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# Taxonomic Studies in Tribe Loteae (Fabaceae) in Egypt. I: Subtribe Anthyllidinae (*Anthyllis, Hymenocarpos* and *Tripodion*)

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THE PLANT morphology, anatomical characters of stem and leaves, SEM of seed coat surfaces were used to reassess the conflicted taxonomic relationships between the genera *Anthyllis, Hymenocarpos* and *Tripodion*. Previous studies treated the genera *Hymenocarpos* and *Tripodion* as synonyms to *Anthyllis*. The present study clearly indicated considerably differences between the three genera. The most important characters used to distinguish the studied genera are habit, inflorescence type, bract shape, calyx, pod shape and seed coat pattern. On the bases of morphology, anatomy and seed characters, three distinct genera, *Anthyllis*, *Hymenocarpos* and *Tripodion* are represented in the Egyptian flora, each with only one species.

**Keywords:** *Anthyllis, Hymenocarpos*, *Tripodion*, Morphological, Anatomy, SEM seed.

## Introduction

The genus *Anthyllis* L. and *Hymenocarpos* Savi. are two genera of the family Fabaceae, belonging to the subfamily Faboideae Rudd., tribe Loteae DC., subtribe Anthyllidinae W.D.J. Koch. The two genera distributed in Mediterranean regions, with some taxa extending into northern Europe, the Atlantic islands, Northern and Eastern Africa, and Western Asia (Polhill, 1981; Castroviejo, 2000 and Sokoloff, 2003 a).

Tournefort (1719) was the first who gave a more or less exact vision of the genus *Anthyllis* (syn. *Vulneraria*), recognizing five species. Linnaeus (1753) included 10 species under the genus *Anthyllis***,** of which *A. tetraphylla* and *A. vulneraria*, and treated *Hymenocarpos circinnatus* as *Medicago circinnata*. Medikus (1787) separated *Anthyllis tetraphylla* as genus *Tripodion,* including one species; *T. tetraphylla*.Savi (1798) separated *Medicago circinnata* as genus *Hymenocarpos*, including one species; *H. circinnatus*. He also reported *Anthyllis* with two species; *A. tetraphylla* and *A. vulneraria*.

Moench (1794) and Gussone (1827/28) included *Anthyllis tetraphylla* as synonymy to *Vulneraria tetraphylla*. Boissier (1838, 1839-1845) separated *Anthyllis tetraphylla* as genus *Physanthyllis*, including one species; *P. tetraphylla*. Boissier (1872) recognized *Anthyllis* into *A. vulneraria*. *H. circinnatus, H. nummularius* and *P. tetraphylla*. Taubert (1894) included *Hymenocarpos* as synonymy to *Circinus.* Lassen (1986, 1987) has shown that *Tripodion* is an earlier name for *Physanthyllis* and recognized three species in *Tripodion*. Akulova (1985, 1986) and Sokoloff (2003 a, b) included *Hymenocarpos* as synonymy to *Anthyllis*.

In Egypt, Täckholm (1974) recognized genus *Anthyllis* into *A. tetraphylla* and *A. vulneraria* and genus *Hymenocarpos* into *H. circinnatus* and *H. nummularius*. El-Hadidi & Fayed (1994/95) and Boulos (1995) recognized *Tripodion tetraphyllum* as a separate genus and treated *A. tetraphylla* as a synonym. Boulos (1999, 2009) treated *Tripodion tetraphyllum* as a synonym to *A. tetraphylla*.

The present study aimed to revise critically the taxonomic relationships between the species of the related genera; *Anthyllis, Hymenocarpos* and *Tripodion* in Egypt.

## Materials and Methods

The present study is based on available fresh material collected from their natural habitats in Egypt in addition to collections kept in Menoufia University Herbarium (MNF). Seeds of *A. vulneraria* and *Tripodion tetraphyllum* are obtained from Institute of Plant Genetics and Crop Research (IPK), Western Regional Plant Introduction Station– Washington State University and Desert Legume Program– The University of Arizona (Table 1). The seeds were cultivated in plastic house, till fruiting stage.

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**TABLE 1. Plant names, collection details and sources of seeds included in the present study.**

| Taxa | Source of seeds | Localities | Geographical coordinates | Date of collection |
|---|---|---|---|---|
| *A. vulneraria* | PI 311348 | - | - | - |
| *Hymenocarpos circinnatus* | - | Al-Mathani Al-Bahria - Marsa Matrouh. | 31° 27.963\ N<br>26° 45.287\ E | 3,4 / 2014-2018 |
| | | Wadi Umm El-Rakham – Marsa Matrouh. | 31° 24.076\ N<br>27° 01.704\ E | |
| *Tripodion tetraphyllum* | Akz-Nr: ANTHY 14 (IPK) | - | - | - |

Samples for anatomy of the stem and mature leaves were chosen from fresh materials. 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 stems and leaves were sectioned at 10-15µm; sections were dehydrated in alcohol-xylol series. Sections were stained in safranin and light green according to Sass (1961). The transverse sections were examined and photographed by Zeiss research microscope. A planimeter was used for estimation of the width of each tissue in the section. Terminology followed Abd El-Rahman et al. (1976), Pandey (1982) and Abd El-Gawad et al. (1989).

SEM study of the investigated seeds was carried out by mounting mature seeds 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 (1981), Brochmann (1992), Stearn (1992) and Kirkbride et al. (2003).

## Results

*Macromorphological studies (Table 2 and Fig. 1)*

***Anthyllis vulneraria*** L., Sp. Pl. 719 (1753). subsp. ***maura*** (Beck) Maire, Bull. Soc. Hist. Nat. Afr. Nord 20: 20 (1929).

Syn. *Anthyllis maura* Beck, Ann. K. K. Naturhist. Hofmus. 11: 64 (1896).

