

Seed Morphology of Some Species of *Indigofera* (Fabaceae) from Saudi Arabia (Identification of Species and Systematic Significance)

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ABSTRACT

Seeds of 18 species of Indigofera L. were examined with the scanning electron microscope and the light microscope. Macro- and micromorphological characters, including seed shape, colour, size, surface, epidermal cell shape, anticlinal boundaries, outer periclinal cell wall and relief of outer cell walls, are presented. Two types of basic anticlinal cell wall boundaries and two types of relief outer cell walls are recognized and two different shapes of the outer periclinal cell wall are described. A key for the identification of the investigated taxa based on seed characters is provided.

Keywords: Seeds, Morphology, *Indigofera*, Fabaceae, Saudi Arabia

1. Introduction

Indigofera L. is a large pantropical genus in Fabaceae, belongs to the tribe *Galegeae* with c. 720 - 730 species [1]. The majority of taxa occur in Africa (c. 520) with other centres of diversity in Arabia to South East Asia, Mexico to subtropical North and South America, Australia and Madagascar. About 280 species of *Indigofera* occur in the flora of Southern Africa region [2,3].

In Saudi Arabia *Indigofera* is represented by about 20 species and five varieties [4,5].

Reference [14] discussed features of the *Indigofera* fruit relevant to the Australian taxa. Reference [6] were the first to recognize that all species have a persistent fruit-base that remains with the calyx and staminal tube after the valves of the open pod have fallen. Reference [1] considered this is a synapomorphy for the tribe. Reference [7] found that all endemic species of *Indigofera* in Australia have endocarp tannins present except in *I. bailyi* and *I. mackinlayi*.

Reference [8] mentioned that the Scanning electron microscopy provides great tool to achieve more accurate seed identification, which could be used as a routine technique in the study of the Spermoderm Morphology [9,10].

Reference [11] established nine categories in his investigation of 340 species of *Papilionoideae*. Also, Reference [12] found three categories of Lersten's estab-

lishments. Belonging to the seeds testa patterns, Reference [11] illustrated a simple reticulate in *T. candida*.

The aim of the present study is to investigate macro- and micro-morphological characters of genus *Indigofera* seeds in Saudi Arabia, using Stereo- and Scanning Electron microscopy, which expected to be reliable for distinguishing the studied taxa. The work is mainly concentrated on collection of field work as well as herbarium collections from King Abdulaziz University KUH, KSU and RIY.

2. Material and Methods

The fresh plant samples were collected from the sites which were reported by [4,5,13,14], with field survey of the species throughout Saudi Arabia regions. The plant specimens nomenclatured according to [4,5,15]. Mature seeds were collected from dehiscent legumes, then cleaned with alcohol and kept for drying. The macro-morphological characters of the studied seeds were carried out using of Stereo-microscopy (Stemi2000-C) and the measurements, shapes, colour, and the position of hilum were recorded. On the other hand, the mature seeds of the investigated taxa were chosen for SEM study, where seeds were mounted on stubs using double face carbon tape, and coated with gold/palladium at 1.2 kv for 15 minutes under high vacuum in an ion sputter coating unit. The examined samples were detected and photographed using Scanning Electron Microscopy (Jeol JSM-20). The

terminology used here follows authors such as [10] and [16].

3. Results

Fruit and Seed characters are very important to separate among species in the genus *Indigofera*.

3.1. Fruits Colour

The colour of fruits is very important to separate among

the studied species. The colour varies from brown, light brown, deep brown, grayish, creamer, deep brown to creamer. It is deep brown in *I. argentea* and *I. spicata*, light brown in *I. sessiliflora* and *I. spiniflora*, grayish in *I. Arabica* and *I. Linifolia*, creamer in *I. intricata*, deep brown to creamer in *I. oblongifolia* and brown in the rest of the species. The fruit colour is used to distinguish between species of *I. Arabica*, *I. Linifolia*, *I. intricata* and *I. oblongifolia* from the other species (see **Table 1**).

Table 1. The macro-morphological characters of the studied *Indigofera* seeds.

Taxa	Fruits					Seeds						
	colour	constriction level	len. (cm)	shape	number (mean)	colour	hilum position	size (mm)	shape	ornament.		
										pr.	colour	
1. <i>I. amorphoides</i>	Br.	-	0.6	St., Cy.	1 - 2(-3)	Br.	Subcentral	0.21 × 0.16	Irr.	-	-	
2. <i>I. arabica</i>	Gr.	-	1.3	Fl., Fic.	4	Br.	Central	0.17 × 0.14	Irr.	-	-	
3. <i>I. argentea</i>	D. Br.	-	1.5	St., Cy.	10	D. Br.	Subcentral	0.95 × 0.12	Rect.	-	-	
4. <i>I. arrecta</i>	Br.	-	3.2	St., Cy.	7 - 9	Black	Subcentral	0.2 × 0.15	Irr.	-	-	
5. <i>I. articulata</i>	Br.	De.	1.1	±De., Cy.	3 - (-4)	D. oily	Central	0.22 × 0.22	Cir.	-	-	
6. <i>I. coerulea</i> var. <i>occidentalis</i>	Br.	Sh.	1.7	De, Cy.	5	L. oily	Central	0.25 × 0.18	Rect.	-	-	
7. <i>I. colutea</i>	Br.	-	1.5	St., Cy.	6	Oily	Subcentral	0.15 × 0.1	Cir.	-	-	
8. <i>I. hochstetteri</i>	Br.	-	1.7	De., Fl.	9	Br.	Subcentral	0.18 × 0.16	Cir.	+	Br.	
9. <i>I. intricata</i>	Cr.	-	2.5	St., Cy.	15	L. Br./Or.	Subcentral	0.14 × 0.13	Cir.	-	-	
10. <i>I. Linifolia</i>	Gr.	-	0.3	Cir.	1	Br.	Central	0.08 × 0.09	Cir.	+	Br.	
11. <i>I. oblongifolia</i>	D. Br. to Cr.	De.	2.2	±De., Cy.	6	Br.	Subcentral	0.14 × 0.1	Irr.	-	-	
12. <i>I. sessiliflora</i>	L. Br.	De.	1.0	St., Cy.	7	D. oily	Central	0.11 × 0.11	Cir.	+	Gr. - oily	
13. <i>I. spicata</i>	D. Br.	-	1.4	St., Cy.	6	D. oily	Central	0.14 × 0.14	Cir.	+	D. Br.	
14. <i>I. spiniflora</i>	L. Br.	De.	3.5	Cu.	9	Br.	Central	0.25 × 0.12	Irr.	+	Pu. to D. pu	
15. <i>I. spinosa</i>	Br.	-	1.7	St., Cy.	6 - 7	Cr.	Subcentral	0.15 × 0.13	Rect.	+	Oily-D. Br.	
16. <i>I. tinctoria</i>	Br.	-	2.5	St., Cy.	7 - 9	Oily/Gr.	Subcentral	0.25 × 0.16	Rect.	+	D. Br.	
17. <i>I. trita</i> var. <i>subulata</i>	Br.	-	1.0 - 2.5	St., An.	7 - 10	D. Br.	Subcentral	0.17 × 0.1	Irr.	-	-	
18. <i>I. volkensii</i>	Br.	V. Sh.	1.5 - 2.0	St., Cy.	6	Br.	Subcentral	0.08 × 0.1	Rect.	+	Pu-Bl.	

