

Two subspecies of *Galium setaceum* (Rubiaceae) in Egypt

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Abstract. The systematics, distribution and morphology of *Galium setaceum* (Rubiaceae) in Egypt are described in the article. A full discussion is provided of all morphological characters, systematic treatment and nomenclature based on macro characters, such as habit, distribution, leaf, inflorescence, peduncle, pedicel, flowers, and micro characters of trichomes. *G. setaceum* subsp. *decaisni* is identified for the flora of Egypt for the first time. Distribution maps, ecological information and a taxonomic key are provided for identification of the two subspecies.

Key words: distribution, Egypt, fruits, *Galium*, morphology, *Rubiaceae*, systematics, taxonomiy

Introduction

The genus *Galium* L. (Rubiaceae) was described by Linnaeus (1753) who reported then the occurrence of 26 species. Today more than 600 species of *Galium* occur worldwide, mostly in meridional to temperate, but also in alpine and arctic regions, or in subtropical and tropical zones at higher elevations (Chen Tao & Ehrendorfer 2011).

From Egypt, Forskal (1775) reported three species of *Galium*; Delile (1813) reported only *G. spurium*; Ascherson and Schweinfurth (1889) reported four species; Sickenberger (1901) accounted for two species; Muschler (1912) wrote about five species; Ramis (1929) reported six species; Täckholm (1956) reported eight species; Montasir and Hassib (1956) reported seven species; Täckholm (1974) distinguished 12 species; Boulos (2000) recognized only 10 species; Elkordy (2007) stated that *Galium* in Egypt is represented by 11 species, two subspecies and two varieties (Table 1).

Table 1. Species of genus *Galium* reported from Egypt by different authors.

No	Author	Reported species
1	Forskal (1775)	<i>G. pufillum</i> , <i>G. verum</i> , and <i>G. aparine</i>
2	Delile (1813)	<i>G. spurium</i>
3	Ascherson & Schweinfurth (1889)	<i>G. tricornis</i> , <i>G. nigricans</i> , <i>G. murale</i> var. <i>alexandrinum</i> , and <i>G. columella</i>
4	Sickenberger (1901)	<i>G. murale</i> var. <i>rupestris</i> , and <i>G. lanatum</i>
5	Muschler (1912)	<i>G. tricornis</i> , <i>G. spurium</i> , <i>G. nigricans</i> var. <i>brachychaetum</i> , <i>G. murale</i> var. <i>alexandrinum</i> , and <i>G. lanatum</i>
6	Ramis (1929)	<i>G. lanatum</i> , <i>G. tricornis</i> , <i>G. aparine</i> , <i>G. nigricans</i> var. <i>brachychaetum</i> , <i>G. murale</i> var. <i>alexandrinum</i> , and <i>G. spurium</i>
7	Täckholm (1956)	<i>G. sinaicum</i> , <i>G. mollugo</i> , <i>G. articulatum</i> , <i>G. tricornis</i> var. <i>ceratopodium</i> , <i>G. spurium</i> var. <i>tenerum</i> , <i>G. murale</i> var. <i>alexandrinum</i> , <i>G. nigricans</i> , and <i>G. setaceum</i> var. <i>decaisnei</i>
8	Montasir & Hassib	<i>G. sinaicum</i> , <i>G. tricornis</i> , <i>G. spurium</i> var. <i>tenerum</i> , <i>G. murale</i> var. <i>alexandrinum</i> , <i>G. nigricans</i> var. <i>brachychaetum</i> , <i>G. setaceum</i> , and <i>G. decaisnei</i>
9	Täckholm (1974)	<i>G. sinaicum</i> , <i>G. canum</i> , <i>G. mollugo</i> , <i>G. articulatum</i> , <i>G. murale</i> , <i>G. tricornutum</i> , <i>G. ceratopodium</i> , <i>G. aparine</i> , <i>G. spurium</i> , <i>G. nigricans</i> , <i>G. setaceum</i> , and <i>G. parisiense</i>
10	Boulos (2000)	<i>G. sinaicum</i> , <i>G. canum</i> , <i>G. mollugo</i> , <i>G. murale</i> , <i>G. tricornutum</i> , <i>G. ceratopodium</i> , <i>G. aparine</i> , <i>G. spurium</i> , <i>G. setaceum</i> , and <i>G. parisiense</i>
11	Elkordy (2007)	<i>G. parisiense</i> , <i>G. canum</i> , <i>G. mollugo</i> , <i>G. murale</i> , <i>G. aparine</i> , <i>G. spurium</i> , <i>G. tricornutum</i> , <i>G. ceratopodium</i> , <i>G. nigricans</i> and <i>G. setaceum</i> , <i>G. sinaicum</i>