Perennial herb, 35-45cm height, stem decumbent-erect, branched at base, tomentose, cylindrical, whitish green, internodes up to 1mm long in decumbent stem while 3-3.5cm long in erect branches. Lower leaves simple, while upper leaves imparipinnate, all leaves alternate, whitish green, petiolate or sessile; petiolate leaves with petioles 1.7-3.7cm long, puberulent; lamina in simple leaf 4.2-4.5 × 0.8-0.9cm, narrow elliptic, acuminate apex, entire margin, glabrous in upper surface and tomentulose in lower surface; imparipinnate leaves opposite-alternate with 3-9 leaflets, petiolules 0.5-1mm long; lamina in terminal leaflets 3-5.5 × 0.9-1.5cm while in lateral leaflets 0.5-3 × 0.3-0.7cm, lateral leaflets unequal, narrow elliptic-elliptic acuminate-acute apex, entire margin, glabrous in upper surface and tomentose in lower surface; leaf rachis (4-) 14-25mm long, stipules filiform. Inflorescence head, 11-23 flowers; peduncle cylindrical, tomentulose, 10-12cm long. Bracts palmatisect, 11-17mm long, whitish green, pubescent in upper surface but tomentose in lower surface; lower bracts 5-7 lobes while upper bracts 3 lobes, lobes elliptic-lanceolate-oblong, 5-13 × 2-4mm, acute apex, entire margin. Flowers 14.5-15mm long, pedicel 0.5-1mm long, tomentose; calyx tubular, with oblique mouth, white with violet at apex, tube 7-9mm long, tomentose in outer surface, teeth lanceolate-triangular, 1-2.5 mm long, unequal, acute apex, entire margin, tomentose in outer surface; standard purple white, lamina 13-14 × 4.5-5mm, auriculate, entire margin, obtuse apex, claw 6-6.5 mm long, veins violet, 2-3mm long, glabrous; wings purple greenish white, lamina 12-13 × 2-2.5mm, ovate, entire margin, rounded apex, claw 8-8.5 mm long, auriculate 0.3-0.5 mm long, truncate apex; keel greenish white, lamina 12-13 × 1.5-2mm, straight apex, beak obtuse, dark violet, claw 8-8.5 mm long. Androecium monadelphous, the united filament with the free parts 2-2.5mm long, united part 9-10mm long, filament dilated above, anther uniform. Gynoecium stipitate,

9.5-12.5mm long, gynophore 1.5-2.5mm long, glabrous; ovary 2 × 1mm, ellipsoid, glabrous, style 7-8mm long, lower part thin and purple; stigma capitates. Pod ellipsoid, 4-5 × 2.5-3mm, pale brown-creamy, reticulate venation, included within the calyx, beak 0.5-1mm long, seeds 1-2. Seeds ovoid with rounded poles, 2-3 × 1-1.5mm, brown or yellowish with terminal part pale green, hilum subapical.

**TABLE 2. Morphological characters of the studied taxa.**

| Character | | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|---|
| Plant | Habit | | Herb<br>Perennial | Herb<br>Annual | Herb<br>Annual |
| | | | Decumbent-erect | Decumbent | Decumbent |
| | Height (cm) | | 35-45 | 35-60 | 20-35 |
| | Colour | | Whitish green | Whitish green | Yellowish green |
| Stem | Shape | | Cylindrical | Cylindrical | Cylindrical |
| | Surface | | Tomentose | Pilose | Pilose |
| | Colour | | Whitish green | Whitish green | Reddish brown |
| | Branched | | At base | At base | At base |
| | Internode length (cm) | | Up to 1 mm in decumbent stem<br>3-3.5 in erect stem | 3-6 | 1-2 |
| Stipule | Shape | | Filiform | Absent | Absent |
| | Length (mm) | | Up to 0.5 | - | - |
| Leaf | Type | First | - | 2 Simple | 2 Simple |
| | | Lower | Simple | Imparipinnate | Imparipinnate |
| | | Upper | Imparipinnate | | |
| | Arrangement | | Alternate | Alternate | Alternate |
| | Colour | | Whitish green | Whitish green | Yellowish green |
| Leaf rachis | Length (mm) | | (4-) 14-25 | 5-15 | 3-5 |
| Limb simple leaf | Shape | | Narrow elliptic | Obovate | Elliptic |
| | Size L × W (cm) | | 4.2-4.5 × 0.8-0.9 | 4-5.2 × 1.4-1.7 | 1.5-2 × 0.6-0.7 |
| | Apex | | Acuminate | Acute-rounded | Acute |
| | Margin | | Entire | Entire | Entire |
| | Surface | | Glabrous in upper<br>Tomentulose in lower | Pilose in both | Pilose in both |
| Leaflet | No. | | 3-9 | 2-7 | 2-5 |
| | Petiolule | | 0.5-1 mm | Sessile | Up to 0.5 mm |
| | | | Opposite-alternate | Opposite-alternate | Alternate |
| Limb leaflet | Shape | | Narrow elliptic-elliptic | Elliptic-obovate | Elliptic-obovate |
| | Size L × W (cm) | | Terminal 3-5.5 × 0.9-1.5<br>Lateral 0.5-3 × 0.3-0.7 | Terminal 3-6 × 1-2.3<br>Lateral 0.7-2.6 × 0.3-1.2 | Terminal 1.2-2.5 × 0.7-1.2<br>Lateral 0.3-1.2 × 0.1-0.6 |
| | Apex | | Acuminate-acute | Obtuse-acute | Terminal rounded-truncate<br>Lateral acuminate-acute |
| | Margin | | Entire | Entire | Entire |
| | Surface | | Glabrous in upper<br>Tomentose in lower | Pilose in both | Pubescent in upper<br>Tomentulose in lower |

