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# Biosystematic studies on the genus *Crepis* L. (Asteraceae: Cichorieae) in Egypt

**Mona Hassan, Aamaa Olwey, Mostafa Aboulela**

Department of Botany and Microbiology, Faculty of Science, Assiut University, Assiut, Egypt.

Email address: mostafa.aboulela@aun.edu.eg

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**ABSTRACT:** The taxonomy of the genus *Crepis* L. in Egypt is critically discussed. The genus is represented in Egypt by seven species with four infra-specific taxa. One new record (*C. aspera* var. *inermis* (Cass.) Boiss.) is reported here for the first time for the flora of Egypt. The macro- and micro-morphological characteristics of the studied *Crepis* taxa, including the capitula, phyllaries, achenes, trichomes, and stomata, were investigated. Multivariate (cluster and PCA) analyses based on macro- and micro-morphological characteristics elucidate the phenetic relationships among the investigated taxa at the sectional level. A key, full descriptions, an updated nomenclature, and a revised type citation to the *Crepis* taxa are provided.

**Keywords:** Achenes; Asteraceae; Cichorieae**;** *Crepis*; Stomatal index; Trichomes.

## دراسات بيوتصنيفية على جنس ال *Crepis* L. (القبيلة الشيكورية: الفصيلة المركبة) في مصر

**منى حسن، أسماء علوي و مصطفى أبو العلا**

**الملخص:** نناقش هنا تصنيف جنس *Crepis* L. في مصر بشكل نقدي. الجنس في مصر ممثل بسبعة أنواع بأربعة أصناف فرعية. تم اضافة (*C. aspera* var. *inermis* (Cass.) Boiss) كسجل جديد هنا لأول مرة لفلورة مصر. تمت دراسة الخصائص المورفولوجية الكبيرة والصغيرة لأنواع ال *Crepis* المدروسة، بما في ذلك النورات، القلافات، الثمار، الشعيرات، والثغور. التحليلات متعددة المتغيرات (cluster والـ PCA) المستندة إلى الخصائص المورفولوجية الكبيرة والصغيرة توضح العلاقات الشكلية بين الأنواع التي تم فحصها على مستوى ال sections. تم عمل مفتاح تعريفى، و تقديم وصف كامل، تسميات محدثة، ومراجعة عينات النمط لجنس ال *Crepis*.

**الكلمات المفتاحية:** ثمار الفقيرات، الفصيلة المركبة، القبيلة الشيكورية، جنس ال *Crepis*، مؤشر الثغور، الشعيرات.

## 1. Introduction

Asteraceae Bercht. & J. Presl (1820: 254) is considered one of the largest, highly evolved, and most successful families. It comprises 16 subfamilies and 50 tribes with 1600–1700 genera and 25,000–33,000 species [1]. It has a cosmopolitan distribution and is well-represented in tropical and subtropical regions [2, 3]. There is a huge diversity in size, color, and degree of fusion of corolla, style branches, stigmatic hairs, and plant indumentum [4]. However, the family is considered a monophyletic group by several workers [5, 6].

The tribe Cichorieae includes about 100 genera with about 1,500 species chiefly distributed in the temperate and subtropical zones of the Northern Hemisphere, with the greatest concentration of its species in the Mediterranean, Europe, Asia, and North America [7]. The conspicuously poor morphological features of Cichorieae produced an extensive parallel evolution of characteristics that resulted in the difficult recognition of the natural groups and finally led to obvious differences in the classification of the tribe members at the generic and subgeneric levels by different workers [7, 8].

The genus *Crepis* L. comprises about 200 species distributed throughout Africa and the Northern Hemisphere [9]. The most comprehensive taxonomic study of the genus was presented by [10, 11], who recognized 196 species classified in 27 sections and included *Lagoseris* as a section of the genus *Crepis* based on morphological and karyological similarities.

The capitulum and achene morphological characteristics provide useful tools for the delimitation of the genera in Cichorieae as well as the separation of taxa [7, 8, 12-14]. Also, a large number of studies show that trichome diversity is a useful diagnostic character for delimitation of related taxa, especially at lower taxonomic levels [15-20]. Moreover, several taxonomical, comparative anatomical, and phylogenetic studies have established the importance of stomatal characteristics as taxonomic tools at different levels of plant systematics and have shown that the leaf epidermal and stomatal characteristics were helpful tools in taxonomical revisions of some genera of the Asteraceae [21-23].

In Egypt, *Crepis* has been treated only in broad floristic studies [24-27]. Boissier [28] reported *C. senecioides* Delile and *C. aspera* L.; Ascherson and Schweinfurth [29] added *C. parviflora* Desf.{= *C. micrantha* Czerep. } and *Lagoseris bifida* (Vis.) Koch {= *C. sancata* (L.) Bornm.}. Täckholm [27] added *C. libyca* (Pamp.) Shab., *C. clausonis* (Pomel) Batt. & Trab., *C. nigricans* Viv., and *C. aculeata* (DC.) Boiss.

The present study aims to evaluate the different macro-and micro-morphological characteristics of the taxa of the genus *Crepis* in Egypt, discuss their taxonomic validity, and provide an improved diagnostic key for the taxa.

## 2. Materials and methods

### 2.1 Taxonomic treatment

The current study was based on collections preserved in different Egyptian herbaria: ASTU, CAI, and CAIM; acronyms of herbaria are following [30]. The *Crepis* taxa were identified according to [24, 25]. Capitula, phyllaries, and achenes were photographed by an Olympus SZ61 stereomicroscope provided with a digital Olympus camera SC100 (Olympus, Germany). For scanning electron microscopy (SEM), the samples were prepared as described by [31, 32]. The dry materials were mounted onto clean stubs, coated with gold in an ion-sputtering device (JOEL JFC 1100E), and then examined by SEM (JOEL JSM 5400 LV) operated at an accelerated voltage of 15 KV at the Scanning Electron Microscope Unit, Assiut University.

#### a. Trichomes examinations

The trichome structures of various vegetative parts (stems and leaves) and floral parts (peduncles, phyllaries, and flowers) were observed and documented using light and scanning electron microscopy. Line drawings of trichomes were created with the aid of a camera lucida mounted on a LaborLux 11 (Leitz) light microscope and provided with a 15× drawing eyepiece. According to the [33] approach, the trichomes were detected and classified.

#### b. Stomata observations

Epidermal peels of leaves were prepared, placed on clean slides, and examined under 100× and 400× magnifications with a CX41 Olympus light microscope provided by an SC100 Olympus digital camera and appropriate drawing scale bars to support the measurements of stomata and epidermal cells.

Stomata and epidermal cell densities were counted per unit area of the adaxial surface of leaves. The counts were obtained from at least 30 readings to calculate the average values. The stomatal index (SI) was calculated by the formula described by [34]:

$$\mathrm{SI} = \frac{\mathrm{S}}{\mathrm{S} + \mathrm{E}} \times 100$$

Where S indicates the number of stomata per unit area, and E indicates the number of epidermal cells per the same unit area.

### 2.2 Numerical (Cluster and PCA) analyses

For numerical analysis research, macro- and micro-morphological features were examined and assessed as binary scores (1 for presence and 0 for absence) to create the data matrix (Supplementary Table 1). Using the software program PAST 3.25 (Palaeontological statistics) cluster and ordination analyses were employed to evaluate the phenetic relationships between taxa [35]. Cluster analysis was performed based on the similarity matrix data using the unweighted pair-group clustering method (UPGMA). A

similarity matrix was illustrated according to the Jaccard similarity measure with a co-phenetic correlation coefficient of 0.9684. Principal component analysis (PCA) was performed to support the results of our co-phenetic data.

## 3. Results

### Systematic treatment

The revision of the genus *Crepis* in Egypt revealed the presence of the following taxa: *C. micrantha*, *C. sancta* subsp. *sancta*, *C. sancta* subsp. *obovata*, *C. libyca*, *C. senecioides*, *C. nigricans*, *C. aspera* var. *aspera*, *C. aspera* var. *inermis*, and *C. aculeata*. The Egyptian *Crepis* taxa are distributed in five sections, as shown below.

***Crepis*** L., Sp. Pl. 2: 805 (1753); Gen. Pl. ed. 5:350 (1754).

**Type species:** *C. biennis* L., Sp. Pl. 2: 807 (1753: 807); Sweden. Scaniae & Europae: australioris, LINN 955.14 (lectotype, designated by Babcock [11], conserved type proposed by Jarvis (1992: 561), LINN- image!).

I. *Crepis* sect. Alethocrepis Bisch. (1851: 247) ≡ *Crepis* sect. Phytodesia Babc. (1947b: 763).

*1. C. micrantha* Czerep. in V.L.Komarov (ed.), Fl. URSS 29: 684 (1964).

**Type:** Turkey. Iter Trojanum: Dardanelli, 3.6. 1883.

**Synonyms:** *C. parviflora* Desf. Ex Pers., Syn. Pl.: 376 (1807), non Moench (1794).

**Selected specimens:** Rosetta, 24.10.1986, *Amer* 9546 (CAI); Dikirnis, 21.5.1967, V. *Täckholm* s.n. (CAI); Rosseta, 29.4.1927, *G. Täckholm* s.n. (CAI); Rosseta, 20.5.2003, *Mashaly & Boulos* s.n., (ASTU); Fayoum-Beni Souif road, 25.5.1988, *Fahmy* s.n. (ASTU).

**Distribution:** Common weeds along Nile banks and irrigation canals, as well as in moist places of the Oasis, Eastern Mediterranean regions, and Sinai.

II. *Crepis* sect. Pterotheca (Cass.) Babc. (1947b: 730).

*2. C. sancta* (L.) Bornm. in Mitt.. Thür.. Bot. Ver., nov. ser., 30: 79 (1913).

**Type:** PALESTINE. *Hasselquist.* Herb. Linn. No. 954.18 (lectotype designated by [36], LINN-image!).

**Synonyms:** *Hieracium sanctum* L., Cent. Plant. 2:30: 30 (1756); Pterotheca sancta (L.) K. Koch in Linnaea 23(6): 692 (1851); Lagoseris sancta (L.) K. Malý in Glasn. Zemaljsk. Muz. Bosni Hercegovini 20: 556, 562 (1908); *Lagoseris bifida* (Vis.) Koch, Sym. Fl. Germ. 435(1837); Lagoseris sancta subsp. bifida (Vis.) Hayek in Repert. Spec. Nov. Regni Veg. Beih. 30(2): 828. 1931; *C. sancta* (L.) Babc. in Univ. Calif. Publ. Bot. 19: 403 (1947)

*a.* subsp. *sancta*

**Selected specimens:** Sinai, Wadi Farieh, 4.4.1961, ***V.*** *Täckholm et al.* s.n. (CAI); Sinai, April, 1940, *Hassib* s.n. (CAI).

**Distribution:** Rare weeds in the Mediterranean region, the Eastern desert, and Sinai.

*b.* subsp. *obovata* (Boiss. & Noë ex Boiss.) Babc. in Univ. Calif. Publ. Bot. 22: 741 (1947)

**Type:** Turkey, Subalpinis Armeniae: meridionalis circa Ardana, s.d., *Noë* s.n., holotype, G-Bois).

**Synonyms:** *Pterotheca obovata* Boiss. & Noë in Boiss., Diagn. Pl. Orient., ser. 2, 3: 98 (1856); *Lagoseris orientalis* Boiss., Fl. Orient. 3: 882 (1875), nom. Illeg; *Lagoseris obovata* (Boiss. & Noë) Bornm. in Beih. Bot. Centralbl. 20(2): 176 (1906)

**Selected specimens:** Southern Sinai, Farsh Shoaiby, 3.5.2010, *Fayed et al.* s.n. (ASTU); Sallum, 4.2007, Khadija Bauo s.n. (ASTU); Galala, 15.4.1945, Shabatai, z5642 (CAIM).

**Distribution:** Rare, distinct only in Sinai and Sallum.

III. *Crepis* Sect. Lepidoseris Babc. (1947b: 796).

*3. C. libyca* (Pamp.) Babc. in Bull. Minist. Agric. Egypt, Techn. Sci. Serv. 197: 3 (1938)

**Type:** Libya, Cyrenaica, Bengasi: Suani Osman, presso illago Bedafam, 9.3.1916, V. Zanon 528, (FI003552 – FI!), lectotype designated by [37].

**Synonyms:** *C. vesicaria* L. var. *libyca* (Pamp.) Maire & Weiller in Bull. Soc. Hist. Nat. Afr. Nord 30:288 (1939).

**Selected specimens:** Sallum, 14.5.1934, *Shabetai* Z3097 (CAIM).

**Distribution:** restricted only in the Mediterranean region (Sollum).

IV. *Crepis* sect. Psammosbris Babc.

*4. C. senecioides* Delile, Descr. Égypte, Hist. Nat. 118,t, 42 fig. 2: 262. (1813)

**Type:** Egypt. Aux environs du Caire sur le bord d'un chemin, s.d., *A.R. Delile* s.n., MPU005401 (holotype, MPU-image!).

**Synonyms:** *Barkhausia senecioides* (Delile) Spreng. (1826: 652); Psammoseris senecioides (Delile) Boiss. & Reut. (1849: 52); *C. radiacta* sensu auct., non Forssk. (1175); *Barkhausia senecioides* (Delile) Spreng., Syst. Veg. ed.16, 3: 652 (1826); *Psammoseris arabica* Boiss. & Reut. in Boiss., Diagn. Pl. Orient. Ser. 2, 11: 52 (1849); *C. arabica* (Boiss. & Reut.) Boiss., Fl. Orient. 3: 853 (1875); *C. radicata* var. *arabica* (Boiss. & Reut.) Täckh. & Boulos in Publ. Cairo Univ. Herb. 5: 31 (1974).

