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# Taxonomic revision of the genus *Scorpiurus* L. (Fabaceae)

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## ABSTRACT

The morphological and anatomical characteristics of different parts were utilized to reassess the taxonomic status in *Scorpiurus* L. species naturally growing in Egypt. There were significant differences among the studied species of plants and hence the results clearly showed two distinct species. Based on the studied morphological and anatomical differences *S. muricatus* L. is differentiated into three different varieties. These are *muricatus* L., *laevigatus* (Sibth. & Sm.) Boiss. and *subvillosus* (L.) Fiori. An artificial key to both species and varieties are provided.

**KEYWORDS:** *Scorpiurus*, morphological, anatomy, SEM seed

## INTRODUCTION

The genus *Scorpiurus* L. is one of the genera of the family Fabaceae, belonging to the subfamily Faboideae Rudd., tribe Loteae DC., subtribe Scorpiurinae Rouy. It is distributed in Mediterranean area from the Canary Islands and N W Africa through Portugal, Spain and Southern regions of Europe to Anatolia, W Iran and Iraq [1-4]. Tournefort [5] was the first who gave a more or less exact vision of the genus, recognizing six species.

Linnaeus [6] subsequently reduced them to four species: *S. muricatus*, *S. subvillosus*, *S. sulcatus*, and *S. vermiculatus*, with somewhat vague diagnoses. So, in attempting to explain the difficulties in the delimitation of the species, Lamarck [7] considered the last three species as varieties of *S. echinatus* Lam. In most studies, after Linnaeus, the authors confused some species with others and the descriptions of new taxa were based, only on the characteristics of the fruit morphology.

Later, other authors tried the subdivision of the genus in only two species *S. muricatus* and *S. vermiculatus* [8-10]. Quézel and Santa [11] in their study in Algeria recognized the genus into *S. muricatus* and *S. vermiculatus* and recognized *S. muricatus* into two subspecies viz. *subvillosus* and *sulcatus*. In a study of the species, *S. muricatus*, *S. subvillosus* and *S. sulcatus*, in Israel, Heyn and Raviv [1] reported that there was no indication of any genetic crossing barriers between different taxa and reorganized them as one species, *S. muricatus*

Domínguez and Galiano [2] recognized not only *S. muricatus*, *S. subvillosus*, *S. sulcatus* and *S. vermiculatus*, as full species, but further identified distinct varieties within each of them. Zielinski, [12] distinguished the genus into two species, *S. muricatus* and *S. vermiculatus* while Talaver and Domínguez [13] distinguished the genus into four species *S. muricatus*, *S. subvillosus*, *S. sulcatus* and *S. vermiculatus*. In Egypt, Täckholm [14] recorded only *S. muricatus* and recognized it into var. *laevigatus*, var. *muricatus*, var. *subvillosus* and var. *sulcatus*. El-Hadidi and Fayed [15] and Bolous [16-18] recognized *S. muricatus* as a distinct species.

The objectives of the study were to study the morphological, anatomical and SEM of seeds of available *Scorpiurus* species.

## MATERIALS AND METHODS

The present study is based on fresh material collected from their natural habitats in Egypt in addition to collections kept in Menoufia University Herbarium (MNF). Seeds of *S. vermiculatus* are obtained from Western Regional Plant Introduction Station-Washington State University in US. The seeds were cultivated in plastic house, till fruiting stage.

Samples for anatomy of the stem and mature leaves were chosen from fresh material (Table 1). All assessment was made on all plants at similar developmental stages (fruiting stage) and in comparable positions of each plant. Fresh material was fixed in F.A.A. (5:5:90). After fixation stems and leaves were transformed in ethyl alcohol series, and then embedded in paraffin wax. The

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**Table 1:** List of names, collection details and sources of seeds included in the present study

Taxa	Source of seeds	Localities	Geographical coordinates	Date of collection
<i>S. Muricatus</i> var. <i>laevigatus</i>		15 km west Marsa Matrouh (Marsa Matrouh – Sallum road), 140 m a.s.l. Al-Mathani Al-Bahria - Marsa Matrouh, 15 m a.s.l.	31° 15.788\ N 27° 06.862\ E 31° 28.192\ N 26° 44.520\ E	3,4/2014-2017
<i>S. Muricatus</i> var. <i>muricatus</i>		46 km east Sidi Barani (Marsa Matrouh – Sallum road), 61 m a.s.l. 25 km west Marsa Matrouh (Marsa Matrouh – Sallum road), 150 m a.s.l.	31° 27.890\ N 26° 24.092\ E 31° 17.036\ N 27° 02.648\ E	3,4/2014-2017
<i>S. Muricatus</i> var. <i>subvillosus</i>		15 km west Marsa Matrouh (Marsa Matrouh – Sallum road), 140 m a.s.l. Al-Mathani Al-Bahria - Marsa Matrouh, 15 m a.s.l.	31° 15.788\ N 27° 06.862\ E 31° 28.192\ N 26° 44.520\ E	3,4/2014-2017
<i>Scorpiurus vermiculatus</i>	PI 302962, PI 535676			

stems and leaves were sectioned at 10-15  $\mu$ m; sections were dehydrated in alcohol-xylol series. Sections were stained in safranin and light green according to Sass [19]. The transverse sections were examined and photographed by Zeiss research microscope. A planimeter was used for estimation of the percentage of each tissue to the total section area. Terminology followed Abd El-Rahman *et al.* [20], Pandey [21] and Abd El-Gawad *et al.* [22].

SEM study of the investigated material was carried out by mounting dried material on brass stubs and coated with a thin layer of gold using JEOL JSM 530P SEM at the electron microscopic unit, Faculty of Science, Alexandria University. Terminology followed Lersten [23]), Brochmann [24], Stearn [25] and Kirkbride *et al.* [26].

