Taxonomic revision of the genus Heliotropium (Boraginaceae s.l.) in south Yemen

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Taxonomic revision of the genus *Heliotropium* (Boraginaceae s.l.) in south Yemen

Salah El Naggar, Azza El-Hadidy and Asmaa Olwey

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The flora and fauna of Arabia, particularly southern Yemen, has recently attracted the interest of many authors. In this study, the genus *Heliotropium* L. (Boraginaceae) is taxonomically revised in southern Yemen. Ten species are recognized. Nomenclature, typification, representative specimens and a diagnostic key to all species are provided, along with their distribution in southern Yemen. The taxonomically most valuable characters in the genus are those of flowers (calyx, corolla, androecium and gynoecium) and nutlets, and those characters are thoroughly investigated and discussed. Both light and scanning microscopy are used in the investigation. Papillate anther apices (brush-like) were recognized in some species. Connate anthers and deep or shallow ventral circular depressions on the nutlets were found to be useful in distinguishing members of *H.* sect. *Orthostachys* (viz. *H.* strigosum, *H.* rariflorum and *H.* ovalifolium), while winged nutlets were found only in *H.* pterocarpum. The length and hairiness of the style and stigma also proved to be taxonomically useful.

Boraginaceae s.l. is one of the largest families of dicotyledonous angiosperms. On the account of its broadly drawn limits, it faces some debate on both the ordinal and the infra-familiar levels. It was placed in an uncertain ordinal position by the Angiosperm Phylogeny Group, APG III (2009) [Eudicots – Asterids, subgroup Euasterids I]. The phylogenetic relationships within the family are still unclear. Currently, a concept of six sub-families (Codonoideae, Wellstedioideae, Cordioideae, Ehretioideae, Heliotropioideae and Boraginoideae) is still widely accepted. However, a taxon of ordinal rank (Boraginales), comprising six smaller families (Boraginaceae s.s., Hydrophyllaceae, Heliotropiaceae, Cordiaceae, Ehre-tiaeae, Codonaceae and Wellstediaceae) is increasingly being used instead of Boraginaceae s.l (Böhle and Hilger 1997, Ferguson 1999, Smith et al. 2000, Gottschling et al. 2001, 2004, Stevens 2001, Hilger et al. 2005, Cohen 2013, Refulio-Rodriguez and Olmstead 2014, Weigend et al. 2014).

The terminal style (in contrast to the gynobasic style of sub-family Boraginoideae), and its uniquely modified stigmatic head that consists of a basal annulus and a conical infertile apex, are the best characters distinguishing the sub-family Heliotropioideae. Recently, a phylogenetic analysis using data obtained by *trnL* and ITS 1 gene sequences supported the idea of raising Heliotropioideae to the familiar rank as Heliotropiaceae Schrad. (Diane et al. 2002, Hilger and Diane 2003). At the same time, generic limits have also changed dramatically. Within Heliotropiaceae Schrad, a system of five genera was initially suggested: *Euploca* Nutt., *Heliotropium* L., *Ixorhea* Fenzl, *Myriopus* Small and *Tournefortia* L. Recently, the genus *Euploca* Nutt. has increasingly accepted as a valid genus (Melo and Semir 2006, 2009, 2010, Melo et al. 2009, Acevedo-Rodriguez and Strong 2012, Degen Naumann and Melo 2012), while the validity of the genus *Tournefortia* L. as a separate genus has become questioned and some authors prefer to nest it within *Heliotropium* L. (Craven 2005, Luebert et al. 2011).

Recently, biogeographers have recognized the southwestern region of the Arabian Peninsula and southern Yemen as a part of the floristic hotspot the African Horn (Mittermeier et al. 1998, Myers et al. 2000). *Heliotropium* L. in Arabia, and particularly in Yemen, has always been problematic. Many species exhibit great polymorphism that make them hard to identify accurately. Hence, the number of *Heliotropium* species accepted as represented in Yemen has changed through time. Forsskål (1775) was the first to report 5 taxa belonging to *Heliotropium* in the area, while and Deflers (1889) recorded 7 species. Recently, Gabali and Al-Gifri (1990) recorded 10 species, Wood (1997) reported the presence of 12 species, while Boulos (1988) accepted 9 species and two subspecies.

The present study aims were to: 1) revise the different taxa belonging to *Heliotropium* L. in the flora of Yemen, 2) evaluate the taxonomic characters and attempt to find new ones that can be used in the classification of the genus in the region, and 3) provide a revised synopsis and a diagnostic key for the genus in Yemen.
Material and methods

Plant material

Morphological data of Yemen taxa of *Heliotropium* were scored by examination of herbarium specimens collected from different localities in southern Yemen, representing different habitats, and kept at ASTU. Some Saudi Arabian specimens were also investigated. High quality digital photos of type specimens and authentic material were seen by the authors as indicated by (!) in the text.

Light microscopy

Willd 8 and Willd 3 Zewz stereomicroscopes were used. Illustrations were made with a Camera Lucida and photographs with a Canon IXUS 960 IS digital camera.

