion

Morphometric studies received considerable attention for species closeness in different genera of flowering plants. The morphometric analysis of six different plant species; *Senna auriculata* (L.) Roxb., *Senna italica* Mill., *Senna sophera* (L.) Roxb., *Senna surattensis* (Burm.f.) Irwin & Barneby, *Senna tora* (L.) Roxb., and *Senna uniflora* (Mill.) Irwin & Barneby., using 8 quantitative characters provided justification for the existing classification of the genus. Out of 8 three characters which are related with the leaf i.e. No. of leaflet, leaf length and leaf width are significant in delimitation of the plant species. The morphological charters reveals the highly positive correlation between leaf length and leaf width, plant length and fruit length and leaf width and also fruit width and infl length.

Cluster analysis based on the quantitative parameters shows that the dissimilarities in between *Senna italica* Mill. and *Senna sophera* (L.) Roxb. is greater while that in between *Senna auriculata* (L.) Roxb. and *Senna italica* Mill. is minimum indicating both the species are closely related. The present study shows the significance of morphometric analysis for detecting variation and taxonomic relationships among *Senna* species available in Gokak, Belagavi, Karnataka. Additionally, the numerical characters differences may be a single character will help for the delimitation of species, series or sections. Further it is recommended that an application of this method could be well presented if it is supported by other taxonomic evidence to find the better placement of species in the taxonomic group.

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