Taxonomic Studies of the Genus Indigofera Linn., in Nigeria

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ABSTRACT

Taxonomic studies were carried out on the morphometry and foliar anatomy of ten species of the genus   Indigofera in Nigeria. These studies were carried out to provide a distributional map showing the diversity of the species in Nigeria and to examine the similarities and differences in the morphology and foliar anatomy of the Indigofera species. The ten species have odd-pinnate compound leaves except I. nummulariifolia and I. subulata with simple and trifoliate leaves respectively. The leaflets' surfaces are pubescent in I. hirsuta and glabrous in other species studied. The leaflets' size ranged from $0.7{\times}0.3cm^2$ in I. geminata to $3.2{\times}1.7cm^2$ in I. macrophylla. The epidermal cell shapes are mostly irregular on both surfaces of all the species studied except in I. capitata, I. nummulariifolia and I. oblongifolia in which they are polygonal. Anticlinal wall patterns are curved, sinuate and undulate in all the species studied. All the species studied are amphistomatic with anisocytic and paracytic being the common stomatal types. Trichomes are also present on the adaxial and abaxial surfaces of the leaflets of the ten species studied except in I. spicata which lacks the trichomes on the adaxial surface.The dendrogram revealed that I. capitata, I. congolensis and I. geminata are closely related in their macro-morphology while I. oblongifolia, I. capitata and I. congolensis are related in their foliar anatomy. The leaf type and arrangement, number of leaflets per petiole, flower colour, stomatal type and epidermal cell shapes are significant in the taxonomy of the genus Indigofera. A distributional map showing the diversity of the species in Nigeria is provided.

Keywords: Morphometry, foliar anatomy, Indigofera, Nigeria

INTRODUCTION

The genus Indigofera Linn. with about 750 species, is the third largest genus in the family Papilionaceae [1] [2]. The genus was formerly in the tribe Galegeae with nine genera [1], but presently in the tribe Indigofereae with six genera and in the sub-family Papilionoideae [2]. The species are mostly herbs and shrubs, though few are small trees up to 5 - 6 metres tall [3].

Different numbers of Indigofera species have also been reported by different authors in

West Africa. Hutchinson and [2] reported 78 species while [4] reported 76 species. In Nigeria, Hutchinson and [1] reported 55 species;[4] reported 45 species while [5] reported 60 species with over 60% abundance in the Northern region of the country while about 27% are distributed across the Western region of the country. The reason for the differences in the estimation of the number of taxa in this group of plants could be due to the perceived similarities in their structure and reproductive organs [6]. The morphological characters of angiosperms have been extensively used both for producing classification and for diagnostic purpose.

These characters are indispensable as they play important roles in plant taxonomy. The morphological characters do not undermine the importance of other characters like anatomical and palynological which have been helpful in their own way; the greatest advantage of the morphological characters is that they can be easily observed in the field [7]. There are a large number of anatomical characters of taxonomic importance pointed out by [8] and [9]. Some of these important anatomical characters are: Trichomes, Stomata and Epidermis. Trichomes have been employed very frequently for taxonomic comparisons because of their diversity, their universal presence in the angiosperms and their simple means of preparation [7]. Several trichome types have been recognised. The two major categories are: glandular and non-glandular and these are further subdivided on the basis of their gross form, cellular constitution, degree of branching etc. [8] and [9]. According to [7], [5] proposed first classification of stomata as he recognised four morphological types, named after the families in which they were first observed. Later, [8] and [9] classified the stomata on the same plan with some modifications in terminology. [5] recognised ten types of stomata mainly on the basis of their ontogeny. [9] proposed an elaborate classification of stomata based on the number and position of subsidiaries and on ontogeny. Some examples of the types of stomata suggested by [9] and other authors are: anisocytic, paracytic, actinocytic, staurocytic, anomotetracytic, pericytic, brachyparacytic, diacytic and hemiparacytic. For the epidermis, shape of the cells, thickness, and characteristics of their walls, nature of the sculpturing on their walls as seen in surface view and inclusions of epidermal cells provide useful

taxonomic criteria.

Division of the epidermal cells, although of restricted and sporadic occurrence are also of some diagnostic values in certain families such as Piperaceae. Palynological characters are also important for the classification of angiosperms. The publication of Pollen Morphology and Plant Taxonomy by [10] marked the beginning of a new phase. He made available pollen characters of all families of angiosperms to taxonomists [7]. Since then, they are increasingly used in plant taxonomic work. According to [10], Pollen characters such as number and position of apertures, size, shape and the details of sculpturing of the exines are of taxonomic values. Variations are always observed within the same species of plants as a result of environmental and genetic factors.

According to [5], variations were observed within some species of Indigofera analysed as a result of age. This is because older leaves tend to be leathery and glabrous than younger leaves. They reported that I. nummulariifolia and I. macrophylla were closely related among the taxa analysed. The variations noted within the leaves of the species of Indigofera may be due to environmental and genetic factors within them [11]; [6]. The influence of environmental factors, geographical variations in growth includes racial variation which is due to several mechanisms such as mutation, natural selection, hybridization or combination of the factors [7]. According to [7], leaf shape and size may vary within the same plant. They suggested that light intensity acting on the leaf may affect the carbohydrate balance which in turn could affect the length of the cells in the direction of the length axis thereby leading to the differences in length, shapes and width of the leaves.