Bl. = black; Br. = brown; Cir. = circular; Cr. = creamer; Cu. = curved; D. Br. = dark brown; De. = deep; Gr. = grayish; De., Cy. = deflexed, cylindrical; ±De., Cy. = little deflexed, cylindrical; De., Fl. = deflexed, flat; Fl., Fic. = flat, fickle; Irr. = irregular; Len. = length; L. Br. = light brown; L. Br./Or. = light brown to orange; Ornament. = ornamentation; Pr. = present; Pu. = purple; Rect. = rectangular; Sh. = shallow; V. Sh. = very shallow; St., An. = straight, angular; St., Cy. = straight, cylindrical.

3.2. Fruits Constriction Level

The level of fruits constriction also is important feature to distinguish between even and constricted fruits in studied species. The fruits have deep constrictions in *I. articulata*, *I. oblongifolia*, *I. sessiliflora* and *I. spiniflora*, with shallow constrictions in *I. coerulea* var. *occidentalis* and possess very shallow constrictions in *I. volkensii*. The fruits of the remained studied species are even. The Fruits constriction level is also useful to distinguish between species of *I. articulata*, *I. oblongifolia*, *I. sessiliflora*, *I. spiniflora*, *I. coerulea* var. *occidentalis* and *I. volkensii* from the other investigated species (see **Table 1**).

3.3. Fruits Length

Length of fruits ranges from 0.6 cm - 3.5 cm (see **Table 2**). The smallest fruits are those of *I. species* (0.6 cm) and the largest are those of *I. spiniflora* (3.5 cm). Fruits length of other taxa ranged between (1.0 μ m - 3.2 μ m). Fruits length contributes to differentiate between the related species of *I. amorphoides*, *I. spiniflora*, *I. arrecta* (3.2 cm) from the other species (**Table 1**).

3.4. Fruits Shape

Fruits are more or less similar in shape being straight, cylindrical; deflexed, cylindrical; flat, fickle; deflexed, flat; circular; curved or straight, angular. They are more or little deflexed, cylindrical in *I. articulata*, *I. coerulea* var. *occidentalis* and *I. oblongifolia*, Flat, fickle in *I. Arabica*, Deflexed, flat in *I. hochstetteri*, circular in *I. Linifolia*, curved in *I. spiniflora* and finally straight, angular in *I. trita* var. *subulata*. The fruits shape also contributes to differentiate *I. articulata*, *I. coerulea* var. *occidentalis*, *I. oblongifolia*, *I. Arabica*, *I. hochstetteri*, *I. Linifolia*, *I. spiniflora* and *I. trita* var. *subulata*. species from the other investigated taxa which are characterized by straight, cylindrical fruits (**Table 1**).

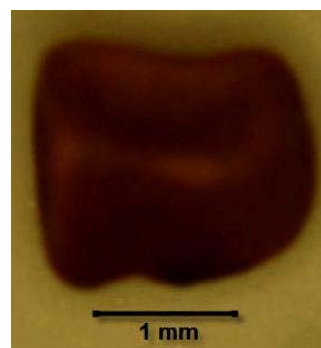
3.5. Seeds Number (Mean)

Number of seeds varies greatly among the examined taxa, the high number of seeds is 15 seeds in *I. intricata* and the low number is 1 - 2 in *I. Linifolia* and *I. amorphoides*, while the number of seeds in the rest of the studied species are ranged from 3 - 10 seeds. The seed number was found useful to separate species of *I. intricata*, *I. Linifolia* and *I. amorphoides* from the other species (see **Table 1**).

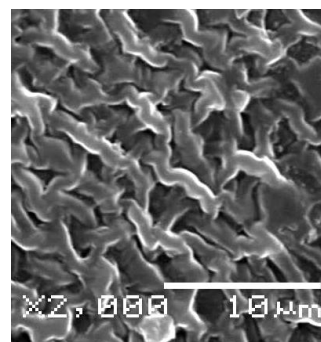
3.6. Seeds Colour

The colour of seeds is of high diagnostic and systematic interest among taxa. The colour varies from brown, dark oily, dark brown, oily, black, light oily, light brown/orange and creamer to oily/grayish. The seeds colour is

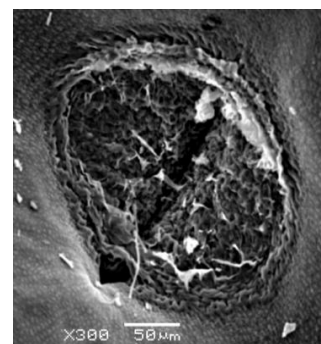
brown in *I. amorphoides*, *I. Arabica*, *I. hochstetteri*, *I. Linifolia*, *I. oblongifolia*, *I. spiniflora* and *I. volkensii*, dark oily in *I. articulata*, *I. sessiliflora* and *I. spicata*, dark brown in *I. argentea* and *I. trita* var. *subulata*, oily in *I. colutea*, with black colour in *I. arrecta*, light oily colour in *I. coerulea* var. *occidentalis*, light brown/orange in *I. intricate*, creamer in *I. spinosa* and finally oily/grayish in *I. tinctoria*. The Seeds colour is also used to distinguish between species of *I. arrecta*, *I. coerulea* var. *occidentalis*, *I. intricate*, *I. spinosa* and *I. tinctoria* from the other investigated taxa where there are more than one species for every colour (**Figures 1-18** and **Table 1**).



(a)



(b)



(c)