Scanning electron microscopy (SEM)

Material for SEM were prepared by mounting plant segments onto clean stubs using double-sided cello tape. The stubs were coated with gold in a JEOL JFC 1100 E ion sputtering device, and then examined in a JEOL JSM 5400LV scanning electron microscopy operated at an accelerated voltage of 15 kV at the Electron Microscopy Unit (EMU), Assiut Univ., Egypt. Terminology follows Lawrence (1959), Radford et al. (1974) and Harris and Harris (1994).

Synopsis of the genus *Heliotropium* L. in south Yemen

The infra-generic classification proposed by Förther (1998) is followed here as outlined below, with the species (numbered) represented in Yemen indicated within each section and subsection.

**Heliotropium** L. (1753, p. 130)


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Key to the species

1. Corolla completely yellow, or yellowish green; anthers bidentate .................................. 10. *H. zeylanicum*  
   2. Inflorescence bracteate; calyx-lobes unequal; nutlets with ventral cavities .......................... 3  
   3. Inflorescence ebracteate; calyx-lobes equal or not; nutlets with or without ventral cavities ...... 4  
   4. Subshrubs or herbs; bracts prominent; corolla 1.5–2.0 (–2.5) mm long; anthers with erect apiculate apex; stigma depressed ............................................ 3. *H. rariflorum*  
   5. Herbs; bracts reduced upwards; corolla 2.0–4.0 mm long; anthers with curved apiculate apex, stigma not depressed .................................................. 2. *H. strigosum*  
   6. Style at least 0.2 mm long ............................................. 7  
   7. Flowers lax, in 1-rank, swollen at the base; anther ovate, inserted 1.00–1.25 mm from the base; style 0.2–0.5 mm long; stigma 0.50–0.75 mm long, glabrous, longer than the style .................................. 7. *H. ramosissimum*  
   8. Flowers dense, in 2-ranks, swollen at the middle; anther oblong-lanceolate, inserted 0.5–1.0 mm from the base; style 0.5–0.7 mm long; stigma 0.7–1.0 mm long, glabrous, or with few scattered hairs, equaling or longer than the style .................................. 6. *H. bacciferum*  
   9. Nutlets 2 (2-seeded), with symmetric groove at apex; leaves 0.5–4.0 × 0.3–2.0 cm .................. 9  
   9. Nutlets 4 (1-seeded), without groove; leaves longer and wider, up to 10.0 cm long and 7 cm wide .... 9. *H. longiflorum*  
   10. Greyish annual; calyx-lobes unequal; stamens inserted below the middle of the corolla-tube; anthers 1.0–1.5 mm long; style 0.5–0.7 mm long; nutlets narrowly to broadly winged ........................................ ..... 8. *H. pterocarpum*  
   11. Grey perennial; calyx-lobes equal; stamens inserted above the middle and reaching the throat; anthers 0.75–1.00 mm long; style 1.5–2.0 mm long, nutlets without wings ............................................. 5. *H. abyssinicum*
1. Heliotropium europaeum L. (1753, p.130) (Fig. 1a)


**Type:** Europe: Netherlands, G. Clifford s.n. (lectotype: BM, BM000557900!), cultivated material from the garden of George Clifford III: Hartekamp Garden, Holland (designed by Förther), for typification see Jarvis (1993, p. 57): *Heliotropium follis ovatis integerrimis, spicis conjunctis.*

**Taxonomic synonym:** H. majus Garsault (1764, t. 299) [nom. inval.].

**Description**
Annual to perennial herb, 20–50 cm high. Stem ± terete, erect, much branched. Leaves ovate to elliptic, 1.0–4.0 × 0.5–2.0 cm; apex obtuse; base cuneate; margin entire; petiole 0.5–3.5 cm. Inflorescence 2.0–7.0 cm long, dense, with 10–32 flowers in 2-ranks; flowers ebracteate, sessile. Calyx 5-lobed; lobes fused close to the base, equal, lanceolate to linear-oblong, 1.5–3.0 mm × 0.5–1.0 mm, hairy outside, glabrous inside. Corolla white, 2.0–3.5 mm, hairy outside on tube, glabrous inside; tube 1.5–2.5 mm long; lobes oblong-ovate to orbicular, 0.5–0.7 mm long. Stamens inserted at 0.8–1.0 mm from the base; anthers ovate, 1.00–1.25 mm long, apex ± acute and papillate; filament indistinct. Ovary globose to subglobose; style absent, stigma elongate conical to conical-subulate, 0.75–1.25 mm, deeply 2-fid at apex, glabrous. Fruit of 4 nutlets; nutlets ovoid, 1.5–2.5 × 1.0–2.0 mm, hairy, tuberculate-rugose.

**Distribution**
Mediterranean area northwards to central and southern Europe; Asia: south Russia, Caucasus, Iran, Turkey, Afghanistan, Pakistan and India; Saudi Arabia (Najran and Al Damam) and north Africa (especially in Libya). Yemen: Taiz, Lahj, Dhamar, Sanaa, Ibb and Hiddah.

