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Posted on 29/09/2020

DOI: <https://doi.org/10.3897/arphapreprints.e58902>

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Not peer-reviewed, not copy-edited manuscript submitted to:

PhytoKeys

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Taxonomic revision of *Ceropegia* sect. *Huernia* (Asclepiadoideae – Apocynaceae) in Saudi Arabia with four new combinations

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Abstract

This study provides a taxonomic revision for *Ceropegia* sec. *Huernia* in the flora of Saudi Arabia. Forty-eight quantitative and qualitative morphological characters were analysed using principal component analysis (PCA), principal coordinates analysis (PCoA) and the unweighted pairs group using mean average (UPGMA) to separate and help delimit taxa. We proposed to reduce the number of names reported in Saudi Arabia from 11 to four species: *C. arabica* **comb. nov.**, *C. khalidbinsultanii* **comb. nov.**, *C. laevis* and *C. lodarensis*. This study also suggested reducing two of Plowes' new names to a variety level under *C. lodarensis* (var. *foetida* **comb. nov.** and var. *rubrosticta* **comb. nov.**). A key to the species, detailed morphological descriptions, illustrations, distribution maps, ecology, etymology and preliminarily conservation assessments following IUCN criteria are provided.

Keywords

arid plants, *Huernia*, stapeliads, stem-succulent, the flora of Saudi Arabia, taxonomy, succulents of Arabian Peninsula

Introduction

The stapeliads, essentially stem-succulent leafless members of the tribe Ceropegieae (Asclepiadoideae, Apocynaceae), comprise 357 species placed in 31 genera. All of which were reduced to sections of *Ceropegia* after a broad circumscription of the genus based on a recent molecular study (Bruyns et al. 2017). The stapeliads are widely distributed in semi-arid to arid areas of the Old World from southern Africa north-eastwards to India and Myanmar (Bruyns 2005). Their flowers are among the most beautiful of the dicotyledons, as well as the most complex with almost all of them more or less scented

of carrion, or bad fish and similar pungent odours (Court 2000; Pillans 1920). They exhibit an extraordinarily wide range of floral shapes and sizes and a wide range of complicated structures in the centre of the flower that are associated with the pollination process (Bruyns 2005). The flowers are specialised exclusively for fly pollination and this diversity appears to have arisen in response to the wide range of sizes of flies that are present in the region combined with the wide spectrum of geological and topographical niches in the area (Bruyns 2005).

Ceropegia sect. *Huernia* (R.Br.) Bruyns (formerly the genus *Huernia* R.Br.) has the widest distribution of all stapeliads, extending from west of Al-Madinah in Saudi Arabia, north of the Tropic of Cancer, to near Cape Town in South Africa, to the south of the Tropic of Capricorn (Plowes and McCoy 2003). As can be expected in a section with a range this large, *Huernia* has a great number of species and subspecies, with over 54 species presently being recognised, making it the second diverse section in the stapeliads after *Caralluma* (Bruyns et al. 2017). It is distinguished from other angled-stemmed stapeliads by the leaf-rudiments without stipular denticles; corona very rarely raised above the base of the tube on a stipe, outer series spreading at the base of the tube and often partially fused to it, tube often with an annular thickening around the mouth, but not entirely formed by an annulus (Bruyns 2014). *Huernia* plants have almost identical stems so that the species cannot always be identified accurately without flowers. Flowers also sometimes show a variety of forms within a single species. Consequently, the number of species approved for *Huernia* has varied widely over time: 45 for White and Sloane (1937), 64 for Leach (1988), 49 for Bruyns (2005) and a little over 54 currently.

In Saudi Arabia, section *Huernia* is restricted to the mountainous area of the western and southwestern part of the country (the mountains of Sarat and Hejaz) (Collenette 2000). The famous plant collector, Mrs I. S. Collenette, was first to collect *Huernia* from Saudi Arabia. Between 1972 and 1998, she collected various undescribed species of *Huernia* with relatively large papillate flowers (Plowes 2014). These specimens have been deposited at the Royal Botanic Gardens herbaria at Kew (K) and Edinburgh (E). Only one species had previously been described by Field, in 1980, in the course of naming her collections at Kew, this was *H. saudi-arabica* D.V.Field (Field 1980). Somewhat later, in 1985, Collenette published her first book on Saudi Arabian plants, *An Illustrated Guide to the Flowers of Saudi Arabia*. She recorded two species, *H. lodarensis* Lavranos and *H. saudi-arabica*, and four unnamed species (Collenette 1985). In her subsequent publications (Collenette 1998; 1999; 2000), three species were recognised: *H. arabica* N.E.Br., *H. laevis* J.R.I.Wood and *H. saudi-arabica*. In addition to five species which lacked names some of them have an affinity to *H. boleana* M.G.Gilbert and *H. lodarensis*. Soon after, Al-Hemaid published the name *H. haddaica* for Collenette specimen No. 5944 from Al-Hadda (Al-Hemaid 2001) but this name has been shown not to be validly published (Goyder and Al-Hemaid 2009). Tom A. McCoy collected a similar plant in 1999 from Khamis Mushait, which flowered in the Darrel Plowes' study collections in Zimbabwe and was described in 2003 as *H. khalidbinsultanii* Plowes and McCoy (Plowes and McCoy 2003). Just two years later, in 2005, Bruyns reduced the number of *Huernia* species in north-eastern Africa and Arabia down to 14 species. In his treatment, he considered *H. saudi-arabica* and *H. khalidbinsultanii* synonyms of *H. Lodarensis*, and *H. arabica* synonym of *H. penzigii* N.E.Br. (Bruyns, 2005). However, this was not accepted by

Plowes who published seven new names for Collenette's other Saudi Arabian species of *Huernia* that lack of names (Plowes 2012; Plowes 2014). Thus, based on the taxonomic perspective of Plowes, *Huernia* in Saudi Arabia represented by 11 species: *H. anagaynensis* Plowes, *H. arabica*, *H. asirensis* Plowes, *H. collenetteae* Plowes, *H. decaloba* Plowes, *H. foetida* Plowes, *H. laevis*, *H. radhwana* Plowes, *H. rubrosticta* Plowes and *H. saudi-arabica*.