[6], in their study of eight neotropical species of Indigofera noted that distribution and gland types differed between species and that these gland distribution patterns can be used as diagnostic characters. According to [5], each of the eight species of Indigofera they analysed had at least two different types of trichomes occurring in the reproductive and vegetative organs of the taxa.[8] in their studies on tannins, starch grains and crystal types in the vegetative organs of eight species of the genus observed that the type and

distribution of the phytochemical substances varied in the species. Number of leaflets, leaflets' length and width have a significant contribution in distinguishing individual members of the genus Indigofera [5]. In contrast to the observation of [5], [12] in their study of forty-one species of Indigofera accessions reported that clustering on the basis of macro-morphological characters alone failed to consistently and satisfactorily reveal variations between accessions in terms of agronomic performance. Consequently, in the study of [12], a character discarded resulted in the selection of only eight determinant characters which included: growth habit, days of 50% flowering, extent of branching, leaflets' length, leaf yield, plant height or length of the principal stem, leaf percentage and canopy spread measured at the widest point. These were regarded as the core attributes for Indigofera germplasm characterization, which can be used for the identification of suitable breeding material for specific purposes. It is important to note that morphometric analysis is not enough in delimiting taxa though it has benefited systematics. Other methods which include anatomical, palynological, cyto-taxonomic and chemotaxonomic differences should be investigated with morphometry in order to confirm or change the existing classification based on morphology in the genus [12]. Leaf anatomy of eight species of Indigofera carried out by [8] shows that the shape of epidermal cells is hexagonal in Indigofera hirsuta while it varied from pentagonal through rectangular and sinuous in other species studied. According to [13] epidermal characters are stable and might be reliable in taxonomic work.

MATERIALS AND METHODS

Freshly collected specimens of Indigofera species were used for this study. They are: I. capitata, I. congolensis, I. deightonii, I. geminata, I. hirsuta, I. macrophylla, I. nummulariifolia, I. oblongifolia, I. spicata and I. subulata. Morphometric studies: Leaflets' length and width, petiole length and internode length were measured following the method of [7]. From each specimen, a total of 20 leaflets were randomly selected for measurement. Foliar anatomical studies: Epidermal preparation methods followed [4]. The standard median portions of the leaflets obtained by cutting with razor blade were soaked in concentrated trioxonitrate (v) acid for about 25 to 35 minutes depending on the nature of the leaflets.

The appearance of air bubbles on the surfaces of the leaflets indicated their readiness for separation. They were transferred into some water in the Petri dish with a pair of forceps.

13

Both epidermises were carefully separated by teasing them apart and pulling the epidermis back on itself using camel hair brush and dissecting needle. The camel hair brush was also used to remove the adhering tissue debris. The separated surfaces were rinsed in distilled water and then transferred into 50% ethanol for about two to three minutes to harden. They were rinsed again in distilled water and stained with safranin for about five minutes and excess stains were washed off in water. They were mounted in 25% glycerol on slides with the edge of the cover slips sealed with nail varnish to prevent dehydration. The slides were labelled appropriately and examined under the light microscope while photomicrograph of each slide was taken at a magnification (x400), using Olympus digital camera fixed to Zeis 9901 light microscope and connected to personal computer. From each species, a total of 20 cells and stomata were randomly selected for measurement. The stomatal Index (S.I) was calculated for all the representative taxa using the formula as reported by [5]and stomatal terminologies followed [6] and [7].

Stomatal Index = $\dfrac{S}{E+S} \times 100$

100, where S = Mean number of stomata per view calculated for each species, E = Mean number of epidermal cells per view calculated for each species.

Geographical distributional studies of the species: The geographical distributional studies of the species were solely based on the information from herbarium collections deposited at University of Ibadan herbarium (UIH) of the Department of Botany, University of Ibadan Nigeria.

RESULTS

The important characters of the ten species of Indigofera studied are summarized in Tables 1 - 4 and illustrated in figures 1 - 3. Figure1 shows the geographical distribution of the ten species in Nigeria while the dendrogram shows the relationship between the morphometric and foliar anatomical characters of the species are shown in.

MORPHOMETRIC CHARACTERS

The ten species of Indigofera studied have odd-pinnate compound leaves except I. nummulariifolia and I. subulata with simple and trifoliate leaves respectively. Leaflets

arrangements are mostly opposite in all the species except in I. spicata and I. oblongifolia with alternate arrangement. Leaf arrangement is spiral in I. capitata and I. geminata and alternate in I. congolensis, I. deightonii, I. macrophylla, I. spicata and I. subulata. Indigofera hirsuta has both spiral and alternate leaf arrangement. The apices are cuspidate, mucronate, emarginate, round, cuneate and acute in all the ten species studied while the bases are mostly cuneate, acute and round (Table 2). The leaflets' margins are ciliate in I. hirsuta while they are entire in all other species studied. The leaflets' shapes are oblanceolate in I. capitata and I. spicata, oval in I. congolensis, obovate in I. geminata, I. hirsuta and I. oblongifolia. It is elliptic in I. deightonii, I. macrophylla, I. nummulariifolia and I. subulata. The leaflets' surfaces are pubescent in I. hirsuta and glabrous in other species studied. The leaflets' size showed considerable variation within the genus with the smallest recorded in I. geminata ($0.7\times0.3cm^2$) and the largest in I. macrophylla ($3.2\times1.7cm^2$).

