Grewia tiliifolia Vahl (Malvaceae): a Newly Recorded Species of Taiwan

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Abstract. The first record of *Grewia tiliifolia* Vahl in Taiwan was by Henry (1896). However, Li (1963) pointed out that this record was a misidentification of *G. eriocarpa,* and no formal record of *G. tiliifolia* was found after that. Recently, we discovered that this species is native to Taiwan, and Taiwan is the northeastern boundary of the global distribution of this species. The diagnostic characters of *G. tiliifolia* which distinguish it from *G. eriocarpa* are the smooth abaxial surface of the leaf and villose fruits, in contrast with the leaf abaxial surface and fruits of *G. eriocarpa* which are densely covered with stellate hairs. We provide photos, a morphological description, pollen and epidermal morphologies, a distribution map, and color drawing, and compare differences with *G. eriocarpa*.

Key words: *Grewia eriocarpa*, *Grewia tiliifolia*, Malvaceae, new record, Taiwan.

INTRODUCTION

The genus *Grewia* L. (Malvaceae: Grewioideae) is comprised of roughly 280~300 species, mainly distributed in tropical Asia, Australia, and Africa (Chung, 2006). Twenty-seven species are native to China (Tang et al., 2007), and four species are native to Taiwan (Liu and Lo, 1993). This genus is characterized by the shoot usually being covered with stellate hairs, serrate leaf margins, axillary umbels, flowers with a gynandrophore, and drupes usually 1~4-lobed and depressed-globose (Liu and Lo, 1993; Chung, 2006). In the past, *Grewia* belonged to the Tiliaceae (Hutchinson, 1967; Cronquist, 1981). Recently, Kubitzki and Bayer (2003), based on molecular sequencing data and morphological characters, merged the Bombacaceae, Sterculiaceae, Tiliaceae, and Malvaceae *sensu stricto* into a generalized Malvaceae *sensu lato*.

According to Burret (1926) monograph of the Tiliaceae, four sections were treated in *Grewia*, and key characters included the sexuality of the flower, the morphology of the stigma lobes, the shape of the petals, and the number of fruit lobes. Among them, two sections are native to Taiwan. Sect. *Axillares* Burret, which includes only *G. eriocarpa* Juss., is characterized by hermaphrodite flowers, entire stigma lobes, and 1- or 2-lobed fruits; while sect. *Glomeratae* Burret, which includes *G. biloba* G. Don, *G. piscatorum* Hance, and *G. rhombifolia* Kanehira *et* Sasaki, is characterized by a dioecious habit, stigma lobes with a filamentary division, and 2~4-lobed fruits.

The first record of *G. tiliifolia* Vahl in Taiwan was by Henry (1896), and the cited specimens were examined (*A. Henry 496* and *557*, Fig. 1), followed by records of Matsumura and Hayata (1906) and Hayata (1911). However, Sasaki (1928) pointed out that its linear stipules and short petioles differed from those of *G. tiliifolia*, and so treated this taxon as a new species, *G. boehmerifolia* Kanehira *et* Sasaki. Later, Li (1963) treated the aforementioned *G. tiliifolia* as a misidentification and *G. boehmerifolia* as a synonym of *G. eriocarpa*, followed by Liu and Lo (1977), Liu and Lo (1993), Liu et al. (1994), and Lu et al. (2006). In summary, the presence of *G. tiliifolia* was denied by previous studies.

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Recently, we found wild populations of *G. tiliifolia* in suburbs of Changhua City, in the west-central coastal region of Taiwan. After studying specimens in some herbaria, we determined that this species has a few more populations in the southwestern region and on Lanyu (Orchid Island). This study reports the real *G. tiliifolia* in Taiwan for the first time, and this also represents the northeastern boundary of this species. Photos, a description, color drawings, and pollen and epidermal morphologies are provided.

MATERIALS AND METHODS

Herbarium Examination

Materials used in the present study were freshly collected from the field, and voucher specimens were deposited in the TNM (Index Herbarium, the following abbreviations have the same meaning) and TCF. Herbarium specimens were also consulted and compared at HAST, KYO, PPI, TAI, TAIE, TAIF, TCF, TI, TNM, and TNU, in addition to specimens at the Arnold Arboretum of Harvard University (AAH) and Natural History of British Museum (BM), which were available as images (Fig. 1).

Pollen and Epidermal Morphologies

After pollen grains and leaves were fixed in 60% ethanol, serially dehydrated and critical point dried, they were coated with gold (model: Quorum SC7620) and examined under a scanning electron microscope (model: Hitachi S-3400N). Terminology of pollen grains followed Erdtman (1952) and Hesse et al. (2009); and terminology of the leaf epidermal morphology was based on Dilcher (1974) and Barthlott et al. (1998). In addition, the leaf abaxial surface of *G. eriocarpa* is covered with dense stellate hair, but due to analyzing the epidermal structure, we removed part of the stellate hairs. Specimen references are listed in Table 1.

Key to *Grewia* L. Species of Taiwan

1. Leaves 6~15 cm long, 6~13 cm wide, base rounded to cordate; flowers hermaphroditic; sepals reflexed during anthesis, yellow; stigma lobes entire; fruit 1- or 2-lobed..... .....sect. *Axillares*
2. Abaxial surface of leaves nearly smooth; petals and stamens turn from yellow to red before withering; fruits villose.....*Grewia tiliifolia*
2. Abaxial surface of leaves covered with dense stellate hairs; petals and stamens turn from yellow to orange, not red; fruits covered with dense stellate hairs.....*G. eriocarpa*
1. Leaves 0.5~8 cm long, 0.5~5 cm wide, base cuneate to obtuse; flowers dioecious, seldom polygamous; sepals not reflexed, white; stigma lobes with a filamentary division; fruit 2~4-lobed .....sect. *Glomeratae*