**TABLE 2. Cont.**

| Character | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|
| Petiole leaf | Length (cm) | 1.7-3.7 or sessile | 1.5-2 | Up to 0.5 |
| | Surface | Puberulent | Pilose | Tomentulose |
| Peduncle | Length (cm) | 10-12 | 1-2 | Sessile |
| | Surface | Tomentulose | Pilose | - |
| Inflorescence | Type | Head | Umbellate | Cluster |
| No. of flowers | | 11-23 | 2-3 | 4-6 |
| Bract | No. | 1 | 1 | 1 |
| | Type | Palmatisect | Simple | Simple |
| | Shape | 5-7 lobes and 3 lobes, elliptic-lanceolate- oblong | Elliptic | Elliptic |
| | Length (mm) | 11-17 | 8.5-14 × 4-7 | 4.5-5.5 × 2-2.5 |
| | Lobe length (mm) | 5-13 × 2-4 | - | - |
| | Colour | Whitish green | Whitish green | Green |
| | Apex | Acute | Acute | Acute |
| | Margin | Entire | Entire | Entire |
| | Surface | Pubescent in upper Tomentose in lower | Pilose in both | Pubescent in both |
| Flower | Length (mm) | 14.5-15 | 6-7 | 14-18 |
| Pedicel | Length (mm) | 0.5-1 | 0.5-1 | 0.5-1 |
| | Surface | Tomentose | Pilose | Tomentose |
| Calyx | Colour | White with violet apex | Whitish green | Greenish white with red vein |
| | Tube shape | Tubular, with oblique mouth | Campanulate | Tubular |
| | Tube length (mm) | 7-9 | 1-1.5 | 8-10 |
| | Tube surface | Tomentose in outer | Pilose in outer | Tomentose in outer |
| | Teeth shape | Lanceolate -Triangular | Linear | Lanceolate |
| | Teeth length (mm) | 1-2.5 | 3-3.5 | 2.5-3 |
| | Teeth apex | Acute | Acute | Acute |
| | Teeth margin | Entire | Entire | Entire |
| | Teeth surface | Tomentose in outer | Pilose in outer | Tomentose in outer and inner |
| Standard | Shape | Auriculate | Circular | pandurate |
| | Colour | Purple white | Orangish yellow | Greenish white |
| | Lamina L × W (mm) | 13-14 × 4.5-5 | 4-4.5 × 3.5-4 | 14.5-17 × 4.5-5.5 |
| | Claw length (mm) | 6-6.5 | 0.5-1 | 8-10 |
| | Vein colour | Violet | Absent | Crimson |
| | Vein length (mm) | 2-3 | - | 5-6 |
| | Margin | Entire | Entire | Entire |
| | Apex | Obtuse | Rounded | Rounded |
| | Surface | Glabrous | Glabrous | Tomentose in outer |

**TABLE 2. Cont.**

| Character | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|
| Wings | Shape | Ovate | Oblong | Ovate |
| | Colour | Purple greenish white | Yellow | Greenish yellow |
| | Lamina L × W (mm) | 12-13 × 2-2.5 | 4-4.5 × 1.5-2 | 12.5-15 × 2-2.5 |
| | Claw length (mm) | 8-8.5 | 1-1.2 | 8-9 |
| | Apex | Rounded | Rounded | Rounded |
| | Margin | Entire | Entire | Entire |
| | Surface | Glabrous | Glabrous | Glabrous |
| | Auricule length (mm) | 0.3-0.5 | 0.4-0.6 | 0.5-0.8 |
| | Auricule apex | Truncate | Rounded | Truncate |
| Keel | Colour | Greenish white | Shiny yellow | Greenish white |
| | Lamina L × W (mm) | 12-13 × 1.5-2 | 4.5-6 × 1.5-2 | 12-14 × 1.5-2 |
| | Claw length (mm) | 8-8.5 | 1-1.5 | 9-9.5 |
| | Apex | Straight beak, obtuse | Straight beak, obtuse | Straight beak, acute |
| | Surface | Glabrous | Glabrous | Glabrous |
| | Beak colour | Dark violet | Yellow | Dark violet |
| Androecium | Type | Monadelphous | Diadelphous | Diadelphous |
| Stamens | Free length (mm) | - | 3.5-4 | 10-13 |
| | Filaments united (free parts length mm) | 2-2.5 | 5 = 3-3.5<br>4 = 2-2.5 | 1-2 |
| | Filaments united (united parts length mm) | 9-10 | 2-2.5 | 9-11 |
| | | Filament dilated above | Filament dilated above | Filament dilated above |
| | Anthers | Uniform | Uniform | Uniform |
| Ovary | Shape | Ellipsoid | Narrow oblong | Narrow oblong |
| | Size L × W | 2 × 1 | 1.2-1.5 × 0.5 | 3 × 0.5 |
| | Surface | Glabrous | Puberulent | Puberulent in apex |
| | Colour | Green | Green | Light green |
| Gynophores | Length (mm) | 1.5-2.5 | 0.2-0.3 | 1.5-2 |
| | Surface | Glabrous | Glabrous | Puberulent |
| Style | Length (mm) | 7-8 | 4-4.5 | 6-8 |
| | | Lower part thin and purple | Lower part thin | Lower part thin |
| Stigma | Shape | Capitates | Ellipsoid | Capitates |
| Pod | Shape | Ellipsoid | Orbicular- reniform | Ellipsoid - cylindrical |
| | Size L × W (mm) | 4-5 × 2.5-3 | 12-18 × 11-16 | 4-5.5 × 3-3.5 |
| | Colour | Pale brown-creamy | Blackish brown-pale brown-brown | Pale brown-creamy |
| | Surface | Reticulate | Reticulate, appressed hairy | Reticulate, pubescent |
| | Margin | - | Margins denticulate, membranous wing | - |
| | Constriction | - | - | Constricted between the seeds |
| | | Included within the calyx | - | Included within the calyx |
| | Beak length (mm) | 0.5-1 | - | 2-3 |
| Seed No. | | 1-2 | 2 | 1-2 |


**Fig. 1. Habit of the studied taxa: A. Anthyllis vulneraria; B. Hymenocarpos circinnatus; C. Tripodion tetraphyllum.**

*Hymenocarpos circinnatus* (L.) Savi, Fl. Pis. 2:205 (1798).

Syns. *Medicago circinnata* L., Sp. Pl., ed. 1, 778 (1753). *Medicago nummularia* DC., Cat. Hort. Monsp. 124 (1813). *Hymenocarpos nummularis* (DC.) G. Don, Gen. Hist. 2:173 (1832). *Hymenocarpos nummularius* (DC.) Boiss., Fl. Orient. 2:160 (1872). *Cornicina circinnata* (L.) Boiss., Voy. Bot. Midi Esp. 2:163 (1839). *Anthyllis circinnata* (L.) D.D. Sokoloff, Byull. Moskovsk. Obshch. Isp. Prir., 108 (3):46 (2003).