Figure 1. *I. amorphoides*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

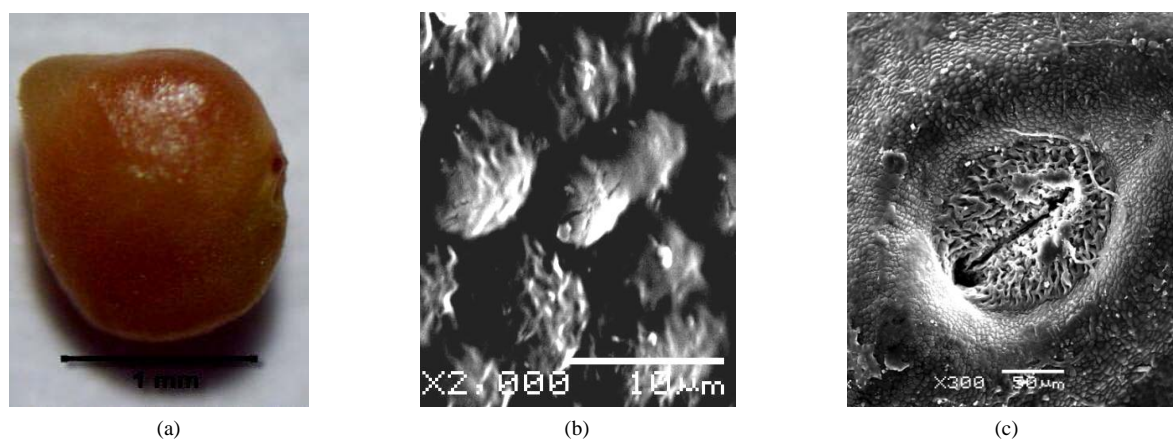


Figure 2. *I. arabica*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

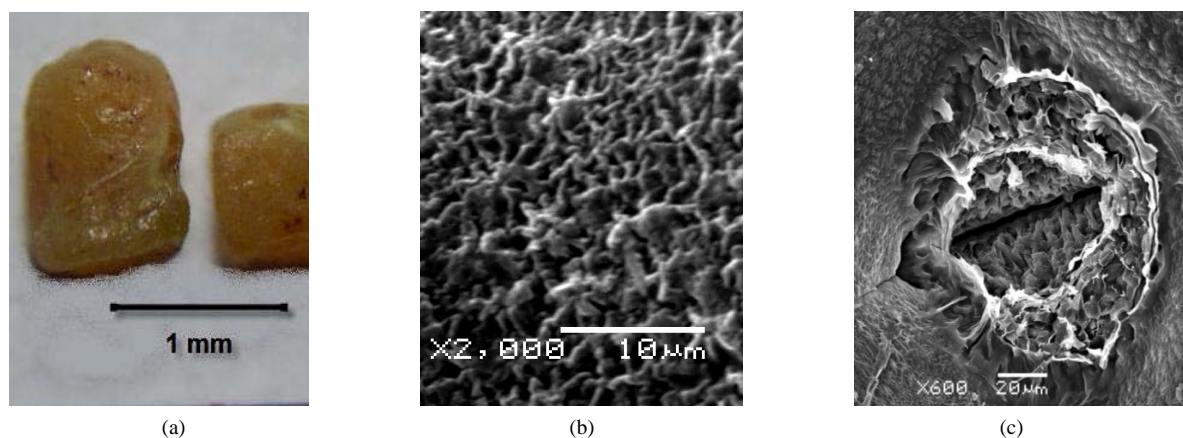


Figure 3. *I. argentea*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

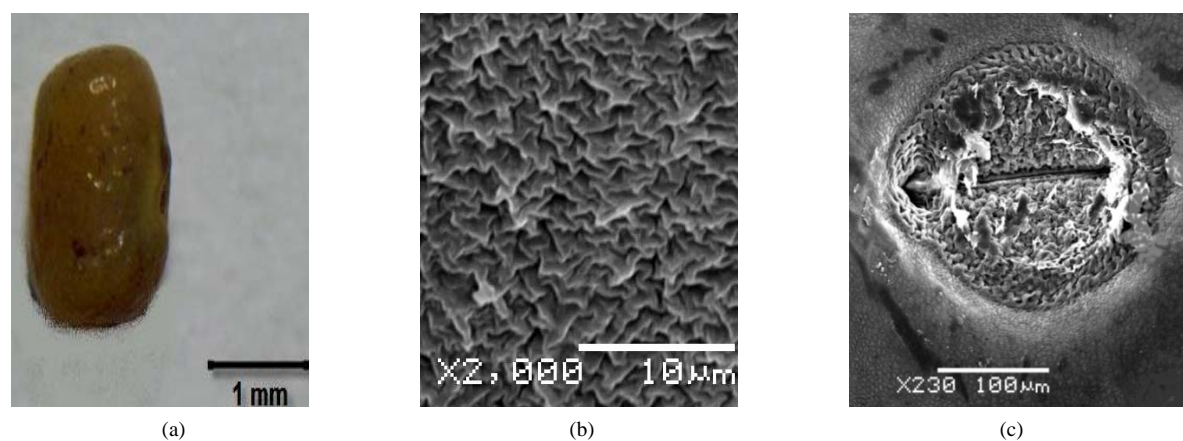


Figure 4. *I. arrecta*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

3.7. Hilum Position

There are two forms to hilum position, it is may be sub-central or central. Hilum is central in *I. Arabica*, *I. articulata*, *I. Linifolia*, *I. sessiliflora*, *I. spicata* and *I.*

spiniflora and subcentral in the remained species. Position of the hilum was useful to distinguish between two groups in the studied taxa, group with subcentral hilum and another one with central hilum (**Figures 1-18** and **Table 1**).

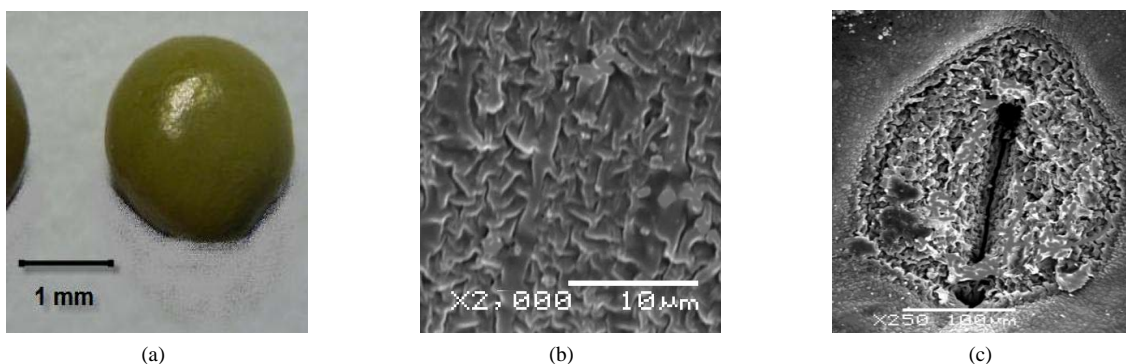


Figure 5. *I. articulata*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

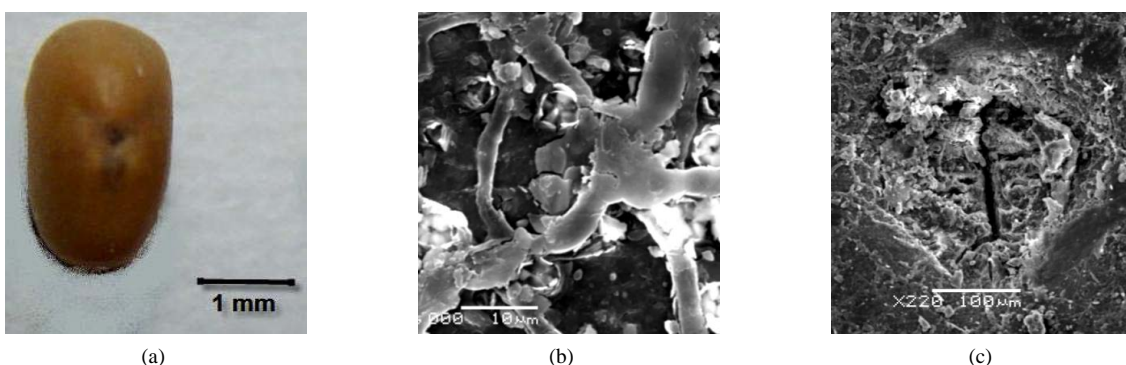


Figure 6. *I. coerulea* var. *occidentalis*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