Table 1. Specimen references of pollen and epidermal morphology

Observed	Taxa	Location	Coordinates	Elevation	Date	Voucher
Pollen	*Grewia eriocarpa*	TAIWAN. Tainan City, Caoshan Moon World	23°00'N, 120°25'E	100 m	25 May 2013	*C.M. Wang 15407* (TNM)
Epidermis	*G. eriocarpa*	TAIWAN. Tainan City, Nanhua Reservoir	23°06.93'N, 120°34.42'E	240 m	15 July 2015	*C.Y. Chang 628* (TNM)
Epidermis	*G. eriocarpa*	TAIWAN. Tainan City, Nanhua Reservoir	23°06.93'N, 120°34.42'E	240 m	5 Oct. 2015	*C.Y. Chang 773* (TNM)
Pollen, epidermis	*G. tiliifolia*	TAIWAN. Changhua County, Mt. Antou	24°03.85'N, 120°33.10'E	50 m	8 Nov. 2015	*C.Y. Chang 58* (TCF)

Fig. 1. Specimen examined of *Grewia tiliifolia* Vahl in Henry (1896). A: *A. Henry* 496 and *557* (AAH). B: *A. Henry 557* (BM).

3. Procumbent shrub; leaves <2 cm long, round to elliptic.....*G. piscatorum*
3. Erect shrub or medium-sized tree; leaves >2 cm long, ovate, elliptic, or rhomboid
4. Leaves ovate, narrow-rhomboid-ovate, or elliptic, 5~10 cm long, 2~5 cm wide.....*G. biloba*
4. Leaves rhomboid or rhomboid-ovate, 4~8 cm long, 2~4 cm wide.....*G. rhombifolia*

TAXONOMIC TREATMENT

Grewia tiliifolia Vahl in Symbolae Botanicae 1: 35. 1790 (*Tiliaefolia*).

椴葉捕魚木Figs. 2, 3, 4, 6A, 7

Diagnosis: Differs from *Grewia eriocarpa* Juss. by having sparsely stellate hairs on the shoot and both leaf surfaces; petals and stamens turning from yellow to red when withered; fruits villose rather than with stellate hairs.

Description: Semi-deciduous, medium-sized tree up to 5 m high; bark grayish-white; shoots nearly smooth, stellate hairs easily shed. Leaves simple, alternate, broadly ovate to elliptic, 13.7±6.0(~30) cm long, 8.8±3.9(~15) cm broad, coriaceous, oblique, base rounded or cordate, margin serrate, apex acute or acuminate, palmately 4- or 5-nerved, nearly smooth, stellate hairs sparsely distributed along main vein; petioles 1.98±0.54(~4) cm long, swollen at both ends, nearly smooth; stipules 2, falcate, (0.5~)1.6±0.3 cm long, 2.4±0.4 mm broad, deciduous. 1~4(or 6) umbels clustered, axillary, hermaphroditic, bracteoles easily shed; peduncles 1.0±0.4 cm long; 1~3(or 4) flowers in an umbel, pedicels 5.8±1.4 mm long; densely covered by stellate hairs. Flowers perfect, actinomorphic, ca. 2.0±0.58 cm in diam.; sepals 5, oblong-linear, 1.2±0.3 cm long, 3.1±1.1 mm broad, yellow, densely covered with stellate hairs on abaxial surface, valvate, reflexed during anthesis; petals

5, oblong-lanceolate, 5.9±1.4 mm long, 1.9±0.6 mm broad, turning from yellow to red; glands circular, 2.05±0.36 mm in diam.; gynophore 2.3±0.5 mm long; stamens numerous; filaments 5.3±2.0 mm long, turning from yellow to red; ovary globose, surface villose; style slender, 5.9±1.3 mm long, villose at base; stigma 5-lobed, usually exposed among anthers. Fruits drupaceous, 1- or 2-lobed, globose, 8.3±3.6 mm long, 9.5±3.1 mm in diam., purple when mature, villous, gynophore clear. Seeds globose, 4.4±0.5 mm in diam., surface with irregular depressions.

Phenology: Flowering from May to November; fruiting from June to December.

Distribution: Widely distributed in the Old World Tropics, East Africa, India, the Indochina Peninsula, and southern China. In Taiwan, this species was discovered in Changhua, Kaohsiung, and Lanyu (Orchid Island), at elevations of <500 m (Fig. 4). This is the northeastern boundary of the global distribution of this species.

Specimens examined: TAIWAN. Changhua County, Mt. Antou, elev. 50 m, 29 Oct. 2011, *C.M. Wang 14516* (TNM); same locality, 1 Aug. 2014, *C.Y. Chang 58* (TCF). Kaohsiung City, Mt. Hsiaokang, 2 Sept. 1987, *B.L. Shih s.n.* (TNU); same locality, 19 Oct. 1989, *S.Y. Lu s.n.* (TAIF); same locality, 17 Jan. 2004, *C.F. Chen 1034* (PPI); Meinong Mt. Hsiaokuei, 17 Aug. 2001, *S.J. Yang 25840* (PPI). Taitung County, Lanyu, 10 Sept. 1997, *S.Y. Lu s.n.* (TAIF).

Note. *Grewia tiliifolia* was published in "Symbolae Botanicae" by Vahl (1790), and its type specimen was collected from East India. This species prefers sunny environments at low elevations; it has high drought tolerance and a fast-growing habit, and is often discovered in the *Ficus-Machilus* forest zone of hills of western Taiwan (Fig. 4). Common companion species are *Vitex negundo* L. (Labiatae), *Clausena excavata* Burm. f. (Rutaceae), *Celtis sinensis* Pers. (Cannabaceae), *Broussonetia papyrifera* (L.) L'Herit. ex Vent. (Moraceae), *Pittosporum pentandrum* (Blanco) Merr. (Pittosporaceae), and *Macaranga tanarius* (L.) Muell.-Arg. (Euphorbiaceae).