Annual herb, 35-60cm height, stem decumbent, branched at base, cylindrical, pilose, whitish green, internodes 3-6mm long. The first two leaves simple, alternate, whitish green, petiolate, petioles 1.5-2cm long, pilose, lamina 4-5.2 × 1.4-1.7cm, obovate, acute-rounded apex, entire margin, pilose in both surfaces; leaves imparipinnate, exstipulate, sessile, with 3-7 leaflets; leaflets opposite-alternate, petiolate- subsessile, elliptic-obovate, obtuse-acute apex, entire margin, pilose in both surfaces, unequal; lamina in terminal leaflet 3-6 × 1-2.3cm while in lateral leaflet 0.7-2.6 × 0.3-1.2cm, leaf rachis 5-15mm long. Inflorescence umbellate, 2-3 flowers; peduncle 1-2cm long, cylindrical, pilose. Bracts simple, elliptic, 8.5-14 × 4-7mm, whitish green, pilose in both surfaces, acute apex, entire margin. Flowers 6-7mm long, pedicel 0.5-1mm long, pilose; calyx whitish green, campanulate, tube 1-1.5mm long, pilose in outer surface, teeth linear, 3-3.5mm long, equal, acute apex, entire margin, pilose in outer surface; standard orange-yellow, lamina 4-4.5 × 3.5-4mm, circular, entire margin, rounded apex, claw veinless, glabrous 0.5-1 mm long; wings yellow, lamina 4-4.5 × 1.5-2mm, oblong, entire margin, rounded apex, claw 1-1.2mm long, auricule 0.4-0.6mm long, rounded apex; keel shiny yellow, lamina 4.5-6 × 1.5-2mm, straight apex, beak obtuse, claw 1-1.5mm long. Androecium diadelphous, free filament 3.5-4mm long, the other united filament with the free parts have two lengths, five filaments 3-3.5mm long, four filaments 2-2.5mm long, united part 2-2.5mm long, filament dilated above, anther uniform. Gynoecium stipitate, 5.4-6.3mm long, gynophore 0.2-0.3mm long, glabrous; ovary 1.2-1.5 × 0.5mm, narrow oblong, puberulent, style 4-4.5mm long, lower part thin; stigma ellipsoid. Pod orbicular-reniform, 12-18 × 11-16mm, blackish brown-pale brown, reticulate venation, appressed hairy, margins denticulate, membranous wing, with two seeds. Seeds reniform, 3-3.5 × 2-2.5mm, yellowish-creamy-pale brown, with rounded poles, hilum blackish brown and lateral.

*Tripodion tetraphyllum* (L.) Fourr., Ann. Soc. Linn. Lyon, ser. 2, 16:359 (1868).

Syns. Anthyllis tetraphylla L., Sp. Pl. 719 (1735). Vulneraria tetraphylla (L.) Guss., Fl. Sicul. Prodr. 2:395 (1828-32). Physanthyllis tetraphylla (L.) Boiss., Voy. Bot. Espagne 2:162 (1840).'

Annual herb, 20-35cm height, stem decumbent, branched at base, cylindrical, pilose, reddish brown, internodes 1-2mm long. The first two

leaves simple, alternate, yellowish green, petiolate, petioles up to 0.5cm long, tomentulose; lamina 1.5-2 × 0.6-0.7cm, elliptic, acute apex, entire margin, pilose in both surfaces; leaves imparipinnate, exstipulate, alternate, yellowish green, petiolate, petioles up to 0.5 cm long, tomentulose; leaf 3-5 leaflets, petiolules up to 0.5 mm long, lamina in terminal leaflet 1.2-2.5 × 0.7-1.2cm while in lateral leaflet 0.3-1.2 × 0.1-0.6cm, leaflets unequal, apex elliptic-obovate, rounded-truncate in terminal leaflet while acuminate-acute in lateral leaflet, entire margin, pubescent in upper surface while tomentulose in lower surface; leaf rachis 3-5mm long. Inflorescence axillary clusters, 4-6 flowers. Bracts simple, elliptic, 4.5-5.5 × 2-2.5mm, green, pubescent in both surfaces, acute apex, entire margin. Flowers 14-18mm long, pedicel 0.5-1 mm long, tomentose; calyx tubular, greenish white with reddish at apex and veined, tube 8-10mm long, tomentose in outer surface, teeth lanceolate, 2.5-3mm long, equal, acute apex, entire margin, tomentose in both surfaces; standard greenish white, lamina 14.5-17 × 4.5-5.5mm, pandurate, entire margin, rounded apex, claw 8-10mm long, veins crimoson, 5-6 mm long, tomentose in lower surface; wings greenish white, lamina 12.5-15 × 2-2.5mm, ovate, entire margin, rounded apex, claw 8-9mm long, auricule 0.5-0.8mm long, truncate apex; keel greenish white, lamina 12-14 × 1.5-2mm, straight apex, beak acute, dark violet, claw 9-9.5mm long. Androecium diadelphous, free filament 10-13 mm long, the other united filament with the free parts 1-2 mm long, united part 9-11mm long, filament dilated above, anther uniform. Gynoecium stipitate, 10.5-13mm long, gynophore 1.5-2 mm long, puberulent; ovary 3 × 0.5mm, narrow oblong, puberulent in apex, style 6-8 mm long, lower part thin; stigma capitate. Pod ellipsoid-cylindrical, 4.5-5 × 3-3.5mm, pale brown-creamy, reticulate venation, pubescent, constricted between the seeds, included within the calyx, beak 2-3mm long, with 1-2 seeds. Seeds oblong-ellipsoid crispate, 3-3.5 × 2-2.5mm, brown with black spots, with rounded- truncate poles, hilum lateral.

*Anatomical studies*

The anatomical investigations of the stem and leaf of the studied taxa is represented in Tables 3, 4 and Fig. 2, 3.

*Stem anatomy*

*Anthyllis vulneraria*

Stem circular, 1.2-1.3mm diameter; epidermal layer 12.5-15µm thickness covered with 2.5-5µm cuticle thickness. Cortex 7-8 parenchymatous layers, 100-137.5µm thickenss. Vascular cylinder 15-16 bundles, each bundle 150-200µm long, pericyclic fibers 3-4 layers, 37.5-55µm thickness. Phloem 3-4 layers, 20-30µm thickness. Cambium 2 layers, 10-12.5µm thickness. Xylem 2-7 arches, 4-5 vessels per arch, 100-160µm length. Pith cells parenchymatous, 520-530µm diameter.

*Hymenocarpos circinnatus*

Stem circular, 1.9-2mm diameter; epidermal layer 12.5-20µm thickness covered with 2.5-5µm cuticle thickness. Cortex 5-6 layers parenchymatous; 112.5-175µm thickenss. Vascular cylinder 16-17 bundles, each bundle 220-300µm long, pericyclic fibers 4-5 layers, 50-75µm thickness. Phloem 4-5 layers, 35-50µm thickness. Cambium 2 layers, 10-12.5µm thickness. Xylem 2-5 arches, 3-4 vessels per arch, 100-150µm length. Pith cells parenchymatous, 1000-1025µm diameter.