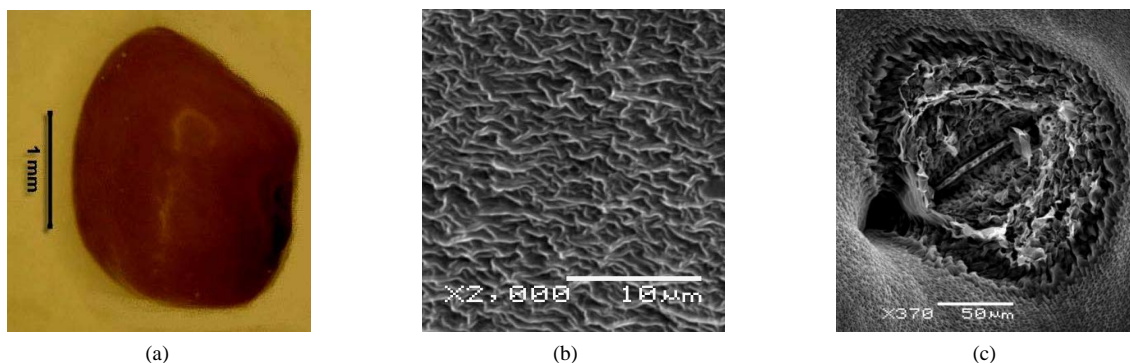


Figure 7. *I. colutea*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

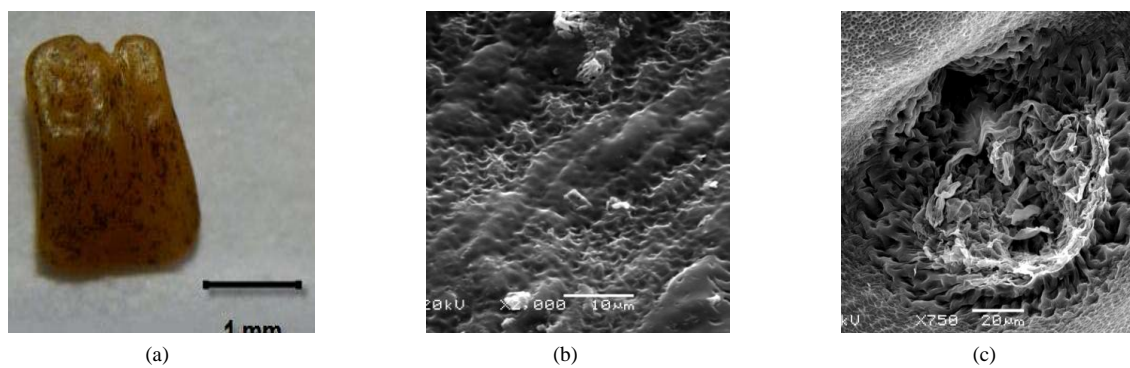


Figure 8. *I. hochstetteri*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

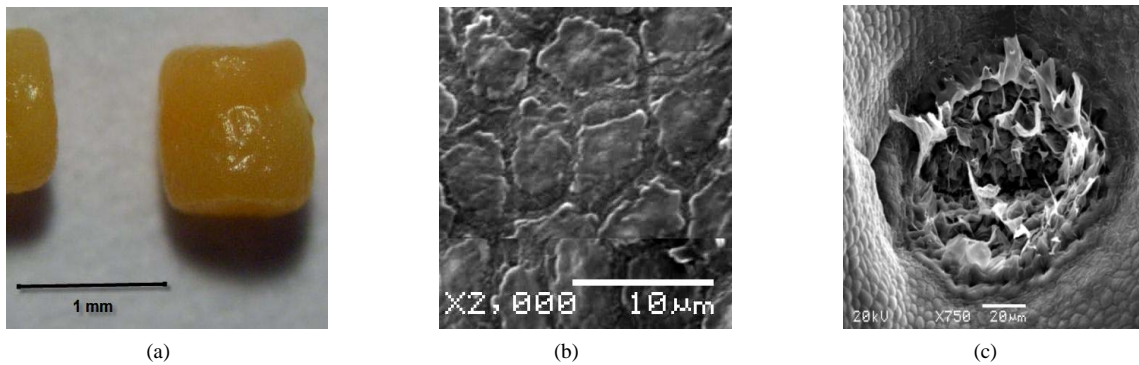


Figure 9. *I. intricate*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

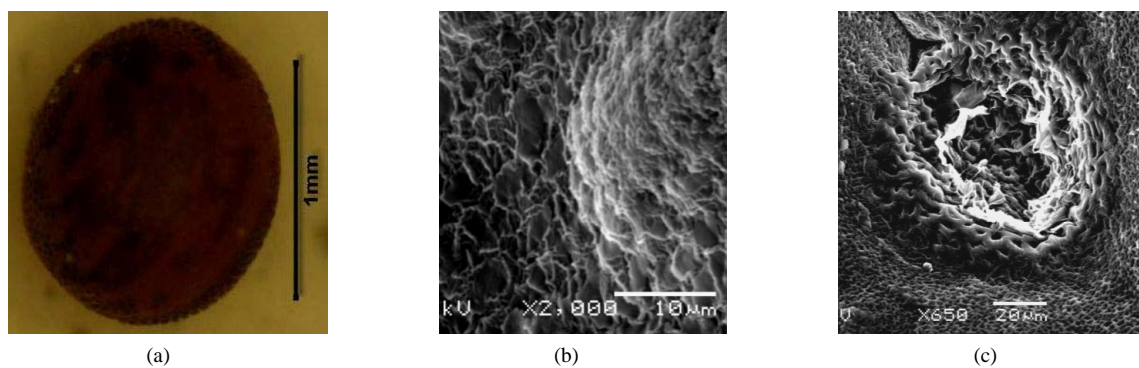


Figure 10. *I. linifolia*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

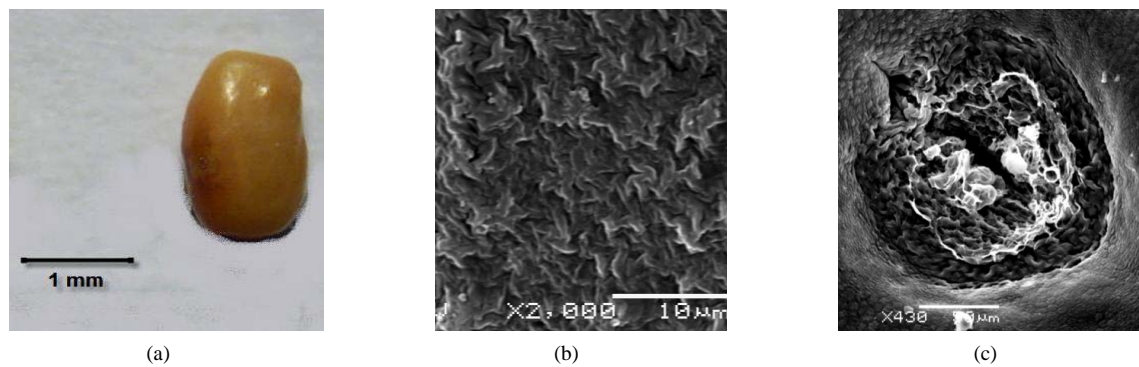


Figure 11. *I. oblongifolia*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