Morphology: Both *G. tiliifolia* and *G. eriocarpa* (Fig. 5) belong to sect. *Axillares*, which is characterized by hermaphroditic flowers, entire stigma lobes, and 1- or 2-lobed fruit, but *G. tiliifolia* can be easily distinguished by the nearly smooth leaf abaxial surface (vs. densely covered with stellate hair). The differences between these two species are listed in Table 2. Overall, *G. tiliifolia* has larger flowers and fewer stellate hairs than does *G. eriocarpa*.

Palynology: Pollen grains of *G. tiliifolia* and *G. eriocarpa* are tricolporate, mediae, prolate. Pollen grains of these species are compared in Table 3 and Fig. 6. *Grewia tiliifolia* has larger pollen grains and reticulate surface sculpturing.

Huang (1972) observed pollen grains of *G. piscatorum* (32~50×25~37 μm in diam.) and *G. rhombifolia* (35~51×25~33 μm in diam.) of sect. *Glomeratae*. Pollen grains of these species are similar in size, but slightly smaller than those of *G. tiliifolia*, and larger than those of *G. eriocarpa*. In addition, the surface sculpturing of *G. tiliifolia*, *G. piscatorum,* and *G. rhombifolia* are reticulate, whereas, only that of *G. eriocarpa* is microreticulate.

Epidermal structure: Both *G. tiliifolia* (Fig. 7) and *G. eriocarpa* (Fig. 8) have similar epidermal structures, such as a random arrangement of epidermal cells, densely covered with membranous platelets as surface ornamentation; the anticlinal walls of both surfaces are straight, amphistomatous; the abaxial surface of the epidermis has a greater stomatal density than the adaxial surface; the stomatal complex is distributed along the main vein on the adaxial surface; subsidiary cells are anomocytic and have stellate hairs on both surfaces; and glandular hairs were only discovered on the adaxial surface. The detailed epidermal structures of these two species are compared in Table 4.

Conservation status: Following the IUCN Categories and Criteria (IUCN 2014), we regard this species as Endangered (EN B2ab(ii,iii); C2a(i); D). *Grewia tiliifolia* was previously known from only four sites, the population of Changhua suburb has only ca. 20 mature individuals, and it is seriously affected by human activities. In Kaohsiung *G. tiliifolia* is only known from Mt. Kangshan and the hills of Meinong, which are also facing human disturbances and habitat fragmentation. A specimen was only once collected from Lanyu (Orchid Island) in 1997 by *S.Y. Lu s.n.* (TAIF!); we assumed this was a small population and may even be extinct now. Therefore, we suggest this species urgently needs to be protected against becoming extinct.

Table 2. Comparison of characters of *Grewia tiliifolia* and *G. eriocarpa*

Character	*G. tiliifolia*	*G. eriocarpa*
Leaf abaxial surface	Nearly smooth, with only a few stellate hairs distributed along main vein	Densely covered with stellate hair
Petioles	Often longer, 2.0±0.5 cm	Shorter, 1.2±0.2 cm
Flower number in an umbel	Often 3 (1~5)	Often more than 3 (1~5)
Flower size	Larger, ca. 2.0±0.6 cm in diam.	Smaller, ca. 1.3±0.2 cm in diam.
Petal and stamen color	Turns from yellow to red	Turns from yellow to orange, not red
Fruit	Villose	Densely covered with stellate hair
Distribution	Known from a few sites in western Taiwan and Lanyu (Orchid Island), at elev. below 500 m	Sporadically distributed in southern Taiwan mostly in badlands, at elev. below 1000 m

Table 3. Palynological characters of *Grewia tiliifolia* and *G. eriocarpa*

Taxon	Polar axis length (P)	Equatorial axis length (E)	P/E ratio	Surface sculpturing	Reticulation size
G. tiliifolia	49.2±2.3 μm	29.1±3.7 μm	1.71±0.14	Reticulate	2.3±0.7 μm
G. eriocarpa	33.2±0.8 μm	21.3±2.4 μm	1.6±0.2	Microreticulate	0.8±0.3 μm

Table 4. Epidermal structural characters of *Grewia tiliifolia* and *G. eriocarpa*

Taxon/ Tropism	Epidermal cells		Stomatal complex					
	Length (μm)	Width (μm)	Orientation	Subsidiary cell form	Length (μm)	Width (μm)	Stomatal indexes (%)	Stomatal number per mm^2
G. tiliifolia/ adaxial	37.8± 14.7	21.0±3.9	Along main vein	Anomocytic	19.8±2.4	9.6±2.5	2.5±2.1	58.5± 50.2
G. tiliifolia/ abaxial	26.4± 7.9	14.4±3.5	Random	Anomocytic	18.0±1.5	15.1±1.9	15.4± 2.2	983.5± 120.1
G. eriocarpa/ adaxial	19.6± 5.3	12.7±2.6	Along main vein	Anomocytic	16.7±3.0	10.6±1.7	1.3±0.9	65.4± 36.7
G. eriocarpa/ abaxial	13.1± 3.0	6.5± 1.7	Random	Anomocytic	13.4±1.3	12.7±1.2	15.0± 1.5	2285.0± 404.1