In fact, Plowes' classification of Saudi Arabian *Huernia* needs further investigation. His taxonomic treatment of several taxa was based on a single photo (e.g., *H. decaloba*) or a single specimen (e.g., *H. anagaynensis*, *H. radhwana*, *H. foetida*, *H. khalidbinsultanii*). Furthermore, morphological characters used by Plowes are not strong enough for species delimitation within sect. *Huernia*. For example, corolla tube size and its exterior colour, the number of flowers in the inflorescence and flower odour used as diagnostic characters to separate *H. anagaynensis*, *H. radhwana* and *H. asirensis*. Such characters are not considered to be constant in this complex group based on the observations of the first author. In addition, Plowes' description of the species is not sufficiently detailed and not even illustrated to make the distinction between closely related species more readily. Moreover, the relationship between Saudi *Huernias* and their allied species (e.g. *H. boleana* and *H. lodarensis*) is questionable. There is, therefore, a need for much more sampling with a detailed examination before a conclusive taxonomic statement on Saudi Arabian *Huernia* can be made.

Remarkably *Huernia* has received little taxonomic attention in Saudi Arabia, other than Plowes' work. The taxonomic revision of this plant group in Saudi Arabia is urgently needed. *Huernia* plants commonly used in traditional medicine, especially for diabetes treatments, in the western and southwestern regions of Saudi Arabia (Hamam et al. 2018). Ongoing investigations on the biological activities of Saudi *Huernias* are being performed actively (Ali et al. 1984; Almehdar et al. 2012; Alzahrani et al. 2015; El Sayed et al. 2020; El Sayed et al. 2018; Hamam et al. 2018; Mossa and Abdul Hameed 1991). However, in some recent studies (e.g., (Alzahrani et al. 2015; Hamam et al. 2018) *Huernia* have been identified as *Huernia* sp. nov. aff. *boleana* according to Collenette (1999) where many species lack taxonomic recognition. The precision and utility of medicinal investigations on *Huernia* of Saudi Arabia may be increased by providing detailed taxonomic treatment. It will also enable studies on the species' conservation status to be made, as it would appear that some of them are being severely threatened by overgrazing, infrastructure and housing development (Abulfatih and Nasher 1988; Collenette 2000; Plowes 2012).

The objectives of the present study are: 1) to revise the *Ceropegia* sect. *Huernia* in the flora of Saudi Arabia, 2) examine morphological characters in detail and try to find new ones that can be used in the classification of the section in Saudi Arabia, 3) investigate the relationship between Saudi Arabian *Huernia* and other allied species in the Arabian Peninsula, and 4) provide a diagnostic key for the species in Saudi Arabia. This will enable us to test whether the taxonomic treatment established in Plowes (2012) was justified.

Material and methods

Taxon sampling

Twenty individuals of *H. asirensis* and *H. collenetteae* were sampled from Ash Shafa area in Al-Taif province, western Saudi Arabia 21°3.6583'N; 40°20.1917'E. Numerous field expeditions took place to the area between September 2010 and May 2011. Several duplicate specimens were preserved for each species in Bally's Mix (2 ml Formalin, 1 ml Glycerol, 20 ml Water) following Leach (1995). The herbarium specimens were then made from this spirit collection as described in Leach (1995). Voucher specimens have been deposited in the herbarium of Umm Al-Qura University (UQU, proposed abbreviation). Pickled and herbal materials of *Huernia* from Saudi Arabia and the Arabian Peninsula were examined at the Royal Botanical Gardens herbaria at Kew (K) and Edinburgh (E).

Morphological characteristics

The morphological characters were examined and recorded from the availability of specimens (one *H. anagaynensis*, 12 *H. asirensis*, 10 *H. collenetteae*, one *H. foetida*, one *H. laevis*, one *H. radhwana*, one *H. rubrosticta* and one *H. saudi-arabica*). Since some characters are difficult to interpret in dry specimens, herbal materials of *H. collenetteae*, *H. rubrosticta* and *H. saudi-arabica* are excluded from morphometric analysis. For species with unavailable specimens, such as *H. arabica* and *H. khalidbinsultanii*, and closely related species from Arabian Peninsula *H. boleana* and *H. lodarensis*, measurements and character states have been extracted from the relevant literature (Albers and Meve 2002; Field 1980; Gilbert 1975; Leach 1976; Plowes 2012; Plowes 2014; Plowes and McCoy 2003). Height of the plant and colours were immediately documented in the field. Floral characters were examined using the NOVEX AP-8 binuclear microscope. Pollinia, inner corona and papillae apices were examined using XSZ-107BN compound optical microscope. Quantitative morphological characteristics were measured using a ruler. Initially 69 characters were recorded, but 21 proved invariant leaving 48 (19 quantitative and 29 qualitative) for the analysis (Table 1 and Table 2). The data were entered into an Excel spreadsheet (Microsoft Excel version 2007) and were later transformed into a file format suitable for morphometric analysis. These morphological characteristics have been used as the basis for taxonomic revision for the *Huernia* species in Saudi Arabia. The features are richly illustrated using ibisPaint X ver.6.4.3 for Android, which allows visual comparison between the specimen and the author species.

Data analysis

Qualitative characters were coded as multi-state, for example (1.erect, decumbent, 2.decumbent, 3.dense clumps, diffuse mats or Pendulous). Quantitative variables were standardised using the R studio. Version (2017), Scale balance function to remove bias due to size alone, following Katapally and Muhajarine (2014). The standardised data were analysed with R studio package Factor Analysis of Mixed Data (FAMD) version 1.2.3; this method included principal component analysis (PCA), used here to extract relevant information from high dimensional data sets. Cluster analysis including principle coordinates analysis (PCoA) and unweighted pairs group using mean average (UPGMA) were carried out using the statistical software Minitab ver.18.1.1.0 (Minitab, Inc., State College, PA).

IUCN preliminary conservation status

To assess the conservation status of each taxon, the guidelines for using the IUCN Red List categories and criteria version 13 (IUCN Standards and Petitions Subcommittee 2017) and the Guidelines for the Application of the IUCN Red List Criteria at the regional and national levels version 4.0 (IUCN 2012) were followed without deviation or modification. Current threats and point distribution data were gathered from field observations and available scientific literature. These distribution data were then inputted into the GeoCAT software (Bachman et al. 2011), which, in turn, calculated two main spatial metrics: the Extent of Occurrence (EOO) and Area of Occupancy (AOO). In case that the EOO was less than the AOO, the EOO was changed to make it equal to the AOO to ensure consistency with the definition of the AOO as an area within the EOO following the IUCN guideline recommendation (IUCN Standards and Petitions Subcommittee 2017). Criterion B was only used for the species assessment due to data availability. Distribution maps were created using ArcGIS Online (Esri, 'Topography').