Mean of the leaf petiole length ranged from 0.2cm in I. spicata to 2.1cm in I. subulata while the mean of the leaflets' petiole length ranged from 0.1cm in I. capitata, I. congolensis, I. geminata, and I. spicata to 0.3cm in I. macrophylla and I. hirsuta. Mean number of the leaflets per petiole ranged from 3.1 in I. subulata to 8.4 in I. macrophylla and the mean of leaflets' internode length ranged from 0.4cm in I. spicata to 1.6cm in I. hirsuta while the mean of leaf internode length ranged from 0.8cm in I. congolensis to 4.3 in I. macrophylla.

FOLIAR ANATOMICAL CHARACTERS

Foliar anatomical characters of the ten species of Indigofera studied are summarized in Table 4 and shown in figure 1-3. The epidermal cell shapes are mostly irregular on both surfaces except in I. capitata, I. nummulariifolia and I. oblongifolia in which they are polygonal. In I. macrophylla they are pentagonal and irregular on the adaxial surface and irregular on the abaxial surface. Anticlinal wall patterns are curved in I. capitata and sinuate in I. congolensis and I. subulata. They are undulate on the adaxial and curved/undulate on the abaxial surfaces of I. macrophylla. The anticlinal wall patterns are undulate on the adaxial and straight on abaxial surfaces of I. geminata and I. hirsuta. In I. deightonii, they are sinuate and undulate on the adaxial and sinuate on the abaxial surfaces

15

(Table 4). All the species studied are amphistomatic with anisocytic and paracytic being the common types of stomata. Other types of stomata recorded are anomocytic, anomotetracytic, staurocytic and diacytic. Hemiparacytic and brachyparacytic types are only recorded in I. macrophylla (Table 4). Mean of epidermal cell number varied from 71.3 in I. spicata to 258.5 in I. geminata and 86.1 in I. Spicata to 257.7 in I. geminata on the adaxial and abaxial surfaces respectively. Mean number of stomata per view ranged from 2.0 in I. macrophylla to 39.0 in I. spicata on the adaxial surfaces and 20.9 I. macrophylla to 49.3 in I. spicata on the abaxial surfaces. Sizes of the stomata varied from ($16.6{\times}10.4\mu m^2$) in I. spicata to ($23.4{\times}13.9\mu m^2$) in I. nummulariifolia on the adaxial surfaces and ($17.0{\times}9.2\mu m^2$) in I. spicata to ($24.3{\times}17.0\mu m^2$) in I. nummulariifolia on the abaxial surfaces. All the species studied are also amphi-trichomic except, I. spicata which lacks the trichomes on the adaxial surface.

The trichomes are simple and double-armed which are short and long with modified and unmodified bases except I. hirsuta which has single arm with unmodified base. Mean number of trichomes per view ranged from 0.0 in I. spicata to 4.8 in I. hirsuta on the adaxial surfaces and 0.2 in I. nummulariifolia and I. oblongifolia to 7.2 in I. deightonii on the abaxial surfaces while the mean of trichome base ranged from 0.0 in I. spicata and I. subulata to 2.7 in I. capitata on the adaxial surfaces. It is mostly absent in the species on the abaxial surfaces except in I. congolensis, I. oblongifolia and I. capitata in which it is 0.5, 1.3 and 3.9 respectively .

DISCUSSION AND CONCLUSION

The morphometric and foliar anatomical characters of the ten species of the genus Indigofera reported here are remarkable and could be used for taxonomic purposes. The dendrogram is the summary of the similarities and differences observed among the ten species of Indigofera studied. The dendrogram is the combination of thirtyeight characters observed from the morphometry and foliar anatomy. Considering the dendrogram at 33.33%, there are five clusters which are: (1, 4, & 8), (9), (2, 3, 10 & 5), (6) and (7). It shows that the operational taxonomic unit 9 (I. spicata) is a distant relative of 1, 4 and 8 (I. capitata, I. geminata and I. oblongifolia) and that the operational taxonomic unit 7 (I. nummulariifolia) shared no relationship with other taxa analysed

16

and this is in contrast to the observation of [5] who reported that I. nummulariifolia and I. macrophylla are closely related.

Furthermore, there is a considerable variation between a voucher specimen of I. subulata in University of Ibadan herbarium with the number UIH 21514 collected by J. Lowe/09 on 5/02/1990 and the fresh specimen of I. subulata used in this study. The voucher specimen was described as imparipinnate trifoliate leaf with the maximum of three leaflets per petiole and pubescent on abaxial surface while the fresh specimen has the mixture of imparipinnate and paripinnate leaves with the maximum of four leaflets per petiole and glabrous on both surfaces. The paripinnate leaf of the fresh specimen of I. subulata is in contrast to the imparipinnate leaves of other taxa analysed. The reason for the variation of the leaves may be more of genetical factors than environmental [5], since the voucher and fresh specimens were both collected from the same geographical location, precisely, University of Ibadan campus.