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Figure 1. Habit of (a) *H. europaeum*, (b) *H. strigosum* var. *strigosum*, (c) *H. strigosum* var. *brevifolium*, (d) *H. rariflorum*, (e) *H. ovalifolium*. Scale: 1 cm in (a), 5 cm in the rest.
**Specimens examined**


**2. Heliotropium strigosum Willd.** (1798, p. 743) (Fig. 1b–c)


**Based on the same type:** *Euploca strigosa* (Willd.) Diane & Hilger (2003, p. 49).

**Type:** Ghana [Guinea], Isert s.n. (holotype: B, B-WILLLD 3253, isotypes: C, C10003972!; P, P-JU 6571).

Two varieties of *H. strigosum* can be recognized in Yemen:

1. Bracts linear–lanceolate (1.0–2.0 mm wide); corolla lobes triangular; nutlets small (1.0–1.2 mm) ……var. *strigosum* – Bracts ovate (2.0–3.0 mm wide); corolla lobes rounded; nutlets large (1.3–1.5 mm) …………..var. *brevifolium*

**Description**

Annual herb or short-lived perennial with woody base, 5–40 cm high. Stem ± terete, much-branched; branches prostrate to erect. Leaves lanceolate to linear or narrowly elliptic, 0.5–4.0 × 0.1–0.5 cm; apex acute; base cuneate; margin revolute; petiole 0.1–0.2 cm. Inflorescence lax, 1.5–8.5 cm, of 5–15 flowers in 1-rank; flowers bracteate (bract 1.0–3.0 mm), subsessile or shortly pedicellate; pedicel 0.5–1.5 mm. Calyx 5-lobed; lobes fused close to the base, unequal, ovate to narrowly elliptic, 1.5–3.0 × 0.50–0.75 mm, hairy outside, glabrous inside. Corolla white, 2.5–4.0 mm, hairy outside on lobes and upper part of tube, hairy inside above the anthers; tube 2.0–3.0 mm; lobes triangular or rounded to oblong, 0.5–1.0 mm. Stamens inserted 1.00–1.25 mm from the base; anthers conenate when young, ovate, 0.75–1.00 mm, their apex apiculate and hairy, with connective tissue prolonged and curved; filament ca 0.1 mm. Ovary globose to subglobose; style 0.25–0.50 mm, glabrous; stigma short conical, (0.30–) 0.50–0.75 mm, 4-lobed at apex, hairy and papilllose, longer than or equal to the style. Fruit of 4 nutlets; nutlets ovoid, 1.0–1.5(–2.0) × 0.5–1.0 mm, hairy, with two deep ventral circular depressions.

**Distribution**

Egypt; tropical region of Africa; Saudi Arabia (Najran and Hejaz); Asia: Pakistan, Iran, India and Sri-Lanka; and eastern Asia: China and Japan. Yemen: Taiz, Lahj, Tihama, Abyen, Hadhramaut and Socotra.

**Specimens examined**


*Heliotropium strigosum* var. *brevifolium*: Yemen. Hamood s.n., Tor El-Baha, Jun 2012; El Naggar and Hamood s.n., Top of Jisr Akan (Akan Bridge), 1 Jun 2012.

**3. Heliotropium rariflorum** Stocks (1852, p. 174) (Fig. 1d)


**Type:** Pakistan, Scinde, Jemadar Ka Landa near Kurrachi [Karachi], Stocks 492, 1851 (lectotype: K). For typification see Akhani and Förther (1994, p. 260).

**Taxonomic synonym:** *H. pseudostrigosum* Dinter (1922, p. 250).

**Description**

Strigose subshrub or perennial herb with woody base, 40–80 cm high. Stem terete, erect, much-branched; branches with white peeling epidermis. Leaves lanceolate to linear, 0.4–2.0 × 0.1–0.5 cm; apex acute; base cuneate; margin revolute; sessile or shortly petioled with petiole up to 0.1 cm long. Inflorescence lax, 1.3–9.0 cm, of 6–20 flowers in 1-rank; flowers bracteate and pedicelled; bracts linear-lanceolate, 1.5–2.5 mm; pedicel 0.5–1.0 mm. Calyx 5-lobed; lobes fused close to the base, unequal, lanceolate to ovate, 1.0–2.0 × 0.5–1.0 mm, hairy outside, glabrous inside. Corolla white, 1.5–2.5 mm, hairy outside and inside; tube 1.5–2.0 mm; lobes ovate to oblong, 0.5–1.0 mm, curved inwards. Stamens inserted 1.00–1.25 mm from the base; anthers conenate when young, ovate, 0.5–1.0 mm long, apiculate at apex, with connective tissue prolonged and erect; filament ca 0.1 mm long. Ovary subglobose; style 0.5–0.1 mm, papillate, two to three times longer than stigma; stigma depressed capitulate/conical, 0.2–0.5 mm, entire at apex, papilllose and with apical tufts of hairs. Fruit of 4 nutlets; nutlets ovoid, (1.0–) 2.0–2.5 × 1.0–1.5 mm, hairy, with two ventral circular depressions.