Table 1. Nineteen quantitative morphological characters used in morphometric analysis of *Ceropegia* sect. *Huernia* species in Saudi Arabia. All measurements in (mm)

No.	Characters	No.	Characters
1	Stem length	11	Flower diam.
2	Stem tubercles length	12	Corolla tube length
3	Stem tubercles base width	13	Corolla tube diam.
4	Number of flowers per inflorescence	14	Intermediate lobe length
5	Pedicel length	15	Corolla lobe length
6	Pedicel diam.	16	Corolla lobe base width
7	Sepals length	17	Outer corona diam.
8	Sepals base width	18	Inner corona length
9	Papillae length in throat (max.)	19	Inner corona base width
10	Papillae base width		

Table 2. Twenty-nine qualitative morphological characters and character states used in morphometric analysis of *Ceropegia* sect. *Huernia* in Saudi Arabia.

No.	Characters	Character state
1	Habit	1. Erect, decumbent 2. Decumbent 3. Dense clumps, diffuse mats or pendulous
2	Stem grooves between tubercle rows	1. Deep 2. Shallow
3	Flower smell	1. No bad smell 2. faint or no bad smell 3. very foetid 4. faint unpleasant smell
4	Flowers opening	1. Successively 2. Simultaneously 3. Successively, sometimes two simultaneously
5	Pedicele tapering toward the point of flower attachment	1. Not tapering 2. Slightly 3. Conspicuously
6	Pedicele growth direction	1. Spreading and holding flower facing horizontally 2. Ascending holding flower facing upwards
7	Corolla shape	1. Shallow bowl shape 2. Broadly funnel-shaped, margin weakly bulging like an annulus 3. Tubular-campanulate 4. Campanulate
8	Corolla lobe apex groove	1. Absent 2. Present not deep (concave) 3. Present deep (channel)
9	Corolla inside surface texture	1. Tube base smooth, tube throat and lobes papillate 2. Glabrous with very short papillae at corolla lobes apices
10	Corolla tube	1. Cupular 2. Pentagonal
11	Papillae shape	1. Very small wart like 2. Slender (hairlike) 3. Conical, compressed 4. Cylindrical or slightly compressed
12	Corolla (background colour)	1. Cream 2. Shiny creamy- yellow 3. White 4. Creamy- white
13	Corolla (streak colour)	1. Purplish-red 2. Maroon
14	Corolla exterior (colour pattern)	1. Dark spots especially on the lower portion of corolla tube 2. Pale spots uniformly scattered 3. Dark spots on the upper half 4. No spots
15	Corolla tube interior (colour pattern)	1. Uniform colour (purplish-red) 2. Shiny irregular broad streaks and scrolls 3. Concentric broken lines and dashes 4. Concentric short dashes 5. Uniform colour (cream) 6. Dots
16	Corolla lobes colour	1. Uniform colour (purplish-red) 2. Shiny irregular broad streaks and scrolls 3. Irregular shaped fine short lines and dashes 4. Dots 5. Rounded spots or dashes 6. Deep coloured areas concentrated between the lobes; apex is streaked with irregular short lines and dashes 7. Irregular shaped short lines and dashes

No.	Characters	1. Character state
17	Corolla lobes spreading	2. Ascending 3. Reflexed 4. Slightly spreading 5. Spreading with recurved apex
18	Corolla lobe shape	1. Deltoid-acuminate 2. Deltoid-acute 3. Deltoid-caudate
19	Outer corona colour	1. Blackish maroon 2. Cream at the base of the lobes that gradually turning maroon towards Blackish maroon apex
20	Outer corona shape	1. Discrete 5 lobes 2. Pentagonal disc 3. Disc 4. Lobes fused into disc-like
21	Outer corona lobe shape	1. Subquadrate 2. No distinct lobes 3. Rectangular 4. Short and broad rounded lobes
22	Outer corona lobe apex	1. Emarginate or slightly crenate 2. Shallowly bifid 3. Slightly crenate 4. Crenate 5. Emarginate 6. Slightly emarginate 7. Mucronate 8. Bifid 9. Dentate
23	Outer corona fleshy tubercle	1. Present 2. Absent
24	Inner corona shape	1. Exceeding anthers and meeting in centre 2. Shorter than anthers 3. Adpressed to anthers in their lower half then rising up connivent and then diverging towards apices
25	Dorsal gibbosity	1. Broadened transversely conspicuously gibbous 2. Ascending obtuse conspicuous gibbous 3. Inflated transversal 4. Slightly inflated transversal
26	Inner corona base end	1. Acute 2. Rounded 3. Truncate 4. Truncate with very slightly inflated small hump appear in the staminal tube under corona base 5. Acute with a small conspicuous acute hump appear in the staminal tube under corona base 6. Rounded with hook-like appendages grow from both sides of the base meet above the guardrails
27	Inner corona apices	1. Obtuse 2. Acute 3. Taper to fine, slender points
28	Inner corona colour	1. Maroon 2. Purple with cream at base 3. Ivory white with a few maroon spots at the tips 4. Ivory white 5. Purplish black with cream at base
29	Inner corona apex texture	1. Bristly 2. Smooth 3. Minutely scabrous

Results

The first two axes of PCA accounted for 74.7% of the overall variation (Fig.1). Screen plot Eigenvalues for identification of principal components and Boxplot showing differences in morphological characters can be seen in the supplementary information

Cluster analysis by UPGMA of quantitative and qualitative data indicated the presence of four clearly distinguished functional groups: Group 1, with *H. arabica* and *H. laevis* is the furthest distance from all other groups; Group 2, consisting of *H. asirensis*, *H. anagaynensis*, *H. khalidbinsultanii*, *H. radhwah*, *H. foeteda* and *H. rubrusticta*; Group 3, comprising *H. lodarensis* and *H. boleana*; and Group 4, with *H. collentteae* and *H. saudi-arabica* (Fig. 2).

PCoA separated 33 specimens into four distinct groups corresponding largely to those obtained by UPGMA. Group 1 and 2 represent *H. arabica* and *H. laevis*, respectively, which were separated and placed far away from others. *H. asirensis* accessions were clustered together in one group and weakly separated from *H. anagaynensis*, *H. radhwah*, *H. foeteda* and *H. khalidbinsultanii*. *Huernia collentteae* and *H. saudi-arabica* accessions were grouped in one cluster in the positive axes and weakly separated from individuals of *H. rubrusticta*, *H. lodarensis* and *H. boleana* (Fig. 3).