Most taxonomists agree that the macro- and microstructure of fruits and seeds are good characteristics. The present investigations deal with the micro- and macromorphological (LM and SEM) characters of fruits (mericarps) of *Galium setaceum* from the Rubiaceae in Egypt, in an effort to show the ranges of variability in fruit (mericarp) characters so as to determine their usefulness for future taxonomic work.

Material and methods

The present study was based on herbarium specimens from Cairo University (CAI), Agricultural Research

Center, Flora and Phytotaxonomy Research, Ministry of Agriculture, Cairo, Egypt (CAIM); Assiut University (AST- proposed abbreviation); Sohag University (SHG); Kew (K); and Leiden (L) and Wageningen University Herbaria (WAG). Furthermore, fresh material was studied and field observations were recorded from several localities in Egypt. The geographic localities of the studied taxa in Egypt were mapped according to the ecological territories proposed by El Hadidi & Hasnaa (2000) (Fig. 1).

Some of the investigated fruits (mericarps) were collected from mature plants in Egypt; others were taken from herbarium specimens. Only mature fruits were used for this study. The dried fruits were soaked in boiling water for 2–4 minutes to compensate for shrinkage, and examined by light microscope (Olympus type BH-2). Ten to fifteen seeds for each taxon were sampled to cover the range of variation. Measurements were standardized with ocular. Mature fruits were mounted on stubs with double adhesive tape. The stubs were sputter-coated with gold/palladium for 4 min in an Apolaron E 1100 ion sputtering device. After coating, the specimens were examined with a JEOL-6300 Scanning Electron Microscope (SEM), using accelerating voltages at 20–30 KV. All photomicrographs were taken at the SEM Laboratory, Sohag University, Egypt.

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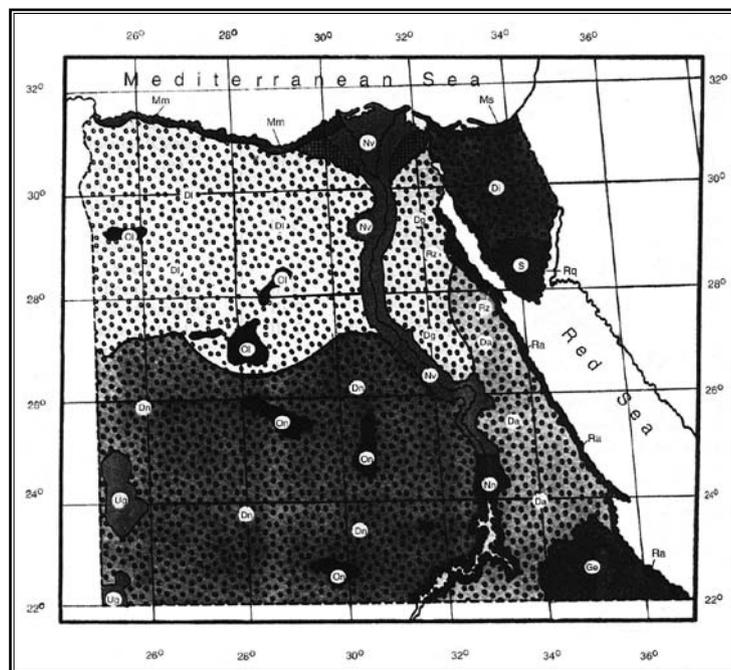


Fig. 1. Phytogeographical territories of Egypt (El Hadidi & Hasnaa 2000).