**Selected specimens:** Sinai, 27.4.1924, *Simpson* 2788 (CAI); El-Saff, Wadi Rishrash, *Hassan L.* 3062 (CAI); Sallum-Sidi-Barrani road, 17.4.1934, *Shabetai* s.n. (CAI); Burg Al-Arab, Spring, 1961, *Halwagy* s.n. (CAI); El-Marg, 23-4-1928, *Drar* s.n., (CAIM); Maruit, 4.3.1914, *Bolland s*.n., (CAIM); Wadi Habs, 24.3.1974, *V. Täckholm* s.n. (CAI).

**Distribution:** Mediterranean region, Nile Valley region, deserts, and Sinai.

*C.5. C. nigricans Viv., Fl. Libyc. Spec.: 51 (1824).*

**Type:** Libya, Montibus Cyrenaicae: El Gubba (8699), 7. 4. 1933, *R. Pampanini* s.n., FI003547, (lectotype designated by [37], FI-image!).

**Synonyms:** *C. radicata* f. *nigricans* (Viv.) Pamp. In Bull. Soc. Bot. Ital. 48 (1921); *C. senecioides* subsp. *nudiflora* (Viv.) Alavi in Fl. Libya 107: 419 (1983); C. nudiflora Viv., Fl. Libyc. Spec.: 51

(1824); C. senecioides subsp. nudiflora (Viv.) Alavi in Jafri & El-Gadi, Fl. Libya 107: 419 (1983); Barkhausia kralikii Pomel in Bull. Soc. Sci. Phys. Algérie 11: 5 (1874); C. kralikii (Pomel) Pomel, Nouv. Mat. Fl. Atl.: 261 (1875); C. radicata f. gigantea Pamp. In Nouvo Gior. Bot. Ital. n. s. 24: 158 (1917).

**Selected specimens:** Libya, Kuwayfiyah-Doryana road, 10.3.1968, *Boulos* s.n., (CAI).

**Distribution:** Nile Valley. This species is very rare and no Egyptian material was available to the authors. Babcock [11] and Boulos [25] cited one collection from Abu Rawash, near the Giza Pyramids from a lupin field collected by Ascherson 185 (B). The description above was based on Libyan material.

V. *Crepis* Sect. Nemauchenes (Cass.) Benth.

*6. C. aspera* L., Sp. Pl., ed. 2: 1132 (1763).

*a.* var. *aspera*

**Type:** Unknown. *Anonymous* s.n., LINN-HL955-10, lectotype designated by [11]: 879, (LINN-image!).

**Synonyms:** *Barkhausia aspera* (L.) Rchb. in Mössler, Handb. Gewächsk., ed. 22: 1405 (1829); *Endoptera aspera* (L.) DC., Prodr. 7:178 (1838); *Nemauchenes aspera* (L.) Steud., Nomencl. Bot., ed. 2 2: 189 (1841); *Pterotheca aspera* (L.) Rchb., Icon. Fl. Germ. Helv. 19: tab. 77 (1858-1859); *Hieracioides aspera* (L.) Kuntze, Revis. Gen. Pl. 1: 345 (1891); *Nemauchenes aculeata* Cass. in Cuvier, Dict. Sci. Nat. 34: 362 (1825), nom. illeg.

**Selected specimens:** Giza, 21-3-1965, *Täckholm et al.* s. n. (CAI); Rafah, 22.3.1928, *Gunnar Täckholm* s. n. (CAI); Rafah, 3-4-1988, *Shiamss* s. n. (CAI); El-Arish, 3-4-1988, *Shiamss* s.n., (CAI); Rafah, 3.3.1987, *Gabali M.* s. n. (CAI); Burg Al-Arab, 15.3.1928, *Gunnar Täckholm* s. n. (CAI).

**Distribution in Egypt:** Mediterranean region, Eastern deserts, and Sinai.

*b.* var. *inermis* (Cass.) Boiss., Fl. Orient 3: 875(1875).

**Type:** Hab. In totâ Syria littorali cum typo, eo frequentior (Bl, Gaill).

**Synonyms:** *Nemauchenes inermis* Cass., Dict. Sci. Nat. 34: 363 (1825); Nemauchenes ambigua Cass. in Bull. Sci. Soc. Philom. Paris 1818: 77 (1818).

**Selected specimens:** Rafah, 19-3-1928, *Shabatai* s.n. (CAIM); Southern Sinai, 14-5-1939, Drar 855 (CAIM).

**Distribution in Egypt:** Very rare and restricted only to Sinai.

*7. C. aculeata* (DC.) Boiss., Fl. Orient. 3: 856 (1875).

**Type:** Syria. loco non notato, s.d., *J. J. H. Labillardière* de s.n., G-DC-351672/1 (holotype, G-DC-image!).

**Synonyms:** *Barkhausia aculeata* DC., Prodr. 7 (1): 159 (1838); *Hieraciodes aculeata* (Boiss.) Kuntze in Revis. Gen. Pl. 1: 345 (1891); *C.aculeata* var. *bornmuelleri* Huter in Oesterr. Bot. Z. 57: 114 (1907).

**Selected specimen:** Rafah, 23. 3.1928, *G. Täckholm* s.n. (CAI).

**Distribution:** Sinai and Red Sea.

**Macro-morphological characteristics**

Figures 1-7 summarize the most crucial vegetative and reproductive morphological features that proved to have high taxonomic value in the identification and the delimitation of the studied taxa.

**Habit**

The examined taxa of the genus *Crepis* in Egypt were either perennial (*C. libyca*) or annual (the remaining taxa). The growth pattern was erect in only *C. libyca* whereas it was erect ascending in the remaining taxa (Supplementary Table 1). The short plant height (maximum height of 20 cm) distinguished *C. sancta*, *C. senecioides*, and *C. nigricans* from the remaining taxa (exceeding 20 cm) (Supplementary Table 1).

**Vegetative characters**

The shape of basal leaves showed four categories: oblong-lanceolate in *C. libyca*, *C. senecioides*, and *C. nigricans*; oblanceolate in *C. micrantha*, *C. sancta* subsp. *sancta*, and *C. sancta* subsp. *obovata*; oblong-spathulate in *C. aspera* var. *aspera* and *C. aspera* var. *inermis*; and obovate-oblanceolate in *C. aculeata* (Supplementary Table 1). The blades of the basal cauline leaves were reduced to scales or mostly absent (*C. sancta*); linear with remotely dentate margin towards the base (*C. senecioides*); linear-lanceolate with an entire margin (*C. micrantha*); linear-lanceolate with a laciniate margin (*C. aspera*); oblong-linear with a pectinately lobed (*C. aculeata*); or oblong-lanceolate with a triangle lobed (*C. libyca*). The length of basal cauline leaves was a key characteristic to distinguish *C. sancta* from other studied taxa by having the smallest cauline leaves (less than 1 cm) in addition to the abscence or reducion of upper cauline leaves to bract-like structures. Moreover, *C. libyca* can be identified by the dentate auricles of the basal cauline leaves. Whereas, the auricles of the basal cauline leaves were entire in *C. micrantha*, *C. aspera* var. *aspera*, *C. aspera* var. *inermis*, and *C. aculeata* and missing in the remaining taxa (Supplementary Table 1).

**Reproductive characters**

The length of the peduncle at the fruiting stage provided a taxonomic tool to differentiate studied taxa and was divided into three categories (Supplementary Table 1): short peduncle (reached 3 cm in *C. micrantha* and *C. aspera)*, medium-length peduncle (reached 6 cm in *C. libyca*, *C. senecioides*, *C. nigricans*, and *C. aculeata*), and long peduncle (reached 10 cm in *C. sancta*). Further, capitula size showed an important taxonomic characteristic to separate *C. libyca* from other studied taxa (Figure 1). The capitulum of *C. libyca* was the largest at the fruiting and anthesis stages (17 mm), whereas the capitula of other species at the same stages were much smaller (ranged from 6 mm to 10 mm in length) (Figure 1).

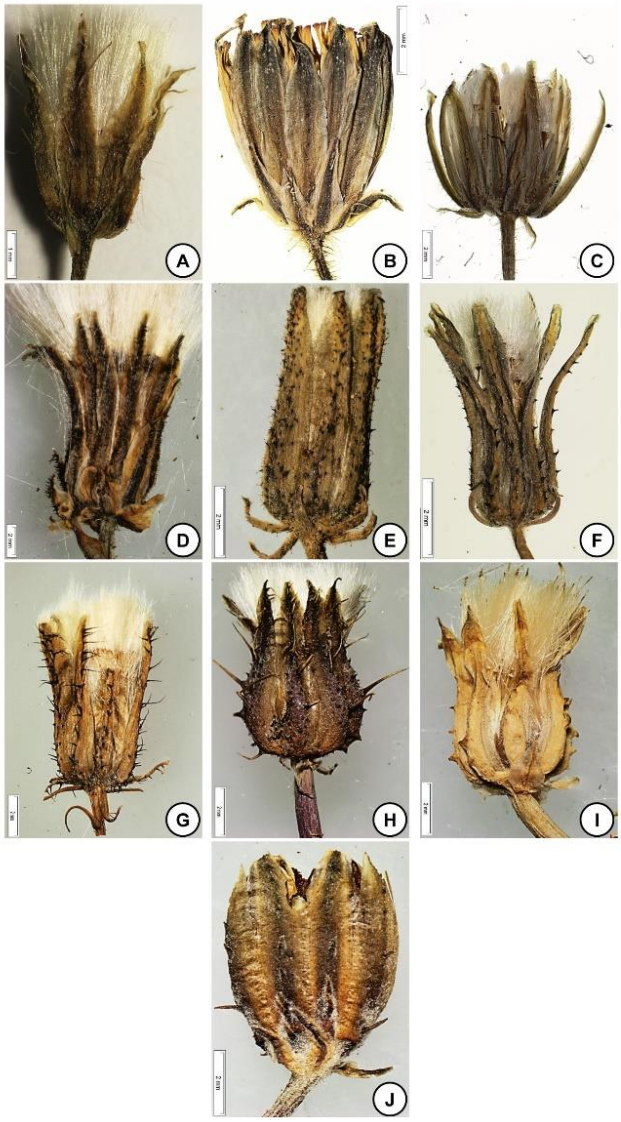


**Figure 1.** Stereomicrographs of heads of *Crepis* taxa: **A**, *C. micrantha*; **B**, *C. sancta* subsp. *sancta*; **C**, *C. sancta* subsp. *obovata*; **D**, *C. libyca*; **E**, *C. senecioides*; **F**, *C. nigricans*; **G**, *C. aspera* var. *aspera*; **H**, *C. aspera* var. *inermis*; **I**, *C. aculeata*. Scale bars as indicated at each image.

The phyllaries (involucres) of the capitula were arranged in two to multi-seriate layers, with the outer phyllaries having mostly heterogeneous sizes while the inner phyllaries had homogenous sizes (Figure 2). Also, the inner phyllaries were much longer than the outer ones (Figure 2). Four types of outer phyllaries were recognized: lanceolate-ovate in *C. micrantha*, broadly ovate to ovate in *C. libyca*, *C. sancta* subsp. *obovata*, and *C. aculeata*, ovate in *C. sancta* subsp. *sancta* and *C. aspera*, and linear in the remaining investigated taxa (Figure 2). Moreover, the scarious margin of the outer phyllaries was either wide scarious (*C. sancta*, *C. libyca*, *C. aspera*, and *C. aculeata*), narrow scarious (*C. micrantha*), or non-scarious (*C. senecioides*, and *C. nigricans*) (Figure 2). The color of the style branches enabled the differentiation between the two subspecies of *C. sancta*: yellow in subsp. *obovata* and greenish in subsp. *sancta* (Figure 3).

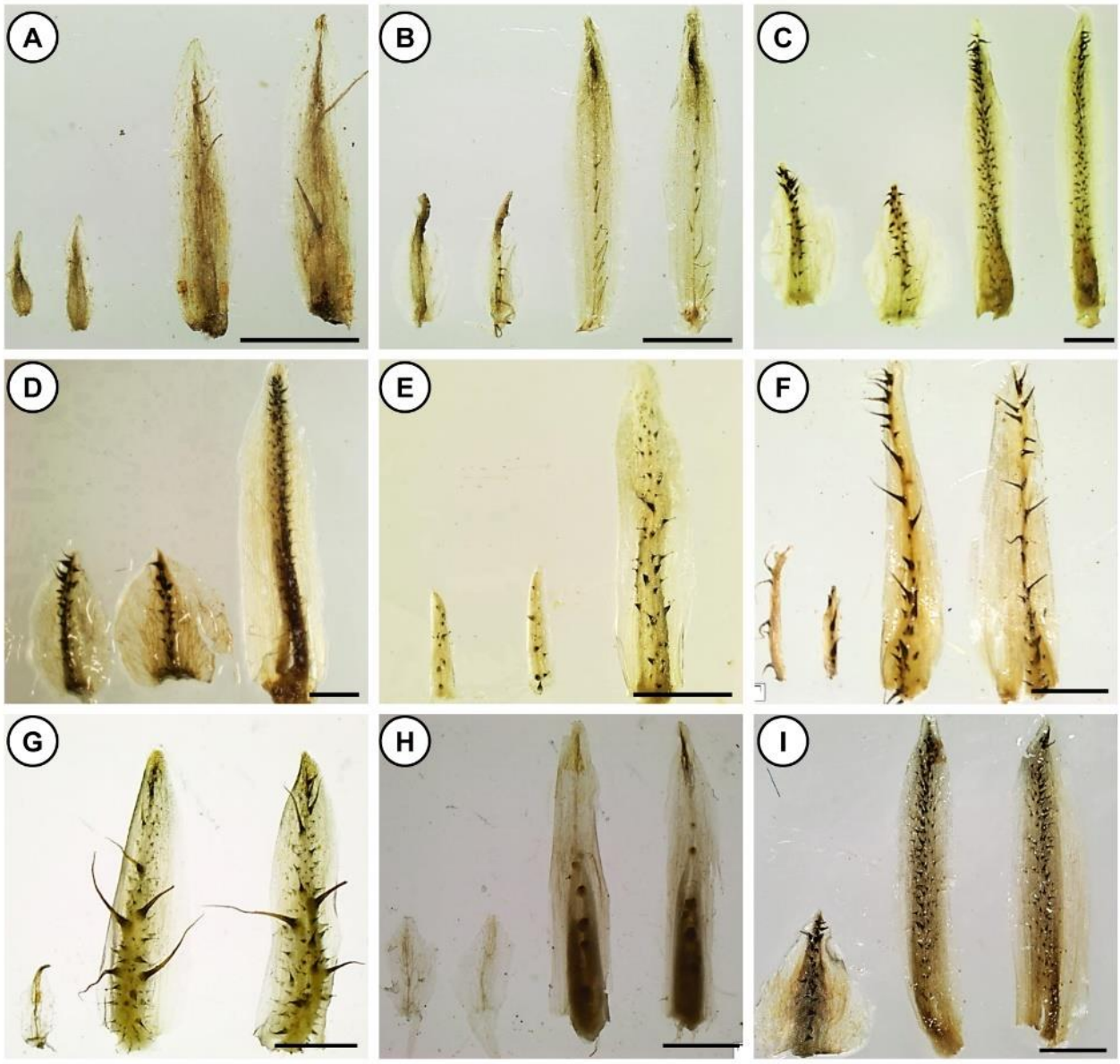


**Figure 2.** Stereomicrographs of marginal and inner phyllaries of *Crepis* taxa: **A**, *C. micrantha*; **B**, *C. sancta* subsp. *sancta*; **C**, *C. sancta* subsp. *obovata*; **D**, *C. libyca*; **E**, *C. senecioides*; **F**, *C. nigricans*; **G**, *C. aspera* var. *aspera*; **H**, *C. aspera* var. *inermis*; **I**, *C. aculeata*. Left panels indicate marginal phyllaries while right panels indicate inner ones. Scale bars = 2 mm.