In conclusion, it is noteworthy that leaf type and arrangement, number of leaflets per petiole, flower colour, stomatal type and epidermal cell shape are significant in the taxonomy of the genus Indigofera. The variations observed among the ten species concluded to be as a result of environmental factors do not undermine further studies on the species of the genus Indigofera, especially, I. macrophylla, I. subulata and I. nummulariifolia in order to obtain their status in the taxon. Other taxonomic methods such as Cytotaxonomic and Chemotaxonomic in conjuction with macro-morphometric and anatomical can be employed to achieve the goal.

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17

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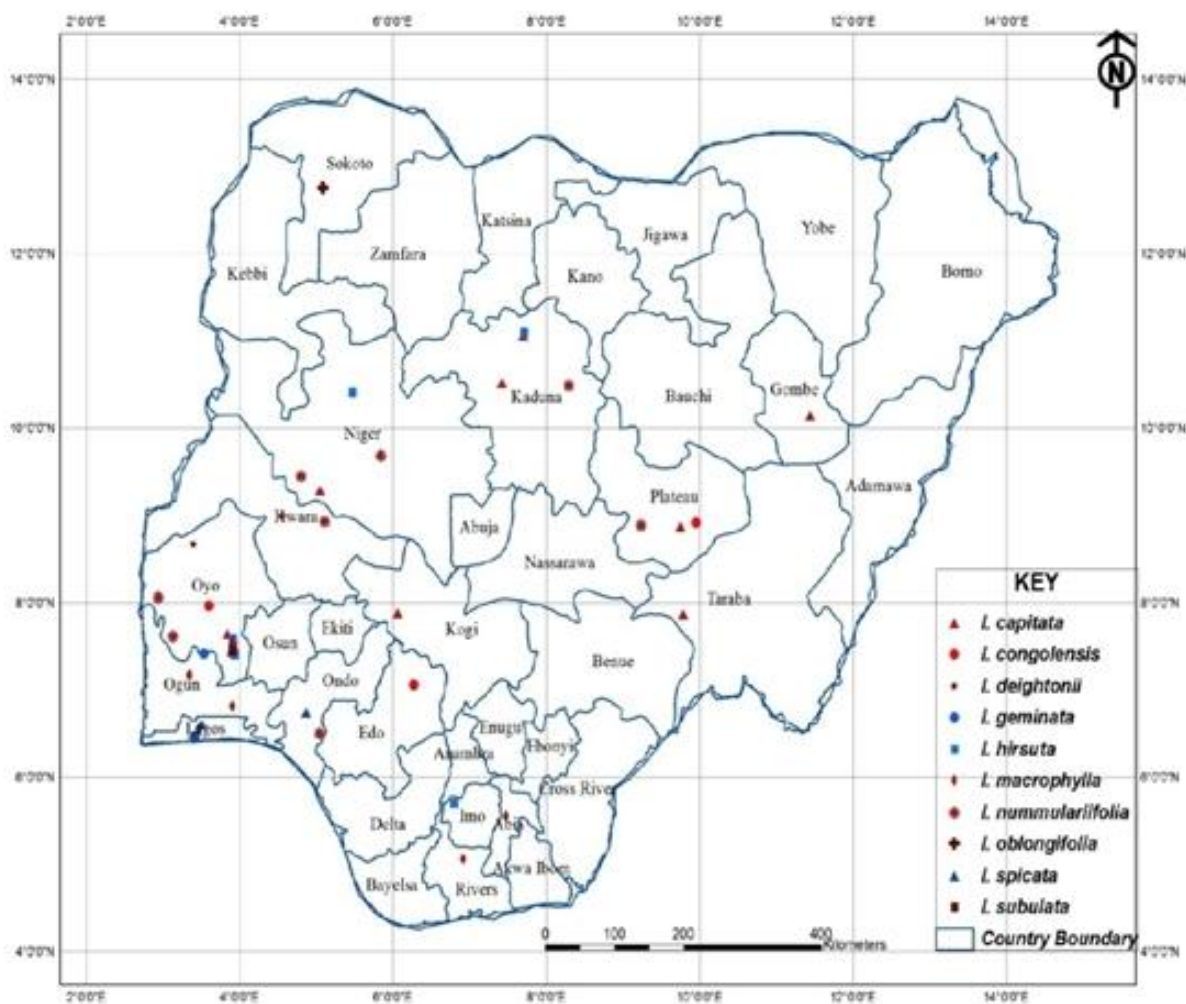1- 157

Fig. 1: Map showing the geographical distribution of the ten species of *Indigofera* studied.

Table 1: Qualitative macro-morphological characters of the ten species of Indigofera studied.