The most important characters contributing to group separation were corolla characteristics (corolla shape, corolla tube diam. and shape, corolla lobes spreading, corolla streak colour and papillae shape) and corona characteristics (outer corona shape, diam., and lobe shape; inner corona length, apex and dorsal gibbosity) Table 3.

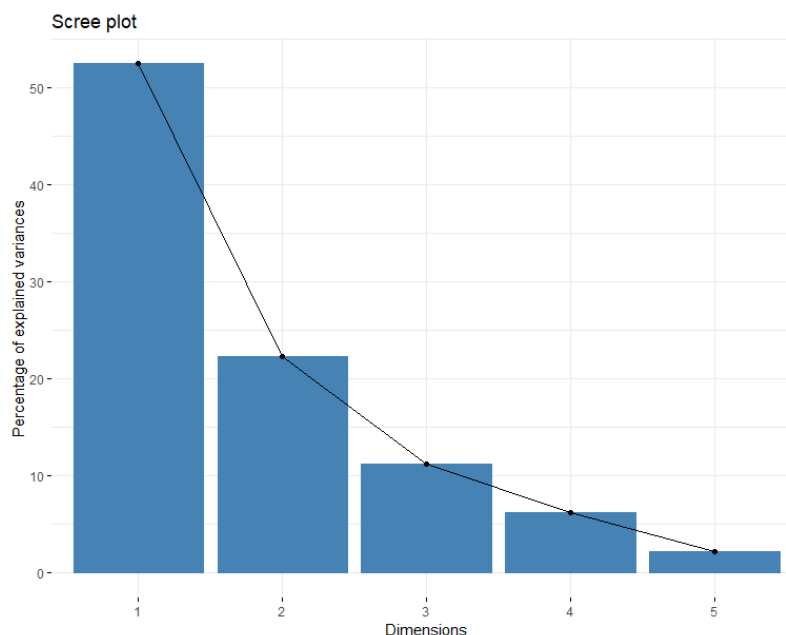


Figure 1. The proportion of variance retained by the different dimensions (axes), in PCA.

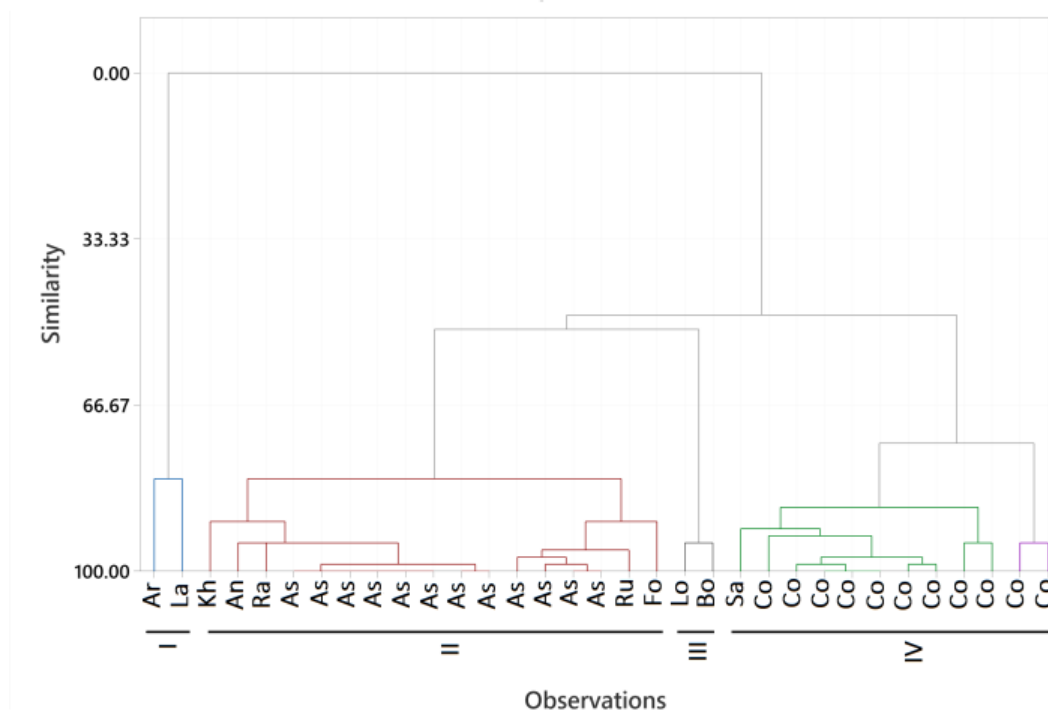


Figure 2. Unweighted pair group method with arithmetic mean (UPGMA) phenogram resulting from cluster analysis. Explanations: Ar-*Huernia arabica*, La- *H. laevis*, Kh- *H. khalidbinsultanii*, Ra- *H. radhwah*, An- *H. anagaynensis*, As- *H. asirensis*, Ru- *H. rubrusticta*, Fo- *H. foeteda*, Lo- *H. lodarensis*, Bo- *H. boleana*, Sa- *H. saudi-arabica*, Co- *H. collentteae*

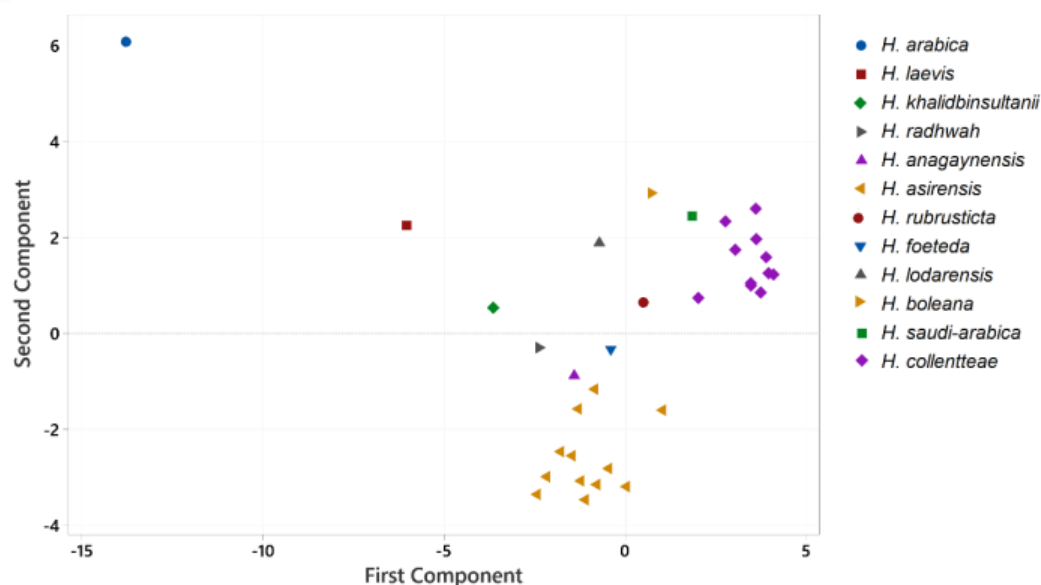


Figure 3. PCoA representation of morphological data of accessions of *Huernia*. Principal Component axis 1 and 2.