Legend:

- Da:** Arabian Desert. The Southern province of the desert East of the Nile.
Dg: Galala Desert. The Northern province of the desert East of the Nile.
Di: Isthmic Desert. The Northern part of the Sinai peninsula. South of the Mediterranean Coastal land and its extension westward to the Nile Delta.
Dl: Libyan Desert. The Northern province of the desert West of the Nile.
Dn: Nubian Desert. The Southern province of the desert West of the Nile.
Ge: Gebel Elba District. At the SE corner of the Arabian Desert.
Mm: Mareotis sector of the Mediterranean coastal land extending between Egypt-Lybian border, Eastward to Rosetta.
Ms: Sinaitic sector of the Mediterranean coastal land extending between Port Said eastward to Rafah at the Egyptian – Palestinian border.
Nn: Nubian sector of the Nile land. Extending from the Sudanese border northwards to Kom Ombo.
Nv: Nile Valley sector of the Nile land. Extending from Kom Ombo northwards to include the Nile-fed Faiyum area and the Nile Delta with its extensions of reclaimed lands of Tahrir Province to the West and Salhiya District to the East.
Ol: Oases of the Libyan Desert province.
On: Oases of the Nubian Desert province.
Ra: Arabian sector of the Red Sea coastal plains extending between 22°–28°N.
Rq: Aqaba Gulf sector of the Red Sea coastal plains which extends along the Western coast of Aquaba Gulf between 28°–29°30'N.
Rz: Suez Gulf sector of the Red Sea coastal plains in the Eastern Desert and Sinai between 28°–30°N.
S: Mountainous Southern Sinai.
Ug: Gebel Uweinat massive on Egypt's border with Lybia and Sudan and the Northerly situated El Gilf El Kebir Plateau.

Results

Systematic treatment

The *Galium setaceum* subsp. *decaisnei* has been treated at a different taxonomic level described as species (Boissier 1846; Nasir, E. & S.I. Ali 1980–2005), and at subspecies level (Ehrendorfer, 1958; Täckholm, 1974; Ehrendorfer, F. & Schönbeck-Temesy, E. 1980, Feinbrun-Dothan N., 1978). The latter treatment is presented here, with classification as subspecies in Ehrendorfer, Schönbeck-Temesy & Puff (2005).

Galium setaceum Lam., Encycl. 2: 584 (1788)

Stems annual, herbaceous, slender, but quadrangular at the base, delicate, glabrous, 11.5–25.0 cm, erect or ascending, branching, usually dichotomously branching. Lower leaves in pairs, ovate to oblanceolate, simple, 3.0–4.5 × 0.9–1.6 mm, hairy to glabrous, margins revolute or flat, apex acute to obtuse, tapering at the base, subsessile, exstipulated; upper leaves in whorls of 3–8, linear, oblanceolate to needle-like, 2.0–7.0 × 0.1–3.0 mm, sparsely hairy to densely hairy at the base, leaf margins slightly to strongly revolute, apex acute, ending with very short hyaline apex, sessile to subsessile, exstipulated. Inflorescence cymes, lax, terminal and axillary, 3–20 flowered, bracted. Bracts narrowly linear to filiform, 1.5–16 × 0.1–2.0 mm, sparsely hairy to densely hairy at the base, margins revolute, apex acute. Peduncle erect, slender or quadrangular, glabrous, 3–20 mm. Pedicel erect, capillary, slender, glabrous, 1–9 mm, divaricating. Flowers small, 1.0 mm in diameter, hermaphrodite. Calyx absent. Corolla 4-lobed, rotated, 0.5–2.0 mm in diameter. Petals ovate to lanceolate, 0.5–1.0 × 0.25–0.5 mm, glabrous, margins entire, apex acute, shortly attenuate and curved inward, yellowish-green with three brown veins. Androecium with 4 stamens, filament slender, glabrous, 0.1–0.3 mm, anther ovate to elliptic, 0.1–0.2 mm. Ovary subglobose, 0.1–0.9 × 0.1–1 mm, composed of two mericarps, covered with pressed or hooked hairs, style 0.3–0.5 mm, two-branched, stigma capitate. Fruit schizocarp, composed of two mericarps; mericarps reniform, 0.2–1.0 × 0.1–0.5 mm, covered with pressed or setose hooked hairs, purple to brown. Seeds reniform, 0.4–0.9 × 0.2–0.6 mm, yellow to yellow-brown.