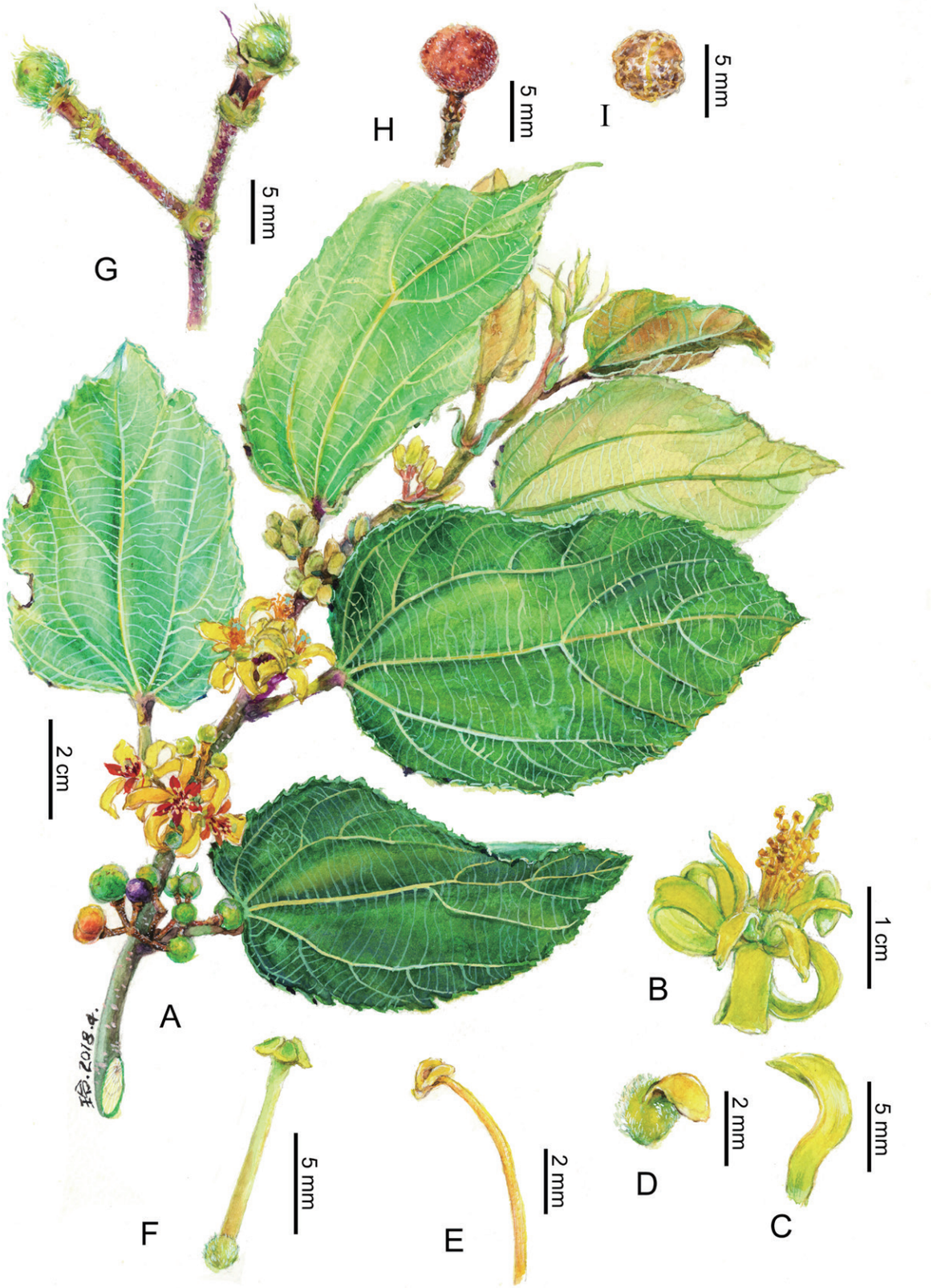

Fig. 2. Color drawing of *Grewia tiliifolia* Vahl. A: Habit. B: Flower. C: Sepal. D: Petal. E: Stamen. F: Pistil. G: Fruiting branches. H: Mature fruit. I: Seed.