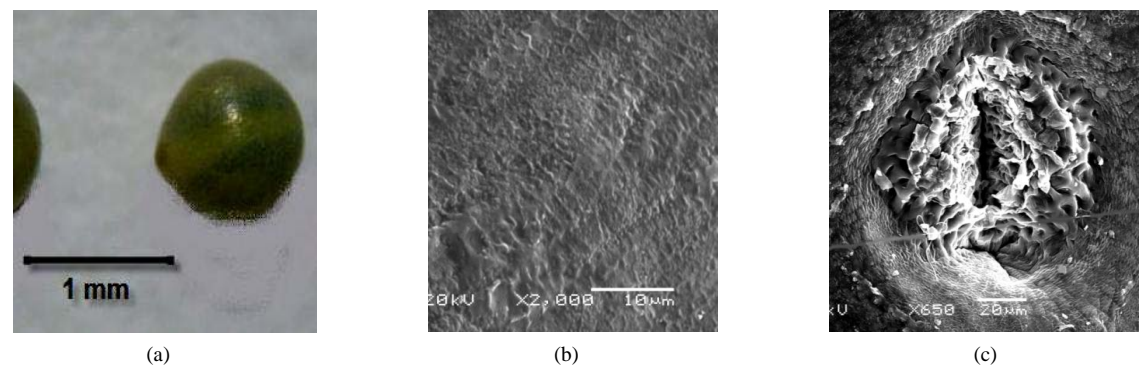


Figure 12. *I. sessiliflora*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