2n = 22, 44 (Ehrendorfer, F. 1982; Montmollin, B. d. 1986)

Type: Spain; without locality, collected by Vahl (holotype P).

Two subspecies of *G. setaceum* are recognized in Egypt:

Key to subspecies

- 1a.** Fruit setose with numerous hooked hairs **1. subsp. *setaceum***
1b. Fruit with a few short papillae or bristles speckled with raphides **2. subsp. *decaisnei***

1. *G. setaceum* subsp. *setaceum*

Leaves in whorls of 4–6, linear to oblanceolate, 6.0–16.0 × 1.5–3.0 mm, margins sparsely retrorse hairy, apex acute, margins flat, tapering at the base. Inflorescence axillary, cymes, few-flowered with 3–7 flowers, with corymbiform branching, bracted. Bracts leaf-like, linear to needle-like, 10.0–14.0 × 0.5–2.0 mm, sparsely hairy, margins slightly revolute, apex acute, shortly attenuate and curved inward. Peduncle 10.0–25.0 mm, erect, quadrangular, glabrous, exceeding the subtending leaves. Flower small, 1.2 mm in diameter. Corolla 4-lobed. Petals 0.5–0.6 × 0.2–0.3 mm, ovate, margins entire, yellowish-green with three brown veins. Mericarps reniform, 0.5–1.0 × 0.3–0.5 mm, setose with numerous hooked hairs, brown. Seeds reniform, 0.4–0.9 × 0.2–0.4 mm, yellow-brown.

Vernacular names (Arabic): Bessasa

Habitat: In rock crevices, dry banks or hillsides, occasionally in dried-up river beds; Flowering – Fruiting: March–May.

Distribution: Widely distributed in the Mediterranean region eastwards of Iran.

Specimens examined

EGYPT: (DI), North Sinai, Gebel El Halal, E.G. Eldin s.n., 16.4.1992 (SCU); Wadi Edid, S. Hassan s.n., 29.4.1994; Gebel El Halal, E. Gamal Eldin 811, 16.4.1992 (SCU); (GE), Gebel Elba, Wadi Drawina, Abdel Khalik s.n., 3.3.1999 & 8.1.2004 (SHG); Wadi Mawaw, V. Täckholm & al. s.n., 28.1.1962 (CAI); Beir Kan Sisrob, V. Täckholm & al. 1289, 3.2.1962 (CAI); Wadi Oolak, V. Täckholm & al. 713, 27.1.1962 (CAI); Gebel Karam Elba, V. Täckholm & al. 1739, 7.2.1962 (CAI). **IRAN:** S. Lorestan-Sheshom, Alt 70 m Ne. 33 06, E. 47 43 M. Jacobs 6364, 24.4.1963 (L). **PALESTINE:** Jerusalem, Freds & al. 2699, 2.5.1911 (L).

2. *G. setaceum* subsp. *decaisnei* (Boiss) Ehrend.

Notes Roy. Bot. Gard. Edinburgh 22: 392. 1958.

Synonyms:

- ≡ *G. decaisnei* Boiss., Diagn. Ser. 1, 6: 69 (1846); Ehrendorfer, F., Schönbeck-Temesy, E. (1980).
- = *G. setaceum* Lam. var. *longipedicellatum* Post, Fl. Pal. ed. 1, 389 (1896).
- = *G. setaceum* Lam. var. *leiocarpum* Boiss. ex Post Flora of Syria, Palestine, and Sinai 389. 1896.