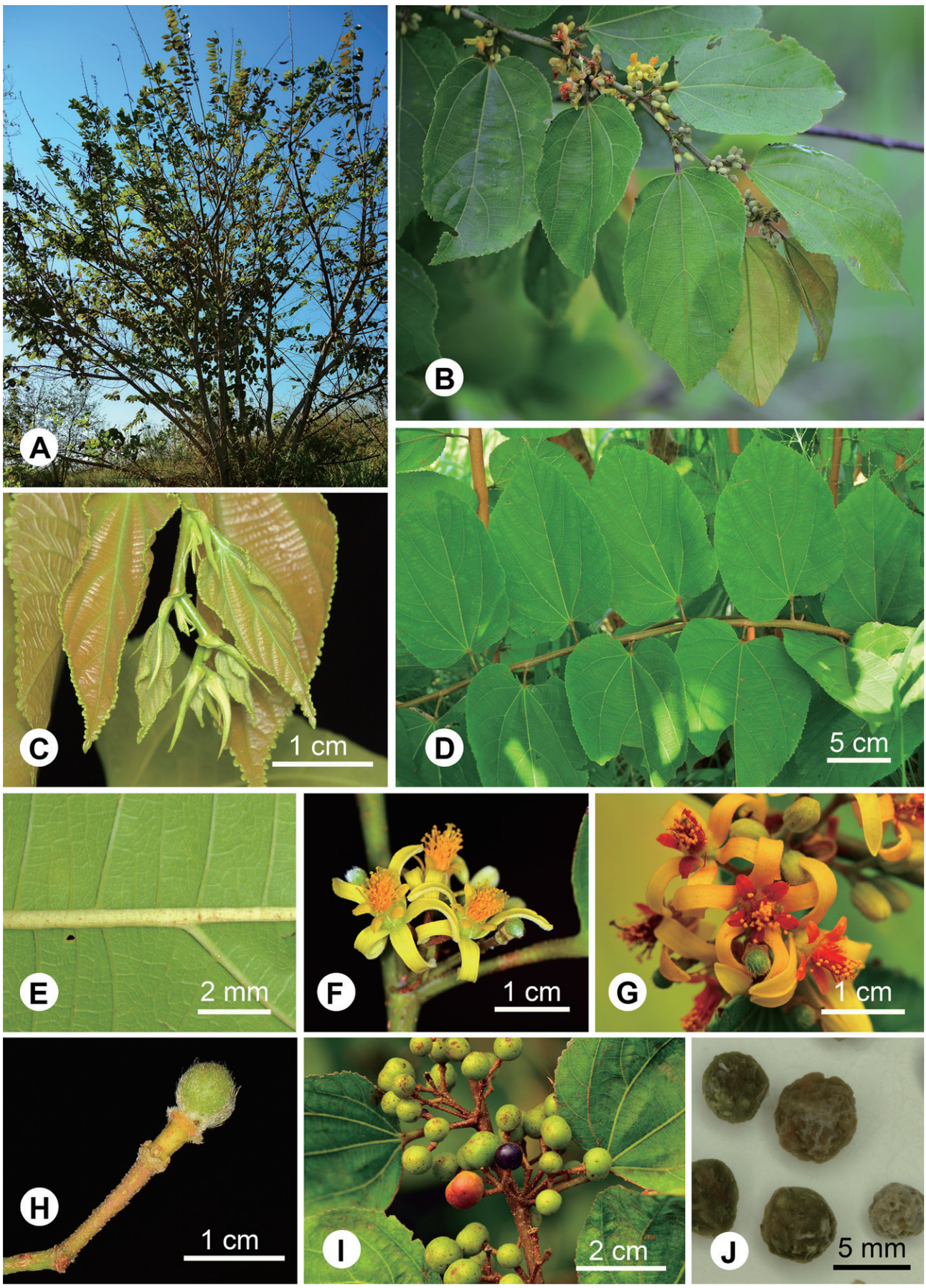

Fig. 3. *Grewia tiliifolia* Vahl. A: Habitat. B: Habit. C: Young shoot. D: Leaves. E: Leaf, abaxial surface. F: Inflorescences in anthesis. G: Nearly withered inflorescences. H: Immature fruit. I: Mature fruit. J: Seeds.

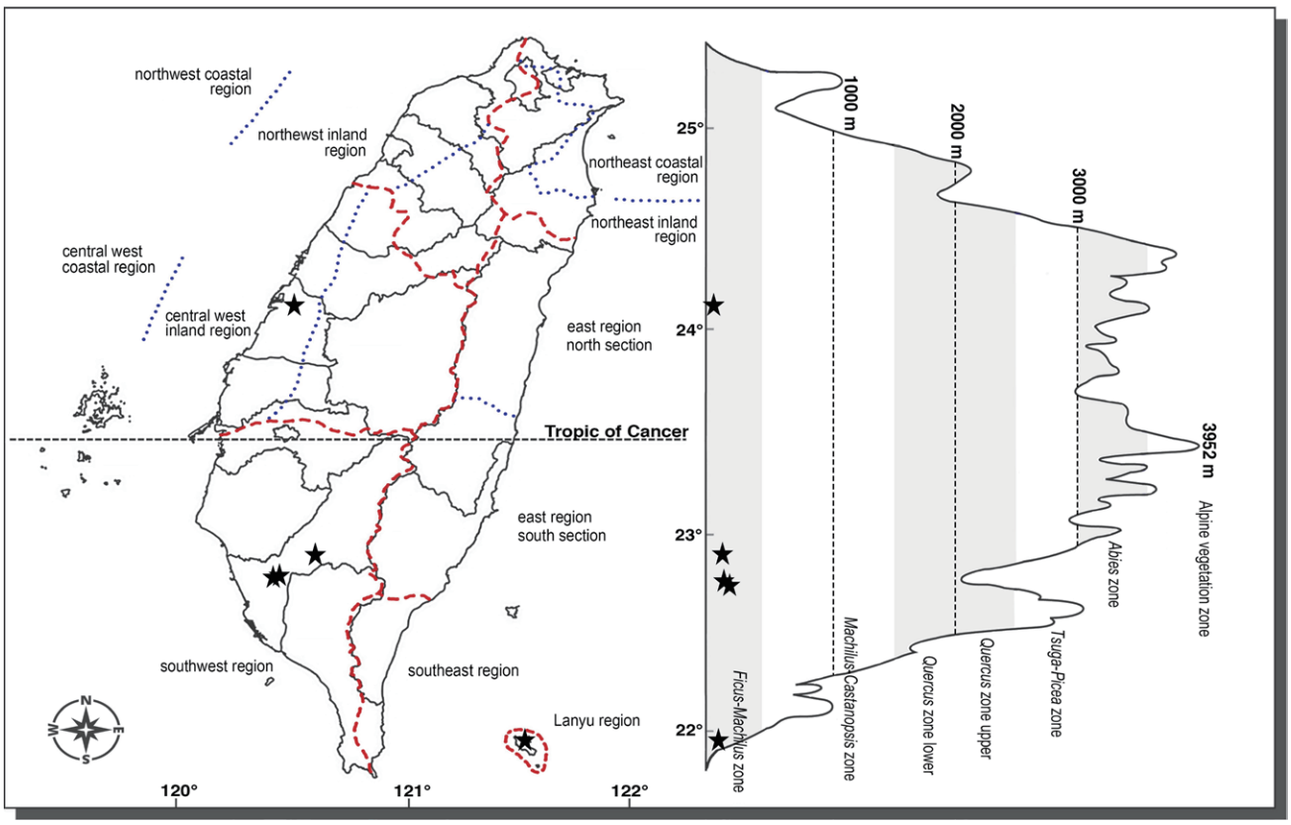

Fig. 4. Distribution map of *Grewia tiliifolia* Vahl in Taiwan. Geographical climatic regions of Taiwan follow Su (1985).