**Note**

According to Verdcourt (1991), *H. rariflorum* can be divided into two subspecies: subsp. *rariflorum* and subsp. *hereoense* (Schinz) Verdc. This classification is based upon nutlet hairs. Our specimens are characterized by spreading bristly hairs on nutlets which matches subspecies *rariflorum*.

**Distribution**

Northeast tropical Africa (in Dijouti, Eritrea, Ethiopia, Sudan and Somalia); tropical Africa (in Kenya, Tanzania, Angola and Namibia); Arabia (Saudi Arabia: Asir); Asia (Iran and Pakistan). Yemen: Lahj, Aden, Abyen and Socotra.

**Specimens examined**

Yemen. Hamood s.n., Tor El-Baha, 2012.

**4. Heliotropium ovalifolium** Forssk. (1775, p. 38) (Fig. 1e)

Type: [Yemen]; Al-Hadiyah [Hadīe], 3.1763 Forsskål 299 (holotype: C, C10002362!, isotype: BM).


Description
Greyish herbaceous annual or short-lived perennial, 10–90 cm high, woody at the base, covered with appressed hairs. Stem ± terete, much-branched; branches procumbent or erect to ascending. Leaves ovate or elliptic, 0.5–5.0 × 0.3–3.0 cm; apex acute; base attenuate; margin entire; petiole 0.2–2.0 cm. Inflorescence dense, 2.0–10.0 cm, of 10–30 flowers in 2-ranks; flowers ebracteate, sessile or shortly pedicelled with pedicle 0.5–1.5 mm. Calyx 5-lobed; lobes fused close to the base, unequal with one lobe distinctly larger, ovate to lanceolate-oblong, 1.0–3.0 × 0.2–0.8 mm; hairy outside, glabrous inside. Corolla white, 3.0–5.0 mm long, hairy outside and inside; tube 2.0–4.0 mm; lobes ovate to oblong or elliptic, 0.5–1.0 mm. Stamens inserted 0.75–1.00 mm from the base; anthers connate when young, elliptic to ovate, 0.5–1.0 mm long, apiculate and hairy at apex, with connective tissue prolonged, elongated and curved; filament indistinct. Ovary subglobose; style absent; stigma short conical, 0.5–1.0 mm, 2-lobed at apex, papilllose and with apical hairs. Fruit of 4 nutlets; nutlets ovoid to elliptic, 1.0–2.0 × 1.0–1.5 mm, hairy, with two ventral circular depressions.

Distribution
North Africa: Egypt and Libya; Arabia (Oman: Dhofan); southeast Asia; tropical Africa: Somalia, New Guinea, Madagascar and Mascarene Islands; with slight extension to Australia and Europe (in Turkey). Yemen: Taiz, Bura’a, Lahj, Tihama and Socotra.

Specimens examined

5. *Heliotropium abyssinicum* Vatke (1875, p. 168) (Fig. 2a)


Description
Perennial herb, 10–100 cm high, woody at the base. Stem terete, branched; branches erect to ascending. Leaves broadly ovate, 0.5–4.0 × 0.3–2.0 cm; apex acute; base cuneate; margin undulate; petiole 0.5–2.0 cm. Inflorescence lax, 1.1–6.0 cm, of 10–27 flowers in 2-ranks; flowers ebracteate, sessile. Calyx 5-lobed; lobes free almost to the base, equal, lanceolate to lanceolate-oblong, 1.5–2.0 × 0.2–0.4 mm; hairy outside, glabrous inside. Corolla white with green center, 4.0–7.0 mm, hairy outside, glabrous inside; tube 3.5–4.0 mm; lobes ovate, 1.5–2.0 mm. Stamens inserted 2.25–2.50 mm from the base; anthers oblong, 0.75–1.00 mm, acute at apex; filament indistinct. Ovary globose to subglobose; style 0.5–2.0 mm, glabrous, distinctly longer than stigma; stigma elongate conical, 0.5–1.0 mm; apex shortly 2-fid, glabrous. Fruit of 2 nutlets; nutlets broadly ovoid and shallowly notched at apex and base, 2.0–2.5 × 1.5–2.0 mm, with a shallow groove at the middle from apex to base, laterally constricted near apex, hairy, rugulose.