S/N	Species	Flower colour	Leaf type	Leaflet arrangement	Leaf arrangement	Leaflet apex	Leaflet base
1	I. capitata	Red	Pinnate compound	Opposite	Spiral	Cuspidate	Cuneate
2	I.congolensis	Red	Pinnate compound	Opposite	Alternate	Mucronate/Emarginate	Cuneate
3	I. deightonii	Red	Pinnate compound	Opposite	Alternate	Mucronate	Cuneate
4	I. geminata	Red	Bipinnate compound	Opposite	Spiral	Rounded	Cuneate
5	I. hirsuta	Red	Pinnate compound	Opposite	Alternate/Spiral	Mucronate	Cuneate
6	I.macrophylla	Purple/Red	Pinnate compound	Opposite	Alternate	Acute/ Mucronate	Rounded/ Cuneate
7	I. nummular-ifolia	Red	Simple	_	Alternate	Acute	Cuneate
8	I. oblongifolia	Red	Bipinnate compound	Alternate	Alternate	Mucronate	Cuneate
9	I. spicata	Red	Pinnate compound	Alternate	Alternate	Mucronate	Cuneate
10	I. subulata	Red	Trifoliate	Opposite	Alternate	Acute	Acute

Table 2: Quantitative macro-morphological characters of the ten species of Indigofera studied.

S/N	Species	Leaflet length (cm)	Leaflet width (cm)	Leaf petiole length (cm)	Leaflet petiole length (cm)	Leaf internode length (cm)	Leaflet	No. of leaflets per petiole
1	I. capitata	0.9 (1.3 ± 0.1)1.7	0.2(0.3 ± 0.0)0.5	0.5(0.6 ± 0.0) 0.7	0(0.1 ± 0.0)0.1	0.5(1.4± 0.1) 2.7	0.2(0.5 ± 0.0) 0.7	3(5.7 ± 0. 4)7
2	I. congolensis	0.6 (0.8 ± 0.0)1.1	0.3(0.4 ± 0.0) 0.5	0.5 (0.5 ± 0.0)0.7	0(0.1 ± 0.0) 0.1	0.5(0.8 ± 0.1) 1.5	0.2(0.4 ± 0.0) 0.7	3(4.9 ± 0.1) 5
3	I. deightonii	1.1(2.0 ± 1.0) 3.4	0.5(0.7 ± 0.1)1.1	0.7 (0.9 ± 0.0) 1.0	0.1(0.2 ± 0) 0.2	1.0(2.6 ± 0.3) 6.2	0.3(0.6 ± 0.1)0.9	3(4.9 ± 0.1) 5
4	I. geminata	0.5(0.9 ± 0.0) 0.9	0.2 (0.3 ± 0.0)0.4	0.0(0.6 ± 0.0)0.5	0.0(0.1 ±0.0)0.1	0.7(1.6 ± 0.2) 3.5	0.0(0.5 ± 0.1) 0.6	3(5.9 ± 0.3) 7
5	I. hirsuta	1.3(2.8 ± 0.2) 4.2	0.9(1.7 ± 0.1) 2.6	0.6 (1.4 ± 0.1) 2.8	0.2(0.3 ±0.0)0.4	1.3(3.5 ± 0.3) 6.0	0.4(1.6 ± 0.1) 2.2	3(6.0 ± 0.4) 7
6	I. macrophylla	1.3(3.2 ±0.2)5.5	1.0(1.7 ±0.1)2.5	1.1(1.5 ±0.1)3.3	0.2(0.3 ±0.0)0.4	1.5(4.3 ±0.5)9.6	0.6(1.0 ±0.1)2.5	5(8.4 ±0.4)11
7	I.nummularii-folia	1.2(3.1 ±0.3)5.2	1.0(1.8 ±0.1)2.5	0.1(0.2 ±0.0)0.3	_	_	1.0(1.6 ±0.1)3.0	_
8	I. oblongifolia	0.9(1.8 ±0.1)2.6	0.3(0.6 ±0.0)1.0	0.4(0.6 ±0.0)0.7	3.0(4.4 ±0.2)6.0	0.1(0.1 ±0.0)0.2	0.1(0.7 ±0.1)1.1	1.5(3.0±0.2)4.8
9	I. spicata	0.8(2.1 ± 0.2)3.3	0.5(0.9 ± 0.0)1.2	0.1(0.2 ± 0.0) 0.4	0.1(0.1 ±0.0)0.2	1.3(3.8 ± 0.4) 6.7	0.1(0.4 ± 0.0) 0.7	7(9.2 ± 0.4)11
10	I. subulata	1.8(2.2 ± 0.1) 2.6	0.9 (1.1 ± 0.0)1.4	1.5(2.1 ±0.1) 2.8	0.2(0.2 ±0.0)0.3	1.8(2.8 ± 0.2) 4.4	0.6(0.9 ± 0.1) 2.4	3(3.1 ± 0.1) 4

All measurements are in centimetres: minimum (mean ± standard error) maximum.

Table 3: Qualitative foliar anatomical characters of the ten species of Indigofera studied