**Figure 3.** Stereomicrographs of styles of : **A**, *C. sancta* subsp. *sancta*; **B**, *C. sancta* subsp. *obovata*.

Achene characters also proved that they have high taxonomic value; the morphism of achene can be classified into three categories: sub-homomorphic (as in *C. micrantha*), homomorphic (*C. libyca*), and heteromorphic in (*C. senecioides* , *C. nigricans*, *C. sancta, C. aspera* and *C. aculeata*,) (Figure 4). Also, the winged achene was only found in the species *C. aspera* and *C. sancta* subsp. *sancta*. The length of the achene varies from 2.4 mm in *C. micrantha* to 13 mm (the largest) in *C. libyca* (Figure 4). The outer achenes were peaked in *C. libyca*, *C. senecioides*, and *C. nigricans*, non-peaked truncate in *C. micrantha*, or non-peaked attenuate in *C. sancta*, *C. aspera*, and *C. aculeata* (Figure 4). The surface of the outer and inner achenes within the taxa of *Crepis* proved to be a crucial characteristic to distinguish between studied taxa of *Crepis*. The outer achenes showed a wide variation in features among studied taxa, including light scaberulous in *C. micrantha* (Figure 4A); smooth in *C. sancta* subsp. *sancta* (Figure 4B); muricate with antrorsely spinulose on the ribs in *C. sancta* subsp. *obovata*, *C. libyca* (Figure 4C, D), *C. senecioides*, and *C. nigricans* (Figure 4E, F). The pubescent character was distinguished for the two varieties of *C. aspera* and *C. aculeata* (Figure 4G-I). Moreover, inner achenes varied in appearance across the examined species, ranging from scaberulous in *C. micrantha* (Figure 4A), *C. sancta* subsp. *sancta* (Figure 4B) and *C. sancta* subsp. *obovata* (Figure 4C), or finely muricate in *C. aculeata* (Figure 4I) to muricate with antrorsely spinulose on the ribs in *C. senecioides*, *C. nigricans* and *C. aspera* (Figure 4E-H). Based on the pappus character, all the studied taxa of *Crepis* were characterized by pappose achenes except *C. sancta* subsp. *sancta* which was distinguished by the epappose outer achenes (Figure 4B). Additionally, all the taxa of *Crepis* had a deciduous pappus, except *C. libyca* and *C. aculeata* which had a persistent pappus. Pappus length was documented separately; and the *C. senecioides* showed the shortest pappus (1.5-2.5 mm) whereas *C. libyca* had the longest ones (7-8 mm). The irregular short pappus was characteristic to *C. aspera* and *C. aculeata*.

**Micro-morphological characteristics**

**Diversity of trichomes**

Light microscopy and SEM examinations revealed the great diversity of trichomes in various parts of the studied *Crepis* taxa (Figures 5, 6). The trichomes on the entire areal portions of *Crepis* taxa (stem, adaxial and abaxial leaf blade surfaces, dorsal and inner phyllaries surfaces, and peduncle) were recorded in Table 1 and drawn in Figure 5. We classified the trichomes into glandular trichomes (comprise types A and B) and eglandular trichomes (comprise types C–G) as follow.

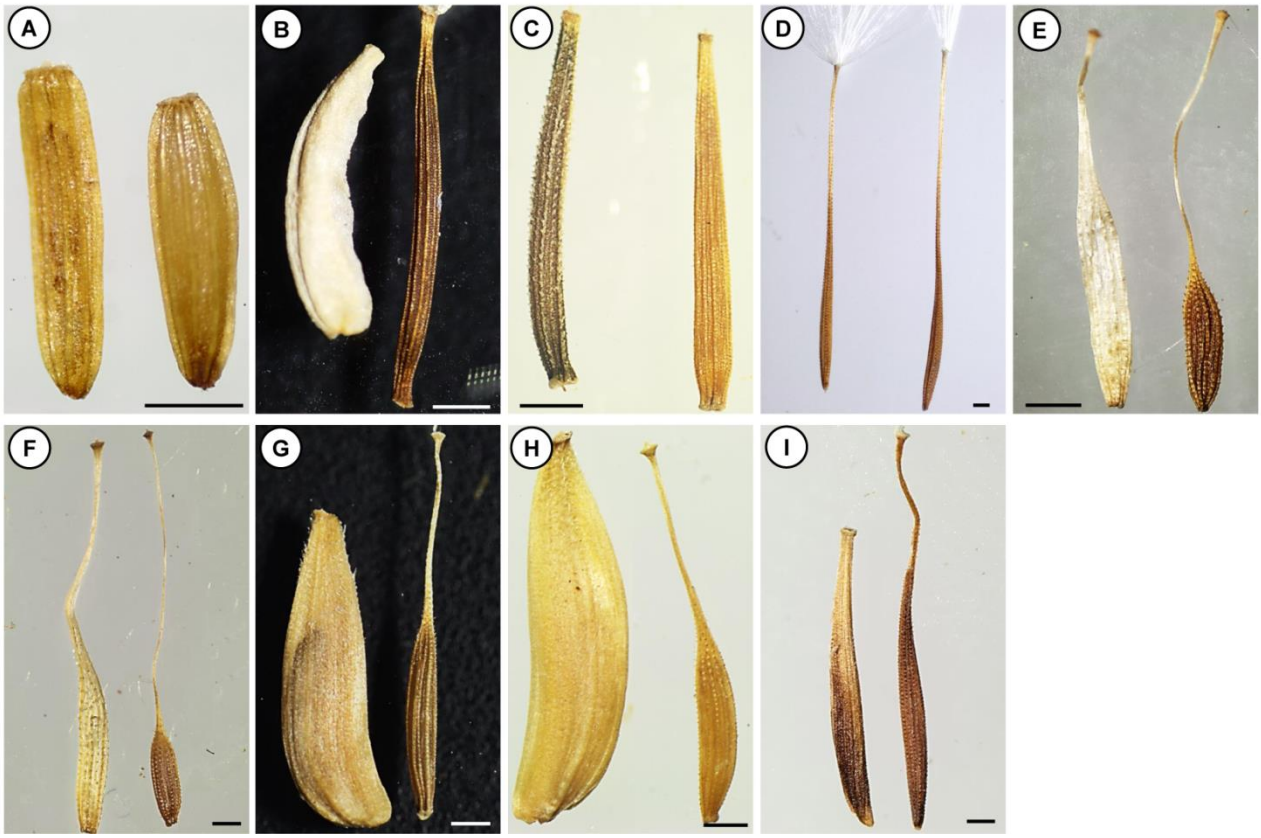


**Figure 4.** Stereomicrographs of achenes of *Crepis* taxa: **A**, *C. micrantha*; **B**, *C. sancta* subsp. *sancta*; **C**, *C. sancta* subsp. *obovata*; **D**, *C. libyca*; **E**, *C. senecioides*; **F**, *C. nigricans*; **G**, *C. aspera* var. *aspera*; **H**, *C. aspera* var. *inermis*; **I**, *C. aculeata*. Left panels indicate marginal achenes while right panels indicate inner ones. Scale bars = 0.5 mm.

**A- Glandular biseriate trichomes**

Trichomes had neck cells arranged in two parallel multicellular rows, with a broad base narrowing towards the apex. Head either unicellular or multicellular.

A1- With unicellular clavate head

The trichomes of this sub-type were composed of 6-10-celled narrow biseriate stalk and unicellular clavate gland, 500–750 µm in length (Figures 5, 6A, B). This sub-type of trichomes was found exclusively in *C. sancta* subsp. *sancta* (Table 1).

A2- With multicellular globular head

The trichomes of this sub-type were composed of one raised foot cell, 1-5-celled biseriate stalk and a multicellular globular gland, 300-600 µm in length (Figures 5, 6C). This sub-type of trichomes was observed exclusively in *C. sancta* subsp. *obovata* (Table 1).

A3- With multicellular doliform head

The trichomes of this sub-type were composed of one raised foot cell, 4-6-celled biseriate stalk and a multicellular peltate gland, 150–200 µm (Figures 5, 6D). This sub-type of trichomes occurred exclusively in *C. libyca* (Table 1).

**B- Glandular multiseriate trichomes with multicellular doliform gland**

Trichomes had neck cells arranged in two or more multicellular rows, with a multicellular broad base narrowing towards the apex, 4-6-celled stalk, a broad multiseriate base, and a multicellular doliform head, 200–250 µm (Figures 5, 6E). This type of trichomes was found in *C. senecioides*, *C. aspera* var. *aspera*, and *C. aculeata* (Table 1).

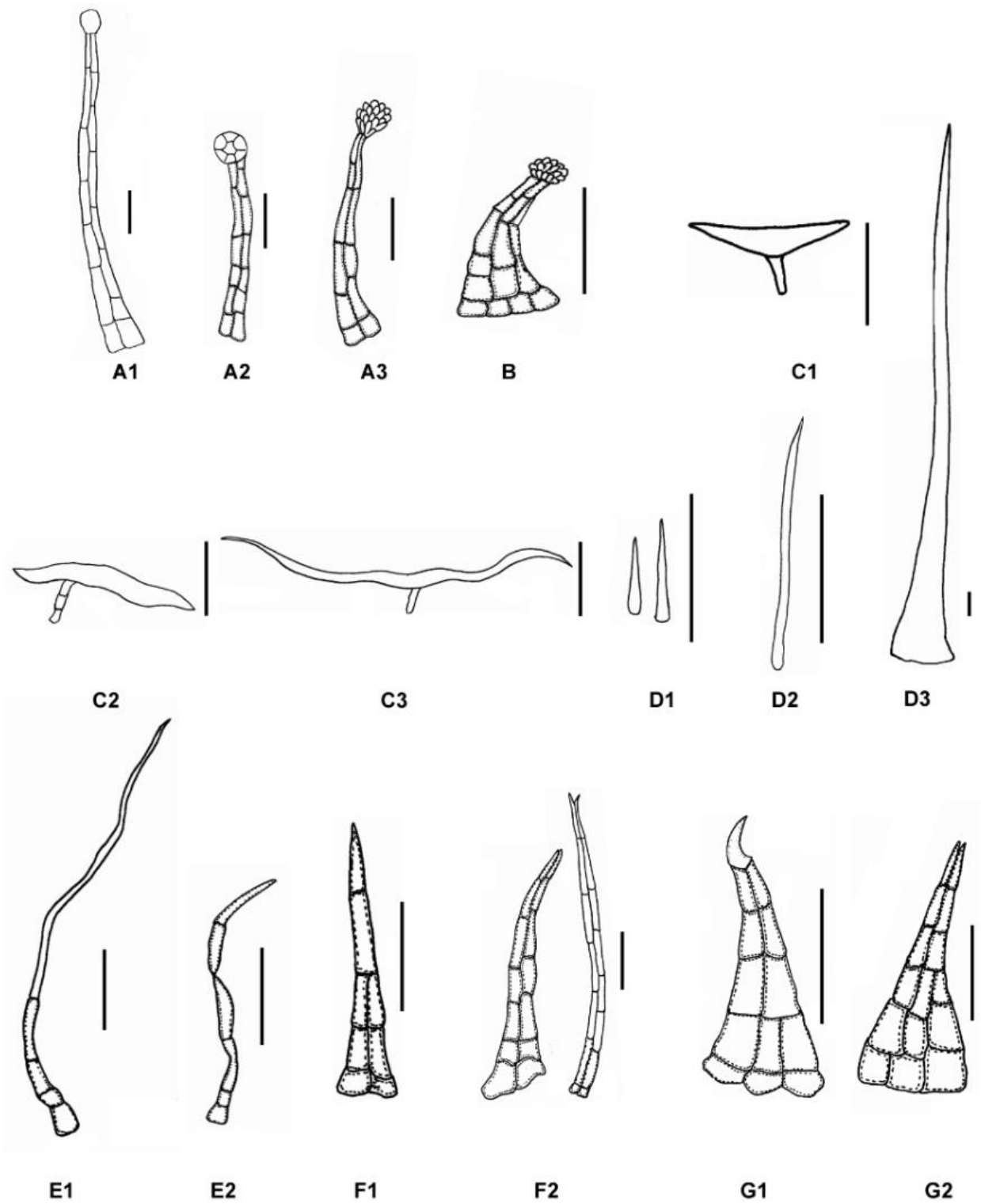


**Figure 5.** Line drawings of trichomes of *Crepis* taxa. **A1,** glandular biseriate trichome with unicellular clavate head; **A2,** glandular biseriate trichome with multicellular globular head; **A3,** glandular biseriate trichome with multicellular doliform head; **B,** glandular multiserate trichome with multicellular doliform head; **C1,** eglandular symmetrical branched straight T-shape trichome; **C2,** eglandular asymmetrical branched straight T-shape trichome; **C3,** eglandular branched curly T-shape trichome; **D1,** unbranched adpressed short conical trichome; **D2,** eglandular unbranched adpressed long conical trichome; **D3,** eglandular unbranched upright stiff needle-like trichome; **E1,** eglandular multicellular uniseriate trichome with flagelliform apical cell; **E2,** eglandular multicellular uniseriate trichome with tubular apical cell; **F1,** eglandular multicellular biseriate trichome with unbranched tip; **F2,** eglandular multicellular biseriate trichome with branched tip, **G1,** eglandular multicellular multiseriate trichome with unbranched tip; **G2,** eglandular multicellular multiseriate trichome with branched tip. Scale bars = 100 µm.