Distribution

Specimens examined

6. *Heliotropium bacciferum* Forssk. (1775, p. 38) (Fig. 2b–c)


Description
Perennial herb, 20–40 cm high, woody at the base, covered by scabrous indumentum. Stem terete, much-branched; branches erect or ascending. Leaves lanceolate to linear, 0.5–3.0 × 0.5–1.5 cm; apex acute; base cuneate or attenuate; margin undulate-crenate and revolute; petiole 0.0–1.0 cm. Inflorescence dense, 0.5–4.2 cm, of 5–13 flowers in 2-ranks; flowers ebracteate, sessile. Calyx 5-lobed; lobes free almost to the base, equal, ovate-oblong or lanceolate, 1.0–3.0 × 0.5–0.75 mm, hairy outside and in the upper part inside. Corolla white, 3.0–5.0 mm, hairy on tube outside, glabrous inside; tube 2.0–4.0 mm; lobes ovate to oblong or suborbicular, 0.5–1.5 mm. Stamens inserted 0.5–1.0 mm from the base; anthers oblong-lanceolate, 0.75–1.00 mm, acute or shortly apiculate at apex; filament indistinct. Ovary ovate; style 0.4–0.7 mm, glabrous; stigma elongate conical, 0.7–1.0 mm (with stigmatic ring 0.1–0.2 mm high), 2-/4-lobed or 2-fid at apex, glabrous or with few scattered hairs, equaling or longer than style. Fruit of 4 nutlets; nutlets ovoid to elliptic,
1.5–2.0 × 0.75–1.00 mm, with narrow wing-like margins, hairy or glabrous, often with corky tissue, rugulose.

**Distribution**
Extending from Egypt in Mediterranean north Africa eastwards to Pakistan, southwards in Sudan and northeast Africa and in Saudi Arabia (Asir). Yemen: Taiz, Ibb, Sana’a, Tihama and Hadhramaut

**Specimens examined**

7. *Heliotropium ramosissimum* (Lehm.) Sieb. ex A. DC., in DC. (1845, p. 536) (Fig. 2d–e)


**Basionym:** *H. undulatum* Vahl var. *ramosissimum* Lehm. (1831, p. 24, t.40).

**Taxonomic synonym:** *H. persicum* Boiss. (1875, p. 147), non Lam. (1789). Schwartz (1939, p. 207).

**Description**
Perennial herb, 20–50 cm high, woody at the base, covered by scabrous indumentum of simple hairs associated with white sharp bristles. Stem terete, much-branched; branches erect
or ascending. Leaves elliptic, 0.5–3.0 × 0.5–1.5 cm; apex acute; base cuneate or attenuate; margin undulate-crenate to entire and revolute; petiole 0.0–1.0 cm. Inflorescence lax, 0.5–1.5 cm, of 5–14 flowers in 1-rank; flowers ebracteate, sessile. Calyx 5-lobed; lobes free almost to the base, equal, lanceolate-oblong to lanceolate, 1.0–3.0 × 0.50–0.75 mm, hairy outside, hairy inside. Corolla white, 3.0–5.0 mm long, hairy on tube outside, glabrous inside; tube 2.0–4.0 mm long; lobes ovate to oblong or suborbicular, 1.0–2.0 mm. Stamens inserted at 1.00–1.25 mm from the base; anthers ovate, 0.75–1.00 mm long, apex acute or shortly apiculate; filament indistinct. Ovary globose to ovate; style 0.2–0.5 mm, glabrous; stigma elongate-conical, 0.50–0.75 mm, 2(4-)lobed at apex, glabrous, equaling or longer than style. Fruit of 4 nutlets; nutlets ovoid, 1.0–1.5 × 0.75–1.00 mm, with narrow wing-like margins, hairy or glabrous, rugulose.

**Distribution**
Extending from India westwards through Iran, Afghanistan and southwest Asia to Palestine, Egypt (Sinai); across north Africa to Morocco and southwards to northeast Africa, and in eastern and northeastern Arabia. Yemen: Jisr Akan between Taiz and Lahj, Socorta.

**Specimens examined**
Yemen. El Naggar and Hamood s.n., Top of Jisr Akan (Akan Bridge), 1 Jun 2012.

8. *Heliotropium pterocarpum* (A. DC.) Hochst. & Steud. ex Bunge (1869, p. 331) (Fig. 2f)


**Basionym:** *Heliophytum pterocarpum* A. DC. in DC. (1845, p. 552).

**Type:** Arabia, in planitia deserti prope Dscheddam, 29 Feb 1836. Schimper 835 (ed. 1, 1837, ed. 2, 1843) (holotype: G-DC, styntype: K).

**Taxonomic synonym:** *Heliotropium deserti* Vatke (1875, p. 166).

**Description**
Annual herb, 10–55 cm high, covered with scabrous indument of white bristles intermixed with simple deflexed hairs. Stem terete, simple or branched; branches prostrate to ascending. Leaves rhombic-ovate, 0.5–3.5 × 0.3–1.5 cm; apex acute or obtuse; base attenuate; margin undulate-crenate; petiole 0.2–0.5 cm. Inflorescence very dense and crowded, 0.5–1.2 cm long, of 8–14 flowers in 2-ranks; flowers ebracteate, sessile. Calyx 5-lobed; three lobes free almost to the base and two connate almost to the top, unequal, oblong to linear, 3.5–4.5 × 0.5–1.0 mm, hairy outside and inside. Corolla white, (3.5–) 4.0–7.0 mm, hairy on tube outside, glabrous inside; tube 3.5–5.0 mm; lobes ovate, 0.8–2.0 mm long. Stamens inserted 1.5–2.0 mm from the base; anthers lanceolate, 1.0–1.5 mm, acute or apiculate at apex; filament indistinct. Ovary subglobose to elliptic; style 0.5–0.7 mm, glabrous; stigma elongate conical, 0.4–0.6 mm, obscurely 4-lobed at apex, papilllose, equaling or shorter than style. Fruit of 2 nutlets; nutlets ± oblong (excluding wings) and with a deep sinus at apex and base, 2.0–3.0 × 3.0–4.0 mm (excluding wings), winged (narrow to broad, wings 1.0–3.0 mm wide), glabrous, minutely tuberculato and rugulose.