Table 3. Eigenvalue in two principal components (PC1 And PC2) of value relative to 48 morphological characters of *Huernia* in Saudi Arabia

Characters	PC1	PC2
Stem tubercles base width (mm)	0.078	-0.038
Stem length (mm)	0.003	-0.107
Stem tubercles length (mm)	0.050	0.254
Stem grooves between tubercle rows	0.132	-0.208
Flower smell	-0.079	-0.317
Number of flowers per inflorescence	0.014	-0.023
Flowers opening	-0.025	-0.261
Pedicel length (mm)	0.171	0.053
Pedicel diam. (mm)	0.162	0.019
Pedicel tapering toward the point of flower attachment	0.139	-0.077
Pedicel growth direction	0.194	0.268
Sepals length (mm)	0.141	-0.202
Sepals base width (mm)	0.125	-0.043
Corolla shape	-0.252	0.009
Corolla lobe apex groove	0.036	0.027
Corolla inside surface texture	-0.085	0.072
Corolla tube	0.160	-0.215
Papillae shape	0.241	0.092
Papillae apex	0.142	-0.139
Papillae length in throat (max.)	0.160	0.074
Papillae base width	0.171	0.142
Corolla (background colour)	-0.108	0.011
Corolla (streak colour)	0.076	-0.224
Corolla exterior (colour pattern)	0.158	0.153
Corolla tube interior (colour pattern)	0.075	-0.158
Corolla lobes colour pattern	0.172	0.011
Corolla lobes spreading	0.128	0.229

Characters	PC1	PC2
Corolla lobe shape	0.194	0.110
Flower diam.	0.089	0.022
Corolla tube length (mm)	0.198	-0.139
Corolla tube diam. (mm)	0.209	-0.045
Intermediate lobe length (mm)	0.156	0.004
Corolla lobe length (mm)	0.186	-0.085
Corolla lobe base width (mm)	0.131	-0.077
Outer corona colour	0.043	0.056
Outer corona shape	-0.031	-0.237
Outer corona lobe shape	0.091	-0.259
Outer corona lobe apex	0.164	0.058
Outer corona fleshy tubercle	-0.039	-0.075
Outer corona diam. (mm)	0.216	0.080
Inner corona shape	0.219	-0.183
Inner corona length (mm)	0.244	0.054
Inner corona base width (mm)	0.173	-0.029
Dorsal gibbosity	0.255	0.071
Inner corona base end	0.145	0.180
Inner corona apices	0.214	-0.210
Inner corona apex texture	0.031	-0.265
Inner corona colour	0.100	-0.072

Discussion

Huernia is considered a difficult group in the flora of Saudi Arabia, and it has not received the proper attention. Perhaps the most comprehensive taxonomic study is the one carried out by Plowes (2012). However, the diagnostic characters of Plowes are questionable. In this study, multivariate analysis of 48 quantitative and qualitative morphological characters was conducted. Multivariate analysis by PCA, PCoA and UPGMA were used to determine the useful characteristics that could be used in the taxonomy of *Huernia* species in Saudi Arabia. While stem characters, such as growth habit, number of angles, tubercle and leaf-rudiment shape, are diagnostic, they were valueless in the taxonomy of Arabian *Huernia* due to the considerable similarity between species. And, therefore, the species were differentiated mainly on the basis of their floral characters.

In the multivariate analysis, accessions of *H. radhwana* (Fig.6 D), *H. asirensis* (Fig.6 F), *H. anagaynensis* (Fig.6 G) and *H. khalidbinsultanii* (Fig.6 H) and were grouped into one big cluster (Figs 2,3). Plowes (2012) has distinguished between those species by: 1) size of corolla tube, 2) exterior corolla colour, 3) the number of flowers and the succession of the opening and 4) the flower odour. A scrutiny examination of the type specimens suggests that they are samples of a single species, and these characters have proved to be unreliable. The first point is not of any value since the corolla tube size is easily accommodated within the known range of *H. asirensis*. Variation found in *Huernia* specimens examined from Wadi Thee Gazal has also showed invalidity of the second point. In the case of the third, Plowes distinguished *H. radhwana* from other species in the group by the solitary flowers. This is encountered often in *H. asirensis* where several specimens were found to have few flowers opened in succession. In the fourth point, flower odour is not considered here to be a prominent character. Flower foetid odour in *H. asirensis* population is observed to become faint or completely vanished after all pollinia is removed from the gynostegium. In addition, this character is not considered diagnostic as it is difficult to interpret in the preserved specimens. Thus, this paper suggests that Plowes' names of these slender papillae, tubular-campanulate flowered species should be included as synonymous under *H. khalidbinsultanii*, since it was the first valid name known from this group.

In 2005, Bruyns reduced *H. khalidbinsultanii* to a synonym under *H. lodarensis*; here, the two taxa are differentiated according to the shape of papillae and corolla (see the taxonomic key in the next section). In *Huernia*, papillae shape provides important identification ('key') characters when combined with other characters, such as inner corona, and the corolla shape is the most important character indicative of the relationship between species (Leach 1983). Thus, this study treated *H. khalidbinsultanii* as a valid species.

Huernia collenetteae and *H. saudi-arabica* accessions overlapped in one cluster in both the UPGMA (Fig.3) and PCoA (Fig.3). The close examination of the specimens shows that *H. saudi-arabica* characters were accommodated within the variation range of

H. collenetteae. The most noticeable character in Plowes (2012) which can be used to distinguish them is corolla interior streaking patterns see figs 1-6 in Plowes (2012). Corolla tube in *H. saudi-arabica* (Jabal Sawdah population) is uniformly coloured with purple and deep coloured areas concentrated between the lobes; sometimes the corolla inside is entirely purple (Fig.10 D, H, K). However, this colour pattern has also been seen in the *H. collenetteae* population from Ash Shafa region (379.87 km north of Jabal Sawdah) (Fig.10 E, I; S4B), but with concentric broken maroon lines and stripes corolla tube instead of a uniform maroon colour. Intraspecific colour variation is common in the widespread species of *Huernia* such as that recorded in *H. thurtii* and *H. hallii* from South Africa (Bruyns 2005). Thus, separating these two entities into distinct species is inaccurate and this study will handle all data obtained from *H. collenetteae* specimens as *H. saudi-arabica* in the subsequent discussion.