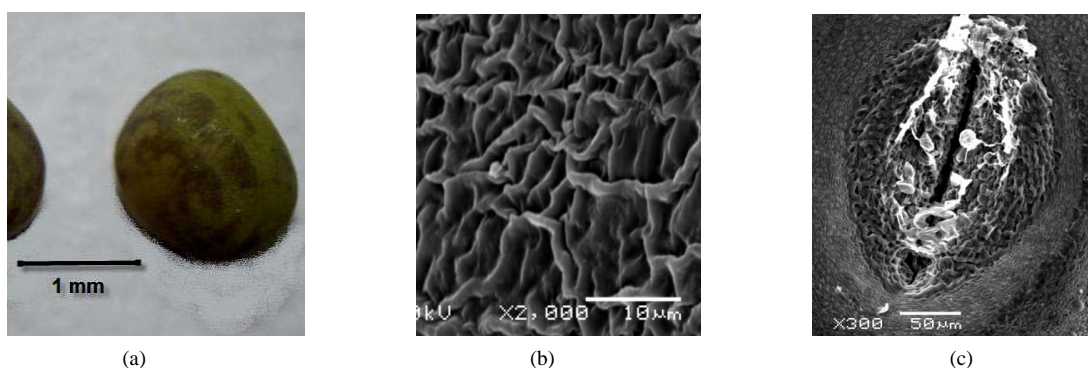


Figure 13. *I. spicata*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

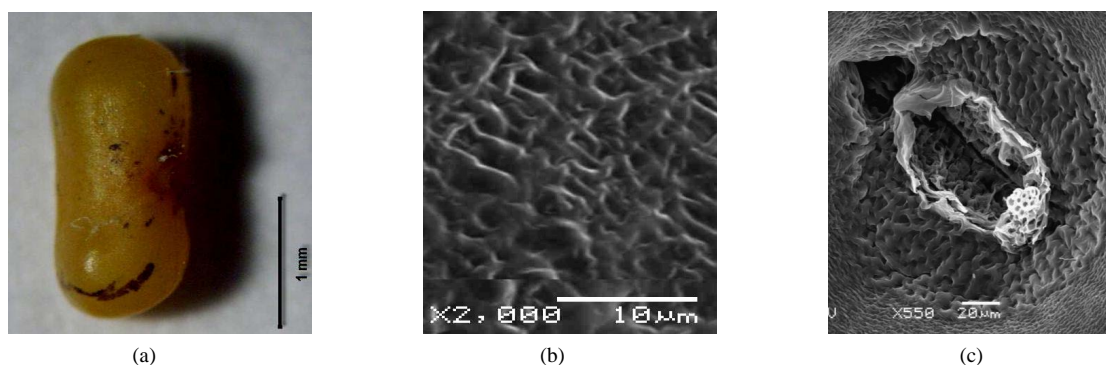


Figure 14. *I. spicata*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

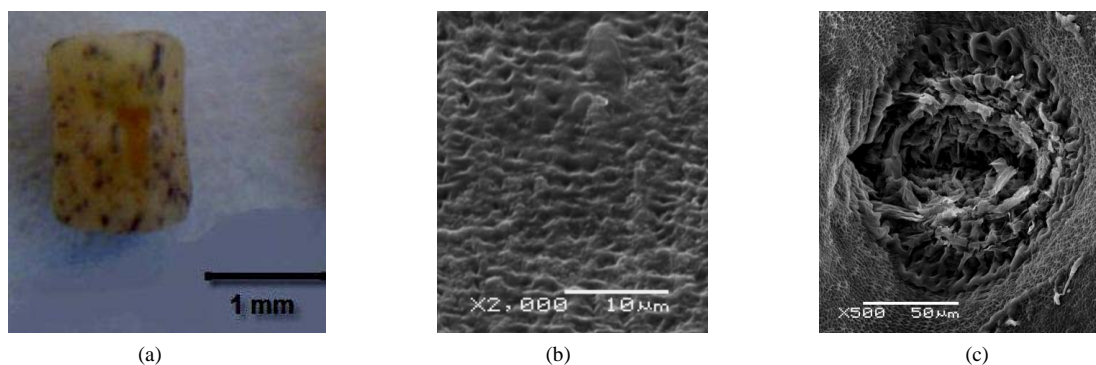


Figure 15. *I. spinosa*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

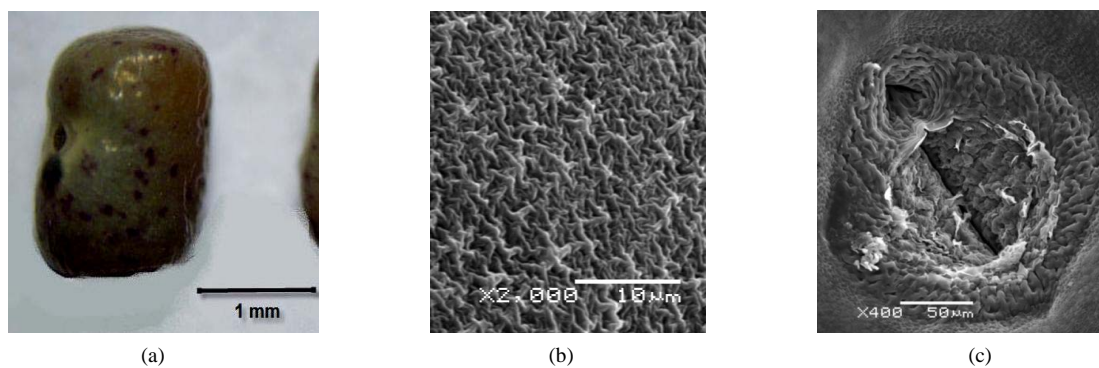


Figure 16. *I. tinctoria*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

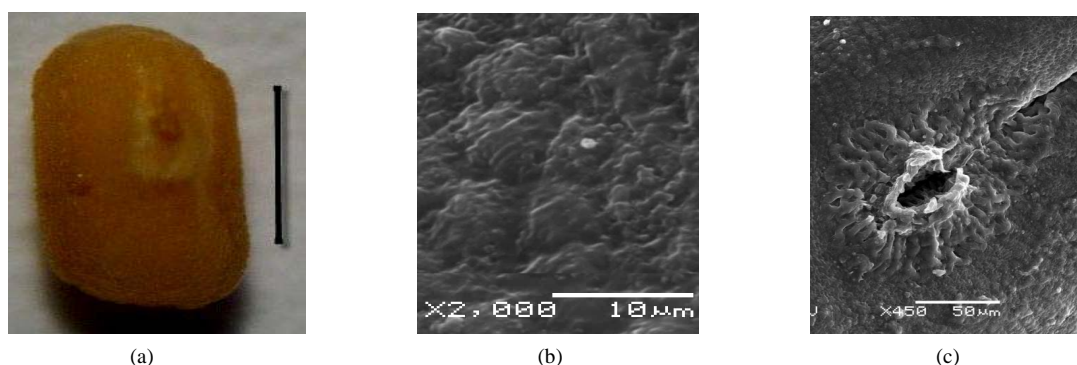


Figure 17. *I. trita* var. *subulata*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

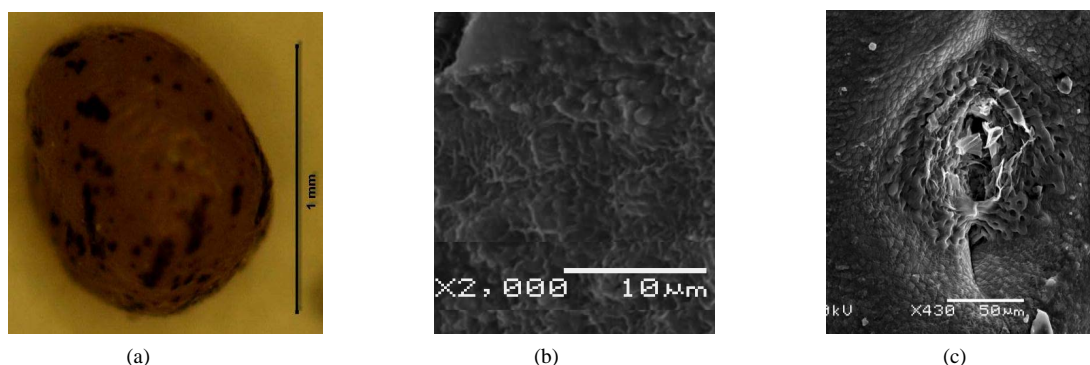


Figure 18. *I. volkensii*: (a) entire seed; (b) enlargement of seed coat; (c) Hilum shape.

Table 2. SEM observations on seeds surface character of 18 species of *Indigofera* (Leguminosae).

Taxa	Seeds surface character texture								scaled	rough
	ridged		reticulate							
	wrinkly	groovy	simple		compound (bireticulate)			opened		
			irregular	regular	I	II	III			
1. <i>I. amorphoides</i>	—	—	—	—	—	+	—	—	—	—
2. <i>I. arabica</i>	+	—	—	—	—	—	—	—	—	—
3. <i>I. argentea</i>	—	—	—	—	+	—	—	—	—	—
4. <i>I. arrecta</i>	—	—	+	—	—	—	—	—	—	—
5. <i>I. articulata</i>	—	—	+	—	—	—	—	—	—	—
6. <i>I. coerulea</i> var. <i>occidentalis</i>	—	—	+	—	—	—	—	—	—	—
7. <i>I. colutea</i>	—	—	—	—	—	+	—	—	—	—
8. <i>I. hochstetteri</i>	—	—	—	—	—	—	—	—	—	+
9. <i>I. intricata</i>	—	—	—	—	—	—	—	—	+	—
10. <i>I. linifolia</i>	—	+	—	—	—	—	—	—	—	—
11. <i>I. oblongifolia</i>	—	—	—	—	—	+	—	—	—	—
12. <i>I. sessiliflora</i>	—	—	—	—	—	—	—	+	—	—
13. <i>I. spicata</i>	—	—	—	—	+	—	—	—	—	—
14. <i>I. spiniflora</i>	—	—	—	—	—	+	—	—	—	—
15. <i>I. spinosa</i>	—	—	—	+	—	—	—	—	—	—
16. <i>I. tinctoria</i>	—	—	—	—	—	—	+	—	—	—
17. <i>I. trita</i> var. <i>subulata</i>	+	—	—	—	—	—	—	—	—	—
18. <i>I. volkensii</i>	+	—	—	—	—	—	—	—	—	—

Por.-Sret. = porate to simplereticulate; + = the feature present; – = the feature absent; +* = wrinkly ridged to bireticulate; I = the outer reticulum is thin and inner one is thick; II = the outer reticulum is thick and the inner one is thin; III = the outer and the inner reticulum are the similar.

3.8. Seed Size

Seed dimensions vary greatly among the examined taxa, the largest seeds in *I. argentea* have a diameter of 0.95×0.12 mm, and the smallest seeds measure $0.08 \times 0.09 - 0.1$ mm in *I. Linifolia* and *I. volkensii*, while the rest of the studied species have seeds their dimensions from $0.11 \times 0.11 - 0.25 \times 0.18$ mm. The seed size was found useful to separate species of *I. argentea*, *I. Linifolia* and *I. volkensii* from the other species (see **Table 1**).

3.9. Seeds Shape

The shape of seeds is showed a large variation among the investigated taxa. Most of seeds have circular shape and others are irregular or rectangular in shape (**Table 2**). Seeds are rectangular in *I. argentea*, *I. coerulea* var. *occidentalis*, *I. spinosa*, *I. tinctoria* and *I. volkensii*; irregular in *I. amorphoides*, *I. Arabica*, *I. arrecta*, *I. oblongifolia*, *I. spiniflora* and *I. trita* var. *subulata* and circular in the rest of the studied taxa (**Figures 1-18**). The shape of seeds was found useful to distinguish between three groups in the studied *Indigofera* species (**Figures 1-18** and **Table 1**).