**Distribution**
North Africa: Egypt; western Arabia; northeast tropical Africa through Sudan and Ethiopia. Yemen: Jisr Akan, Lahj, Taiz, Tihama and Hadhramaut.

**Specimens examined**

9. *Heliotropium longiflorum* (A. DC.) Jaub. & Spach (1852, p. 96, t. 360) subsp. *longiflorum* (Fig. 2g)


**Basionym:** *Heliophytum longiflorum* A. DC. in DC. (1845, p. 555).

**Type:** Arabia: Saudi Arabia; Djebel Sidr [Mt Sedder], inter ruptes montis Sedder Arabiae felicism 29 Feb 1836, Schimper 842 (holotype: G-DC, GH00097510!, isotype: BM).

**Taxonomic synonym:** *H. gracile* R. Br. (1814, p. 62) [Nom. nud.].

Two varieties of *H. longiflorum* can be recognized:
1 Leaves ovate, 0.5–1.5 cm wide; inflorescence 10.5–23.0 cm long, slightly lax; corolla constricted above the base ......................................................... var. *longiflorum* – Leaves linear-lanceolate, 0.2–0.5 cm wide; inflorescence 5.0–10.0 cm long; more dense, corolla not constricted … .......................................................... var. *stenophyllum*

**Description**
Perennial herb, 50–60 cm high, woody at the base, densely covered with 2-branched unicellular hairs (T-shaped). Stem ± terete, branched; branches erect to ascending. Leaves ovate, 1.0–6.0 × 0.1–3.5 cm; apex acute; base cuneate; margin entire; petiole 0.1–2.0 cm. Inflorescence lax to slightly dense, (2.0–)10.0–15.0 cm, of 22–77 flowers in 1-rank; flowers ebracteate, sessile. Calyx 5-lobed; lobes free almost to the base, equal, oblong to lanceolate-linear, 0.5–1.5 × 0.2–0.5 mm, hairy outside, glabrous inside. Corolla white, 3.0–6.0 mm, hairy outside, glabrous inside; tube 2.0–4.0 mm; lobes triangular, 1.0–1.5(–2.0) mm. Stamens inserted 1.0–2.5 mm from the base; anthers lanceolate or lanceolate-oblong, 1.0–2.5 mm, obtuse apex at; filament ca 0.1 mm. Ovary subglobose, glabrous; style 0.5–1.5 mm, glabrous; stigma elongate conical, 0.5–1.0 mm, apex shortly 2- or 4-fid, glabrous, shorter than style. Fruit of 4 nutlets;
nutlets ovoid, (1.5–) 2.0–3.0 × 1.0–1.5 mm, with ridge-like margin, glabrous, reticulate-rugose; margin rugose to aculeate.

**Distribution**


**Specimens examined**


10. *Heliotropium zeylanicum* (Burm. f.) Lam. (1789, p. 94) (Fig. 2h)


**Basionym:** *H. curassavicum* L. var. *zeylanicum* Burm.f. (1768, p. 41, t. 16/2).

**Type:** south India: Madras; Tutikorin, Garcin s.n. (holotype: G-BURM).


**Description**

Perennial herb, 30–60 cm high, woody at the base. Stem terete, branched; branches erect. Leaves lanceolate to linear, 0.8–10.0 × 0.2–2.5 cm; apex acute; base attenuate; margin entire; petiole (0.1–)0.3–1.5 cm. Inflorescence lax, (5.0–)10.0–23.0 cm, of 11–34 flowers in 1-rank; flowers ebracteate, sessile. Calyx 5-lobed; lobes free almost to the base, equal, ovate to narrowly elliptic, 1.0–3.0 mm × 0.5–1.0 mm, hairy outside and in the upper part inside. Corolla yellow to yellowish green, 5.0–7.0 mm, hairy outside, glabrous inside; tube 3.0–4.0 mm; lobes ovate, 2.0–3.5 mm, with small intercalary teeth. Stamens inserted 1.5–2.5 mm from the base; anthers oblong-lanceolate, 1.0–1.5 mm, apex bidentate; filament indistinct. Ovary globose, glabrous; style 0.7–1.5 mm, glabrous; stigma elongate-conical, 1.0–1.7 mm, 2-lobed at apex, hairy throughout and with apical tufts, longer than or equaling style. Fruit of 4 nutlets; nutlets ovoid, 1.5–2.0 × 1.0–1.5 mm, glabrous, rugose.