*Scorpiurus* L. Sp. Pl. ed. I (1753) 745.

Syns.: *Scorpioides* Tourn. ex Adans., Fam. II (1763) 328.

*Scorplus* Loisel, Fl. Gal. (1806) 468.

### Description of the Genus

Annual herbs, stems decumbent; leaves simple, petioled, blade entire, with 3-5 parallel veins; stipules linear, free or partly adnate to the petiole, conspicuous, acute; inflorescence umbellate, axillary, long pedunculate, 1- or few flowered; bracts small, scarious; bracteoles absent; flowers yellow to or orange; calyx deeply 5-teeth somewhat unequal, the upper teeth long connate, shortly campanulate; standard suborbicular, wings oblong; keel oblong, incurved, androecium diadelphous, stamens alternately dimorphous, filaments dilated at apex, anthers uniform; ovary sessile, many ovuled; style incurved, dilated at the middle, attenuate at apex; stigma capitate; pod subterete, circinate-convolute, indehiscent, many seeded, constricted between the seeds; longitudinally ribbed, ribs smooth, tuberculate or spiny; seeds reniform to ovoid-cylindrical, truncate, depending on the shape of the joint in which it develops, estrophiolate.

### Taxonomic Studies

On the bases of morphology, anatomy and seed characters, the present study indicated that two distinct species, *S. muricatus*

and *S. vermiculatus* can be distinguished and *S. muricatus* represented by three varieties; viz. *muricatus*, *laevigatus* and *subvillosus*.

### A: Macromorphological Studies (Table 2 & Figures 1)

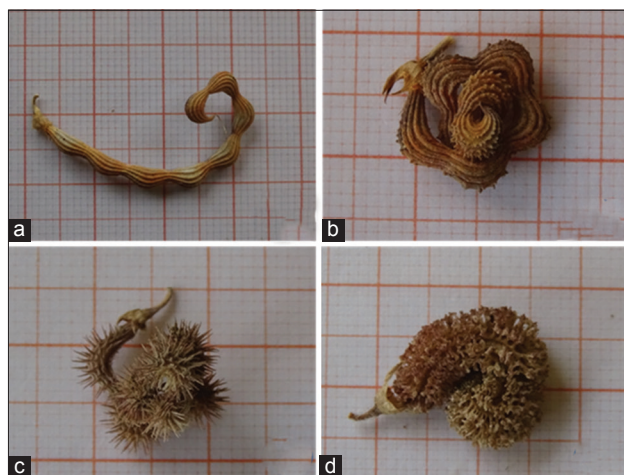
*Scorpiurus muricatus* L., Sp. Pl.: 745 (1753) var. *muricatus*

Syn.: *Scorpiurus echinatus* Lam. in Lam. & Poir., Encycl. 1:726 (1785)

Annual herb, 6-33 cm height. Stem decumbent, branched at base, pubescent, ribbed, green, reddish brown at the lower part, internodes 2.5-4 cm long. Leaves simple, alternate, petiolate; petioles 1.4-2.2 cm; lamina 6.3-8.5 x 1.3-2.1 cm, oblanceolate-elliptic, acute apex, entire margin, 3 main veins on lower surface, both petiole and lamina appressed hairy, hairs with bulging base. Stipules dimorphic, long one 11-22 mm, short one 6-11 mm, lanceolate, entire-membranous margin, acute apex. Inflorescence umbellate, 1-3 flowers; peduncle 5.4-11.6 cm long at flowering, 12.7-17.2 cm long at fruiting, ribbed, appressed hairy. Bracts scarious, 1-2 mm long. Flower 11-11.5 mm long; pedicel 1-1.2 mm, appressed hairy; calyx campanulate, tube 3-3.2 mm long, appressed hairy, teeth lanceolate, 3 mm long, acute apex, entire-membranous margin; standard yellow, clawed, lamina 9-9.5 x 7-7.3 mm, oblate, entire margin, acute apex, claw 3-3.5 mm long, veins 6 mm long, red coloured; wings yellow, lamina 7 x 3 mm, oblong, round apex, entire margin, claw 3 mm long, auricule 0.5 mm long; keel greenish yellow, lamina 8 x 3 mm, slightly curved apex, acute beak, claw 3 mm long. Androecium diadelphous, 1+ (9), free filament 6-6.5 mm long, the other united filament with the free parts have two lengths, five filaments 3-3.5 mm long, four filaments 2-2.3 mm long, united part 4-4.2 mm long, filament dilated above, anthers oblong, uniform. Gynoecium 8 x 0.5 mm, ovary sessile, 4 x 0.5 mm, cylindrical, slightly curved, style 4 mm long, stigma capitate. Pod loosely coiled, constricted between the seeds, yellowish brown-blackish, ribbed, 7-10 ribs covered with tubercles, 1-4 ribs smooth, beak 3-3.5 mm long, 8-10 seeds. Seeds reniform-cylindrical, 3-5 x 1.5 mm, yellowish brown- brown, with rounded poles, hilum blackish and lateral.