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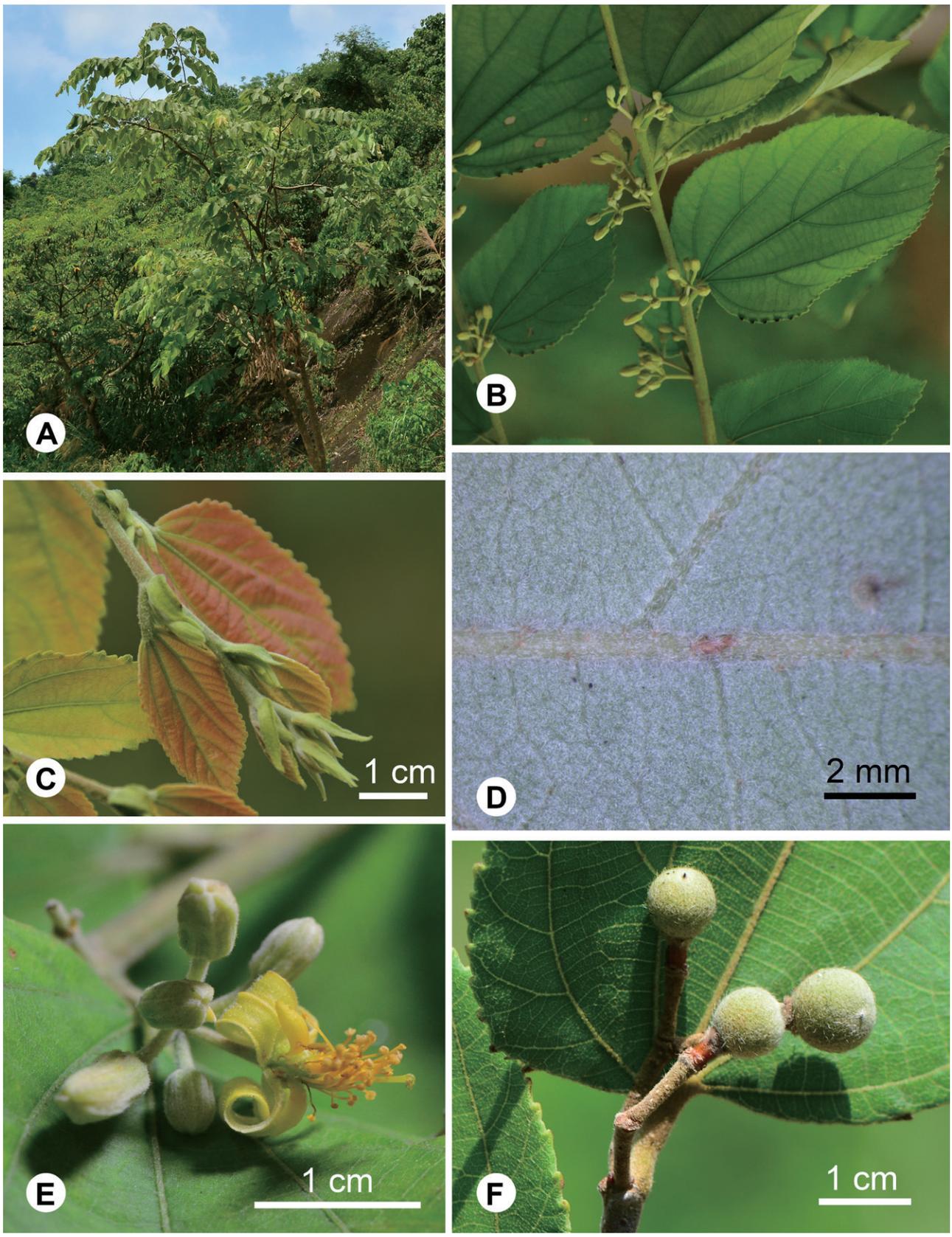

Fig. 5. *Grewia eriocarpa* Juss. A: Habitat. B: Habit. C: Young shoot. D: Leaf, abaxial surface. E: Inflorescences. F: Immature fruit.