Leaves in whorls of 3–8, narrowly linear to needle-like, 2.0–17.0 × 0.1–2.0 mm, sparsely to densely hairy at the base, leaf margins strongly revolute, apex acute, ending with a very short hyaline apex, sessile. Inflorescence cymes, terminal and axillary, lax, 3–20 flowered, bracted. Bracts narrowly linear to filiform, 1.5–16.0 × 0.1–0.6 mm, sparsely to densely hairy at the base, margins revolute, prominent dorsal midrib, apex acute, ending with very short hyaline apex and curved inward. Peduncle 3.0–20.0 mm, erect, slender, glabrous. Corolla rotated, 0.5–2.0 mm in diameter, 4-lobed. Petals 0.5–1.0 × 0.25–0.5 mm, ovate to lanceolate, yellowish-green with three brown veins. Mericarps reniform, 0.5–0.8 × 0.4–0.7 mm, covered with depressed hairs or with a few short papillae or bristles speckled with raphides, purple to brown. Seeds reniform, 0.4–0.7 × 0.4–0.6 mm, yellow to yellow-brown

Specimens examined

CRETE: Caria, Sam-sun-dagh, Priene, Bornmüller 9585, 2.6.1906 (K). **EGYPT: (DI)**, North Sinai, Gebel El Halal, E.G. Eldin s.n., 16.4.1992 (SCU); Wadi Edid, S. Hassan s.n., 29.4.1994 (SCU); Gebel El Halal, E. Gamal Eldin, 811, 16.4.1992 (SCU); Mt. Sinai, W. Schimper 235, 1.5.1835 (K); **(S)**, S. Sinai, Wadi Feiran, J.R. Shabetai 5, 15.4.1937 (KEW); Sinai, G.K. Lords 10168, 4.5.1968 (K); Gebel Serbal, N: 28°63'891", E: 33°64'566", Alt. 1683m, Abdel Khalik et al., 2033, 26.4.2004 (SHG); S. Sinai, Gebel Abass Basha (St. 52), N: 28°33'35", E: 33°54'28", Alt. 1883m, K. Shaltout & al. s.n., 17.4.2004 (SHG); Wadi Tmara, Wadi Feiran, J.R. Shabetai 4179, 15.4.1937 (CAIM); **(GE)**, Wadi Yahameeb, N: 22°12'28", E: 36°20'12", Alt. 600m, Abdelkhalik 2033, 3.3.1999 (SHG); V. Täckholm, 23–27.1.1929 (CAIM); South of the well, Khattab 6327, 19.11.1928 (CAIM); Gebel El-Shalal, J.R. Shabetai 5215, 3.3.1938 (CAIM); Wadi Mawaw, V. Täckholm & al. s.n., 28.1.1962 (CAI); Beir Kansisrob, V. Täckholm & al. 1289, 3.2.1962 (CAI); WADI Oolak, V. Täckholm & al. 713, 27.1.1962 (CAI); Gebel Karam Elba, V. Täckholm & al. 1739, 7.2.1962 (CAI). **GERMANY:**

Berlin, from Schweinfurth's now burnt (CAI). **GREECE:** Kazematten of Tirijns, Amshoff s.n., May 1855 (WAG); in Rhodos, in Park, Amshoff s.n., May 1955 (WAG). **IRAQ:** Bekhme, Gillett 8265, 1947 (K); Afayif, Alizzi & Husain 34058, 6.5.1965 (K); AL-Majarrh 50 km, S.W. of Falluja, K. Hamad & H. Hamid, 44512, 30.3.1976 (K). **ITALY:** Montis Cofani, E & A. Huet du Pavillon s.n. 18.4.1855 (WAG). **JORDAN:** Jebel El- Uweined, W. of Azraq, C.C. Townsend 65168, 21.4.1965 (K); Qasr Amra, V. Täckholm & al. 9123, 14.5.1976 (K). **LEBANON:** Reyform, Gunnar Samuelsson s.n., 3.6.1932 (K). **PALESTINE:** Jerusalem, F. Meyers & J.E. Dinsmore 1638, 22.4.1911 (K); Jerusalem, Fred S. Meyers & J. E. Dinsmore 2699, 6.2.1912 (L). (K). **SYRIA:** Nahr el Kalb, Gunnar Samuelsson 1223, 13.5.1932 (K). **TUNISIA:** Matmata, J. Pitard 396, 6.1908 (L). **TURKEY:** Prov. Antalya, Bileybi, E. Hennipman & al. 449, 18.4.1959 (WAG).