Table 2: Morphological characters of the studied taxa

Character	<i>Scorpiurus</i>			
	<i>muricatus</i> var. <i>laevigatus</i>	<i>muricatus</i> var. <i>muricatus</i>	<i>muricatus</i> var. <i>subvillosus</i>	<i>vermiculatus</i>
Plant	Annual	Annual	Annual	Annual
Habit	Herb	Herb	Herb	Herb
Height (cm)	Decumbent	Decumbent	Decumbent	Decumbent
surface	21-35	6-33	9-40	20-32
	Pubescent	Pubescent	Pubescent	Villous
Inflorescence				
Type	Umbellate	Umbellate	Umbellate	Solitary
No. of flowers	2-4	1-3	(2-) 3-4 (-5)	1
No. of bract	2-4	1-3	(2-) 3-4 (-5)	1
Flower				
Length (mm)	8-11.5	11-11.5	8-10 (-11)	13-13.5
Standard				
Colour	Yellow	Yellow	Yellow	Yellow in the center and orange in the outer part
Apex	Acute	Acute	Acute	Obtuse
Wings				
Colour	Yellow	Yellow	Yellow	Yellowish orange
Keel				
Colour	Greenish yellow	Greenish yellow	Greenish yellow	Whitish yellow
Stamens				
Filament free length (mm)	5.5-6.5	6-6.5	4-6	8-8.5
Filaments united (free parts length mm)	5=3-3.2	5=3-3.5	5=3-3.3	5=5-5.4
	4=1.5-2	4=2-2.3	4=1.5-2	4=3-3.5
Pod	Straight, falcate at apex	coiled	Very closely twisted	Curved
Shape	45-55 x 2-3	45-50 x 2-3	35-45 x 2-3	25-30 x 3
Size L×W (mm)	Yellowish brown	Yellowish brown - blackish	Yellowish brown - blackish	Pale brown
Colour	Ribbed, ribs smooth	Ribbed, ribs covered with tubercles	Ribbed, ribs covered with spines	Ribbed, ribs covered with capitate tubercles
Surface	11	7-10 tuber, 1-4 smooth	9-10 spiny, 1-2 smooth	11
No. ribs	3-3.3	3-3.5	3-3.5	5-5.3
Beak length (mm)	7-8	8-10	6-7	2-3
Seed No.	7-8	8-10	6-7	2-3



**Figure 1:** Fruit photographs of the studied taxa: A. *Scorpiurus muricatus* var. *laevigatus*, B. *S. muricatus* var. *muricatus*, C. *S. muricatus* var. *subvillosus*, D. *S. vermiculatus*

*Scorpiurus muricatus* var. *laevigatus* (Sibth. & Sm.) Boiss., Fl. Orient. 2: 178 (1872).

Syns.: *Scorpiurus laevigatus* Sibth. & Sm., Fl. Graec. Prodr. 2: 81 (1813).

*S. muricatus* subsp. *laevigatus* (Sibth. & Sm.) Thell., Fl. Adv. Montpellier: 338 (1912).

*S. muricatus* var. *laevigatus* differs than var. *muricatus* by the following: plant 21-35 cm height; leaf lamina 9.4-12.4 x 2.7-2.9 cm; pod 45-55 x 2-3 mm, straight, falcate at apex, yellowish brown, ribbed, ribs smooth, 7-8 seeds; seeds lunate-cylindrical, brown, with rounded-truncate poles.

*Scorpiurus muricatus* var. *subvillosus* (L.) Fiori, in Fiori & Paol., Fl. Anal. Ital. 2: 89 (1900).

Syns.: *Scorpiurus subvillosus* L., Sp. Pl.: 745 (1753).

*S. muricatus* subsp. *subvillosus* (L.) Thell., Fl. Adv. Montpellier: 339 (1912).

*S. muricatus* var. *subvillosus* differs than var. *muricatus* by the following: pod very closely twisted, yellowish brown-blackish, 9-10 ribs covered with spines, 1-2 ribs smooth, 6-7 seeds; seeds reniform, 2.5-3.5 x 1.5 mm, with rounded poles.

*Scorpiurus vermiculatus* L., Sp. Pl.: 744 (1753).

Annual herb, 20-32 cm height. Stem decumbent, villous, ribbed, green, reddish brown at the lower part, branched at base,

internodes 2-3.5 cm long. Leaves simple, alternate, petiolate; petioles 1.6-2.3 cm; lamina 5.9-9.8 x 1.4-2.3 cm, oblanceolate-elliptic, acute apex, entire margin, 3 main veins on lower surface, both petiole and lamina appressed hairy, hairs with bulging base. Stipules lanceolate, entire-membranous margin, acute apex, present in two length, one up to 10 mm long and the second 10-18 mm. Flowers solitary, unibracteate; pedicle 3.7-4.5 cm long at flowering, 8.6-11.2 cm long at fruiting, ribbed, appressed hairy. Bracts scarious, 1-2 mm long. Flowers 13-13.5 mm long; pedicel 1.5-1.8 mm, appressed hairy; calyx campanulate, tube 3-3.4 mm long, appressed hairy, teeth lanceolate, 4-4.3 mm long, acute apex, entire-membranous margin; petals clawed, standard yellow in the center and orange in the outer part, lamina 12.5 x 11 mm, oblate, with red veins, entire margin, obtuse apex, claw 4.5-4.8 mm long, wings yellowish orange, auriculate, lamina 10 x 4 mm, oblong, round apex, entire margin, claw 3-3.5 mm long, auricle 0.7 mm long; keel whitish yellow, lamina 10 x 3 mm, apex looks like beak and slightly curved, claw 2.5-2.7 mm long. Androecium diadelphous, filaments free 8-8.5 mm long, the free parts of united filaments have two lengths, five filaments 5-5.4 mm long, four filaments 3-3.5 mm long, united part 5-5.2 mm long, filaments dilated above, anthers oblong, uniform. Gynoecium, 10-10.4 x 1-1.2 mm, ovary sessile, cylindrical, slightly curved, 5-5.4 x 1-1.2 mm, style 5 mm long, stigma capitate. Pod curved, pale brown, 25-30 x 3 mm, ribbed, all ribs covered with capitate tubercles, beaked, beaks 5-5.3 mm long, few seeded, 2-3 seeds, constricted between seeds. Seeds reniform-cylindrical, 4.5-5 x 1.5 mm, yellowish brown-brown, with rounded poles, hilum blackish and lateral.