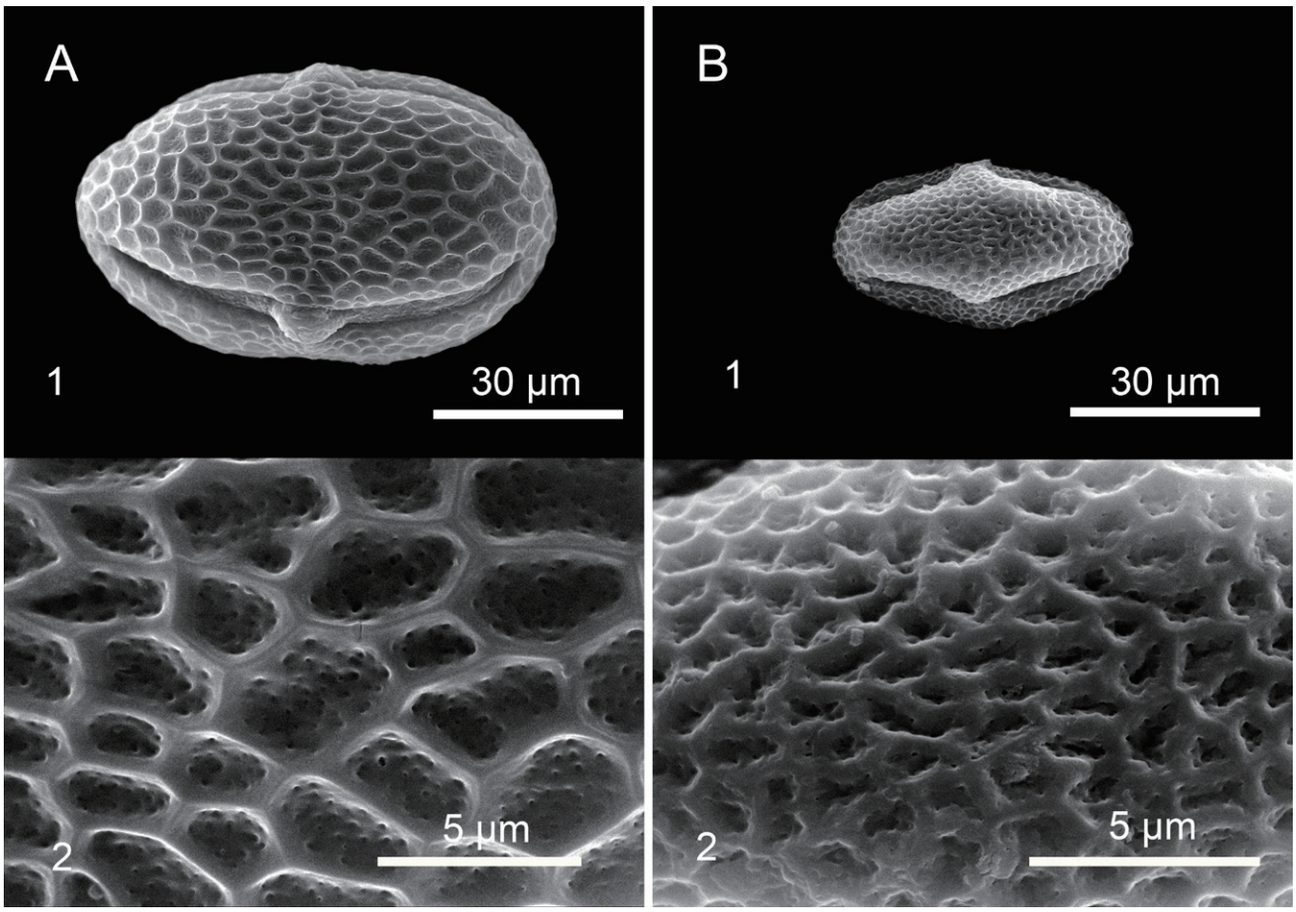

Fig. 6. Comparison of pollen morphology of allied species. A: *Grewia tiliifolia* Vahl. B: *Grewia eriocarpa* Juss. 1: Equatorial view. 2: Sculpturing.

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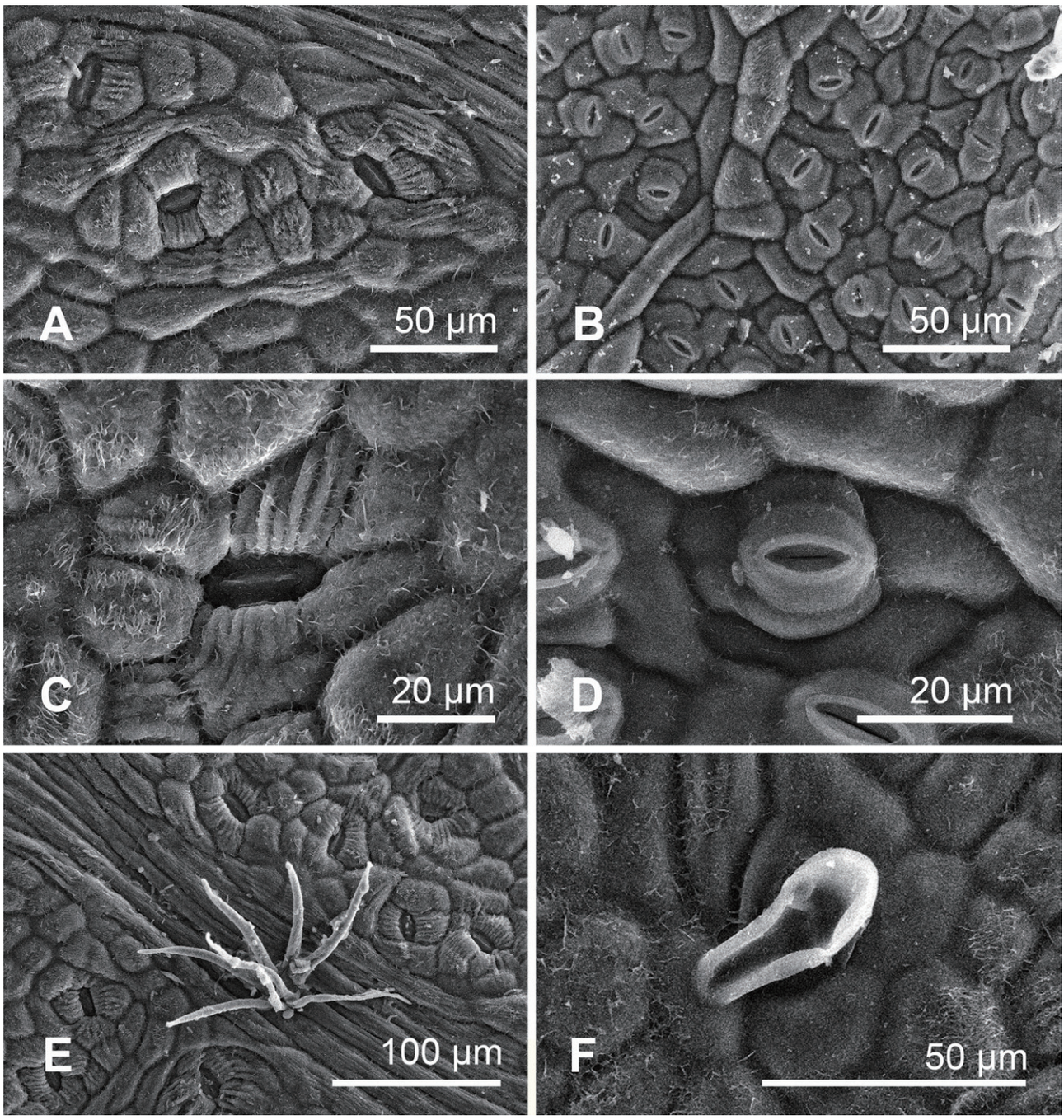

Fig. 7. Epidermal structure of *Grewia tiliifolia* Vahl (by SEM). A: Leaf, adaxial surface. B: Leaf, abaxial surface. C: Stomatal apparatus of leaf adaxial surface. D: Stomatal apparatus of leaf abaxial surface. E: Stellate hair. F: Glandularity hair.