*Tripodion tetraphyllum*

Stem circular, 1.9-2.1mm diameter; epidermal layer 12.5-22.5µm thickness covered with 2.5-5µm cuticle thickness. Cortex 7-9 layers parenchymatous; 200-370µm thickenss, with solitary crystals. Vascular cylinder 17-19 bundles, each bundle 140-270µm wide, pericyclic fibers 4-6 layers, 40-62.5µm thickness. Phloem 3-4 layers, 25-37.5µm thickness. Cambium 2 layers, 12.5-15µm thickness. Xylem 2-8 arches, 3-8 vessels per arch, 60-150µm length. Pith cells parenchymatous, 950-975µm diameter, with solitary crystals. Tannin cells few in pith.

*Leaf anatomy*

*Anthyllis vulneraria*

The leaf in midrib region is v-shaped, 400-420µm thickness, upper and lower epidermis uniseriate, 12.5-25µm thickness, covered with 2.5µm cuticle thickness. In midrib region, parenchyma 2-3 layers, isodiametric- flattened, 87.5-100µm thickness. Xylem 4-6 arches, 2-6 vessels per arch, xylem arch 75-82.5µm length. Phloem 3-4 layers, 20-25µm thickness. Phloem fibers at midrib region below the main vascular bundle, 3-4 layers, 25-37.5µm thickness. Below the main vascular bundles 3-4 layers of parenchyma cells, 100-107.5µm thickness. The wings 300-350µm thickness, mesophyll tissue chlorophyllous with wide air spaces, 5-6 rows, 250-315µm thickness, with solitary crystals.

**TABLE 3. Anatomical characters of stem in the studied taxa.**

| Stem character | | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|---|
| Outline | | | Circular | Circular | Circular |
| Diameter (µm) | | | 1250-1275 | 1925-1970 | 1925-2025 |
| Cuticle thickness (µm) | | | 2.5-5 | 2.5-5 | 2.5-5 |
| Epidermal cell | Shape | | Isodiametric-radially elongated | Isodiametric-radially elongated | Isodiametric-radially elongated |
| | Width (µm) | | 12.5-15 | 12.5-20 | 12.5-22.5 |
| Cortex | Parenchyma number of layers | | 7-8 | 5-6 | 7-9 |
| | Parenchyma | Width (µm) | 100-137.5 | 112.5-175 | 200-370 |
| | | Cell shape | Isodiametric-tangentially elongated | Isodiametric | Isodiametric-tangentially elongated |
| Vascular bundles number | | | 15-16 | 16-17 | 17-19 |
| Vascular bundles width (µm) | | | 150-200 | 220-300 | 140-270 |
| Pericyclic fiber number of layers | | | 3-4 | 4-5 | 4-6 |
| Pericyclic width (µm) | | | 37.5-55 | 50-75 | 40-62.5 |
| Phloem number of layers | | | 3-4 | 4-5 | 3-4 |
| Phloem width (µm) | | | 20-30 | 35-50 | 25-37.5 |
| Cambium number of layers | | | 2 | 2 | 2 |
| Cambium width (µm) | | | 10-12.5 | 10-12.5 | 12.5-15 |
| Xylem number of arches | | | 2-7 | 2-5 | 2-8 |
| Xylem number of layers vessels | | | 4-5 | 3-4 | 3-8 |
| Xylem width (µm) | | | 100-160 | 100-150 | 60-150 |
| Pith | Cell shape | | Isodiametric-tangentially elongated | Isodiametric-flattened | Isodiametric-flattened |
| | Diameter (µm) | | 520-530 | 1000-1025 | 950-975 |
| Crystals | In cortex | | Absent | Absent | Solitary |
| | In pith | | Absent | Absent | Solitary |
| Tannin cells | In cortex | | Absent | Absent | Absent |
| | In pith | | Absent | Absent | Few |

*Hymenocarpos circinnatus*

The leaf in midrib region is u-shaped, 450-500µm thickness, upper and lower epidermis uniseriate, 12.5-37.5µm thickness, covered with 2.5 µm cuticle thickness. In midrib region, parenchyma 3-4 layers, angular-irregular, 120-132.5µm thickness. Xylem 3-4 arches, 3-5 vessels per arch, xylem arch 87.5-107.5µm length. Phloem 3-4 layers, 25-30µm thickness. Phloem fibers 3-4 layers, 25-37.5µm thickness. Below the main vascular bundles 3-4 layers of parenchyma cells, 112.5-125µm thickness. The wings 280-310µm thickness, mesophyll tissue chlorophyllous with wide air spaces, 5-6 rows, 210-275µm thickness.

*Tripodion tetraphyllum*

The leaf in midrib region is u-shaped, 480-500µm thickness, Upper and lower epidermis uniseriate, 15-40µm thickness, covered with 2.5µm cuticle thickness. In midrib region, parenchyma 3-4 layers, flattened-tangentially elongated, 112.5-125µm thickness. Xylem 5-6 arches, 2-3 vessels per arch, xylem arch 55-62.5µm length. Phloem 3-4 layers, 30-32.5µm thickness. Phloem fibers 2-3 layers, 12.5-25µm thickness. Below the main vascular bundles 4-5 layers of parenchyma cells, 187.5-200µm thickness, have 2-3 tannin cells. The wings 220-230µm thickness Mesophyll tissue consists of palisade and spongy tissues. Palisade tissue 2-3 rows, 62.5-85µm thickness, spongy tissue 3-4 rows, 70-87.5µm thickness.