## B: Anatomical studies

The anatomical investigations of the stem and leaf of the studied taxa is represented in table (3,4) and figures (2, 3) respectively.

## I: Stem anatomy

### 1- *Scorpiurus muricatus*

- a- var. *muricatus* Stem angular, 2.3-2.5 mm diameter; cuticle 2.5-5  $\mu$ m thickness; epidermal cells isodiametric-radially elongated, 25-42.5  $\mu$ m thickness. Cortex consists of collenchyma and parenchyma; collenchyma one layer in ridges, isodiametric-radially elongated, 30-37.5  $\mu$ m thickness. Parenchyma 6 layers, isodiametric-tangentially elongated, 120-210  $\mu$ m thickness. Vascular cylinder 15-17 bundles, each bundle 220-340  $\mu$ m wide with 4-7 sclerenchymatous layers, pericyclic fibers 42.5-117.5  $\mu$ m thickness. Phloem 3-4 layers, 30-37.5  $\mu$ m thickness. Cambium 2 layers, 10-15  $\mu$ m thickness. Xylem 3-6 arches, 2-4 vessels per arch, 80-150  $\mu$ m length. Pith cells isodiametric-cylindrical, 1.6-1.9 mm diameter. tannin cells represented in both cortical and pith parenchyma.
- b- var. *laevigatus* has the same previous anatomical characters except: epidermal cells radially elongated; collenchymas isodiametric; vascular bundles 14-15 and pith cells angular, isodiametric-cylindrical, with solitary crystals.
- c- var. *subvillosus* has the same anatomical characters of *S. muricatus* var. *muricatus* except: epidermal cells radially

elongated; collenchymas isodiametric; vascular bundles 11-12. Pith cells angular, isodiametric-cylindrical with solitary crystals.

### 2- *Scorpiurus vermiculatus*

Stem angular, 1.7-1.8 mm diameter, cuticle 2.5  $\mu$ m thickness. Epidermal cells isodiametric-radially elongated, 23.5-25  $\mu$ m thickness. Cortex consists of only parenchyma. Parenchyma 5-9 layers, isodiametric, 220-330  $\mu$ m thickness. Vascular cylinder up to 13 bundles, each bundle 150-230  $\mu$ m wide with 4-9 sclerenchymatous layers, pericyclic fibers 45-105  $\mu$ m thickness. Phloem 4-5 layers, 20-25  $\mu$ m thickness. Cambium 2 layers, 10-12.5  $\mu$ m thickness. Xylem 2-6 arches, 2-4 vessels per arch, 45-80  $\mu$ m length. Pith cells isodiametric-cylindrical, angular, 370-420 mm diameter, tannin cells represented in both cortical and pith parenchyma.

## II: Leaf Anatomy

The leaf in midrib region is u-shaped in all the studied taxa, 0.9-1 mm thickness var. *laevigatus* and var. *muricatus*, 0.7-0.8 mm thickness in var. *subvillosus* and 0.6-0.7 mm thickness in *S. vermiculatus*. Cuticle 2.5-5  $\mu$ m thickness in all the studied taxa. Upper and lower epidermis uniseriate, tubular in var. *muricatus*, radially elongated in var. *laevigatus*, radially – isodiametric in var. *subvillosus* and *S. vermiculatus*. 20-75  $\mu$ m thickness in all the studied taxa. Upper the main vascular bundles consists of collenchyma and parenchyma in var. *laevigatus* and var. *subvillosus*, other taxa consists only parenchyma. Collenchyma one layer, 30-50  $\mu$ m thickness. Parenchyma 2-3 layers in three varieties, 5-6 layers in *S. vermiculatus*, isodiametric – radially elongated in all the studied taxa, 230-240  $\mu$ m thickness in *S. vermiculatus*, 270-290  $\mu$ m thickness in var. *subvillosus*, 320-450  $\mu$ m thickness in other varieties, with 1-2 tannin cell in all the studied taxa. Xylem 4-6 arches, 2-6 vessels per arch in all the studied taxa, xylem arch 110-160  $\mu$ m length in three varieties, 87.5-100  $\mu$ m length in *S. vermiculatus*. Phloem 4 layers in all studied taxa, 30-60  $\mu$ m thickness in three varieties, 25-27.5  $\mu$ m thickness in *S. vermiculatus*. Mechanical tissue represented by pericyclic fibers at midrib region dorsal the main vascular bundle. Pericyclic fibers 3-4 layers in three varieties, 5-6 layers in *S. vermiculatus*, 50-100  $\mu$ m thickness in all studied taxa. Below the main vascular bundles 4-6 layers of parenchyma cells, 120-130  $\mu$ m thickness in var. *subvillosus*, 170-220  $\mu$ m thickness in other taxa, have solitary crystals in var. *muricatus*, absent in other taxa, 2-5 tannin cells in three varieties, 6-8 tannin cells in *S. vermiculatus*. The wings 400-420  $\mu$ m thickness in var. *laevigatus*, 200-380  $\mu$ m thickness in other taxa. Mesophyll tissue consists of palisade and spongy tissues. Palisade tissue four rows, two rows under the upper epidermis and two rows above lower epidermis, 110-120  $\mu$ m thickness in var. *laevigatus*, 50-87.5  $\mu$ m thickness in other taxa, spongy tissue 2-3 rows in between in all taxa, 62.5-65  $\mu$ m thickness in var. *muricatus*, 100-110  $\mu$ m thickness in var. *laevigatus*, 70-75  $\mu$ m thickness in var. *subvillosus* and 50-55  $\mu$ m thickness in *S. vermiculatus*, with solitary crystals in var. *subvillosus* and *S. vermiculatus*, absent in other taxa, and with few tannin cells in all studied taxa.