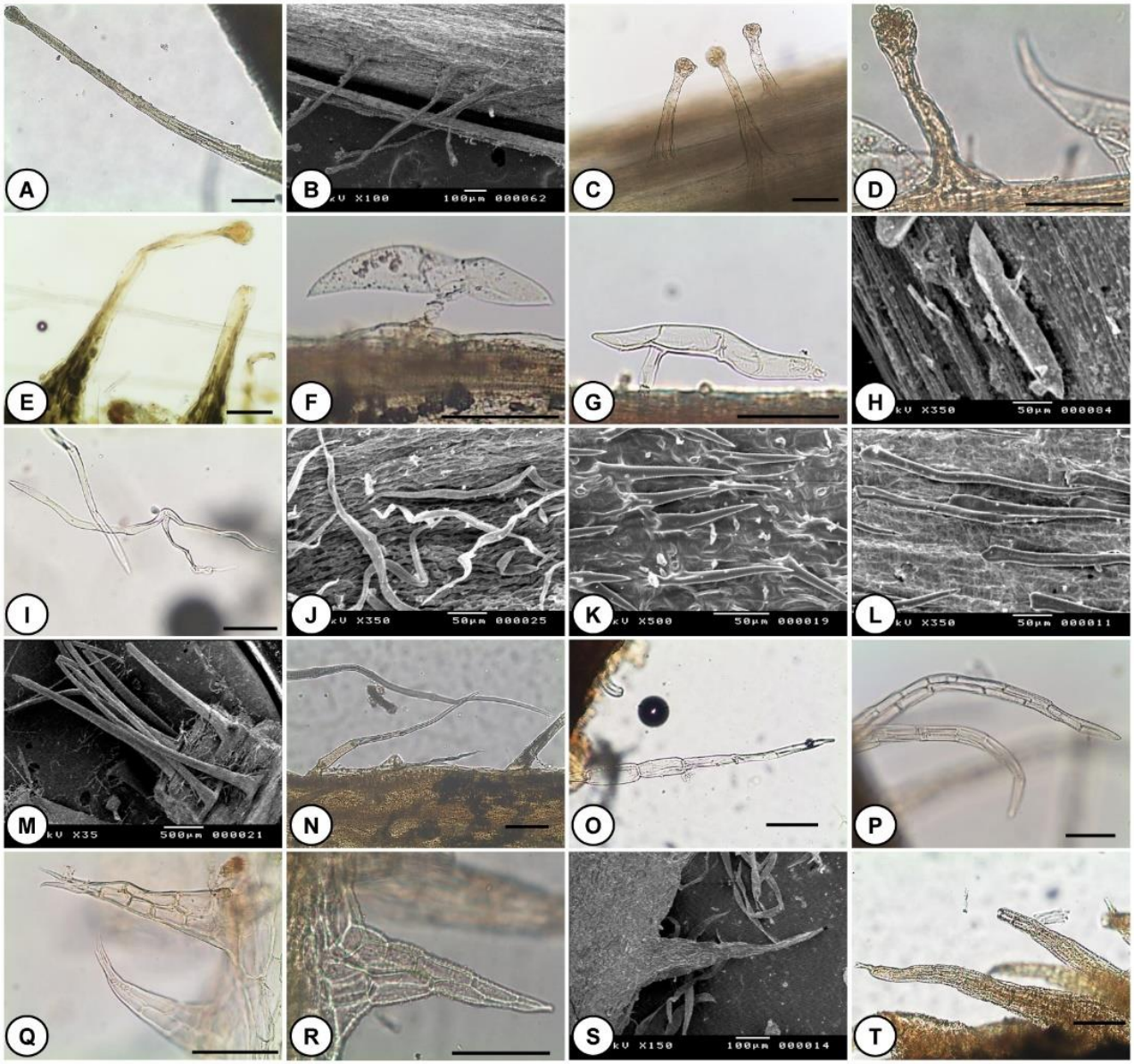

**Figure 6.** Light and scanning electron micrographs of trichomes of *Crepis* taxa: **A, B** glandular biseriate trichome with unicellular clavate head (*C. sancta* subsp. *sancta*); **C,** glandular biseriate trichome with multicellular globular head (*C. sancta* subsp. *obovata*); **D,** glandular biseriate trichome with multicellular doliform head (*C. senecioides*); **E,** glandular multiserate trichome with multicellular doliform head (*C. aculeata*); **F,** eglandular symmetrical branched straight T-shape trichome (*C. nigricans*); **G, H,** eglandular asymmetrical branched straight T-shape trichome (*C. senecioides*); **I, J,** eglandular branched curly T-shape trichome (*C. aspera* var. *aspera*); **K,** unbranched adpressed short conical trichome (*C. senecioides*); **L,** eglandular unbranched adpressed long conical trichome (*C. aculeata*); **M,** eglandular unbranched upright stiff needle-like trichome (*C. aspera* var. *aspera*); **N,** eglandular multicellular uniseriate trichome with flagelliform apical cell (*C. sancta* subsp. *sancta*); **O,** eglandular multicellular uniseriate trichome with tubular apical cell (*C. sancta* subsp. *sancta*); **P,** eglandular multicellular biseriate trichome with unbranched tip (*C. sancta* subsp. *obovata*); **Q,** eglandular multicellular biseriate trichome with branched tip (*C. sancta* subsp. *sancta*), **R, S,** eglandular multicellular multiseriate trichome with unbranched tip (*C. micrantha*); **T,** eglandular multicellular multiseriate trichome with branched tip (*C. micrantha*). **A, C, D, E, F, G, I, N, O, P, Q, R, T** are light micrographs and **B, H, J, K, L, M, S** are scanning electron micrographs. Scale bars = 100 µm except **H, J, K, L** = 50 µm and **M** = 500 µm.

### C- Eglandular unicellular branched trichomes

Trichomes were composed of a short basal cell with a single apical cell branching into two arms at the apex (T-shaped trichomes). Sometimes the stalk of the tricome was composed of more than one cell (1–3). These trichomes were often dense, coating the surface, and forming a fine cobweb-like matrix in all studied taxa. We recognized the following three sub-types:

C1- Short straight T-shape, symmetrical

The trichomes of this sub-type had two short and straight arms, and the two arms were of an equal length (Figures 5, 6F). In a few cases, the two arms were slightly curved. The length of C1 trichomes ranged from 100–220 µm. This sub-type of trichomes was observed in *C. senecioides* and *C. nigricans* (Table 1).

C2- Short straight T-shape, asymmetrical

The trichomes of this sub-type had two short and straight arms, and the two arms were of an unequal length (Figures 5, 6G, H). The length of C2 trichomes ranged from 100–220 µm. This sub-type of trichomes observed in *C. senecioides*, and *C. nigricans* (Table 1).

C3- Long curly T-shape

The trichomes of this sub-type had two long and curved arms and, the two arms were more or less of an equal length (Figures 5, 6I, J). The length of C3 trichomes ranged from 250–450 µm. This sub-type of trichomes was found in *C. micrantha*, *C. libyca*, *C. aspera* var. *aspera*, *C. aspera* var. *inermis*, and *C. aculeata* (Table 1).

**D- Eglandular unicellular unbranched trichomes**

This type had trichomes was composed of a short basal cell and a conical apical cell. This type can be classified into three sub-types:

D1- Adpressed short conical

The trichomes of this sub-type were unicellular with smooth walls and pointed tips, 70–130 µm in length (Figures 5, 6K). This sub-type of trichomes was found in most of the examined taxa (*C. micrantha*, *C. sancta* subsp. *sancta*, *C. senecioides*, *C. nigricans*, *C. aspera* var. *aspera*, and *C. aspera* var. *inermis*) (Table 1).

D2- Adpressed long conical

The trichomes of this sub-type were similar to those of the previous type but with lengths ranging from 250–400 µm (Figures 5, 6L). This sub-type of trichomes was observed in *C. libyca* and *C. aculeata* (Table 1).

D3- Upright stiff needle-like

The trichomes of this sub-type were unicellular upright calcareous setae, needle-like, exceptionally long, with a pointed tip, 1.8–3.5 mm (Figures 5, 6M). This sub-type of trichomes was characteristic of *C. aspera* var. *aspera* (Table 1).

**Table 1.** Trichome diversity in the studied *Crepis* taxa.

| Taxa | Type of trichomes | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | B | C1 | C2 | C3 | D1 | D2 | D3 | E1 | E2 | F1 | F2 | G1 | G2 |
| ***C. micrantha*** | | | | | | | + | + | | | | | | | + | + |
| ***C. sancta* subsp. *sancta*** | + | | | | | + | | + | | | + | + | + | + | + | + |
| ***C. sancta* subsp. *obovata*** | | + | | | | | | | | | | | + | + | + | + |
| ***C. libyca*** | | | + | | | | + | | + | | | | | | + | + |
| ***C. senecioides*** | | | | + | + | + | | + | | | | + | | | + | + |
| ***C. nigricans*** | | | | | + | + | | + | | | | | | | + | + |
| ***C. aspera* var. *aspera*** | | | | + | | | + | + | | + | | | | | + | + |
| ***C. aspera* var. *inermis*** | | | | | | | + | + | | | | | | | + | + |
| ***C. aculeata*** | | | | + | | | + | | + | | | | | | + | + |

The codes are as indicated in the text.

**E- Eglandular multicellular uniseriate trichomes**

This type of trichomes was composed of one row of cells, usually sparse. The apical cell was either flagelliform or tubular.

E1- With flagelliform apical cell

The trichomes of this sub-type were long, uniseriate, with a pointed tip, and with a delicate, much elongated whip-like terminal cell, 0.5–1.6 mm (Figures 5, 6N). This sub-type of trichomes was found exclusively in *C. sancta* subsp. *sancta* (Table 1).

E2- With tubular apical cell

The trichomes of this sub-type were long, uniseriate, with a rounded tip, and a short terminal cell, 0.4–0.7 mm (Figures 5, 6O). This sub-type of trichomes was found in *C. sancta* subsp. *sancta* and *C. senecioides* (Table 1).

**F- Eglandular multicellular biseriate trichomes**

These were stiff trichomes composed of two parallel rows of cells, 210–350 µm long. According to the branching of the apical cells, two sub-types can be recognized:

F1-With unbranched tip.

The trichomes of this sub-type ended with a single pointed apical cell (Figures 5, 6P). This sub-type of trichomes was characteristic of *C. sancta* subsp. *sancta* and *C. sancta* subsp. *obovata* (Table 1).

F2-With branched tip.

The trichomes of this sub-type ended with two pointed apical cells. The two apical tips might be equal or different in length (Figures 5, 6Q). This sub-type of trichomes was also characteristic of *C. sancta* subsp. *sancta* and *C. sancta* subsp. *obovata* (Table 1).

**G- Eglandular multicellular multiseriate trichomes**

These were stiff trichomes composed of multiple rows of cells, gradually tapering above, and noticeably longer than the biseriate trichomes. Two sub-types can be recognized:

G1- with unbranched tip

The trichomes of this sub-type ended with two pointed apical cells (Figures 5, 6R, S). This sub-type of trichomes was observed in all studied taxa (Table 1).

G2- with branched tip

The trichomes of this sub-type ended with two pointed apical cells. The two apical tips might be equal or different in length (Figures 5, 6T). This sub-type of trichomes was also observed in all studied taxa (Table 1).

## Stomata characteristics

The results obtained from the stomatal examinations are summarized in Table 2. Stomata in all the studied taxa were anomocytic (without subsidiary cells) and of the amphistomatic type (present on both the adaxial and abaxial surfaces of the leaf). No substantial differences were recorded between the adaxial and abaxial surfaces of the leaf. They were surrounded by polygonal (especially pentagonal and hexagonal) or irregular-shaped epidermal cells. The polygonal epidermal cells were found in *C. sancta* subsp. *sancta*, *C. nigricans*, and *C. aculeata*, whereas the irregular-shaped epidermal cells were observed in the remaining taxa (Figure 7; Table 2). The anticlinal walls of the epidermal cells were undulate (in *C. micrantha*, *C. senecioides*, *C. aspera* var. *aspera*, and *C. aspera* var. *inermis*), slightly undulate (in *C. nigricans*), or straight (in *C. sancta* subsp. *obovata*, *C. libyca*, *C. sancta* subsp. *sancta*, and *C. aculeata*) (Figure 7; Table 2).

Three stomata dimensional categories were revealed by light microscopy: large (29.31–29.41 × 20.37–21.60 µm), medium (26.88–26.94 × 18.35–18.93 mm), and small (19.69–22.96 × 13.47–15.91 mm). Larger stomata were found in *C. libyca*, *C. aspera* var. *inermis*, and *C. aculeata* (Figure 7), with *C. libyca* exhibiting the largest stomata. Medium-sized stomata were characteristic of *C. micrantha*, *C. sancta* subsp. *sancta* and *C. sancta* subsp. *obovata* (Figure 7). Smaller stomata were observed in *C. senecioides*, *C. nigricans*, and *C. aspera* var. *aspera* (Figure 7). Among these, *C. senecioides* stomata were the smallest.