**Distribution**

Egypt; Arabia; Pakistan; India; tropical Africa; south Africa; Madagascar and Mascarene Islands. Yemen: Taiz, Sana’a, Tihama, Lahj and Socotra.

**Specimens examined**


**Discussion**

In spite of its distinct characters, taxonomically, *Heliotropium* is considered a difficult genus in the flora of Yemen, and it has not got proper attention. In the classical works, the taxonomy of *Heliotropium* in Yemen was poorly investigated under the wide-scope floristic studies of the Arabian Peninsula (Forsskål 1775, Deflers 1889). Perhaps, the most comprehensive floristic study of Yemen is the one done by Wood (1997). However, it lacks synonyms as well as type citations. Many unclear matters concerning the recognition of *Heliotropium* taxa in Yemen were still debatable. For example, there have been no clear delimitation of *H. bacciferum*, *H. ramosissimum* and *H. pterocarpum*; some authors such as Akhani and Förther (1994) and Förther (1998) preferred to treat *H. bacciferum* and *H. ramosissimum* as a species complex under the name of *H. bottae*. In the other hand, Wood (1997) stated that the type of *H. bacciferum* described by Forsskål from Luhayyah, seemed to be *H. pterocarpum*, and consequently he excluded *H. bottae* from the flora of Yemen, here, we recognize that type to be *H. bacciferum* and is fairly distinct from *H. pterocarpum*. Another case is in the taxonomy of *H. bottae*, which was described by Wood (1997) as having 4 nutlets; the specimen seems to be misidentified, because that taxon has only two nutlets and here that taxon is treated under the name *H. abyssinicum*. There is another plant in Somalia and tropical Africa that is morphologically very close to *H. abyssinicum*; Thulin (2006) treated these as one species under the name *H. steudneri* Vatke, however, this point still need to be clarified by examination of Somali and African specimens.

In recent few years, some check-lists claimed to comprise all the plant taxa in the flora of Yemen. However, these lists still need critical taxonomic revision. For example, in the list by Al-Khulaidi (2013), the number of species of *Heliotropium* L. in Yemen (including Socotra) is as high as 44 (and only 5 of them are endemic to Socotra). That number is clearly exaggerated, and is caused by misuse of synonyms.
Nomenclature suggestions

The name *H. absiniscum* is found to have priority over *H. bottae*. As varietal epithets, *strigosum* and *bervifolium* seem to have priority for the two varieties of *H. strigosum* (instead of var. *bicolor* and var. *cordofanum* used by some authors). A full list of synonyms for taxa of *Heliotropium* L. can be found in Förther (1998).

Many authors have stressed the paramount taxonomic importance of reproductive characters in the taxonomy of *Heliotropium*, among them Brown (1810), De Candolle (1845), Bunge (1869), Boissier (1875), Clarke (1885), Güürke (1893), Johnston (1928), Riedl (1967) and Förther (1998). The following is a list of the most important morphological characters for distinguishing species of the genus in the flora of southern Yemen:

1) Calyx: shape and size of calyx-lobes have proved to be of taxonomic importance. *H. strigosum*, *H. rariflorum*, *H. ovalifolium* and *H. pterocarpum* possess unequal calyx lobes; while the other species possess equal ones (Fig. 3). The shape of the calyx lobes varies from ovate to lanceolate-oblong/ -linear, and the lobes varies in size, 0.5–4.5 × 0.2–1.5 mm.

2) Corolla: colour, length, distribution of hairs, shape and size of lobes, as well as the presence of intercalary teeth at the sinus, proved to be valuable. Flowers of *H. zeylanicum* are completely yellow, while the rest of the species possess white flowers. With respect to length, two categories can be recognized: 1) small-flowered species (2.0–5.0 mm long), 2) large-flowered species (5.0–9.0 mm long). *Heliotropium europaeum*, *H. strigosum*, *H. rariflorum*, *H. ovalifolium*, *H. bacciferum* and *H. ramosisissimum* belong to the first category; while *H. absiniscum*, *H. pterocarpum*, *H. longiflorum* and *H. zeylanicum* belong to the second (Fig. 4). The inside of the corolla is glabrous in most species, but hairy in three species: *H. strigosum*, *H. rariflorum* and *H. ovalifolium*. However, these latter species may be distinguished by the distribution of hairs on the outside of the corolla: corolla hairy throughout (in *H. rariflorum*) vs hairy in upper part only.

3) Androecium: shape, apex and connation while young proved to be variable characters. A bidentate apex is unique to *H. zeylanicum* (Fig. 5). Occasionally in *Heliotropium* species, the connective tissue is prolonged to form an apiculate, sterile apex. This apex is erect or curved, papillate (Fig. 6b) or glabrous, free or connate in young stages. Connate (Fig. 6a) and apiculate apices have been used to classify the genus into sections or subgenera (Brown 1810, Bentham and Hooker 1876, Riedl 1967, Verdcourt 1991, Förther 1998) as in *H. strigosum*, *H. rariflorum* and *H. ovalifolium* of sect. *Orthosyachys* (formerly as subgenus).