3.10. Seeds Ornamentation

Seeds ornamentation is a significant character to separate among studied, ornamented species of *Indigofera*. The ornamentation of seeds present in some species like *I. hochstetteri*, *I. Linifolia*, *I. sessiliflora*, *I. spicata*, *I. spiniflora*, *I. spinosa*, *I. tinctoria*, *I. volkensii* and absent in the others. Also ornamentation colour was found useful to distinguish among the ornamented seeds. The colour varies from brown in *I. hochstetteri* and *I. Linifolia*, dark brown in *I. spicata* and *I. tinctoria*, green to oily in *I. sessiliflora*, purple to dark purple in *I. spiniflora*, oily to dark brown in *I. spinosa* and finally purple to black in *I. volkensii*. The ornamentation of seeds was found useful to separate between two groups of seeds, ornamented and not ornamented seeds. Also with ornamentation colour we can distinguish among *I. sessiliflora*, *I. spiniflora*, *I. spinosa* and *I. volkensii* from the others ornamented species (**Figures 1-18** and **Table 1**).

3.11. Character of Seeds Surface Texture

The character of Seeds surface texture can be of considerable diagnostic and systematic value. The texture of seeds surface varies from reticulate, ridged, scaled to rough (**Table 2**). There are three forms of reticulation, it may be opened, simple or compound (bireticulate). Opened reticulate surface present in *I. sessiliflora*, simple reticulate seeds surface texture may be regular or irregular, simple regular reticulate surface exists in *I. spinosa*,

but simple irregular reticulate surface appeared in *I. arrecta*, *I. articulate* and *I. coerulea* var. *occidentalis*. Compound or bireticulate surface also has three forms, it may be thin in the outer reticulum and thick in the inner one, thick in the outer reticulum and thin in the inner layer or the outer and the inner reticulum have the same thickness, the first form present in *I. argentea* and *I. spicata*, the second form present in *I. amorphoides*, *I. colutea*, *I. oblongifolia* and *I. spiniflora* and the third form are showed only in *I. tinctoria*. The ridged seeds surface texture also are appeared in two forms, it may be wrinkly ridged in *I. Arabica* and *I. trita* var. *subulata*, wrinkly ridged to bireticulate in *I. volkensii*, or groovy ridged only in *I. linifolia*. Scaled surface also are existed only in *I. intricata* and rough surface is appeared only in *I. hochstetteri*. It is cleared that, the texture of the seeds surface is essential and of great importance property to distinguish among the investigated taxa, it is used to distinguish clearly among species of *I. spinosa*, *I. sessiliflora*, *I. linifolia*, *I. intricate*, *I. tinctoria* and *I. hochstetteri*.

3.12. The Shape of Hilum

The shape of hilum among the investigated taxa showed a large variation. Shape of hilum varies from ovate, elliptic or circular in shape (**Table 3**). Hilum is wide ovate in *I. amorphoides*, *I. hochstetteri*, *I. linifolia*, *I. oblongifolia*, *I. sessiliflora*, *I. spiniflora* and *I. spinosa*, ovate in *I. coerulea* var. *occidentalis* and *I. trita* var. *subulata*, only elliptic in *I. arabica*, *I. articulate* and *I. volkensii*, wide elliptic in *I. argentea*, *I. arrecta*, *I. intricata*, *I. spicata* and *I. tinctoria*, finally hilum has circular shape only in *I. colutea*.

4. Discussion

From the above it can be seen that a clear cut distinction can be made among taxa based on the main external seed morphology. The variations observed in the seed coat patterns at high magnification were generally species-specific. Seeds texture characters applied to the species of *Indigofera* L. in Egypt proved to be useful in the distinction between four types of which two types represented by only one species, for example, the scaled texture type was discerned in only in *I. intricata*, rough texture type was observed also only in *I. hochstetteri*. Moreover, in *I. arabica*, *I. linifolia*, *I. trita* var. *subulata* and *I. volkensii* species two forms of the ridged texture type was observed, the first wrinkly ridged texture form was showed in *I. arabica*, *I. trita* var. *subulata* and *I. volkensii* and the second groovy ridged form are distinguished only in *I. linifolia*. The latest fourth texture type

Table 3. Tubular summary showing the shape of hilum in investigated species of *Indigofera*.

Taxa	wide ovate	ovate	elliptic	wide elliptic	circular
1. <i>I. amorphoides</i>	+	–	–	–	–
2. <i>I. arabica</i>	–	–	+	–	–
3. <i>I. argentea</i>	–	–	–	+	–
4. <i>I. arrecta</i>	–	–	–	+	–
5. <i>I. articulata</i>	–	–	+	–	–
6. <i>I. coerulea</i> var. <i>occidentalis</i>	–	+	–	–	–
7. <i>I. colutea</i>	–	–	–	–	+
8. <i>I. hochstetteri</i>	+	–	–	–	–
9. <i>I. intricata</i>	–	–	–	+	–
10. <i>I. linifolia</i>	+	–	–	–	–
11. <i>I. oblongifolia</i>	+	–	–	–	–
12. <i>I. sessiliflora</i>	+	–	–	–	–
13. <i>I. spicata</i>	–	–	–	+	–
14. <i>I. spiniflora</i>	+	–	–	–	–
15. <i>I. spinosa</i>	+	–	–	–	–
16. <i>I. tinctoria</i>	–	–	–	+	–
17. <i>I. trita</i> var. <i>subulata</i>	–	+	–	–	–
18. <i>I. volkensis</i>	–	–	+	–	–

+ = the feature present; – = the feature absent.

is the reticulate type, it was observed in three forms, the first form is the opened reticulate texture was discovered only in *I. sessiliflora*, the second one was the simple reticulate texture, it may be with irregular reticulation as shown in *I. arrecta*, *I. articulata* and *I. coerulea* var. *occidentalis* or has regular reticulation as observed only in *I. spinosa* and the third form was the compound (bi-reticulate) reticulate texture, there are three probabilities for the outer and the inner layers of the reticulum, in the first probability the outer reticulum is thick and the inner one is thin and this was showed in both *I. argentea* and *I. spicata*, and in the second probability the outer reticulum is thick and the inner one is thin and was observed in *I. amorphoides*, *I. colutea*, *I. oblongifolia* and *I. spiniflora*, but in the third one the outer and the inner reticulum have the same thickness, this was showed only in *I. tinctoria*.

Fruit and Seed morphological characters were helpful in distinguishing various species (Table 2). The smallest seed is those of *I. Linifolia* (0.08×0.09 mm) and the largest are those of *I. argentea* (0.95×0.12 mm). Seeds size of other taxa ranged between ($0.08 \times 0.1 - 0.25 \times 0.18$ mm). Seeds are more or less similar in shape being straight, cylindrical; flat, fickle; deflexed, cylindrical; deflexed, flat; circular; straight, angular to curved.