The stomatal density (per 1 $mm^2$) varied greatly among the nine taxa under investigation (Table 2). Three categories of stomatal density were revealed: high (243.45–264.10), medium (185.03–199.61), and low (with an average of 113.65 per 1 $mm^2$). Higher stomata densities were observed in *C. senecioides* and *C. nigricans* (Figure 7; Table 2), with *C. nigricans* exhibiting the highest stomatal density. Medium stomata densities were found in *C. micrantha*, *C. sancta* subsp. *sancta*, *C. sancta* subsp. *obovata*, *C. aspera* var. *aspera*, *C. aspera* var. *inermis*, and *C. aculeata* (Figure 7; Table 2). Lower stomata densities were characteristic of *C. libyca* (Figure 7; Table 2).

As well, the epidermal cell density (per 1 $mm^2$) varied greatly among the studied taxa (Table 2). We classified the epidermal cell densities into three categories: high (1084.18–1314.75) in *C. senecioides* and *C. nigricans*, medium (748.66–827.88) in *C. micrantha*, *C. aspera* var. *aspera*, and *C. aculeata*, and low (606.98–691.29) in *C. sancta* subsp. *sancta*, *C. sancta* subsp. *obovata*, *C. libyca*, and *C. aspera* var. *inermis* (Figure 7; Table 2). Among these, *C. nigricans* exhibited the highest stomatal density and *C. sancta* subsp. *obovata* showed the lowest density.

The stomatal index showed great variations among the studied taxa, allowing us to divide them into three categories: high (21.08–24.71%), medium (16.26–18.75%), and low (14.37%). Higher stomatal indices were observed in *C. sancta* subsp. *sancta*, *C. sancta* subsp. *obovata*, *C. aspera* var. *aspera*, and *C. aspera* var. *inermis* (Table 2), with *C. sancta* subsp. *obovata* exhibiting the highest density. Medium stomatal indices were found in *C. micrantha*, *C. senecioides*, *C. nigricans*, and *C. aculeata* (Table 2). Lower stomatal indices were characteristic of *C. libyca* (Table 2).

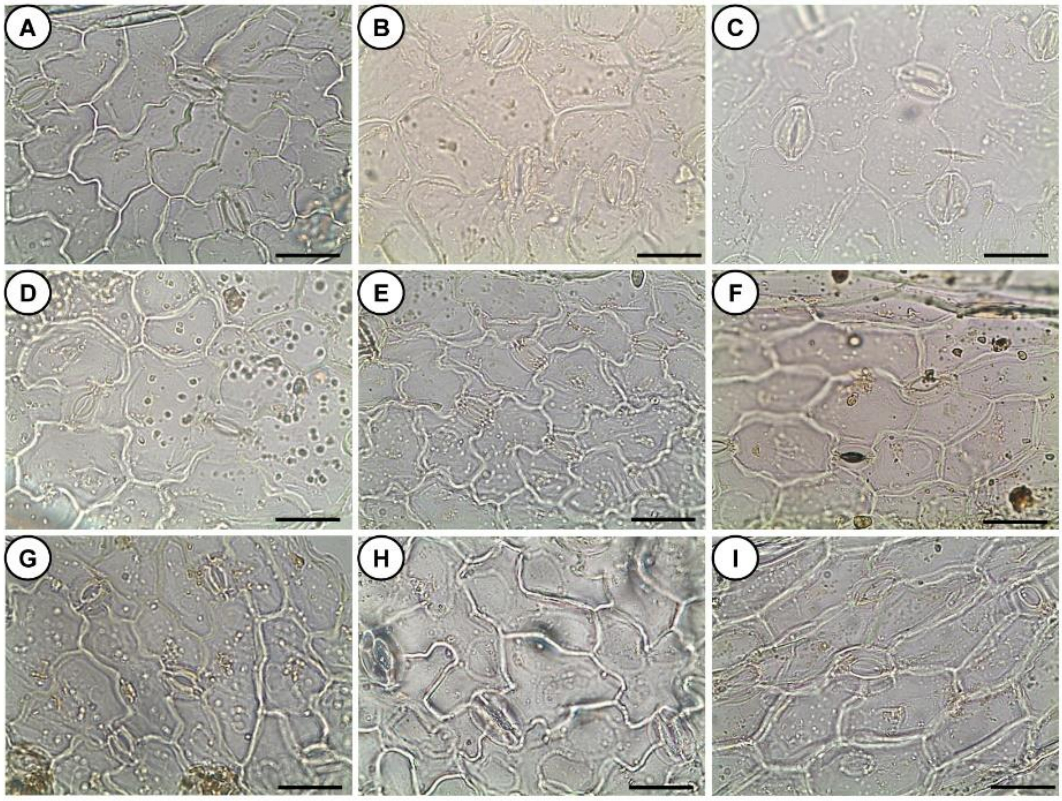


**Figure 7.** Light micrographs of epidermal peels of the abaxial leaf surface of studied *Crepis* taxa. **A**, *C. micrantha*; **B**, *C. sancta* subsp. *sancta*; **C**, *C. sancta* subsp. *obovata*; **D**, *C. libyca*; **E**, *C. senecioides*; **F**, *C. nigricans*; **G**, *C. aspera* var. *aspera*; **H**, *C. aspera* var. *inermis*; **I**, *C. aculeata*. Scale bars = 30 µm.

**Table 2.** Micro-morphological characteristics and measurements of stomata and epidermal cells in the leaves of the studied *Crepis* taxa.

| **Taxa/Character** | Stomata dimensions L × W (µm) | Stomatal density (per 1 $mm^2$) | Epidermal cell density (per 1 $mm^2$) | Stomatal index (%) | Epidermal cell shape | Epidermal cell anticlinal walls |
|---|---|---|---|---|---|---|
| ***C. micrantha*** | 26.94 ± 1.43 × 18.35 ± 2.14 | 185.75 ± 23.88 | 818.68 ± 49.37 | 18.43 ± 1.21 | Irregular | Undulate |
| ***C. sancta* subsp. *sancta*** | 26.94 ± 2.55 × 18.90 ± 1.37 | 185.03 ± 21.56 | 691.29 ± 75.05 | 21.12 ± 1.20 | Polygonal | Straight |
| ***C. sancta* subsp. *obovata*** | 26.88 ± 1.51 × 18.91 ± 1.21 | 198.90 ± 5.24 | 606.98 ± 34.98 | 24.71 ± 0.86 | Irregular | Slightly undulate |
| ***C. libyca*** | 29.41 ± 1.46 × 21.60 ± 1.75 | 113.65 ± 21.23 | 679.58 ± 63.62 | 14.37 ± 2.63 | Irregular | Slightly undulate |
| ***C. senecioides*** | 19.69 ± 1.85 × 13.56 ± 1.42 | 243.45 ± 13.81 | 1253.79 ± 44.47 | 16.26 ± 0.74 | Irregular | Undulate |
| ***C. nigricans*** | 21.99 ± 1.78 × 14.97 ± 1.52 | 264.10 ± 22.75 | 1314.75 ± 104.66 | 16.94 ± 1.39 | Polygonal | Slightly undulate |
| ***C. aspera* var. *aspera*** | 22.96 ± 1.15 × 15.80 ± 1.36 | 199.61 ± 5.09 | 748.66 ± 43.50 | 21.08 ± 1.17 | Irregular | Undulate |
| ***C. aspera* var. *inermis*** | 29.31 ± 1.29 × 20.37 ± 1.33 | 195.09 ± 10.01 | 640.33 ± 47.70 | 23.39 ± 0.82 | Irregular | Undulate |
| ***C. aculeata*** | 29.34 ± 1.82 × 21.07 ± 1.35 | 191.55 ± 24.04 | 827.88 ± 39.43 | 18.75 ± 1.74 | Polygonal | Straight |

**Numerical (Cluster and PCA) analyses**

The results of statistical analyses based on 270 macro- and micro-morphological characteristics are presented in Figures 8, 9. First, from the cumulative data in Table 3 and supplementary Table 1, a matrix of similarity between the studied taxa using a UPGMA dendrogram was illustrated. At a similarity level of 29.2%, five major groups (A, B, C, D, and E) were distinguished, as shown in Figure 8. Group A included only one taxon (*C. libyca*). Group B contained three taxa divided into two sub-groups (separated at a similarity level of 36.2%): a sub-group with *C. aculeata* and a sub-group with *C. aspera* var. *aspera* and *C. aspera* var. *inermis*. Group C comprised two taxa (*C. sancta* subsp. *sancta* and *C. sancta* subsp. *obovata*; separated at a similarity level of 52.4%). Group D contained only one taxon (*C. micrantha*). Group E included two taxa *C. senecioides* and *C. nigricans*. Second, results from PCA analysis (Figure 9) matched and supported those from UPGMA clustering (Figure 9). The scatter plot distinguished the same five groups. The first two principal components in the scatter plot were used and these were responsible for 44.7% of the total observed variation. PCA analysis showed the numerical values corresponding to the macro- and micro-morphological characteristics and provided the most significant attributes explaining the segregation among groups based on the highest factor loadings (shaded; supplementary Table 2).

**Key to *Crepis* taxa using macro- and micro-morphological characteristics**

1- Perennial; inner phyllaries 10, ≥ 12 mm; achenes longer than10 mm ..... *C. libyca*
- Annual; inner phyllaries 8, ≤ 10 mm; achenes shorter than than 8 mm …….....… 2
2- Head length less than 6 mm at fruiting; inner phyllaries shorter than 5 mm ……...…….. *C. micrantha*
- Head length more than 7 mm at fruiting; inner phyllaries longer than 5 mm ….....… 3
3- Inner achenes beakless ……..……..……...… 4
- Inner achenes beaked ……..…..……..… 5
4- Marginal achenes not winged, olive-green; inner achenes shorter than 3 mm; style yellow; phyllaries with glandular biseriate globular headed trichomes ……..……..... *C. sancta* subsp. *obovata*
- Marginal achenes winged, white; inner achenes longer than 3.5 mm; style green; phyllaries with glandular biseriate clavate headed trichomes ……..……..……..…… *C. sancta* subsp. *sancta*
5- Outer phyllaries membranous, inner phyllaries with yellow stiff bristles; outer achenes winged …….…… 6
- Outer phyllaries leathery, inner phyllaries without stiff bristles; outer achenes not winged ……....…….. 7
6- Stem covered with dense stiff bristles, phyllaries glandular-hairy and covered with dense stiff bristles; stomata with small size dimensions (22. 96 × 15.8 µm) and epidermal cells with medium density ……..……..…….. *C. aspera* var. *aspera*
- Stem mostly smooth or covered with sparse stiff bristles, phyllaries smooth; stomata with large size dimensions (29.3 × 20.37 µm) and epidermal cells with low density …..……..…..…..…… *C. aspera* var. *inermis*
7- Outer phyllaries broadly ovate; outer achene beakless; phyllaries with glandular biseriate trichomes with doliform head and long unbranched adpressed conical trichomes ……..……..……..... *C. aculeata*
- Outer phyllaries linear-lanceolate; outer achene beaked; phyllaries with glandular multiseriate trichomes with doliform head and short unbranched adpressed conical trichomes ……...……..… 8
8- Beak of inner achene longer than 4.0 mm; phyllaries and pedicels with eglandular trichomes; leaf epidermal cells polygonal ……..……..…….. *C. nigricans*
- Beak of inner achene shorter than 3.5 mm; phyllaries and pedicels with glandular trichomes; leaf epidermal cells irregular ……..…..……..…..……..……...… *C. senecioides*

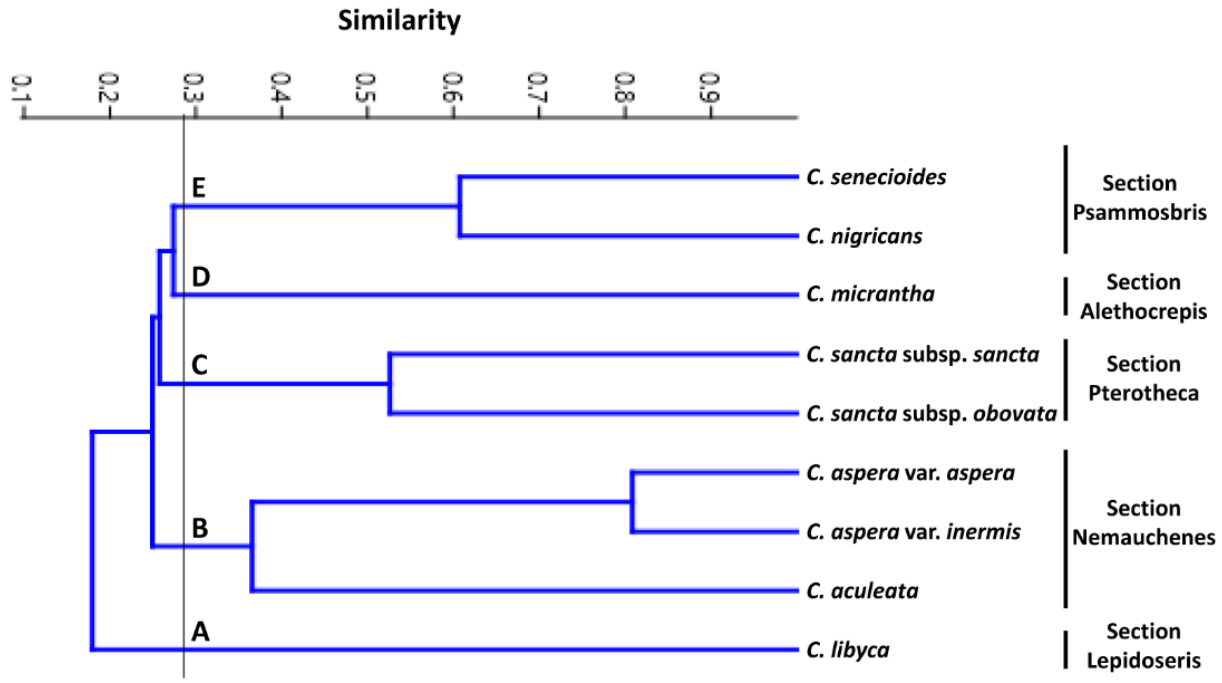


**Figure 8.** UPGMA UPGMA cluster analysis shows the average taxonomic distance among the studied *Crepis* taxa based on 270 macro- and micro-morphological attributes.