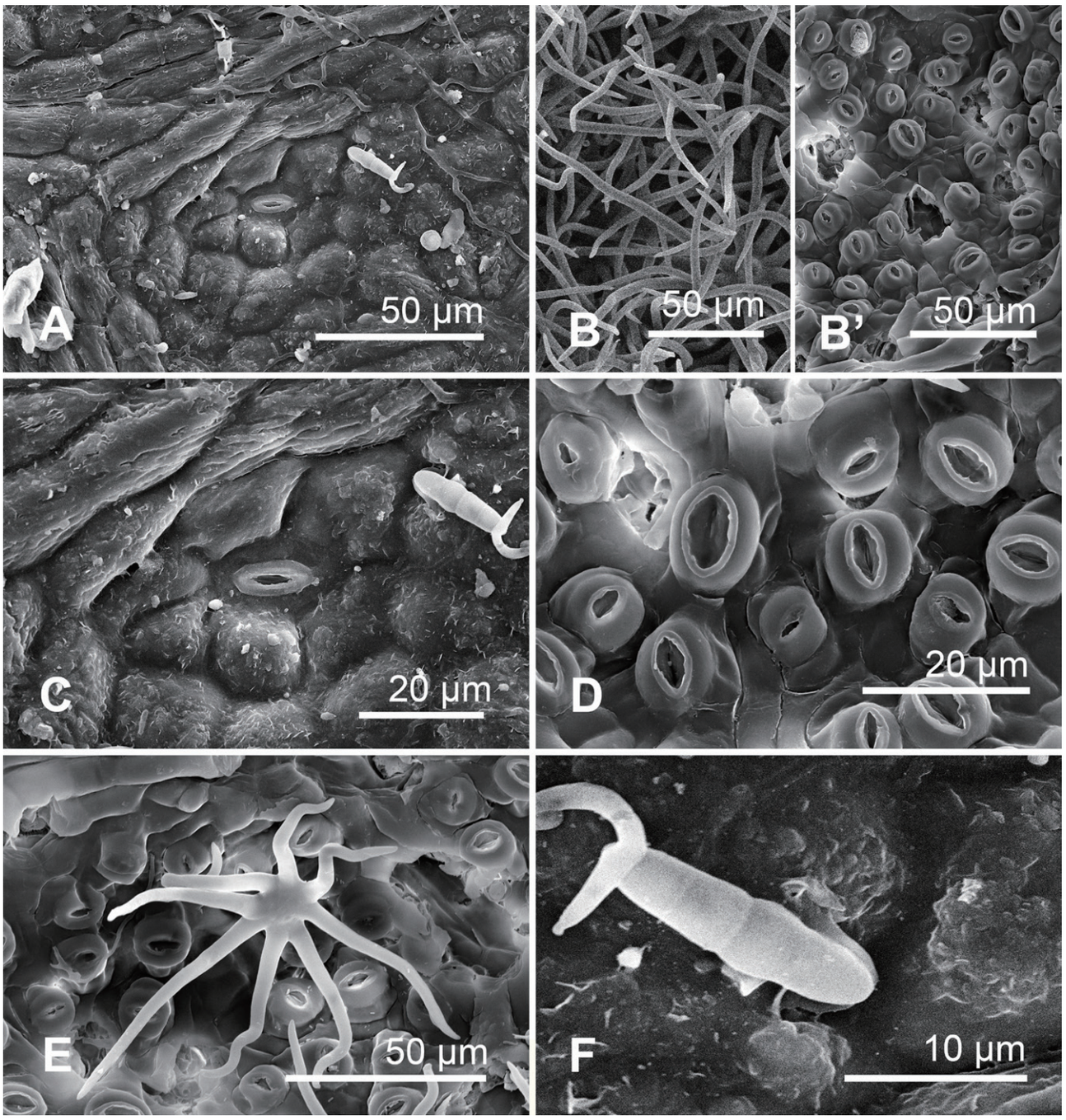

Fig. 8. Epidermal structure of *Grewia eriocarpa* Juss. (by SEM). A: Leaf, adaxial surface. B: Leaf, abaxial surface. B': With stellate hair removed. C: Stomatal apparatus of leaf adaxial surface. D: Stomatal apparatus of leaf abaxial surface. E: Stellate hair. F: Glandularity hair.

臺灣產捕魚木屬(錦葵科)新紀錄植物－椴葉捕魚木

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臺灣的椴葉捕魚木 (*Grewia tiliifolia* Vahl) 最早由Henry (1896) 所記載，但是Li (1963) 指出該份紀錄爲大葉捕魚木 (*G. eriocarpa* Juss.) 的誤認。因此，臺灣至今無椴葉捕魚木的紀載。最近，我們發現椴葉捕魚木亦爲臺灣原生種，爲本種世界分布的東北界。本種與大葉捕魚木最主要的區別在於本種葉背近平滑，果被長柔毛，而大葉捕魚木的葉背及果實則是密布星狀毛。本文提供椴葉捕魚木的彩色照片、形態描述、花粉及葉表皮特徵、分布圖、彩色手繪圖，並比較與大葉捕魚木的差異，以供分類參考。

關鍵詞：椴葉捕魚木、大葉捕魚木、錦葵科、新紀錄、臺灣