4) Style: presence or absence, length and surface of style are of paramount taxonomic value. *Heliotropium strigosum*, *H. bacciferum* and *H. ramosisissimum* possess glabrous styles; while papillate styles are typical for *H. rariflorum*. The style is short (0.2–0.5 mm long) in *H. ramosisissimum*, but relatively longer (0.5–0.7 mm) in the closely allied species *H. bacciferum*.

5) Stigma: shape of the stigma, length, apex, hairiness, and its relation to the style proved to be useful for distinguishing and separating certain taxa (Fig. 7). In the large-flowered species, the stigma is elongated-conical, 0.5–1.7 mm long. Among these, a stigma that is hairy throughout is diagnostic for *H. zeylanicum*. Among the small-flowered species, the stigma of *H. rariflorum* is unique by being depressed capitate or conical with entire apex; while it is short (squat-like) or elongated-conical with 2–4-lobed or -fid apex in the other species. A stigma that is hairy throughout distinguishes *H. strigosum*; while apical hairs separate *H. rariflorum*.

6) Fruit: on the basis of fruit characters (number, shape and surface), *Heliotropium* has been classified into sections (Bunge 1869, Förther 1998), subgenera (Riedl 1967) or even into separate genera (Don 1837). The fruit is separated into 4 (1-seeded) nutlets at maturity, or into 2 (2-seeded) nutlets, or reduced into 1 nutlet by abortion. In this study, nutlet characters proved to be useful in recognizing certain taxa:

![Figure 3. Shape of calyx in (a) H. europaeum, (b) H. strigosum, (c) H. rariflorum, (d) H. ovalifolium, (e) H. absiniscum, (f) H. bacciferum, (g) H. ramosisissimum, (h) H. pterocarpum, (i) H. longiflorum, (j) H. zeylanicum.](image-url)
Figure 4. Corolla of (a) *H. europaeum*, (b) *H. strigosum*, (c) *H. rariflorum*, (d) *H. ovalifolium*, (e) *H. abyssinicum*, (f) *H. bacciferum*, (g) *H. ramosissimum*, (h) *H. pterocarpum*, (i) *H. longiflorum*, (j) *H. zeylanicum*.

Figure 5. Anther shape of (a) *H. europaeum*, (b) *H. strigosum*, (c) *H. rariflorum*, (d) *H. ovalifolium*, (e) *H. abyssinicum*, (f) *H. bacciferum*, (g) *H. ramosissimum*, (h) *H. pterocarpum*, (i) *H. longiflorum*, (j) *H. zeylanicum*.

Figure 6. Androecium of *H. ovalifolium*. (a) LM photograph showing four anthers connate at the apex, (b) SEM micrograph of the anther apex showing clavate papillae.

a) Number and shape: most species in south Yemen possess 4 free nutlets (Fig. 8b, d, e, n). However, *H. pterocarpum* and *H. abyssinicum* have 2 (2-seeded) nutlets (Fig. 8g). *Heliotropium pterocarpum* (sect. *Pterotropium*) is unique by the presence of narrow to broad lateral wings and with a deep notch at apex and base of the nutlets (Fig. 8m); while nutlets of *H. abyssinicum* (sect. *Pseudocoelomea*) lack the lateral wings and has only a shallow notch at apex and base (Fig. 8h).

b) Surface: hairiness, presence or absence of ventral cavities and sculpture are regarded as important characters in distinguishing certain taxa. The nutlets are glabrous in *H. pterocarpum*, *H. longiflorum* and *H. zeylanicum*, while hairy in *H. strigosum*, *H. rariflorum*, *H. ovalifolium* and *H. abyssinicum*. In two species (*H. bacciferum* and *H. ramosissimum*), the nutlets are hairy or glabrous. Nutlets with a shallow groove at the middle from apex to base are found in *H. abyssinicum* (Fig. 8h). *Heliotropium strigosum* (Fig. 8c), *H. rariflorum* and *H. ovalifolium* (Fig. 8f) are uniquely possessing cavities (pits) on the ventral surface of the nutlets. These three species belong to the section *Orthostachys* as defined by this character (Johnston 1928, Frohlich 1978). Diane et al. (2003) recognized this character in some other taxa belonging to the same section.
Figure 7. Shape of gynoecium of (a) H. europaeum, (b) H. strigosum, (c) H. rariflorum, (d) H. ovalifolium, (e) H. abyssinicum, (f) H. bacciferum, (g) H. ramosissimum, (h) H. pterocarpum, (i) H. longiflorum, (j) H. zeylanicum.

Figure 8. SEM micrographs of fruit/nutlet of (a) H. europaeum, (b)–(c) H. strigosum var. strigosum, (d) H. rariflorum, (e)–(f) H. ovalifolium, (g)–(h) H. abyssinicum, (i)–(j) H. bacciferum, (k)–(l) H. ramosissimum, (m) H. pterocarpum, (n)–(o) H. longiflorum, (p)–(q) H. zeylanicum.
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