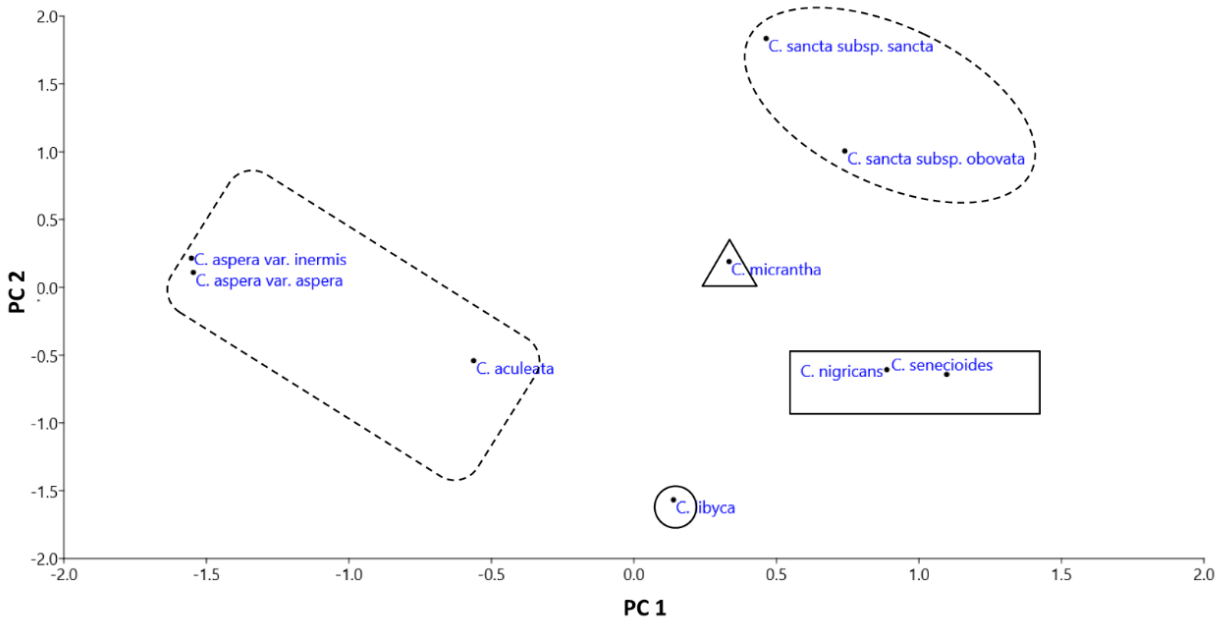


**Figure 9.** Scatter plot of the first two principal components based on 270 macro- and micro-morphological attributes.

**Table 3.** Characters and character states used in the multivariate analyses.

| Character | Character states |
|---|---|
| Habit | 1. Annual<br>2. Perennial |
| Stem texture | 3. Hispidulous-glabrescent<br>4. White crisped to glandular hairy<br>5. Bristly hirsute and glandular hairy<br>6. Dull whitish setulose hispid<br>7. Hispid with stiff yellow bristle<br>8. Pubescent to glabrescent<br>9. Cobwebbed-pubescent to glabrescent |
| Growth pattern | 10. Erect<br>11. Erect-ascending |
| Plant base | 12. Woody<br>13. Herbaceous |
| Plant branching | 14. From base<br>15. From above |
| Plant height (cm) | 16. 3–20<br>17. 20–45<br>18. >50 |
| Branch leafness | 19. Leafy<br>20. Leafless |
| Leaf texture | 21. Pubescent with appressed setulose to hispidulous<br>22. Sparse yellow bristle<br>23. Cobwebbed-pubescent to glabrescent |
| Basal leaf shape | 24. Oblong-lanceolate<br>25. Oblanceolate<br>26. Oblong-spathulate<br>27. Obovate-oblanceolate |
| Basal leaf length (cm) | 28. 1.5-6<br>29. 7–10<br>30. >50 |
| Basal leaf margin | 31. Dentate-lyrate<br>32. Dentate-runcinate<br>33. Dentate-shallowly pinnatifid<br>34. Dentate-deeply pinnatifid |
| Basal leaf lobes | 35. Absent<br>36. Oblong<br>37. Triangle |
| Basal leaf apex | 38. Obtuse<br>39. Acuminate<br>40. Obtuse-acuminate |
| Basal cauline leaf blade | 41. Linear<br>42. Linear-lanceolate<br>43. Oblong-linear<br>44. Oblong-lanceolate<br>45. Absent or reduced to small scales |
| Basal cauline leaf length (cm) | 46. 0.5–1<br>47. 2–2.5<br>48. 3–4<br>49. > 4 |
| Basal cauline leaf margin | 50. Entire-remotely toothed<br>51. Dentate<br>52. Sharply dentate<br>53. Pinnatifid<br>54. Absent |
| Basal cauline leaf apex | 55. Acute<br>56. Acuminate |

| | |
|---|---|
| | 57. Absent |
| Basal cauline leaf auricle | 58. Entire<br>59. Dentate<br>60. Absent |
| Upper cauline leaf | 61. Phyllaries-like (linear)<br>62. Absent |
| Head shape | 63. Campanulate<br>64. Cylindrical |
| Peduncle length (cm) | 65. Reached to 3<br>66. Reached to 6<br>67. Reached to 10 |
| Number of heads in synflorescence | 68. Solitary<br>69. 2–3 |
| Peduncle texture | 70. Slightly tomentose to glabrous<br>71. Densely glandular hairy to pubescent<br>72. Sparsely glandular hairy and pubescent<br>73. Densely stiff needle-like<br>74. Pubescent to sparsely hispidulous<br>75. Glabrous |
| Head length at anthesis (mm) | 76. 3.5–4<br>77. 5–7<br>78. > 8 |
| Head length at fruiting (mm) | 79. 6-6.5<br>80. 7–10<br>81. > 12 |
| Head width at anthesis (mm) | 82. 2–3<br>83. 3–5<br>84. 5–7<br>85. > 9 |
| Head width at fruiting (mm) | 86. 2–3.5<br>87. 4–5<br>88. 5–7 |
| Outer phyllaries length (mm) | 89. 2–3<br>90. 4–4.5<br>91. > 5 |
| Outer phyllaries width (mm) | 92. 0.3–0.5<br>93. 1–1.5<br>94. > 3 |
| Outer phyllaries shape | 95. Ovate<br>96. Broadly ovate<br>97. Linear<br>98. Ovate-lanceolate |
| Outer phyllaries texture | 99. Tomentose<br>100. Sparse short setulose with glandular trichomes<br>101. Dense short setulose with glandular trichomes<br>102. Dense long setulose<br>103. Glabrous |
| Outer phyllaries apex shape | 104. Acute<br>105. Acuminate |
| Outer phyllaries scarious margin | 106. Narrow<br>107. Wide<br>108. Non scarious |
| Inner phyllaries shape | 109. Linear-lanceolate<br>110. Ovate-lanceolate |
| Inner phyllaries length (mm) | 111. 4.5–5<br>112. 6–9<br>113. > 10 |
| Inner phyllaries width (mm) | 114. 1.5–2<br>115. 2.5–3 |

| | |
|---|---|
| | 116. > 3 |
| Inner phyllaries texture | 117. Long setulose<br>118. Sparse short setulose with glandular trichomes<br>119. Dense short setulose with glandular trichomes<br>120. Upright stiff needle-like trichomes<br>121. Glabrous with tubers |
| Inner phyllaries apex shape | 122. Subacute<br>123. Obtuse |
| Inner phyllaries scarious margin | 124. Narrow<br>125. Wide |
| Flower color | 126. Yellow to pale yellow<br>127. Reddish on outer surface and yellow on inner surface<br>128. Yellowish, reddish to purple on outer face<br>129. Yellow-orange |
| Length of flower (mm) | 130. 5–6<br>131. 6–9<br>132. > 10 |
| Width of flower (mm) | 133. 1–1.5<br>134. 1.6–2<br>135. > 2 |
| Corolla tube length (mm) | 136. 1.5–2.2<br>137. 2.5–3<br>138. > 3 |
| Indumentum of corolla tube | 139. Glabrous<br>140. Gochidiate<br>141. Pubescent |
| Style color | 142. Yellow<br>143. Greenish-blackish |
| Style branch length (mm) | 144. 0.5–0.6<br>145. 1–2<br>146. > 2 |
| Style branch texture | 147. Glabrous<br>148. Hairy |
| Achene morphism | 149. Homomorphic<br>150. Sub-homomorphic<br>151. Heteromorphic |
| Outer achene length (mm) | 152. 2–2.5<br>153. 3–3.5<br>154. 4–5<br>155. > 5 |
| Outer achene width (mm) | 156. 0.2–0.4<br>157. 0.4–0.6<br>158. > 1 |
| Outer achene color | 159. White<br>160. Olive-green<br>161. Brown<br>162. Grey<br>163. Whitish to pale yellow |
| Outer achene shape | 164. Straight-oblong<br>165. Laterally compressed cylindrical<br>166. Cylindrical<br>167. Fusiform |
| Outer achene rib appearance | 168. Distinct<br>169. Un-distinct |
| Outer achene wing occurrence | 170. Winged<br>171. Un-winged |
| Outer achene beak | 172. Beaked<br>173. Beakless |
| Outer achene apex | 174. Truncate |

| | |
|---|---|
| | 175. Attenuate<br>176. Stout beaked<br>177. Filiform beaked |
| Outer achene peak length (mm) | 178. 2–2.3<br>179. 2.5–3<br>180. > 4<br>181. Absent |
| Outer achene sculpture | 182. Glabrous<br>183. Scabridulous<br>184. Muricate-antrorsely spinulose on the ribs<br>185. Pubescent |
| Outer achene pappus occurrence | 186. Pappose<br>187. Epappose |
| Outer achene pappus persistence | 188. Persistent<br>189. Deciduous<br>190. Absent |
| Outer achene pappus type | 191. Short irregular<br>192. Long regular<br>193. Absent |
| Outer achene pappus length (mm) | 194. 1.5–3<br>195. 3.5–4<br>196. > 4<br>197. Absent |
| Inner achene length (mm) | 198. 2–2.5<br>199. 3–3.5<br>200. 4–5<br>201. > 5 |
| Inner achene width (mm) | 202. 0.1–0.3<br>203. > 0.3<br>204. Absent |
| Inner achene color | 205. Yellow<br>206. Light Brown<br>207. Dark brown<br>208. Absent |
| Inner achene shape | 209. Oblong<br>210. Straight cylindrical<br>211. Fusiform<br>212. Absent |
| Inner achene apex | 213. Truncate<br>214. Attenuate<br>215. Filiform peaked<br>216. Absent |
| Inner achene wings | 217. Winged<br>218. Un–winged |
| Inner achene peak length (mm) | 219. 1.5–2<br>220. 2.5–3<br>221. > 3.5<br>222. Absent |
| Inner achene sculpture | 223. Scabridulous<br>224. Finely muricate<br>225. Muricate-antrorsely spinulose on the ribs<br>226. Absent |
| Inner achene pappus occurrence | 227. Pappose<br>228. Absent |
| Inner achene pappus persistence | 229. Deciduous<br>230. Absent |
| Inner achene pappus type | 231. Short irregular<br>232. Long regular |

| | |
|---|---|
| | 233. Absent |
| Inner achene pappus length (mm) | 234. 1–3<br>235. 3–5<br>236. > 5<br>237. Absent |
| Glandular trichomes | 238. Biseriate with unicellular clavate head<br>239. Biseriate with multicellular globular head<br>240. Biseriate with multicellular doliform head<br>241. Multiserate with multicellular doliform head |
| Eglandular unicellular trichomes | 242. Branched straight T-shape, symmetrical<br>243. Branched straight T-shape, asymmetrical<br>244. Branched curly T-shape<br>245. Unbranched adpressed short conical<br>246. Unbranched adpressed long conical<br>247. Unbranched upright stiff needle-like |
| Eglandular multicellular trichomes | 248. Uniseriate with flagelliform apical cell<br>249. Uniseriate with tubular apical cell<br>250. Biseriate with unbranched tip<br>251. Biseriate with branched tip<br>252. Multiseriate with unbranched tip<br>253. Multiseriate with branched tip |
| Stomata dimensions | 254. Large stomata<br>255. Medium-sized stomata<br>256. Small stomata |
| Stomatal density | 257. High stomatal density<br>258. Medium stomatal density<br>259. Low stomatal density |
| Epidermal cell density | 260. High epidermal cell density<br>261. Medium epidermal cell density<br>262. Low epidermal cell density |
| Stomatal index | 263. High stomatal index<br>264. Medium stomatal index<br>265. Low stomatal index |
| Epidermal cell shape | 266. Irregular<br>267. Polygonal |
| Epidermal cell anticlinal wall | 268. Undulate<br>269. Slightly undulate<br>270. Straight |

## 4. Discussion

The current study revealed that the genus *Crepis* in Egypt is represented by seven species, two subspecies, and two varieties. *C. aspera* is a polymorphic species adapted to diverse habitats in the East Mediterranean region, thus, several varieties of this species have been described [11, 38]. Although [25] considered all the Egyptian materials belonging to *C. aspera* var. *aspera*, the herbarium materials examined in this study revealed the existence of another variety in Egypt (*C. aspera* var. *inermis*) as a new record for the flora of Egypt. Plants of *C. aspera* var. *inermis* were missing the bristles on the phyllaries and leaves, and only a few bristles were distributed sparsely on the stem. In contrast, plants of *C. aspera* var. *aspera* were densely covered with stiff, yellow bristles throughout. In addition, leaves of var. *aspera* had stomata with small dimensions (22.96 × 15.8 µm) and medium epidermal cell density. On the contrary, leaves of var. *inermis* had stomata with large dimensions (29.3 × 20.37 µm) and low epidermal cell density.