S/N	Species	Cell shape		Anticlinal cell wall pattern		Stomatal type		Trichome	
		Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface	Adaxial surface	Abaxial surface
1	*I. capitata*	Polygonal	Polygonal	Straight	Straight	Paracytic, Anisocytic & Diacytic	Anisocytic & Paracytic	Present	Present
2	*I. congolensis*	Irregular	Irregular	Sinuate	Sinuate	Anomotetra-cytic, & anisocytic	Anomotetr-acytic & anisocytic	Present	Present
3	*I. deightonii*	Irregular	Linear & Irregular	Sinuate & undulate	Sinuate	Anomocytic, Anomotetracy-tic, Anisocytic & Paracytic	Paracytic, Anisocytic & Anomotetracyt-ic	Present	Present
4	*I. geminata*	polygonal	Polygonal	Undulate	Undulate	Paracytic	Paracytic	Present	Present
5	*I. hirsuta*	Irregular	Irregular	Undulate	Straight	Anisocytic & Anomotetracyt-ic	Diacytic & Paracytic	Present	Present
6	*I. macrophylla*	Pentagonal & irregular	Irregular	Straight/ Undulate	Undulate / curved	Hemiparacytic, Brachyparacytic & Anomotetra - Cytic	Paracytic & Diacytic	Present	Present
7	*I. nummularii-folia*	Polygonal	Polygonal	Straight	Straight	Paracytic & Anisocytic	Amphiparacytic & Anisocytic	Presnt	Present
8	*I. oblongifolia*	Polygonal	Polygonal	Straight	Straight	Paracytic & Anisocytic	Paracytic & Staurocytic	Present	Present
9	*I. spicata*	Irregular	Polygonal	Undulate	Straight	Paracytic	Paracytic	Absent	Present
10	*I. subulata.*	Irregular	Irregular	Sinuate	Sinuate	Staurocytic, Anisocytic & Paracytic	Staurocytic & Anisocytic	Present	Present

Table 4: Quantitative foliar anatomical characters of the ten species of *Indigofera* studied