**Table 3: Anatomical characters of stem in the studied taxa**

Stem character	<i>Scorpiurus</i>			
	<i>muricatus</i> var. <i>laevigatus</i>	<i>muricatus</i> var. <i>muricatus</i>	<i>muricatus</i> var. <i>subvillosus</i>	<i>vermiculatus</i>
Outline	Angular	Angular	Angular	Angular
Number of ridges	4	4	4	4
Diameter (µm)	2075-2325	2375-2550	2325-2375	1750-1825
Cuticle thickness (µm)	2.5	2.5	2.5	2.5
Epidermal cell shape	Tangentially elongated	Isodiametric-radially elongated	Radially elongated	Isodiametric -radially elongated
Cortex				
Collenchyma number of layers	1 in corners	1 in corners	1 in corners	Absent
Collenchyma cell shape	Isodiametric-tangentially elongated	Isodiametric-radially elongated	Isodiametric	Absent
Parenchyma number of layers	5-6	6	5-6	5-9
Parenchyma cell shape	Isodiametric-tangentially elongated	Isodiametric-tangentially elongated	Isodiametric-tangentially elongated	Isodiametric
Vascular bundles number	14-15	15-17	11-12	13
Phloem fiber number of layers	4-7	4-7	4-7	4-9
Phloem number of layers	4	3-4	4	4-5
Cambium number of layers	2	2	2	2
Xylem number of arches	3-8	3-6	3-6	2-6
Xylem number of layers vessels	3-4	2-4	3-4	2-4
Pith				
Cell shape	Isodiametric-angular	Isodiametric-cylindrical	Isodiametric-cylindrical-angular	Isodiametric-cylindrical-angular
Diameter (µm)	1600-1900	1125-1250	370-420	1625-1675
Crystals In pith				
In cortex	Absent	Absent	Absent	Solitary
Solitary	Absent	Solitary	Solitary	
Tannin cells In pith				
In cortex	Present	Present	Present	Present
In pith	Present	Present	Present	Present

**Table 4: Anatomical characters of leaf in the studied taxa**

Character	<i>Scorpiurus</i>			
	<i>muricatus</i> var. <i>muricatus</i>	<i>muricatus</i> var. <i>muricatus</i>	<i>muricatus</i> var. <i>subvillosus</i>	<i>vermiculatus</i>
Leaf midrib				
Shape	U	U	U	U
Midrib thickness (µm)	950-1000	1025-1075	800-850	690-700
Epidermal cells shape	Radially elongated	Tubular	Radially –isodiametric	Radially -isodiametric
Xylem number of arches	5-6	4-5	5-6	5-6
Xylem number of vessels in arch	3-6	2-3	2-5	3-4
Phloem number of layers	4	4	4	4
Collenchyma number of layers	1	Absent	1	Absent
Parenchyma number of layers	2-3 up., 4-5 lo.	2-3 up., 5-6 lo.	2-3 up., 4-5 lo.	5-6 up., 5-6 lo.
Parenchyma cell shape	Isodiametric-radially elongated	Isodiametric-radially elongated	Isodiametric-radially elongated	Isodiametric-radially elongated
Crystals	Absent	Solitary	Absent	Absent
fiber number of layers	3-4	3-4	3-4	5-6
Tannin cells				
upper vascular bundle	1	1-2	1	2
lower vascular bundle	4-5	2-3	3-4	6-8
Leaf lamina				
Thickness (µm)	400-420	200-370	320-380	240-260
Palisade layer				
Number of rows	4 (2 up. – 2 lo.)	4 (2 up. – 2 lo.)	4 (2 up. – 2 lo.)	4 (2 up. – 2 lo.)
Thickness (µm)	110-120	50-87.5	55-87.5	50-67.5
Spongy layer				
Number of rows	3	2-3	3	2-3
Thickness (µm)	100-110	62.5-65	70-75	50-55
Tannin cells	Few	Few	Few	few
Crystals	Absent	Absent	Solitary	Solitary

Up.= upper surface; lo.= lower surface

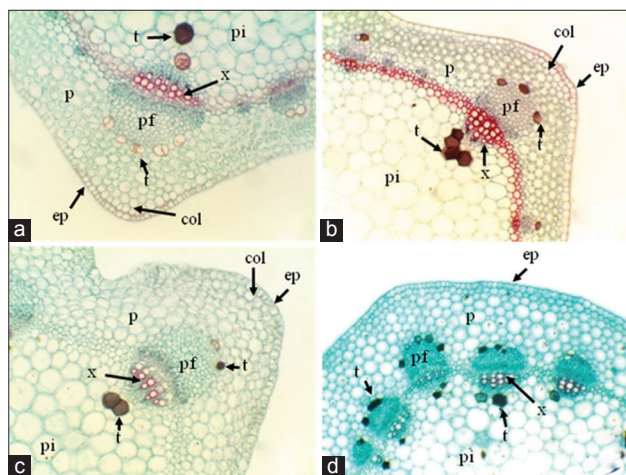


### C: SEM of the spermoderm (Table 5 & Figures 4)

SEM of the epidermal cells clarifies the texture and reticulation of their anticlinal (radial) walls, the appearance of the outer periclinal walls and the persistency of the primary cell walls.

#### *Scorpiurus muricatus* var. *muricatus*

Seed reniform – cylindrical, brown – yellowish brown in colour with blackish hilum, 3-4 x 1.5 mm size, seed poles rounded.