Huernia saudi-arabica (Fig. 10 D), described from a single specimen *Collenette* 549, is related by its author to *H. lodarensis* and *H. boleana* (Field 1980). Distinctive features given are: 1) corolla is slightly larger; 2) the corolla-lobes have a more conspicuous papillose, frill-like margin; 3) the inner surface of the attenuate lobe-tip is covered with short but even-sized papillae; 4) the outer corona is distinctly 5-lobed but, unlike *H. lodarensis*, each lobe is considerably wider than long and narrows towards the bifid tip rather than being somewhat parallel-sided; and 5) inner corona-lobes are smooth and more acute towards the tips see fig.1 in Field (1980). The floral measurements given by Field of *H. lodarensis* and *H. boleana* are easily accommodated within the known range of *H. saudi-arabica*. In the case of the third point, Field stated that "in *H. lodarensis* the indumentum is a mixture of a few papillae and low tubercles" see fig. 1 K in Field (1980). This character can clearly be recognised in a number of *H. saudi arabica* samples. In the case of the last two points, the corona lobes turned out to be far more variable than suspected and this range was found in specimens collected at a single locality. The outer corona lobes range from rectangular to subquadrate or rarely fused entirely to form a disc (e.g. *Alharbi* S5B). Likewise, the inner corona tips vary between specimens from smooth to minutely scabrous. Consequently, this study corresponds to and supports Bruyns' (2005) opinion that *H. saudi-arabica* should be treated as a synonym under *H. lodarensis* (Fig. 10 A).

The numerical analysis carried out in this study did not resolve the relationship between *H. lodarensis*, *H. boleana*, *H. foetida* and *H. rubructica* and the other species. This is probably due to the low number of specimens included in the analysis and incomplete data set obtained from the literature for *H. lodarensis* and *H. boleana*. However, a thorough examination of *H. foetida* (Fig. 12) and *H. rubructica* (Fig. 14B) type specimens reveal that they are very close to *H. lodarensis*. In view of the unique interior corolla streaking patterns that have never been seen in any examined specimens of *H. lodarensis*, these taxa are described here as varieties under *H. lodarensis*. Nevertheless, many more samples and additional taxonomic work are considered necessary to either confirm or modify this treatment.

Delimitation of *H. arabica* (Fig. 4) is a matter of long debate. While Berger (1910) and White and Sloane (1937) considered the taxon to be a variety under *H. penzigii* and *H. macrocarpa*, respectively, Albers and Meve (2002) and Bruyns (2005) considered it to be synonymous under *H. macrocarpa* and *H. penzigii*, respectively. As not enough samples were available for this study to resolve the controversy between the uniformly purplish-maroon flowered species (*H. arabica*, *H. macrocarpa* and *H. penzigii*), Plowes (2014) was followed. He was treating *H. arabica* as an accepted species based on the papillae and coronas characters (Plowes 2014). Further material and research are needed to address the taxonomic position of *H. arabica*.

In order to take a broad view of the variation within taxa, examining too many samples is crucial. It seems that the major weakness of the previous taxonomic works of the Arabian *Huernia*, particularly in Saudi Arabia, depends largely on that the taxa have been described from single or only small amounts of plant materials. This has led to the recognition of many unnatural taxa, as seen in some of Plowes' (2012) names. The 'folk concept' of species (Cronquist 1988), in which groups are formed intuitively by individuals 'essentially similar' and referred to as species, are found in the taxonomy of most succulent plants and largely held sway among the stapeliads (Bruyns 2005). This can clearly be seen in Leach's (1988) taxonomic revision of *Huernia*. As he saw few materials which led him to describe too many taxa (64) and his classifications then turned out to have little predictive value (Bruyns 2005). Thus, dense sampling of *Huernia* or stapeliads in general is essential, especially when describing new names or assessing the status of species. *Huernia* plants in Saudi Arabia still need attention and, with the aid of modern molecular methods, it seems that their complexity can be clarified. This study suggests reducing the number of names reported in Saudi Arabia from 11 to four species: *H. arabica*, *H. khalidbinsultanii*, *H. laevis* and *H. lodarensis* (including three proposed varieties: var. *lodarensis*, var. *foetida* and var. *rubrosticta*).

Based on recent phylogenetic reconstructions in the Ceropegieae, species of genus *Huernis* have transferred to *Ceropegia* under sect. *Huernia* and over 50 new combinations are made (Bruyns et al. 2017). However, Plowes' names of Saudi *Huernias* are still not transformed yet. Therefore, in this paper four new combinations in *Ceropegia* sect. *Huernia* are proposed. Those are: *C. arabica* **comb. nov.**, *C. khalidbinsultanii* **comb. nov.**, *C. lodarensis* var. *foetida* **comb. nov.** and *C. lodarensis* var. *rubrosticta* **comb. nov.**.

Taxonomic treatment

Ceropegia* sect. *Huernia (R.Br.) Bruyns, S. African J. Bot. 112: 423 (2017).

≡ *Huernia* R.Br., Mem. Wern. Nat. Hist. Soc.: 22 (1810).

Lectotype

Huernia campanulata (Masson) Haw. (designated by White and Sloane (1937))

= *Ceropegia clavigera* (Jacq.) Bruyns.

Diagnostic Features

Perennial leafless dwarf succulent herb, mat-forming rarely rhizomatous sometimes prostrate or pendulous succulent. Stems glabrous, smooth, 4- to 16-angled. Leaves reduced mainly to soft point without stipular structures. The leaf-rudiments are borne on a raised tubercle which is a much swollen leaf-base. These tubercles are arranged in rows along the stem and joined towards base into angles along stem with a groove between vertical rows of tubercles. Inflorescence glabrous, usually only one per stem, arising mainly in lower half of stem between tubercles, 1- 10 flowered. Corolla urceolate to campanulate to subrotate, shallowly lobed. Staminal corona in two well-separated series, inner pressed to backs of anthers mostly exceeding them and meeting in centre, often with prominent transversely rounded dorsal projections. Outer spreading along base of tube, discrete to fused into spreading disc with fleshy tubercle beneath guide-rail obscuring entrance to small nectarial cavity. Anthers horizontal on top of style-head, margins shrinking back to expose pollinia, rectangular. Pollinium ellipsoidal, longer than broad, insertion-crest exactly along outer edge, caudicle attached with broad cupular pad to base. Follicles erect, terete-fusiform, obclavate, slender, consisting of two horns diverging at 30-60°, longitudinally mottled with narrow broken purple stripes, glabrous, smooth (Bruyns et al. 2017; Bruyns 2005; 2014).