| S/N	Species	Leaf surface	Stom-atal index	Epidermal cell length (µm)	Epidermal cell width (µm)	Epidermal cell number per view	Stomatal length (µm)	Stomatal width (µm)	Stomatal number per view	Trichome number per view
1	*I. capitata*	Adaxial	11.6%	24.3 (36.7 ± 1.7) 48.6	10.8 (23.8 ± 1.3) 35.1	138 (200.0 ± 9.0) 280	16.2 (20.8±0.7) 24.3	6.8(9.8 ± 0.5)16.2	12(25.5 ± 1.5) 38	0(2.0 ± 0.4) 5
		Abaxial	16.7%	24.3(39..3 ± 2) 48.6	162(28.2 ± 1.6)40.5	138(198.1±9.3)290	16.2 (20.3 ± 0.6)24.3	8.1 (10.7 ± 0.8)24.3	20(39.6 ± 2.8) 69	0(0.8 ± 0.2) 2
2	*I. congolensis*	Adaxial	16.7%	27(44.9 ± 2.7) 81	14(27.1 ± 1.9) 45.9	73(130.9 ± 6.1) 176	13.5(19.9 ± 0.7) 24.3	6.8(9.6 ± 0.3)10.8	14 (26.3 ±1.4)38	0(0.9±0.2)3
		Abaxial	17.5%	32 .4 (45.9 ± 1.8)64.8	16.2(28.8 ± 1.4) 37.8	76 (167.0 ± 8.2) 220	13.5(18.9 ± 0.9) 27	5.4 (9.1 ± 0.5) 16.2	13(35.4 ± 2.4)52	0(1.6 ± 0.3) 4
3	*I. deightonii*	Adaxial	17.8%	32.4 (45 ± 1.5) 59.4	21.6 (27.5±1.2) 40.5	124(178.6 ± 7.8)230	13.5(20.2 ± 0.8) 27	6.8 (10.0 ±0.4)13.5	11 (38.7 ±2.6) 66	1(4.3±0.3)8
		Abaxial	20.5%	27(46.8 ± 2.1) 64.8	21.6(30.7 ± 1.0) 37.8	42(190.8 ± 9.7) 240	16.2 (20.2 ± 0.6) 24.3	8.1(10.3 ± 0.4) 13.5	29(49.2 ± 2.4) 64	2(7.2 ± 0.8)7
4	*I. geminata*	Adaxial	10.2%	32.4 (43.2 ±1.4)54	16.2(27 ± 1.8) 43.2	101(258.5±11.9)314	18.9(21.9 ± 0.5) 25.7	8.1(10.3 ±0.5)16.2	9(29.5 ±1.8) 40	1(4.4±0.7)13
		Abaxial	13.3%	24.3 (40.6 ± 2.2)59.4	16.2(25.9 ± 1.7) 40.5	184 (257.7±112.2) 352	16.2(21.2 ± 0.6)24.3	8.1(14.5 ± 1.5)27	24(39.6 ± 2.1) 53	3(5.4 ±0.8)19
5	*I. hirsuta*	Adaxial	18.3%	21.6(46.3 ± 2.2)59.4	16.2(24.7 ± 0.9) 29.7	44 (171.7±11.5) 220	16.2(19.6±0.6) 24.3	6.8(9.5±0.3)12.2	16(38.6±4.0)74	2(4.8±0.4) 8
		Abaxial	11.2%	27(46.2 ± 1.6)54	18.9(24.4 ± 0.9)32.4	131(185.8 ± 7.5) 260	13.5 (19.3 ± 0.8)24.3	5.4 (8.8 ± 0.4) 10.8	12(23.4 ± 2.2)46	1(3.9 ± 0.3) 6
6	*I. macrophylla*	Adaxial	0.9%	27(46.7 ± 2.8) 86.4	18.9 (26.6 ± 1.1) 37.8	132(214.3 ± 9.5) 270	13.5(22.1 ± 0.7)32.4	8.1(10.4 ±0.7) 24.3	0(2.0 ± 0.7)10	0(2.1±0.3) 5
		Abaxial	8.9%	21.6(42.5 ± 2.1)59.4	16.2(21.9 ± 0.9) 32.4	153 (214.2 ± 6.3) 268	16.2 (22.9 ± 0.7) 27	6.8(10.9 ± 0.4) 12.2	12 (20.9 ± 0.9) 26	3(6.3 ±0.4)11
7	*I. nummular-lifolia*	Adaxial	28.6%	46.8(53.2 ±1.0) 65	33.8(40.4 ±1.0)49.4	89 (124.7 ± 5.0) 171	18.2(23.4 ± 0.5) 26	10.4(13.9 ±0.5)20.8	38(50.1 ±1.4) 62	0(0.2±0.1)1.0
		Abaxial	29.9%	49.4(72.5 ±5.0)130	13.0(33.7 ±2.2)52.0	76 (94.6 ±2.9) 120	18.2(23.4 ±0.5) 26.0	13.0(17.0 ±0.6)20.8	29 (40.4 ±1.5) 50	0(0.9 ±0.2) 2
8	*I. oblongifolia*	Adaxial	16.9%	18.2(26.3 ±1.6)44.2	13.0(17.8 ±0.6) 20.8	194(230.5 ± 6.4) 274	13.0(16.8 ±0.4)18.2	13.0(9.4±0.6)18.2	33(46.8 ±1.3) 55	0(0.2 ±0.1) 2
		Abaxial	20.9%	28.6(38.2 ±1.3)46.8	15.6(23.1 ±0.9)31.2	180(211.1 ±4.7) 258	15.6(17.4 ±0.4) 20.8	10.4(11.1 ±0.3)15.6	42(55.8 ±1.7)68	0(0.3 ±0.2)2
9	*I. spicata*	Adaxial	35.2%	27.0(50.6 ± 2.1) 64.8	16.2(32.1 ± 1.4) 40.5	50 (71.7 ± 4.2) 126	5.4 (16.6 ± 1.1) 27.0	5.4(10.4 ±0.7) 16.2	18 (39.0 ±3.4) 75	Absent
		Abaxial	28.3%	27.0(49.4±2.6) 70.2	16.2 (30.4 ± 1.1) 40.5	67 (86.1 ± 3.6) 130	10.8 (17 ± 0.6) 21.6	5.4 (9.2 ± 0.5) 13.5	23 (34 ± 1.7) 49	1(3.6 ± 0.3) 5
10	*I. subulata*	Adaxial	17.2%	27 (46.4 ± 2.2) 67.5	18.9 (31.6 ± 20) 51.3	70(103 ± 4.8) 136	16.2(20.7 ± 0.5) 24.3	5.4 (9 ± 0.4) 12.2	16 (21.4 ±1.0) 30	1(2.9±0.3) 6
		Abaxial	**21.9%**	**27 (39.3 ± 2.0)54**	**16.2(28.5 ± 1.4) 43.2**	**64(89.0 ± 4.5) 130**	**13.5(19 ± 0.8) 27.0**	**5.4(9.1 ±10.5) 13.5**	**16(25 ± 1.2) 34**	**1(3.2±0.3) 5**
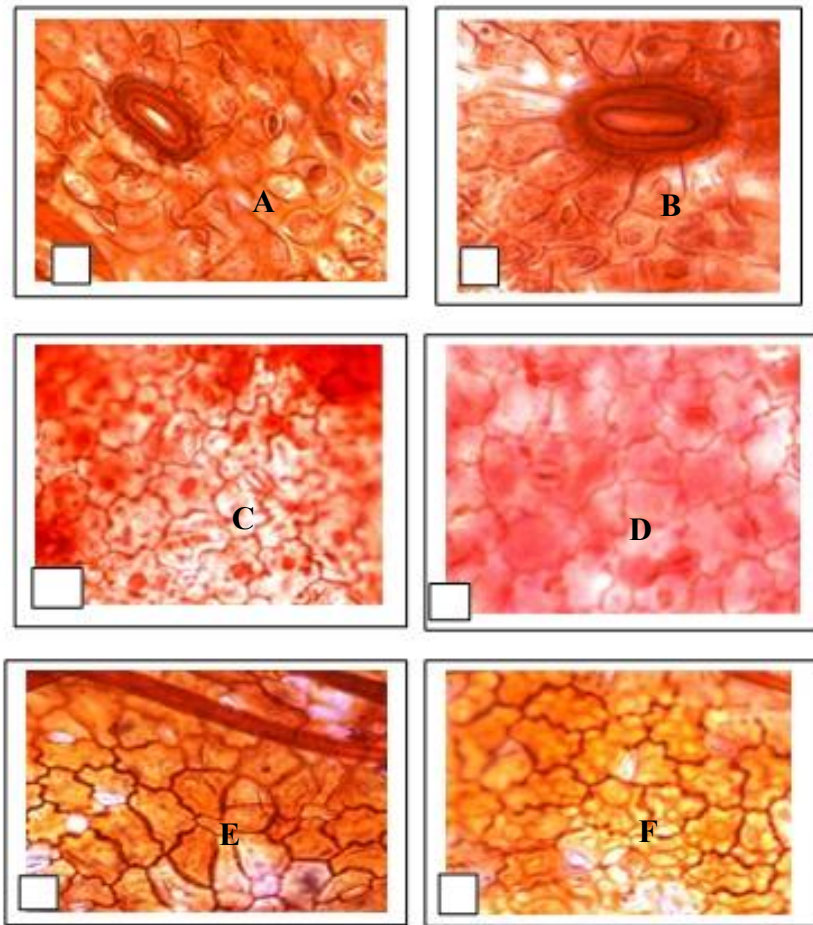
Figure 2: Photomicrographs of the foliar epidermal surfaces of the species of Indigofera studied. A: Adaxial surface of I. capitata showing large trichome base.