Phytogeographical distribution

In our study, we have found that *Galium setaceum* is represented by two subspecies: *G. setaceum* subsp. *setaceum*, which is widely distributed in the Mediterranean region, and *G. setaceum* subsp. *decaisnei* which is widely distributed in the Mediterranean region westwards towards Europe, centrally and westwards of Asia. It is clear that Egypt is the meeting point of the floristic distribution of infraspecific taxa of *G. setaceum* (Figs. 2, 3).

Morphological characters of *Galium setaceum*

Leaf shape was found useful for distinguishing the subspecies of *Galium setaceum*. Linear oblanceolate leaves are found in the *G. setaceum* subsp. *setaceum*; narrowly linear to needle-like leaves are representative of the *G. setaceum* subsp. *decaisnei* (Table 2).

Table 2. Main morphological characters used to distinguish between the studied taxa.

Characters	<i>G. setaceum</i> subsp. <i>setaceum</i> Lam.	<i>G. setaceum</i> subsp. <i>decaisnei</i> (Boiss) Ehrend.
Leaf shape	linear to oblanceolate	narrow linear to needle-like
Leaves in whorls	4–(6)	3–(8)
Leaf size	6.0–16.0 × 1.5–3.0 mm	2.0–17.0 × 0.1–2.0 mm
Peduncle length	10.0–25.0 mm	3.0–20.0 mm
Petal shape	ovate	ovate to lanceolate
Petal size	0.5–0.6 × 0.2–0.3 mm	0.5–1.0 × 0.25–0.5 mm
Number of flowers in inflorescence	3–7 flowers	3–20 flowers
Mericaip shape	reniform	reniform
Mericaip size	0.5–1.0 × 0.3–0.5 mm	0.5–0.8 × 0.4–0.7 mm
Mericaip surface	setose	scabrous

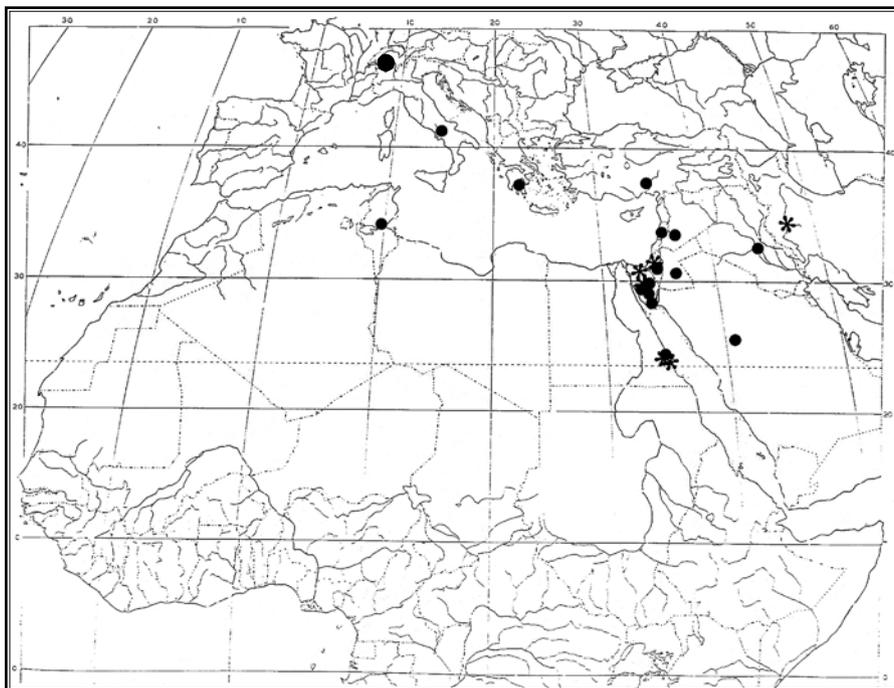


Fig. 2. Distribution of *G. setaceum* subsp. *setaceum* ✱ and subsp. *decaisnei* ● in the world.