**TABLE 4. Anatomical characters of leaf in the studied taxa.**

| Character | | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|---|
| Leaflet midrib | Shape | | V | U | U |
| | Midrib thickness (µm) | | 400-420 | 450-500 | 480-500 |
| | Cuticle thickness (µm) | | 2.5 | 2.5 | 2.5 |
| | Epidermal cells | Thickness (µm) | 12.5-25 up.<br>12.5-20 lo. | 20-37.5 up.<br>12.5-22.5 lo. | 25-40 up.<br>15-20 lo. |
| | | Shape | Isodiametric-tangentially elongated | Tubular-tangentially elongated | Isodiametric-tangentially elongated |
| | Xylem number of arches | | 4-6 | 3-4 | 5-6 |
| | Xylem thickness (µm) | | 75-82.5 | 87.5-107.5 | 55-62.5 |
| | Xylem number of vessels in arch | | 2-6 | 3-5 | 2-3 |
| | Phloem number of layers | | 3-4 | 3-4 | 3-4 |
| | Phloem thickness (µm) | | 20-25 | 25-30 | 30-32.5 |
| | Parenchyma number of layers | | 2-3 up.<br>3-4 lo. | 3-4 up.<br>3-4 lo. | 3-4 up.<br>4-5 lo. |
| | Parenchyma | Thickness (µm) | 87.5-100 up.<br>100-107.5 lo. | 120-132.5 up.<br>112.5-125 lo. | 112.5-125 up.<br>187.5-200 lo. |
| | | Cell shape | Isodiametric- flattened | Angular-irregular | Flattened-tangentially elongated |
| | Crystals | | Absent | Absent | Absent |
| | fiber number of layers | | 3-4 | 3-4 | 2-3 |
| | Fiber thickness (µm) | | 25-37.5 | 25-37.5 | 12.5-25 |
| | Tannin cells | Upper vascular bundle | Absent | Absent | 2-3 |
| | | Lower vascular bundle | Absent | Absent | Absent |
| Leaflet lamina | Thickness (µm) | | 300-350 | 280-310 | 220-230 |
| | Mesophyll with interspace widely | Number of rows | 5-6 | 5-6 | - |
| | | Thickness (µm) | 250-315 | 210-275 | - |
| | Palisade layer | Number of rows | - | - | 2-3 |
| | | Thickness (µm) | - | - | 62.5-85 |
| | Spongy layer | Number of rows | - | - | 3-4 |
| | | Thickness (µm) | - | - | 70-87.5 |
| | Tannin cells | | Absent | Absent | Absent |
| | Crystals | | Solitary | Absent | Absent |

*SEM of the spermoderm (Table 5 and Fig. 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.

*Anthyllis vulneraria*

Seed ovoid with rounded poles, 2-3 × 1-1.5mm size, brown or yellowish with terminal part pale green in colour, covered with wax, hilum circular, 83.87 × 80.65µm size, subapical in position, rim aril raised, micropyle obtriangular, and 7.8 × 7.8µm size. Seed coat pattern irregularly reticulate, anticlinal wall wavy, relief of cell boundary slightly channeled, thickness of cell boundary moderate, curvature of outer periclinal wall smooth and concave.

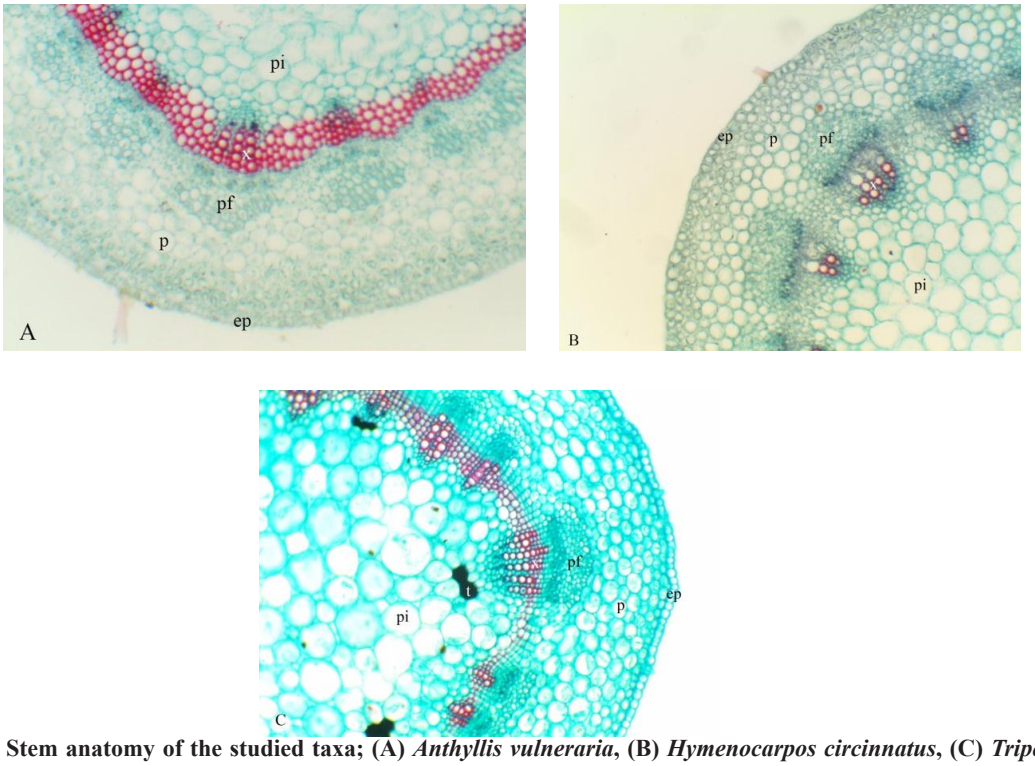


**Fig. 2. Stem anatomy of the studied taxa; (A) *Anthyllis vulneraria*, (B) *Hymenocarpos circinnatus*, (C) *Tripodion tetraphyllum* [ep= Epidermis, pi= Pith, x= Xylem, p= Parenchyma, pf= Phloem fiber, t= Tannin cell (x 100)].**