**Figure 2:** Stem anatomy of the studied taxa: A. *Scorpiurus muricatus* var. *laevigatus*, B. *S. muricatus* var. *muricatus*, C. *S. muricatus* var. *subvillosus*, D. *S. vermiculatus*. ep-epidermis; pi-pith; x- xylem; p-parenchyma; col;collenchyma; pf-phloem fiber; t-tannin cell. (x 100)

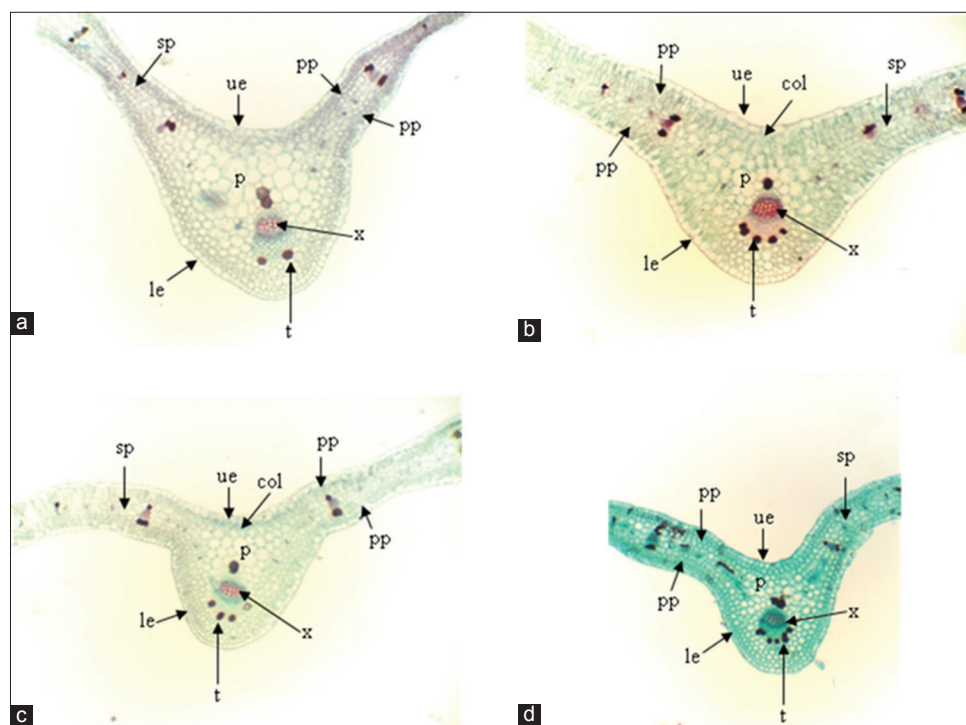
Seed coat pattern reticulate with elevated features, outline of cells reticulate, anticlinal wall wavy, relief of cell boundary channeled, thickness of cell boundary thick, curvature of outer periclinal wall concave – flat. Hilum elliptical, lateral in position, hilum size 100 x 72.58  $\mu\text{m}$ . Rim aril raised in  $\frac{3}{4}$ , flush in  $\frac{1}{4}$  in opposite to micropyle. Micropyle elliptical, 32.2 x 17.71  $\mu\text{m}$  size. Wax present.

*S. muricatus* var. *laevigatus* has the same characters of *Scorpiurus muricatus* var. *muricatus* except: seed semilunate – cylindrical, brown in colour, seed poles rounded – truncate. Rim aril raised. Micropyle ovate.

*S. muricatus* var. *subvillosus* has the same characters of *Scorpiurus muricatus* var. *muricatus* except: seed reniform. Hilum oblate, 87.96 x 69.35  $\mu\text{m}$  size. Rim aril raised in  $\frac{3}{4}$ , recessed in  $\frac{1}{4}$  in opposite to micropyle. Micropyle ovate, 20.93 x 17.71  $\mu\text{m}$  size.

#### *Scorpiurus vermiculatus*

Seed reniform – cylindrical, brown in colour with blackish hilum, 4.5-5 x 1.5 mm size, seed poles rounded. Seed coat pattern reticulate with elevated features, outline of cells reticulate, anticlinal wall wavy, relief of cell boundary channeled – superficial elevated features, thickness of cell boundary thick, curvature of outer periclinal wall concave – flat. Hilum ovate, lateral in position, hilum size 171.42 x 107.14  $\mu\text{m}$ . Rim aril recessed. Micropyle lageniform, 36.32 x 11.35  $\mu\text{m}$  size. Wax present.



**Figure 3:** Leaf anatomy of the studied taxa: A. *Scorpiurus muricatus* var. *laevigatus*, B. *S. muricatus* var. *muricatus*, C. *S. muricatus* var. *subvillosus*, D. *S. vermiculatus*. ue-upper-epidermis; x- xylem; p- parenchyma; col-collenchyma; pp-palisade parenchyma; le-lower epidermis; t-tannin cell(x 50)