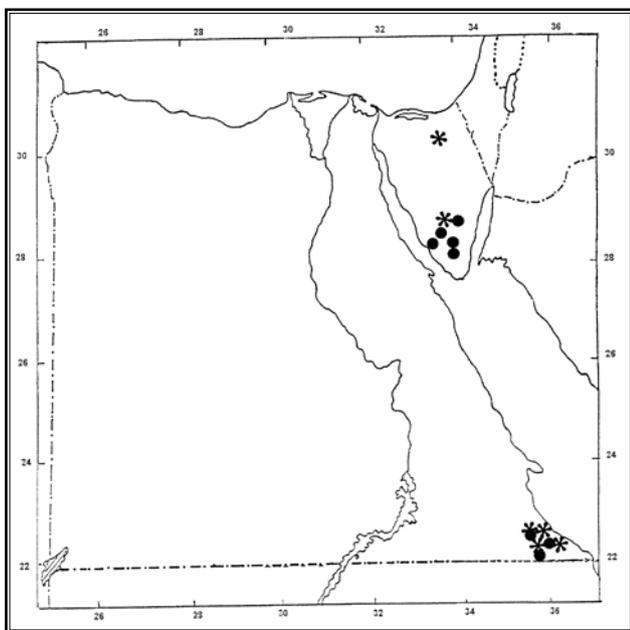


Fig. 3. Distribution of *G. setaceum* subsp. *setaceum* ✱ and subsp. *decaisnei* ● in Egypt.

Inflorescences are cymes, terminal and axillary, lax, and 3–20 flowered. Flower numbers are one of the most important characters for distinguishing between the species and subspecies in *Galium*. They vary from 3–8 flowers in *G. setaceum* subsp. *setaceum* to 15–20 flowers in *G. setaceum* subsp. *decaisnei* (Table 2).

Petals are usually four, equal, rotated, and gamopetalous. They have a less important taxonomic value within the genus *Galium*. However, petal shape varies

and has some taxonomic indication. Petals are ovate in *G. setaceum* subsp. *setaceum* and ovate to lanceolate in *G. setaceum* subsp. *decaisnei* (Table 2). Petal length was found useful in distinguishing between the infraspecific taxa of *G. setaceum*. It varies from 0.5 to 0.6 mm in the *G. setaceum* subsp. *setaceum* and from 0.6 to 1.0 mm in the *G. setaceum* subsp. *decaisnei* (Table 2).

Fruit (mericarp) characters are very important in distinguishing the taxa in genus *Galium*. Fruits are schizocarps composed of two mericarps, each mericarp having only one seed. The shape of mericarps among the investigated taxa is reniform, with little variation in size. Mericarps are 0.4–0.9 × 0.2–0.4 mm in the *G. setaceum* subsp. *setaceum* and 0.4–0.7 × 0.4–0.6 mm in the *G. setaceum* subsp. *decaisnei* (Table 2). There is no significant difference in mericarp shape and size between the two subspecies. Mericarp indumentum, however, is one of the most important characters in the classification of *Galium* at different levels. It varies from scabrous to setose in *G. setaceum*. However, it is always setose in the *G. setaceum* subsp. *setaceum* (Plate I, 1A,B, Table 2) and scabrous in the *G. setaceum* subsp. *decaisnei* (Plate I, 2A,B, Table 2).

The scanning electron microscope has been used by various researchers during the past few years for viewing details of the surface structure of fruits and seed [e.g. Echlin (1968), Heywood (1969), Abdelkhalik (2002)]. SEM was instrumental in this study too for examining the differences in mericarp indumentum between the two subspecies of *G. setaceum*.