In the current study, the taxonomic and phylogenetic implications of cluster and PCA analyses were compared with previous and current sectional classifications of the taxa under investigation. The molecular phylogeny of *Crepis* based on *ITS* and *matK* sequences indicated that it is a polyphyletic group composed of two main clades: the *Crepis* clade (*Crepis* s.str.) and the *Lagoseris* clade [8, 9]. The classification produced by our multivariate analyses based on macro- and micro-morphological features agreed largely with current taxonomic treatments of the taxa. The cluster and PCA analyses placed *C. libyca* solely in a distinct group (A). *C. libyca* is easily distinguished from the remaining Egyptian *Crepis* taxa by its perennial habitat, large heads

(10–17 mm in length), large achenes (10–13 mm in length), and homomorphic type of achenes. In addition, *C. libyca* is characterized by the presence of the glandular biseriate trichomes with a multicellular doliform head and a low stomata density (Tables 1, 2).

Our cluster and PCA analyses revealed that the two *Crepis* taxa, *C. aculeata* and *C. aspera* were clustered together in group B. Babcock [11] placed both species in section *Nemauchenes*. Inside group B, the two varieties of *C. aspera* were separated into a distinct sub-group from *C. aculeata*. They differed from *C. aculeata* by having unicellular eglandular branched and curly T-shape trichomes, pubescent outer achenes surface, deciduous outer achene pappus, laterally compressed cylindrical outer achenes, undulate epidermal anticlinal wall, polygonal epideraml cells, and high stomatal index (Tables 1, 2).

The third group (C) includes *C. sancta* subsp. *sancta*, and *C. sancta* subsp. *obovata* (section Pterotheca). Boulos [25] noted that Egyptian materials might refer to *C. sancta* subsp. *sancta* without describing their diagnostic characters. According to Feinbrun-Dothan [38] and Davis [39], the two subspecies of *Crepis sancta* (subsp. *sancta* and subsp. *obovata*) were evident in the Egyptian flora. Our examinations have confirmed the presence of these two subspecies. Täckholm [24, 27] recorded *Lagoseris sancta* subsp. *obovata*, which is characterized by two features: 1) marginal achenes were white and winged in *subsp. sancta* and yellow to olive, unwinged in subsp. *obovata*, 2) the color of style branches was green in subsp. *sancta* vs. yellow in subsp. *obovata* (Figure 3). In addition, she referred to the rare distribution of subsp. *obovata* in the flora of Egypt. Boulos [25] described *C. sancta* neglecting to refer to the diagnostic characters of achenes. Based on our observations, the two subspecies (subsp. *sancta* and subsp. *obovata*) are represented in the Egyptian flora.

The fourth group includes only one taxon (*C. micrantha*). Recently, the molecular studies of [8] placed *C. micrantha* in clade II among *Crepis* s. str by having polymorphic characters, annularity, the wide distribution, and some gross morphological congruencies. *C. micrantha* is easily distinguished from all the other Egyptian *Crepis* taxa by having ovate-lanceolate outer bracts with a tomentose surface and scarious margins, small inner bracts, a small achene size with an oblong shape and beakless marginal and inner achenes (Figures 2, 4).

Our cluster and PCA results placed *C. senecioides* and *C. nigricans* in one group (group E) in agreement with the sectional classification (section Psammosbris) proposed by [11]. They shared many characteristics, including the non-scarious short outer phyllaries with linear shape, the cylindrical shape of outer achenes with stout beaks, the high stomatal and epidermal cell density, and the presence of eglandular branched straight T-shape trichomes.

In this study, we showed that the genus *Crepis* is represented in Egypt by seven species and four infra-specific taxa. We reported *C. aspera* var. *inermis* (Cass.) Boiss. as a new record for the flora of Egypt. Our results confirmed the importance of *Crepis* macro- and micro-morphological characteristics of the capitula, phyllaries, achenes, trichomes, and stomata which provided valuable insights into the taxonomy and delimitation of closely related taxa within the genus. The vast diversity of the macro- and micro-morphological characteristics allowed us to design an artificial key to differentiate the taxa under investigation.

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**Supplementary Table 1.** Data matrix used for the UPGMA and PCA analyses based on 270 macro- and micro-morphological attributes. Characters and character codes are as listed in Table 3 and supplementary Table 2.

| Taxa/Character code | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| ***C. sancta* subsp. *obovata*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| ***C. libyca*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| ***C. senecioides*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| ***C. nigricans*** | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ***C. aspera* var. *aspera*** | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| ***C. aculeata*** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

| Taxa/Character code | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. sancta* subsp. *sancta*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***C. libyca*** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| ***C. senecioides*** | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| ***C. nigricans*** | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| ***C. aculeata*** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |

| Taxa/Character code | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| ***C. sancta* subsp. *obovata*** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| ***C. libyca*** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. senecioides*** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. nigricans*** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. aspera* var. *inermis*** | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. aculeata*** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |

| Taxa/Character code | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. sancta* subsp. *obovata*** | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| ***C. libyca*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| ***C. senecioides*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. nigricans*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. aspera* var. *inermis*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. aculeata*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |

| Taxa/Character code | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. libyca*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. senecioides*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. nigricans*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. aspera* var. *aspera*** | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. aculeata*** | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |

| Taxa/Character code | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| ***C. libyca*** | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. senecioides*** | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| ***C. nigricans*** | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| ***C. aspera* var. *aspera*** | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| ***C. aculeata*** | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |

| Taxa/Character code | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. libyca*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. senecioides*** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. nigricans*** | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| ***C. aspera* var. *aspera*** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| ***C. aculeata*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

| Taxa/Character code | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| ***C. sancta* subsp. *sancta*** | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| ***C. libyca*** | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| ***C. senecioides*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| ***C. nigricans*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *aspera*** | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| ***C. aspera* var. *inermis*** | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| ***C. aculeata*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

| Taxa/Character code | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| ***C. libyca*** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***C. senecioides*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ***C. nigricans*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| ***C. aculeata*** | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| Taxa/Character code | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| ***C. sancta* subsp. *sancta*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***C. sancta* subsp. *obovata*** | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***C. libyca*** | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| ***C. senecioides*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. nigricans*** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *aspera*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| ***C. aculeata*** | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |

| Taxa/Character code | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***C. sancta* subsp. *obovata*** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| ***C. libyca*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| ***C. senecioides*** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ***C. nigricans*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ***C. aspera* var. *aspera*** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| ***C. aspera* var. *inermis*** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| ***C. aculeata*** | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

| Taxa/Character code | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ***C. sancta* subsp. *sancta*** | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| ***C. sancta* subsp. *obovata*** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| ***C. libyca*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ***C. senecioides*** | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| ***C. nigricans*** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| ***C. aspera* var. *inermis*** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| ***C. aculeata*** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

| Taxa/Character code | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***C. micrantha*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. sancta* subsp. *sancta*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| ***C. sancta* subsp. *obovata*** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| ***C. libyca*** | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| ***C. senecioides*** | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. nigricans*** | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| ***C. aspera* var. *aspera*** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. aspera* var. *inermis*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| ***C. aculeata*** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

**Supplementary Table 2.** Correlation between macro– and micro–morphological attributes used in the study and the first two principal components. Attributes with high factor loading > 0.11 are shaded. The first two principal components are responsible for 44.7 % of total variability.

| Character | Character states | PC1 | PC2 |
|---|---|---|---|
| Habit | 1. Annual | -0.00507 | 0.06034 |
| | 2. Perennial | 0.005071 | -0.06034 |
| Stem texture | 3. Hispidulous–glabrescent | 0.012211 | 0.007343 |
| | 4. White crisped to glandular hairy | 0.04403 | 0.10937 |
| | 5. Bristly hirsute and glandular hairy | 0.045215 | -0.08505 |
| | 6. Dull whitish setulose hispid | 0.032449 | -0.02335 |
| | 7. Hispid with Stiff yellow bristle | -0.05654 | 0.004233 |
| | 8. Pubescent to glabrescent | -0.05679 | 0.008266 |
| | 9. Cobwebbed-pubescent to glabrescent | -0.02057 | -0.02081 |
| Growth pattern | 10. Erect | 0.005071 | -0.06034 |
| | 11. Erect-ascending | -0.00507 | 0.06034 |
| Plant base | 12. Woody | 0.005071 | -0.06034 |
| | 13. Herbaceous | -0.00507 | 0.06034 |
| Plant branching | 14. From base | 0.10826 | 0.04784 |
| | 15. From above | -0.10826 | -0.04784 |
| Plant height (cm) | 16. 3–20 | 0.11662 | 0.06131 |
| | 17. 20–45 | -0.1339 | -0.00831 |
| | 18. >50 | 0.017282 | -0.053 |
| Branch leafness | 19. Leafy | -0.08417 | -0.08466 |
| | 20. Leafless | 0.084174 | 0.084662 |
| Leaf texture | 21. Pubescent with appressed setulose to hispidulous | 0.1339 | 0.008313 |
| | 22. Sparse yellow bristle | -0.05654 | 0.004233 |
| | 23. Cobwebbed–pubescent to glabrescent | -0.07736 | -0.01255 |
| Basal leaf shape | 24. Oblong–lanceolate | 0.077664 | -0.1084 |
| | 25. Oblanceolate | 0.05624 | 0.11672 |

| | | | |
|---|---|---|---|
| | 26. Oblong–spathulate | -0.11333 | 0.012499 |
| | 27. Obovate–oblanceolate | -0.02057 | -0.02081 |
| Basal leaf length (cm) | 28. 1.5-6 | -0.08988 | 0.10106 |
| | 29. 7–10 | 0.084804 | -0.04072 |
| | 30. >50 | 0.005071 | -0.06034 |
| Basal leaf margin | 31. Dentate-lyrate | 0.035668 | 0.095905 |
| | 32. Dentate-runcinate | 0.005071 | -0.06034 |
| | 33. Dentate–shallowly pinnatifid | -0.07319 | -0.01221 |
| | 34. Dentate-deeply pinnatifid | 0.032449 | -0.02335 |
| Basal leaf lobes | 35. Absent | 0.12883 | 0.068653 |
| | 36. Oblong | -0.1339 | -0.00831 |
| | 37. Triangle | 0.005071 | -0.06034 |
| Basal leaf apex | 38. Obtuse | 0.05624 | 0.11672 |
| | 39. Acuminate | -0.10826 | -0.04784 |
| | 40. Obtuse–acuminate | 0.052021 | -0.06888 |
| Basal cauline leaf blade | 41. Linear | 0.040144 | -0.02471 |
| | 42. Linear–lanceolate | -0.06867 | -0.00351 |
| | 43. Oblong–linear | -0.02057 | -0.02081 |
| | 44. Oblong–lanceolate | 0.005071 | -0.06034 |
| | 45. Absent or reduced to small scales | 0.04403 | 0.10937 |
| Basal cauline leaf length (cm) | 46. 0.5–1 | 0.04403 | 0.10937 |
| | 47. 2–2.5 | 0.072593 | -0.04806 |
| | 48. 3–4 | -0.11333 | 0.012499 |
| | 49. > 4 | -0.00329 | -0.07381 |
| Basal cauline leaf margin | 50. Entire–remotely toothed | 0.012211 | 0.007343 |
| | 51. Dentate | 0.072593 | -0.04806 |
| | 52. Sharply dentate | -0.10826 | -0.04784 |
| | 53. Pinnatifid | -0.02057 | -0.02081 |
| | 54. Absent | 0.04403 | 0.10937 |
| Basal cauline leaf apex | 55. Acute | -0.02346 | -0.08856 |
| | 56. Acuminate | -0.02057 | -0.02081 |
| | 57. Absent | 0.04403 | 0.10937 |
| Basal cauline leaf auricle | 58. Entire | -0.12169 | -0.00097 |
| | 59. Dentate | 0.005071 | -0.06034 |
| | 60. Absent | 0.11662 | 0.06131 |
| Upper cauline leaf | 61. Phyllaries–like (linear) | -0.11662 | -0.06131 |
| | 62. Absent | 0.11662 | 0.06131 |
| Head shape | 63. Campanulate | -0.07259 | 0.048064 |
| | 64. Cylindrical | 0.072593 | -0.04806 |
| Peduncle length (cm) | 65. Reached to 3 | -0.10112 | 0.019842 |
| | 66. Reached to 6 | 0.057092 | -0.12922 |
| | 67. Reached to 10 | 0.04403 | 0.10937 |
| Number of heads in synflorescence | 68. Solitary | 0.012211 | 0.007343 |
| | 69. 2–3 | -0.01221 | -0.00734 |