Key for the classification of *Ceropegia* sect. *Huernia* species in Saudi Arabia

1 Corolla inside glabrous or covered with papillae ≤ 1 mm; inner corona lobes not or shortly exceeding anthers, not tapering to a fine point..... 2

+ Corolla inside densely covered with papillae > 1 mm; inner corona lobes much exceeding anthers, tapering to a fine point..... 3

2 Corolla bowl-shaped, papillate, uniformly purplish-maroon without annulus..***C. arabica***

+ Corolla funnel-shaped, glabrous, shiny with irregular broad red streaks on a yellowish background with an annulus like..... ***C. laevis***

3 Stem tubercles up to 16 mm in length; corolla covered with slender (hairlike) papillae, tubular-campanulate, lobes ascending ***C. khalidbinsultanii***

+ Stem tubercles up to 12 mm in length; corolla covered with conical compressed papillae, campanulate, lobes spreading or reflexed ***C. lodarensis***

Ceropegia arabica* (N.E.Br) S.A. Alharbi & R.N. Al-Qthanin, **comb. nov.*

Figs 4,5; Map 1

≡ *Huernia arabica* N.E.Br., Bull. Misc. Inform. Kew 1895 (106): 265 (1895). **Type:**
YEMEN • G. A. Schweinfurth #374 (K! [herb. material: K000911101]); Hile Gebel Bura;
14°57.0569'N, 43°29.8433'E; alt. 1335 m.; 03 Jan, 1889.

≡ *Huemia penzigii* var. *arabica* (N. E. Brown) A.Berger, Stap.u.Klein.: 143 (1910)

≡ *Huernia macrocalpa* var. *arabica* (N. E. Brown) A.C.White and B.Sloane (1937)

Type

YEMEN • G. A. Schweinfurth #374 (K! [herb. material: K000911101]); Hile Gebel Bura;
14°57.0569'N, 43°29.8433'E; alt. 1335 m.; 03 Jan, 1889.

Description

Dwarf succulent forming dense clump. Stems 60 mm long, non-rhizomatous, erect, decumbent, grey-green mottled with purple-red; tubercles up to 10 mm long (including leaf-rudiment), conical, spreading, laterally flattened and joined into 5 angles along stem, each tipped with a soft slender acuminate caducous leaf-rudiment. Inflorescence usually only 1 per stem, arising in lower half of stem, each bearing 2-3 flowers developing mainly successively, flowers with no unpleasant smell; pedicel spreading and holding flower facing horizontally. Corolla 15 mm diam., shallow bowl shape; outside smooth, cream speckled with maroon, with 1 heavy (+ 2 lighter) raised longitudinal veins running from lobes to base of tube; inside uniformly coloured with purplish-red, covered except in lower third of tube with very small wart like papillae; tube cupular; lobes ascending, deltoid, acuminate. Corona without basal stipe; outer lobes spreading on base of tube and fused partially to it, discrete to 5-lobed with each lobe subquadrate emarginate or slightly crenate, blackish maroon; inner lobes maroon, adpressed to backs of anthers exceeding them and meeting in centre, dorsiventrally flattened around laterally broadened base becoming terete above and tapering gradually to obtuse bristly apex, a transversely conspicuously gibbous broadened at the base with an acute end.

Distribution in Saudi Arabia

Rare, known only from Asir between Abha and Jabal Sawdah, SW Saudi Arabia

General distribution

South west Arabian Peninsula (Saudi Arabia, Yemen).

Habitat and ecology

Growing among granite rocks and scattered shrubs on a steep hillside at elevation of 2700 m. above sea level.

Diagnosis

This species can be easily distinguished from other *Huernias* in Saudi Arabia by the small maroon bowl-shaped flowers.

Etymology

Arabica for the occurrence in Arabia.

Preliminary conservation status

The species is known only from one location near Sawda mountain; the estimated EOO and AOO of 8 km² would place the species in Critically Endangered (CR). However, little is known about the size of the population and possible threats. Therefore, Data Deficient (DD) assigned to this species.

Additional specimens examined

Gilbert 2945 (E [fl in spirit])



Map1. Distribution of *Ceropegia arabica* in Saudi Arabia



Figure 4. *Ceropogia arabica*, Jabal Melhan, 20 km E Al Mighlaf, Yemen, ex JRI Wood 1202, sub DP7571 (reproduced from Plowes2014).