Table 5: The morphological aspect of the spermoderm of the studied taxa

Character	<i>Scorpiurus</i>			
	<i>muricatus</i> var. <i>laevigatus</i>	<i>muricatus</i> var. <i>muricatus</i>	<i>muricatus</i> var. <i>subvillosus</i>	<i>vermiculatus</i>
Seed colour	Brown, hilum blackish	Brown – yellowish brown, hilum blackish	Brown – yellowish brown, hilum blackish	Brown – yellowish brown, hilum blackish
Seed size				
L × W mm	3-5 x 1.5	3-4 x 1.5	2.5-3.5 x 1.5	4.5-5 x 1.5
L/W ratio	2.6	2.3	2.6	3.1
Seed pole	Rounded - truncate	Rounded	Rounded	Rounded
Seed shape	Lunate - cylindrical	Reniform - cylindrical	Reniform	Reniform - cylindrical
Seed coat pattern	Reticulate, with elevated features	Reticulate, with elevated features	Reticulate, with elevated features	Reticulate, with elevated features
Hilum				
Position	Lateral	Lateral	Lateral	Lateral
Shape	Elliptical	Elliptical	Oblate	Ovate
L × W µm	100 x 77.41	100 x 72.58	87.96 x 69.35	171.42 x 107.14
Rim aril	Raised	Raised —, flush in ¼ in opposite to micropyle	Raised in —, recessed in ¼ in opposite to micropyle	Recessed
Micropyle				
Shape	Ovate	Elliptical	Ovate	Lageniform
L × W µm	33.81 x 22.54	32.2 x 17.71	20.93 x 17.71	36.32 x 11.35
Outline of cells	Reticulate	Reticulate	Reticulate	Reticulate
Anticlinal wall	Wavy	Wavy	Wavy	Wavy
Relief of cell boundary	Channeled	Channeled	Channeled	Channeled, superficial elevated features
Thickness of cell boundary	Thick	Thick	Thick	Thick
Curvature of outer periclinal wall	Concave, flat	Concave, flat	Concave, flat	Concave, flat
Wax	Present	Present	Present	Present

## DISCUSSION

In the present study, the hairs, flowers characteristics (number, the length, colour of petals, the length of stamens) and the fruit characters are considered to be of systematic value in differentiating the studied taxa. The hairs is variable between the different taxa, it is pubescent in *Scorpiurus muricatus* (three varieties), villous in *S. vermiculatus*. The number of flowers is 1-4 (-5) in *S. muricatus* while solitary in *S. vermiculatus*. The length of flowers 8-11 mm in *S. muricatus* while 13 mm in *S. vermiculatus*. The colour standard and wings are yellow in *S. muricatus*, standard is orange central yellow while wings are yellowish orange in *S. vermiculatus*, the colour of keel is greenish yellow in *S. muricatus*, whitish yellow in *S. vermiculatus*. The length of stamen united 7-8 mm in *S. muricatus*, 10-10.6 mm in *S. vermiculatus* while free part 4-6.5 mm in *S. muricatus* and 8-8.5 mm in *S. vermiculatus*.

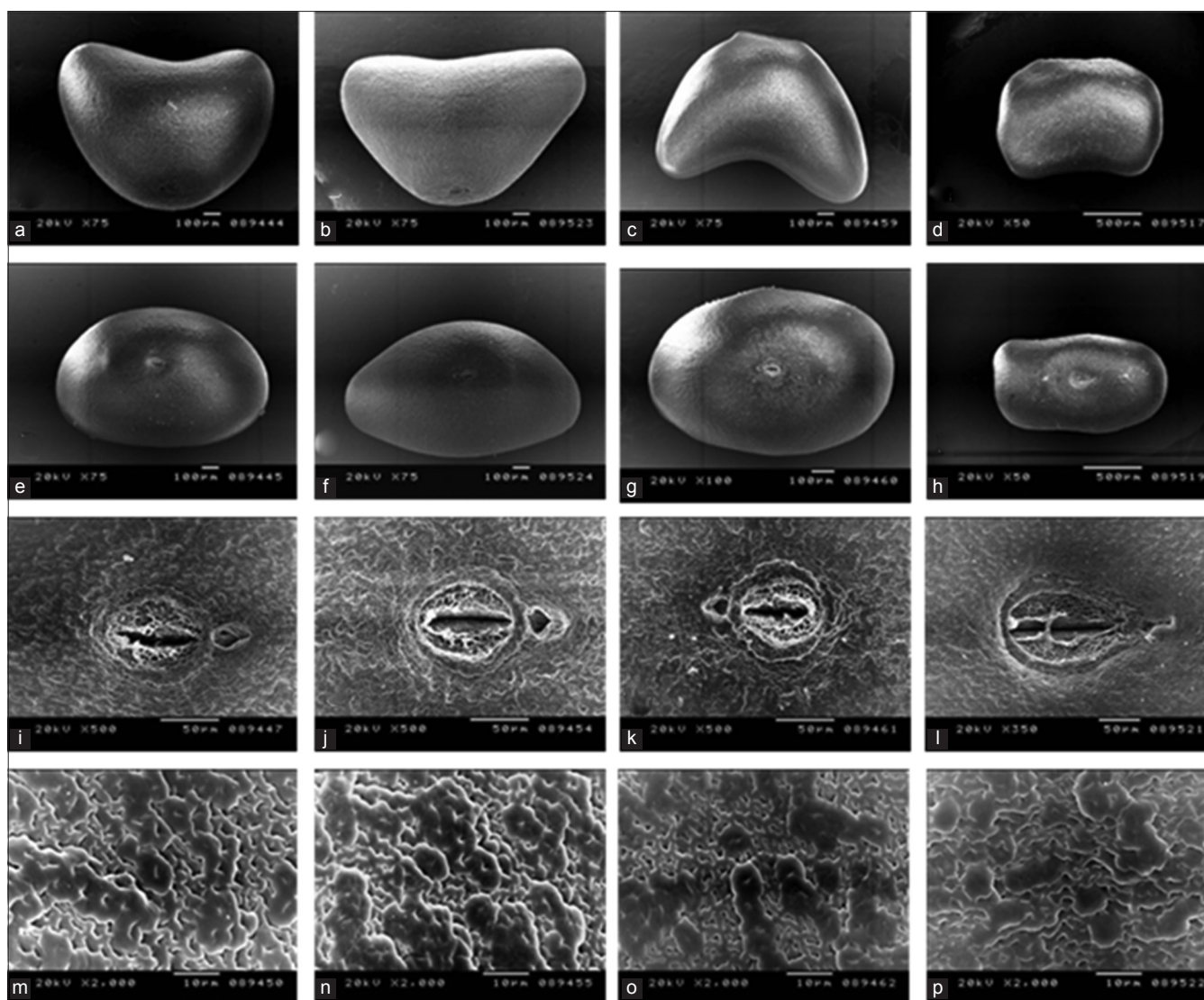
Täckholm [14] and Ball [27] considered the fruit characters as the main character of the identification. The present study indicates that the fruit characters varies between different taxa, it loosely coiled, 11 ribs, 7-10 ribs covered with tubercles, 1-4 ribs smooth, in *S. muricatus* var. *muricatus*, it straight, falcate at apex, 11 ribs, ribs smooth in *S. muricatus* var. *laevigatus*, it very closely twisted, 11 ribs, 9-10 ribs covered with spines, 1-2 ribs smooth in *S. muricatus* var. *subvillosus* and it curved, 11 ribs, all ribs covered with capitate tubercles in *S. vermiculatus*.