| | | | |
|---|---|---|---|
| Peduncle texture | 70. Slightly tomentose to glabrous | 0.012211 | 0.007343 |
| | 71. Densely glandular hairy to pubescent | 0.049101 | 0.049035 |
| | 72. Sparsely glandular hairy and pubescent | 0.040144 | -0.02471 |
| | 73. Densely stiff needle–like | -0.05654 | 0.004233 |
| | 74. Pubescent to sparsely hispidulous | 0.032449 | -0.02335 |
| | 75. Glabrous | -0.07736 | -0.01255 |
| Head length at anthesis (mm) | 76. 3.5–4 | 0.05624 | 0.11672 |
| | 77. 5–7 | 0.040144 | -0.02471 |
| | 78. > 8 | -0.09638 | -0.092 |
| Head length at fruiting (mm) | 79. 6-6.5 | 0.012211 | 0.007343 |
| | 80. 7–10 | -0.01728 | 0.052997 |
| | 81. > 12 | 0.005071 | -0.06034 |
| Head width at anthesis (mm) | 82. 2–3 | 0.084804 | -0.04072 |
| | 83. 3–5 | -0.0693 | 0.12187 |
| | 84. 5–7 | -0.02057 | -0.02081 |
| | 85. > 9 | 0.005071 | -0.06034 |
| Head width at fruiting (mm) | 86. 2–3.5 | 0.040144 | -0.02471 |
| | 87. 4–5 | -0.07227 | 0.046348 |
| | 88. 5–7 | 0.032126 | -0.02164 |
| Outer phyllaries length (mm) | 89. 2–3 | -0.01155 | 0.042448 |
| | 90. 4–4.5 | -0.02057 | -0.02081 |
| | 91. > 5 | 0.032126 | -0.02164 |
| Outer phyllaries width (mm) | 92. 0.3–0.5 | 0.072593 | -0.04806 |
| | 93. 1–1.5 | 0.029185 | 0.078013 |
| | 94. > 3 | -0.10178 | -0.02995 |
| Outer phyllaries shape | 95. Ovate | -0.09636 | 0.083169 |
| | 96. Broadly ovate | 0.011554 | -0.04245 |
| | 97. Linear | 0.072593 | -0.04806 |
| | 98. Ovate-lanceolate | 0.012211 | 0.007343 |
| Outer phyllaries texture | 99. Tomentose | 0.012211 | 0.007343 |
| | 100. Sparse short setulose with glandular trichomes | 0.057119 | 0.045957 |
| | 101. Dense short setulose with glandular trichomes | 0.011554 | -0.04245 |
| | 102. Dense long setulose | 0.032449 | -0.02335 |
| | 103. Glabrous | -0.11333 | 0.012499 |
| Outer phyllaries apex shape | 104. Acute | 0.084804 | -0.04072 |
| | 105. Acuminate | -0.0848 | 0.040722 |
| Outer phyllaries scarious margin | 106. Narrow | 0.012211 | 0.007343 |
| | 107. Wide | -0.0848 | 0.040722 |
| | 108. Non scarious | 0.072593 | -0.04806 |
| Inner phyllaries shape | 109. Linear–lanceolate | -0.00055 | 0.12498 |
| | 110. Ovate–lanceolate | 0.000549 | -0.12498 |
| Inner phyllaries length (mm) | 111. 4.5–5 | 0.012211 | 0.007343 |
| | 112. 6–9 | -0.06391 | 0.059818 |
| | 113. > 10 | 0.051698 | -0.06716 |

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| Inner phyllaries width (mm) | 114. 1.5–2 | 0.069329 | 0.053299 |
| | 115. 2.5–3 | -0.0744 | 0.00704 |
| | 116. > 3 | 0.005071 | -0.06034 |
| Inner phyllaries texture | 117. Long setulose | 0.04466 | -0.01601 |
| | 118. Sparse short setulose with glandular trichomes | 0.016975 | 0.07067 |
| | 119. Dense short setulose with glandular trichomes | 0.051698 | -0.06716 |
| | 120. Upright stiff needle-like trichomes | -0.05654 | 0.004233 |
| | 121. Glabrous with tubers | -0.05679 | 0.008266 |
| Inner phyllaries apex shape | 122. Subacute | -0.04522 | 0.085053 |
| | 123. Obtuse | 0.045215 | -0.08505 |
| Inner phyllaries scarious margin | 124. Narrow | -0.0517 | 0.067161 |
| | 125. Wide | 0.051698 | -0.06716 |
| Flower color | 126. Yellow to pale yellow | 0.05624 | 0.11672 |
| | 127. Reddish on outer surface and yellow on inner surface | 0.040144 | -0.02471 |
| | 128. Yellowish, reddish to purple on outer face | -0.08088 | -0.01085 |
| | 129. Yellow-orange | -0.0155 | -0.08115 |
| Length of flower (mm) | 130. 5–6 | 0.012211 | 0.007343 |
| | 131. 6–9 | 0.11662 | 0.06131 |
| | 132. > 10 | -0.12883 | -0.06865 |
| Width of flower (mm) | 133. 1–1.5 | 0.12883 | 0.068653 |
| | 134. 1.6–2 | -0.11333 | 0.012499 |
| | 135. > 2 | -0.0155 | -0.08115 |
| Corolla tube length (mm) | 136. 1.5–2.2 | 0.12883 | 0.068653 |
| | 137. 2.5–3 | -0.11333 | 0.012499 |
| | 138. > 3 | -0.0155 | -0.08115 |
| Indumentum of corolla tube | 139. Glabrous | 0.016975 | 0.07067 |
| | 140. Gochidiate | 0.096357 | -0.08317 |
| | 141. Pubescent | -0.11333 | 0.012499 |
| Style color | 142. Yellow | -0.01698 | -0.07067 |
| | 143. Greenish–blackish | 0.016975 | 0.07067 |
| Style branch length (mm) | 144. 0.5–0.6 | 0.012211 | 0.007343 |
| | 145. 1–2 | 0.008362 | 0.01347 |
| | 146. > 2 | -0.02057 | -0.02081 |
| Style branch texture | 147. Glabrous | 0 | 0 |
| | 148. Hairy | 0 | 0 |
| Achene morphism | 149. Homomorphic | 0.005071 | -0.06034 |
| | 150. Sub–homomorphic | 0.012211 | 0.007343 |
| | 151. Heteromorphic | -0.01728 | 0.052997 |
| Outer achene length (mm) | 152. 2–2.5 | 0.012211 | 0.007343 |
| | 153. 3–3.5 | 0.04403 | 0.10937 |
| | 154. 4–5 | -0.07319 | -0.01221 |
| | 155. > 5 | 0.016948 | -0.1045 |
| | 156. 0.2–0.4 | 0.096357 | -0.08317 |

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| Outer achene width (mm) | 157. 0.4–0.6 | 0.016975 | 0.07067 |
| | 158. > 1 | -0.11333 | 0.012499 |
| Outer achene color | 159. White | 0.016975 | 0.07067 |
| | 160. Olive–green | 0.027055 | 0.038705 |
| | 161. Brown | 0.017282 | -0.053 |
| | 162. Grey | -0.04074 | -0.03557 |
| | 163. Whitish to pale yellow | -0.02057 | -0.02081 |
| Outer achene shape | 164. Straight–oblong | 0.012211 | 0.007343 |
| | 165. Laterally compressed cylindrical | -0.09636 | 0.083169 |
| | 166. Cylindrical | 0.079075 | -0.03017 |
| | 167. Fusiform | 0.005071 | -0.06034 |
| Outer achene rib appearance | 168. Distinct | 0.096357 | -0.08317 |
| | 169. Un–distinct | -0.09636 | 0.083169 |
| Outer achene wing occurrence | 170. Winged | -0.09636 | 0.083169 |
| | 171. Un–winged | 0.096357 | -0.08317 |
| Outer achene beak | 172. Beaked | 0.077664 | -0.1084 |
| | 173. Beakless | -0.07766 | 0.1084 |
| Outer achene apex | 174. Truncate | 0.012211 | 0.007343 |
| | 175. Attenuate | -0.08988 | 0.10106 |
| | 176. Stout beaked | 0.072593 | -0.04806 |
| | 177. Filiform beaked | 0.005071 | -0.06034 |
| Outer achene peak length (mm) | 178. 2–2.3 | 0.040144 | -0.02471 |
| | 179. 2.5–3 | 0.032449 | -0.02335 |
| | 180. > 4 | 0.005071 | -0.06034 |
| | 181. Absent | -0.07766 | 0.1084 |
| Outer achene sculpture | 182. Glabrous | 0.016975 | 0.07067 |
| | 183. Scabridulous | -0.00836 | -0.01347 |
| | 184. Muricate–antrorsely spinulose on the ribs | 0.10472 | -0.0697 |
| | 185. Pubescent | -0.11333 | 0.012499 |
| Outer achene pappus occurrence | 186. Pappose | -0.01698 | -0.07067 |
| | 187. Epappose | 0.016975 | 0.07067 |
| Outer achene pappus persistence | 188. Persistent | -0.0155 | -0.08115 |
| | 189. Deciduous | -0.00147 | 0.010483 |
| | 190. Absent | 0.016975 | 0.07067 |
| Outer achene pappus type | 191. Short irregular | -0.1339 | -0.00831 |
| | 192. Long regular | 0.11693 | -0.06236 |
| | 193. Absent | 0.016975 | 0.07067 |
| Outer achene pappus length (mm) | 194. 1.5–3 | 0.11186 | -0.00202 |
| | 195. 3.5–4 | -0.1339 | -0.00831 |
| | 196. > 4 | 0.005071 | -0.06034 |
| | 197. Absent | 0.016975 | 0.07067 |
| Inner achene length (mm) | 198. 2–2.5 | 0.012211 | 0.007343 |
| | 199. 3–3.5 | 0.04403 | 0.10937 |
| | 200. 4–5 | -0.07319 | -0.01221 |

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| | 201. > 5 | 0.016948 | -0.1045 |
| Inner achene width (mm) | 202. 0.1–0.3 | 0.04403 | 0.10937 |
| | 203. > 0.3 | -0.04403 | -0.10937 |
| | 204. Absent | 0.005071 | -0.06034 |
| Inner achene color | 205. Yellow | -0.02973 | 0.046971 |
| | 206. Light Brown | 0.012211 | 0.007343 |
| | 207. Dark brown | 0.012453 | 0.006026 |
| | 208. Absent | 0.005071 | -0.06034 |
| Inner achene shape | 209. Oblong | 0.012211 | 0.007343 |
| | 210. Straight cylindrical | 0.04403 | 0.10937 |
| | 211. Fusiform | -0.06131 | -0.05638 |
| | 212. Absent | 0.005071 | -0.06034 |
| Inner achene apex | 213. Truncate | 0.012211 | 0.007343 |
| | 214. Attenuate | 0.04403 | 0.10937 |
| | 215. Filiform peaked | -0.06131 | -0.05638 |
| | 216. Absent | 0.005071 | -0.06034 |
| Inner achene wings | 217. Winged | 0 | 0 |
| | 218. Un–winged | 0 | 0 |
| Inner achene peak length (mm) | 219. 1.5–2 | -0.1339 | -0.00831 |
| | 220. 2.5–3 | 0.040144 | -0.02471 |
| | 221. > 3.5 | 0.032449 | -0.02335 |
| | 222. Absent | 0.061312 | 0.056378 |
| Inner achene sculpture | 223. Scabridulous | 0.012211 | 0.007343 |
| | 224. Finely muricate | 0.023457 | 0.088562 |
| | 225. Muricate–antrorsely spinulose on the ribs | -0.04074 | -0.03557 |
| | 226. Absent | 0.005071 | -0.06034 |
| Inner achene pappus occurrence | 227. Pappose | -0.00507 | 0.06034 |
| | 228. Absent | 0.005071 | -0.06034 |
| Inner achene pappus persistence | 229. Deciduous | -0.00507 | 0.06034 |
| | 230. Absent | 0.005071 | -0.06034 |
| Inner achene pappus type | 231. Short irregular | 0 | 0 |
| | 232. Long regular | -0.00507 | 0.06034 |
| | 233. Absent | 0.005071 | -0.06034 |
| Inner achene pappus length (mm) | 234. 1–3 | 0.072593 | -0.04806 |
| | 235. 3–5 | -0.12169 | -0.00097 |
| | 236. > 5 | 0.04403 | 0.10937 |
| | 237. Absent | 0.005071 | -0.06034 |
| Glandular trichomes | 238. Biserriate with unicellular clavate head | 0.016975 | 0.07067 |
| | 239. Biserriate with multicellular globular head | 0.027055 | 0.038705 |
| | 240. Biserriate with multicellular peltate head | 0.005071 | -0.06034 |
| | 241. Multiserrate with multicellular peltate head | -0.03697 | -0.04129 |
| | 242. Branched straight T–shape, symmetrical | 0.072593 | -0.04806 |
| | 243. Branched straight T–shape, asymmetrical | 0.089568 | 0.022605 |

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| Eglandular unicellular trichomes | 244. Branched curly T–shape | -0.11662 | -0.06131 |
| | 245. Unbranched adpressed short conical | -0.01155 | 0.042448 |
| | 246. Unbranched adpressed long conical | -0.0155 | -0.08115 |
| | 247. Unbranched upright stiff needle–like | -0.05654 | 0.004233 |
| Eglandular multicellular trichomes | 248. Uniserriate with flagelliform apical cell | 0.016975 | 0.07067 |
| | 249. Uniserriate with tubular apical cell | 0.057119 | 0.045957 |
| | 250. Biserriate with unbranched tip | 0.04403 | 0.10937 |
| | 251. Biserriate with branched tip | 0.04403 | 0.10937 |
| | 252. Multiserriate with unbranched tip | 0 | 0 |
| | 253. Multiserriate with branched tip | 0 | 0 |
| Stomata dimensions | 254. Large stomata | -0.07229 | -0.07289 |
| | 255. Medium–sized stomata | 0.05624 | 0.11672 |
| | 256. Small stomata | 0.01605 | -0.04383 |
| Stomatal density | 257. High stomatal density | 0.072593 | -0.04806 |
| | 258. Medium stomatal density | -0.07766 | 0.1084 |
| | 259. Low stomatal density | 0.005071 | -0.06034 |
| Epidermal cell density | 260. High epidermal cell density | 0.072593 | -0.04806 |
| | 261. Medium epidermal cell density | -0.06491 | -0.00924 |
| | 262. Low epidermal cell density | -0.00769 | 0.057301 |
| Stomatal index | 263. High stomatal index | -0.0693 | 0.12187 |
| | 264. Medium stomatal index | 0.064231 | -0.06154 |
| | 265. Low stomatal index | 0.005071 | -0.06034 |
| Epidermal cell shape | 266. Irregular | -0.02885 | -0.02651 |
| | 267. Polygonal | 0.028851 | 0.026506 |
| Epidermal cell anticlinal wall | 268. Undulate | -0.06098 | -0.00487 |
| | 269. Slightly undulate | 0.064575 | -0.04499 |
| | 270. Straight | -0.0036 | 0.049857 |