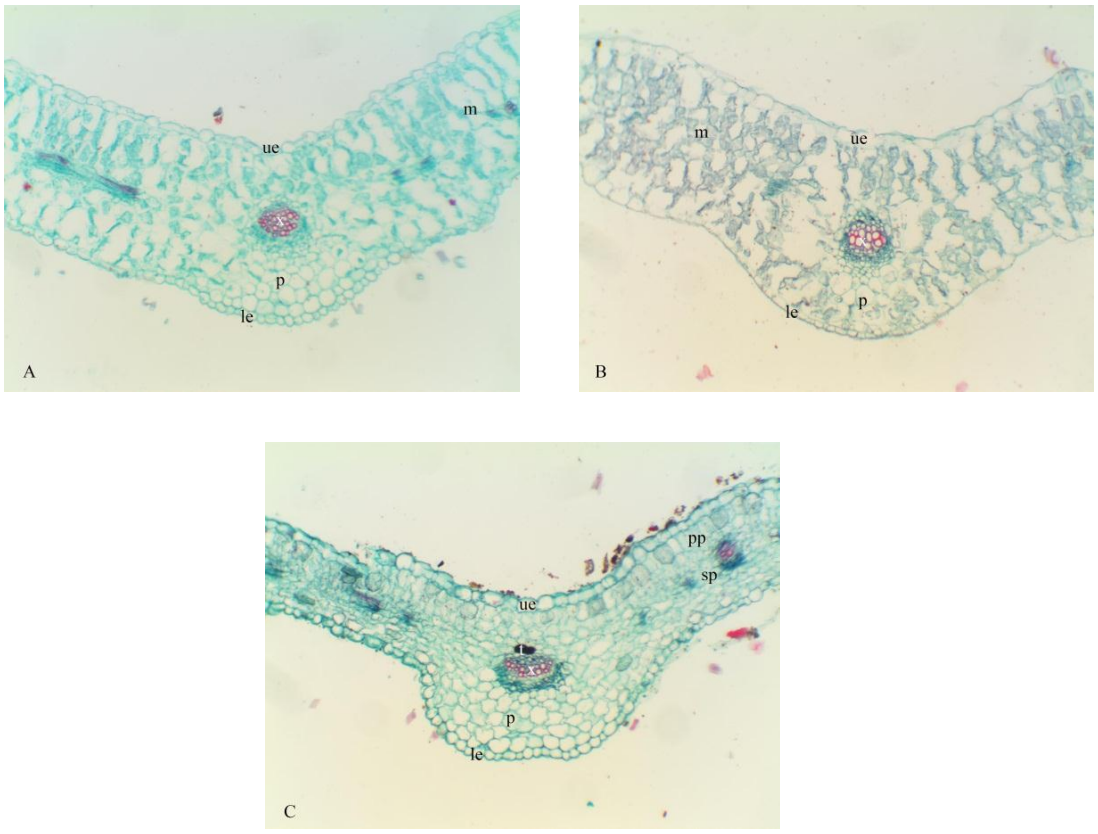


**Fig. 3. Leaf anatomy of the studied taxa, (A) *Anthyllis vulneraria*, (B) *Hymenocarpos circinnatus*, (C) *Tripodion tetraphyllum* [ue= Upper epidermis, x= Xylem, p= Parenchyma; m= Mesophyll, pp= Palisade parenchyma, sp= Spongy parenchyma, le= Lower epidermis, t= Tannin cell (x 50)].**

**TABLE 5. The morphological aspect of the spermoderm of the studied taxa.**

| Character | | *Anthyllis vulneraria* | *Hymenocarpos circinnatus* | *Tripodion tetraphyllum* |
|---|---|---|---|---|
| Seed colour | | Yellowish with green in terminal part - brown | Yellowish – creamy – pale brown, hilum blackish brown | Brown with black spots |
| Seed size | L × W(mm) | 2-3 × 1-1.5 | 3-3.5 × 2-2.5 | 3-3.5 × 2-2.5 |
| | L/W ratio | 2 | 1.4 | 1.4 |
| Seed pole | | Rounded | Rounded | Rounded- truncate |
| Seed shape | | Ovoid | Reniform | Oblong – Ellipsoid Crispate |
| Seed coat pattern | | Reticulate | Micropappilate in rows | Papillae |
| Hilum | Position | Subapical | Lateral | Lateral |
| | Shape | Circular | Oblate | Ovate |
| | L × W(µm) | 83.87 × 80.65 | 75.81 × 88.71 | 83.87 × 77.42 |
| Rim aril | | Raised | Raised | Raised |
| Micropyle | Shape | Obtriangular | Narrow oblong | Narrow oblong with one open end |
| | L × W(µm) | 7.8 × 7.8 | 7.8 × 1.56 | 9.36 × 1.56 |
| Outline of cells | | Reticulate-irregular | Oblong-radial elongated | Tetra-hexagonal |
| Anticlinal wall | | Wavy | Wavy | Lobbed |
| Relief of cell boundary | | Slightly channeled | Slightly channeled | Channeled |
| Thickness of cell boundary | | Moderately | Moderately | Very thick |
| Curvature of outer periclinal wall | | Concave-smooth surface | Concave-smooth surface | Concave- irregular |
| Wax | | Present | Present | Present |

*Hymenocarpos circinnatus*

Seed reniform, 3-3.5 × 2-2.5mm size, yellowish-creamy-pale brown in colour with hilum blackish, seed poles rounded. Seed coat pattern micropapilate in rows, outline of cells oblong-radial elongated, anticlinal wall wavy, relief of cell boundary slightly channeled, thickness of cell boundary moderately, curvature of outer periclinal wall concave, smooth surface. Hilum oblate, 75.81 × 88.71µm size, lateral in position. Rim aril raised. Micropyle narrow oblong, 7.8 × 1.56µm size. Wax present.

*Tripodion tetraphyllum*

Seed oblong-ellipsoid crispate, 3-3.5 × 2-2.5mm size, brown with black spots in colour, seed poles rounded-truncate. Seed coat pattern papillae in rows, outline of cells tetra-hexagonal, anticlinal wall lobbed, relief of cell boundary channeled, thickness of cell boundary very thick, curvature of outer periclinal wall concave irregular. Hilum ovate, 83.87 × 77.42µm size, lateral in position. Rim aril raised. Micropyle narrow oblong with one open end, 9.36 × 1.56µm size. Wax present.

## Discussion

Several attempts have been made in distinguishing and identification of the genera *Anthyllis, Hymenocarpos* and *Tripodion*. Taubert (1894) included *Hymenocarpos* as synonym to *Circinas*. Sokoloff (2003 a) have treated *Hymenocarpos* as synonym to *Anthyllis* (subgenus *Cornicina,* section *Hymenocarpos*). Tikhomirov & Sokoloff (1996), Benedi (2000) and Sokoloff (2003 a) have treated *Anthyllis tetraphylla* as genus *Tripodion*.

The morphological characteristics of the studied taxa revealed that they varied from each other and can be distinguished depending on the habit, characteristics of leaves, inflorescence, flowers, pods, and seeds.

The use of anatomical characters in taxonomic investigation is becoming of increasing interest. Anatomical structure is most likely providing evidence helping to establish the affinities of genera of uncertain taxonomic status, yet in the same time proves very helpful for individual identification (Welkie & Caldweli, 1970 and Osmond et al., 1980). Turki (2007) and Kasem (2016) reported the importance of anatomical differences in the distinction among species.