El Hadidi and Fayed [15] and Boulos [16-18] treated *S. muricatus* as one species, while are treated var. *muricatus*, var. *laevigatus* and var. *subvillosus* a synonym to *S. muricatus*.

Talaver and Domínguez [13] treated *S. muricatus*, *S. subvillosus* and *S. sulcatus* as three distinct species.

The present investigation shows that the variations in some anatomical characters are useful in the differentiation between the studied taxa. The stem diameter is 2-2.5 mm in *S. muricatus* while up to 1.8 mm in *S. vermiculatus*. The collenchyma tissue in cortex is present in *S. muricatus*, absent in *S. vermiculatus*. The number of vascular bundles differs in the different taxa, 14-15 in *S. muricatus* var. *laevigatus*, 15-17 in *S. muricatus* var. *muricatus*, 11 in *S. muricatus* var. *subvillosus* and 13 in *S. vermiculatus*. The pith is also variable in width between different taxa, 1.6 mm in *S. muricatus* var. *laevigatus*, up to 1.9 mm in *S. muricatus* var. *muricatus*, 1.1-1.2 mm in *S. muricatus* var. *subvillosus* and 0.3-0.4 in *S. vermiculatus*. The solitary crystals in cortex are absent in *S. muricatus* while present in *S. vermiculatus*, also in pith are absent only *S. muricatus* var. *muricatus*.

The anatomical features of leaves of the studied taxa are built on the same plan with some differences in midrib width 0.9-1 mm in *S. muricatus* var. *muricatus* and var. *laevigatus*, 0.8 mm in *S. muricatus* var. *subvillosus* and 0.6-0.7 in *S. vermiculatus*. The collenchyma tissues in midrib are present in *S. muricatus* var. *laevigatus* and var. *subvillosus* while absent in *S. muricatus* var. *muricatus* and *S. vermiculatus*. Palisade and spongy tissue ratio is also different in different taxa. The solitary crystals in midrib are present in *S. muricatus* var. *muricatus* while absent in other taxa, also in leaf lamina present in *S. muricatus* var. *subvillosus* and *S. vermiculatus* while absent in other taxa. Turki [28] and Kasem [29] reported the importance of anatomical differences in the distinction among species.



**Figure 4:** SEM micrograph of spermoderm surface of the studied taxa: A-D. *Scorpiurus muricatus* var. *muricatus*, E-H. *S. muricatus* var. *laevigatus*, I-L. *S. muricatus* var. *subvillosus*, M-P. *S. vermiculatus*. A. E. I. M. seed morphology; B, F, J, N. hilum position; C, G, K, O. hilum shape; D, H, L, P. spermoderm surface.

SEM spermoderm investigations indicate the presence of differences between the studied taxa represented in hilum shape is elliptical in *S. muricatus* var. *muricatus* and var. *laevigatus*, oblate in *S. muricatus* var. *subvillosus* and ovate in *S. vermiculatus*. The rim aril is raised in *S. muricatus* var. *laevigatus*, raised  $\frac{3}{4}$ , flush in  $\frac{1}{4}$  in opposite to micropyle in *S. muricatus* var. *muricatus*, raised  $\frac{3}{4}$ , recessed in  $\frac{1}{4}$  in opposite to micropyle in *S. muricatus* var. *subvillosus* and recessed in *S. vermiculatus*. The micropyle shape is ovate in *S. muricatus* var. *laevigatus* and var. *subvillosus*, elliptical in *S. muricatus* var. *muricatus* and lageniform in *S. vermiculatus*. Kaplan *et al.* [30] and Fawzi *et al.* [31] reported seed coat characters are successfully employed in the identification and classification of taxa.

The present study shows that the genus *Scorpiurus* is represented by two species: *S. muricatus* (with three varieties: *muricatus*, *laevigatus* and *subvillosus*) and *S. vermiculatus*.

### Key to *Scorpiurus* Species

- A. Standard yellow with outer part orange, pod curved, with capitate tubercles in ribs. Collenchyma absent, solitary crystals present in cortex. Hilum ovate, micropyle lageniform. *S. vermiculatus*
- B. Standard yellow, pod otherwise. Collenchyma present, solitary crystals absent in cortex. Hilum elliptical-oblate, micropyle ovate-elliptical. *S. muricatus*
  - + Pod coiled, tuberculate ribs. Solitary crystals absent in pith, micropyle elliptical. var. *muricatus*
  - ++ Pod straight-compactly twisted, ribs smooth-spiny. Solitary crystals present in pith. micropyle ovate.
    1. Pod straight, apex falcate, smooth ribs. Hilum elliptical. var. *laevigatus*
    2. Pod compactly twisted, ribs spiny. Hilum oblate. var. *subvillosus*



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