B: Abaxial surface of I. capitata showing large trichome base.

C: Adaxial surface of I. congolensis showing anomotetracytic, and anisocytic stomata.

D: Abaxial surface of I. congolensis showing anomotetracytic, and anisocytic stomata

E: Adaxial surface of I. deightonii showing anomocytic, anomotetracytic, paracytic and anisocytic stomata.

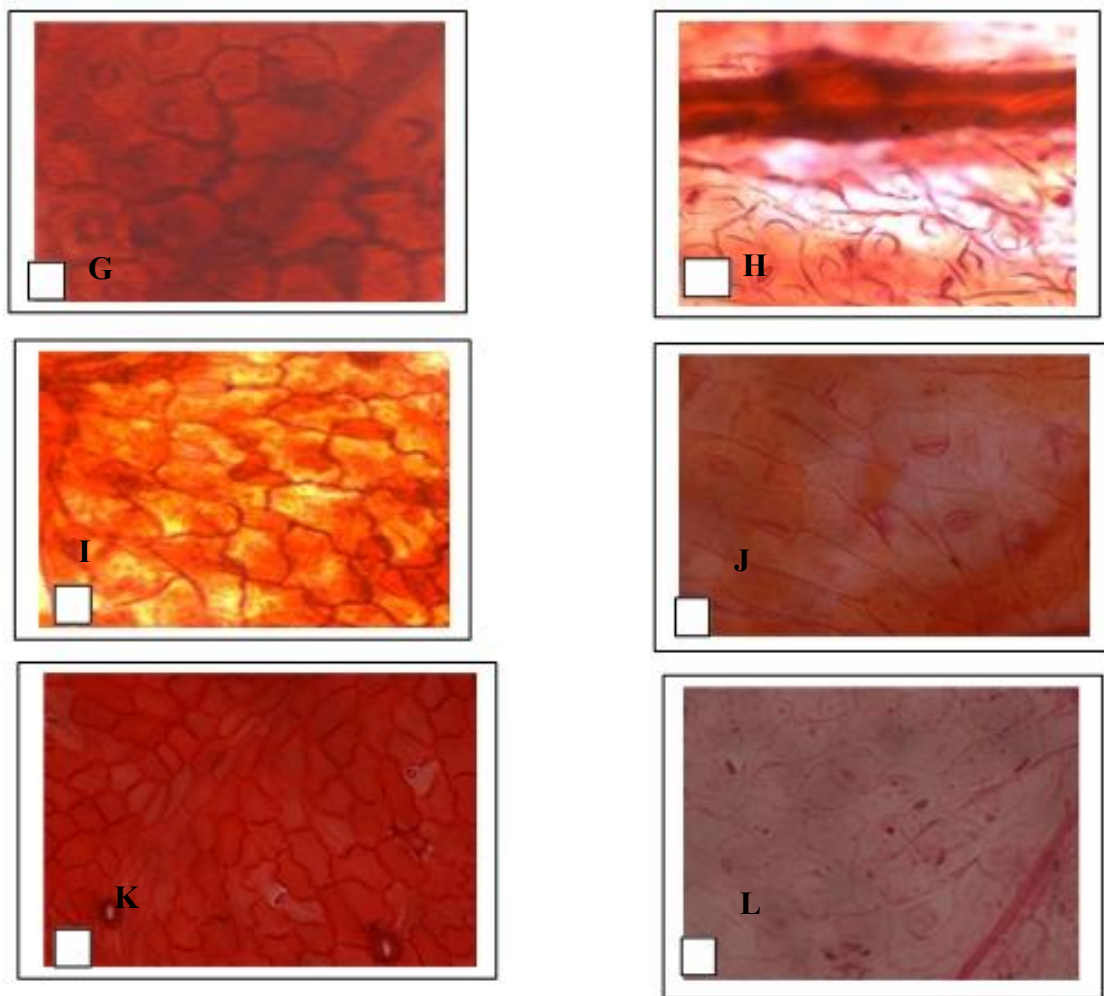F: Abaxial surface of I. deightonii showing anisocytic and paracytic stomata .

Figure 3: Photomicrographs of the foliar epidermal surfaces of the species of Indigofera studied G: Adaxial surface of I. geminata showing undulate anticlinal wall.

H: Abaxial surface of I. geminata showing double

arm trichomes.

I: Adaxial surface of I. hirsuta showing anisocytic
stomata.

J: Abaxial surface of I. hirsuta showing polygonal
cell shape.

K: Adaxial surfaces of I. macrophylla showing
irregular cell shape.

L: Abaxial surface of I. macrophylla showing curved
anticlinal wall.