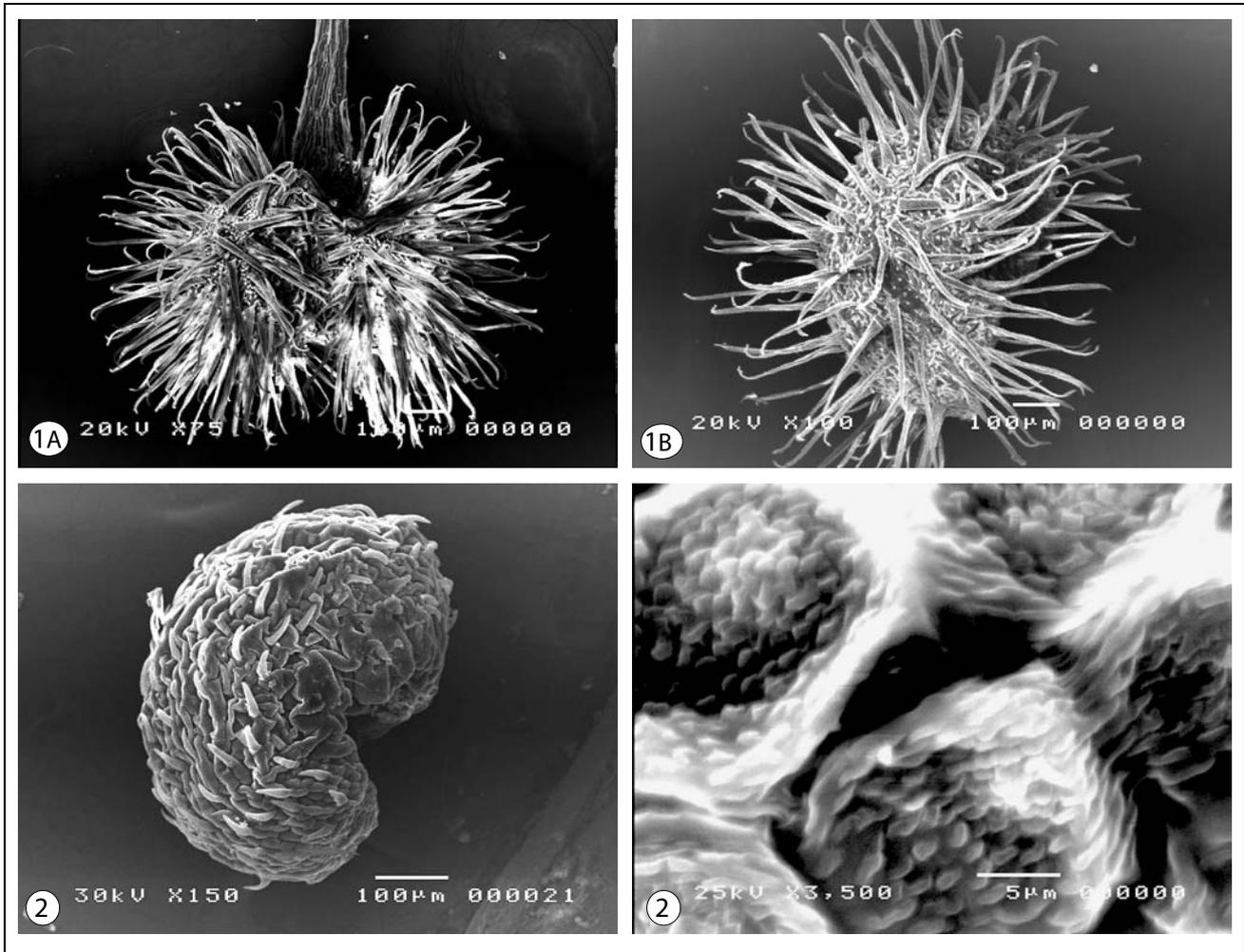


Plate I. SEM photographs of mericarps. **A** – entire mericarps, **B** – enlargement of mericarp coat; **1** – *G. setaceum* subsp. *setaceum*, **2** – *G. setaceum* subsp. *decaisnei*.

Conclusions

The revision of *Galium setaceum* in Egypt based on macro and micro-morphological characters and phytogeographical distribution has revealed the presence of two subspecies: *G. setaceum* subsp. *setaceum* and *G. setaceum* subsp. *decaisnei*. These results complete the taxonomy of Boulos (2000) in the last issue of *Flora of Egypt*, where he named only *Galium setaceum* without any infraspecific taxa.

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