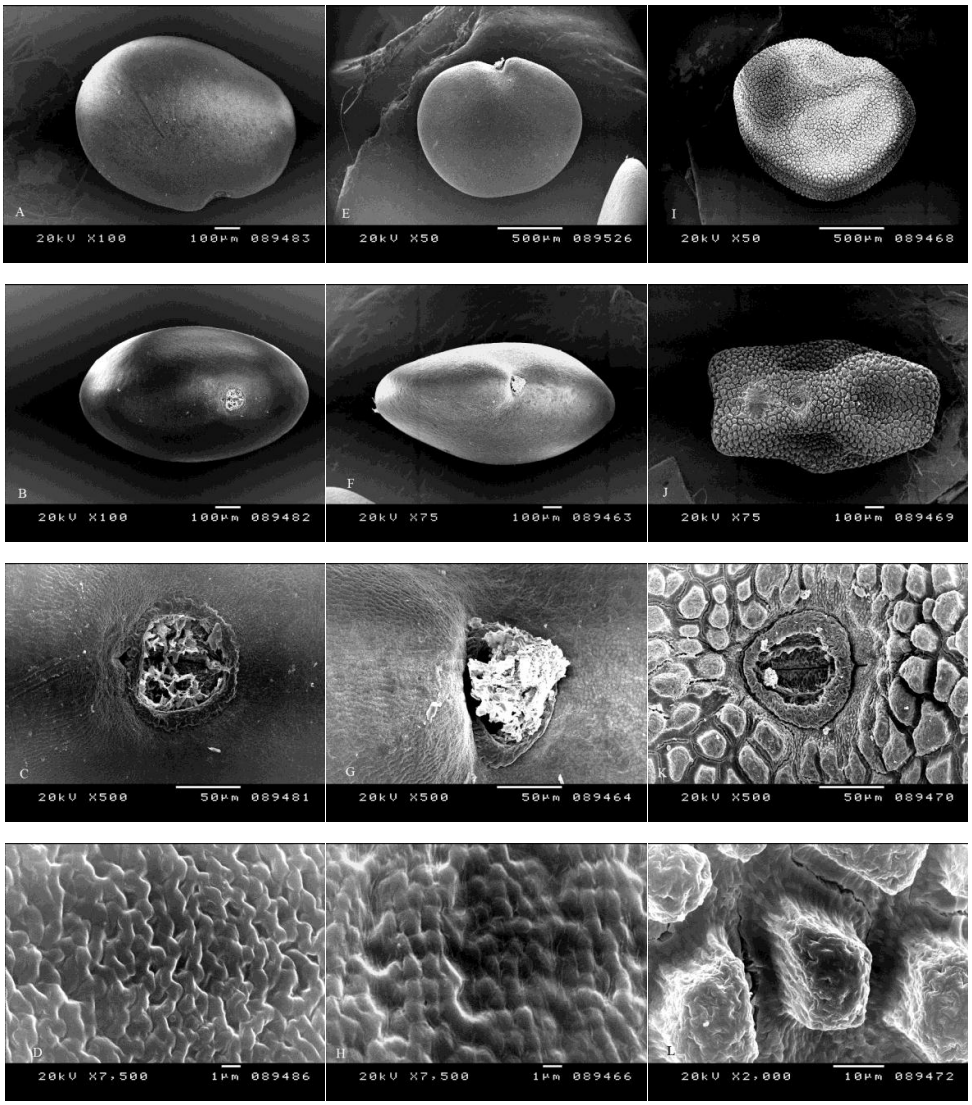


**Fig. 4. SEM micrograph of spermoderm surface of the studied taxa; (A-D) *Anthyllis vulneraria*, (E-H) *Hymenocarpos circinnatus*, (I-L) *Tripodion tetraphyllum* [A, E, I: Seed morphology; B, F, J: Hilum position; C, G, K: Hilum shape; D, H, L: Spermoderm surface].**

The studied taxa displayed remarkable differences in the anatomical investigations of their stems and leaflets. Comparison of the internal structure of the stems revealed differences in cortex, number of vascular bundles, xylem, pith diameter, crystals and tannin cells. Comparison of the internal structure of the leaflets revealed differences in shape and thickness of midrib and xylem, lamina thickness, and crystals and tannin cells.

Anticlinal undulations and characters of cell boundaries in the seed exine are of high taxonomic significance and often characterize between the species and genus level (Barthlott & Voit, 1979 and Barthlott, 1981). Kaplan et al. (2007) and Fawzi et al. (2010) reported seed coat characters are successfully employed in the identification and classification of taxa.

The results of spermoderm SEM revealed differences in seed coat pattern, outline cells, relief and thickness of cell boundary, curvature of outer periclinal wall.

The present study, depending on the results of macromorphological and anatomical investigations, SEM studies on seeds clearly indicates considerably differences between the three studied genera *Anthyllis, Hymenocarpos* and *Tripodion* and support the treatment of them as different genera. The results agree with Medikus

(1787) in that *Tripodion* treated as a separate genus.

*Key to the genera*

1- Perennial herb, inflorescence head, bract palmatisect, the leaf in midrib region is v-shaped, hilum subapical in position, seed coat pattern irregularly reticulate.. *Anthyllis*

- Annual herb, inflorescence umbellate or cluster, bract simple, the leaf in midrib region is u-shaped, hilum lateral in position, seed coat pattern otherwise ……...2

2- Flower 6-7mm long, calyx campanulate, pod orbicular-reniform, cortex up to 6 layers, seed coat pattern micropapilate……*Hymenocarpo*s

- Flower 14-18mm long, calyx tubular, pod ellipsoid- cylindrical, cortex 7-9 layers, seed coat pattern papillae…..…….. *Tripodion*

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## دراسات تصنيفية لعشيرة Loteae (الفصيلة الفولية) في مصر.
## تحت العشيرة Anthyllidinae *(Anthyllis, Hymenocarpos و Tripodion)*

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تهدف الدراسة إعادة تقييم العلاقات التصنيفية المتداخلة بين أجناس *Anthyllis*، *Hymenocarpos* و *Tripodion* على أساس دراسة تفصيلية لكل من الشكل الظاهري للنبات والصفات التشريحية للساق والأوراق، ودراسة قصرة البذور باستخدام المجهر الإلكتروني الماسح. تشير النتائج إلى وجود اختلافات كبيرة بين الأجناس المدروسة وتدعم معاملتها كأجناس مختلفة وليس كما أشار بعض الباحثين أن جنس *Hymenocarpos* وجنس *Tripodion* أسماء مرادفة لجنس *Anthyllis* يمثل في مصر كل جنس من *Anthyllis*، *Hymenocarpos* و *Tripodion* بنوع واحد.