Hilum shape contributes to differentiate among the related species of *Indigofera* L.; *I. amorphoides*, *I. hoch-*

stetteri, *I. linifolia*, *I. oblongifolia*, *I. sessiliflora*, *I. spiniflora*, *I. spinosa*, *I. coerulea* var. *occidentalis* and *I. trita* var. *subulata* are characterized by ovate to wide ovate hilum, while *I. arabica*, *I. articulata*, *I. volkensis*, *I. argentea*, *I. arrecta*, *I. intricata*, *I. spicata* and *I. tinctoria* exhibit elliptic to wide elliptic hilum and only *I. colutea* that has circular hilum.

The Constriction level of fruits also contributes to differentiate *I. articulata*, *I. coerulea* var. *occidentalis*, *I. oblongifolia*, *I. sessiliflora*, *I. spiniflora* and *I. volkensis* species from the other investigated taxa which are characterized by constricted fruits while the other taxa exhibit even fruits. It also points to the close relationship between the *I. Arabica*, *I. articulata*, *I. coerulea* var. *occidentalis*, *I. Linifolia*, *I. sessiliflora*, *I. spicata* and *I. spiniflora* species which exhibit very close seeds being similar in hilum position. The fruits and seeds colour is more or less uniform in most investigated species. The seeds are circular, rectangular to irregular in shape.

In conclusion, the present study supports the use of seed morphological characters as a parameter for species identification. The results suggest both a close relationship between different species of *Indigofera* L. because there are different types of seed surfaces, seed shapes and epidermal cells similar each other from traditional species.

REFERENCES

- [1] B. D. Schrire, "Evolution of the Tribe Indigofereae (Leguminosae-Papilionoideae)," In: M. D. Crisp and J. J. Doyle, Eds., *Advances in Legume Systematics*, Vol. 7, 1995, Royal Botanic Gardens, Kew, pp. 161-244.
- [2] H. K. Airy Shaw, "A Dictionary of the Flowering Plants & Ferns," 8th Edition, Cambridge University Press, Cambridge, 1985.
- [3] D. J. Mabberley, "The Plant Book," 2nd Edition, Cambridge University Press, Cambridge, 1997.
- [4] S. Collenette, "Wild Flowers of Saudi Arabia," National Commission for Wildlife Conservation and Development (NCWCD), Riyadh, Kingdom of Saudi Arabia, 1999.
- [5] S. A. Chaudhary, "Flora of the Kingdom of Saudi Arabia (Vascular Plants), Vol. 1," National Agriculture and Water Research Center, National Herbarium, Ministry of Agriculture and Water, Riyadh, Saudi Arabia, 2001.
- [6] I. De Kort and G. Thijssse, "A Revision of the Genus *Indigofera* (Leguminosae-Papilionoideae) in Southeast Asia," *Blumea*, Vol. 30, No. 1, 1984, pp. 89-151.
- [7] P. G. Wilson and R. Rowe, "The *Indigofera trita* Complex (Fabaceae: Indigofereae) in Australia," *Telopea*, Vol. 5, No. 4, 1994, pp. 637-645.
- [8] J. D. Brisson and R. L. Peterson, "A Critical Review of the Use of Scanning Electron Microscopy in the Study of Seed Coat," *Scanning Electron Microscopy*, Vol. 2, 1976, pp. 477-495.
- [9] V. H. Heywood, "The Characteristics of the Scanning Electron Microscope and Their Importance in Biological Studies," In: *Scanning Electron Microscopy: Systematic and Evolutionary Applications*, The Systematics Association Special Volume, Vol. 4, 1971, pp. 1-16.
- [10] W. Barthlott, "Microstructural Features of Seed Surfaces," In: V. H. Heywood and D. M. Moore, Eds., *Current Concepts in Plant Taxonomy*, Academic Press, Cambridge, 1984.
- [11] N. R. Lersten, "Testa Topography in *Leguminosae* Subfamily Papilionoidae," *Proceedings of the Iowa Academy of Science*, Vol. 88, No. 4, 1981, pp. 180-191.
- [12] J. V. Suba Rao and S. R. Shannmukha Rao, "LM and SEM Studies in Seed Morphology in Some *Tephrosia* PERS. (Leguminosae)," *Feddes Repertorium*, Vol. 103, No. 5-6, 1992, pp. 339-343.
- [13] S. A. Chaudhary and A. A. Al-Jawaid, "Vegetation of the Kingdom of Saudi Arabia," Ministry of Agriculture and Water, Kingdom of Saudi Arabia, 1999.
- [14] A. M. Migahid, "Flora of Saudi Arabia," 2nd Edition, Vol. 2, King Saud University Libraries Publication, 1989.
- [15] L. Boulos, "Flora of Egypt Checklist," Revised Annotated Edition, Al-Hadara Publishing, Cairo, 2009.
- [16] W. Barthlott and B. Ziegler, "Mikromorphologie der Samenschalen als systematisches Merkmal bei Orchideen," *Berichte der Deutschen Botanischen Gesellschaft*, Vol. 24, 1981, pp. 267-273.

Key to the Studied Taxa Based on Seed Characters

1. a. Seeds surface reticulate.....7
- b. Seeds surface otherwise.....2
2. a. Seeds surface groovy ridged.....*I. linifolia*
- b. Seeds surface otherwise.....3
3. a. Seeds surface scaled.....*I. intricata*
- b. Seeds surface otherwise.....4
4. a. Seeds surface rough.....*I. hochstetteri*
- b. Seeds surface wrinkly ridged.....5
5. a. Hilum has ovate-shaped.....*I. trita* var. *subulata*
- b. Hilum has elliptic-shaped.....6
6. a. Seeds colour gray.....*I. Arabica*
- b. Seeds colour brown.....*I. volkensii*
7. a. Seeds surface opened reticulate.....*I. sessiliflora*
- b. Seeds surface otherwise.....8
8. a. Seeds surface compound reticulate.....9
- b. Seeds surface simple reticulate.....15
9. a. The outer and the inner reticulum are similar in thickness.....*I. tinctoria*
- b. The outer and the inner reticulum are otherwise.....10
10. a. The outer reticulum is thin and the inner one is thick.....11
- b. The outer reticulum is thick and the inner one is thin.....12
11. a. Seeds shape is rectangular without ornamentation.....*I. argentea*
- b. The outer reticulum is thick and the inner one is thin.....12
12. a. The hilum shape is circular.....*I. colutea*
- b. The hilum shape is wide ovate.....13
13. a. Fruits are even.....*I. amorphoides*
- b. Fruits are deeply constricted.....14
14. a. The mean of fruits length 2.2 cm.....*I. oblongifolia*
- b. The mean of fruits length 3.5 cm.....*I. spiniflora*
15. a. Seeds surface has simple regular reticulation.....*I. spinosa*
- b. Seeds surface has simple irregular reticulation.....15
16. a. The hilum shape is ovate.....*I. coerulea* var. *occidentalis*
- b. The hilum shape is elliptic to wide elliptic.....17
17. a. Fruits are even.....*I. arrecta*
- b. Fruits are deeply constricted.....*I. articulata*