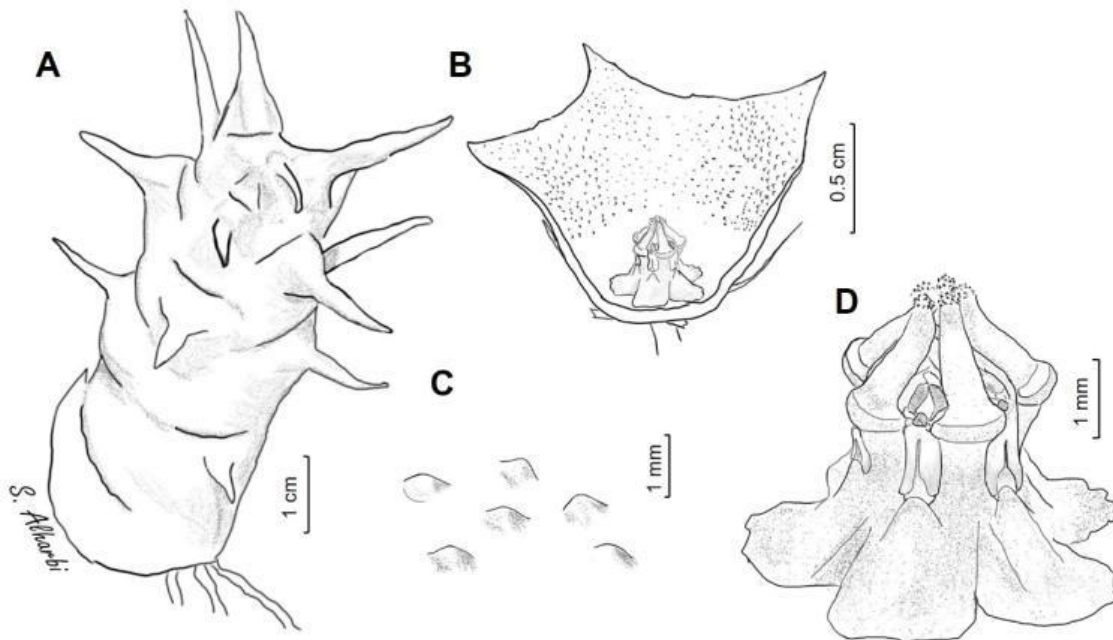


Figure 5. *Ceropogia arabica* **A** stem **B** side view of dissected flower **C** papillae inside corolla in mouth of tube **D** side view of gynostegium. Drawn from photo of ex JRI Wood 1202, sub DP7571, Jabal Melhan, 20 km E Al Mighlaf, Yemen in Plowes (2014).

Ceropegia khalidbinsultanii* (Plowes and McCoy) S.A. Alharbi & R.N. Al-Qthanin, **comb. nov.*

Figs 6,7; Map 2

≡ *Huernia khalidbinsultanii* Plowes and McCoy, Cact. Succ. J. (Los Angeles) 75(1): 19 (2003). **Type:** SAUDI ARABIA – Asir • T.A. McCoy 2446 (holotype: MO; isotypes P & SRGH); 25 km SW of Khamis Mushayt; 18°4.0906'N, 42°43.8908'E; alt. 2100 m; 15 Jan, 1999.

= *Huernia asirensis* Plowes, Asklepios 114: 7 (2012), **syn. nov.** **Type:** SAUDI ARABIA - Tanumah • I.S. Collenette 2655 (Holotype: K!, [fl in spirit: 44279.000]); 12 km S. of An Numas on Taif to Abha Road; 18°56.1481'N, 42°11.2139'E; alt. 1800 m; 10 May, 1981.

= *Huernia radhwana* Plowes, Asklepios 114: 10 (2012), **syn. nov.** **Type:** SAUDI ARABIA - Jabal Radhwa • I.S. Collenette 5944 (Holotype: K!, [fl in spirit: 51187.000]); 75 km NE Yanbu; 24°32.3717'N, 38°20.4741'E; alt. 1750 m; 01 Feb, 1987.

= *Huernia anagaynensis* Plowes, Asklepios 114: 7 (2012), **syn. nov.** **Type:** SAUDI ARABIA - Jabal Anagayn • I.S. Collenette 5970 (Holotype: K!, [fl in spirit: 50937.000]); 95 km south of Madinah; 23°21.5747'N, 39°34.9766'E; 06 Dec, 1986.

Huernia haddaica Hemaïd (*nom. inval.* Art 37.2), Saudi J. Biol. Sci. 8: 168 (2001).

Type

SAUDI ARABIA – Asir • T.A. McCoy 2446 (holotype: MO; isotypes P & SRGH); 25 km SW of Khamis Mushayt; 18°4.0906'N, 42°43.8908'E; alt. 2100 m; 15 Jan, 1999.

Description

Dwarf succulent forming dense clump. Stems 50-100 mm long, non-rhizomatous, decumbent, grey-green mottled with purple-red; tubercles 7-16 mm long (including leaf-rudiment), 1.5-5 mm broad at base, conical, spreading, laterally flattened and joined into 5 angles along stem, each tipped with a soft slender acuminate caducous leaf-rudiment. Inflorescence usually only 1 per stem, arising in lower half of stem, each bearing 1-7 flowers developing mainly simultaneously or in gradual succession from short peduncle, with several filiform bracts without lateral teeth, flowers with mainly very foetid odour, rarely faint or no unpleasant smell; pedicel 5 -21.5 mm long, 1- 2 mm thick, spreading and holding flower facing horizontally, tapering sometimes toward the point of flower attachment; sepals 10 -18 mm long, 1- 2 mm broad at base, attenuate. Corolla 27 – 47 mm diam., tubular-campanulate to campanulate; outside smooth, white to creamy-white or cream speckled with pale maroon spots uniformly scattered sometimes spots become

darker especially on the lower or upper half of corolla tube, with 1 heavy (+ 2 lighter) raised longitudinal veins running from lobes to base of tube; inside creamy- white to cream with irregular shaped narrow short maroon lines and dashes changing to narrow concentric broken lines in lower half of tube, covered except in lower third of tube with slender (hairlike) papillae densely crowded around mouth of tube (up to 3 mm long and 0.75 mm an base in tube mouth) each tipped by minute apical acuminata bristle; tube 7-13 mm long, 9-14 mm broad at mouth, pentagonal; lobes 13-18 mm long, 8-12 mm broad at base, ascending to slightly spreading, narrowly deltoid and usually longer than wide, attenuate usually concave or form channel above, intermediate lobes 1-2.5 mm long. Corona without basal stipe; outer lobes (4.5-8 mm diam.) spreading on base of tube and fused partially to it; fused together into disc with crenate margin to a slightly disc-like with rounded to subquadrate short and broad lobes, rarely discrete to 5-lobed with each lobe subquadrate mucronate, blackish maroon; inner lobes 3-5.5 mm long, 0.5-1.5 mm at base, ivory white sometimes mottled with a few maroon spots at the tips, adpressed to anthers in their lower half then rising up connivent and then diverging towards apices, dorsiventrally flattened around laterally broadened base becoming terete above and tapering gradually to a slender fine minutely scabrous apex, at base with inflated transversal dorsal gibbosity with rounded to acute end. Pollinia 0.1-0.7 mm long.

Distribution in Saudi Arabia

Scattered over a wide area, extending from Khamis Mushait in SW of the country to Jabal Radhwa, 75 km north of Yanbu in western region.

General distribution

Probably endemic to SW Arabian Peninsula known so far from Saudi Arabia.

Habitat and ecology

Grow on granite outcrops often under shrubs, from 1800-2100 m above sea level.
Flowering Dec.-May

Diagnosis

Ceropegia khalidbinsultanii is best distinguished from the closely related *C. lodarensis* by long stem tubercles (up to 16mm) and small white to creamy-white tubular-campanulate corolla streaked with narrow maroon lines, slender (hairy) papillae and a very foetid odour.

Notes

Flower foetid odour becomes weak or completely vanished after all pollinia removed from the flower.

Etymology

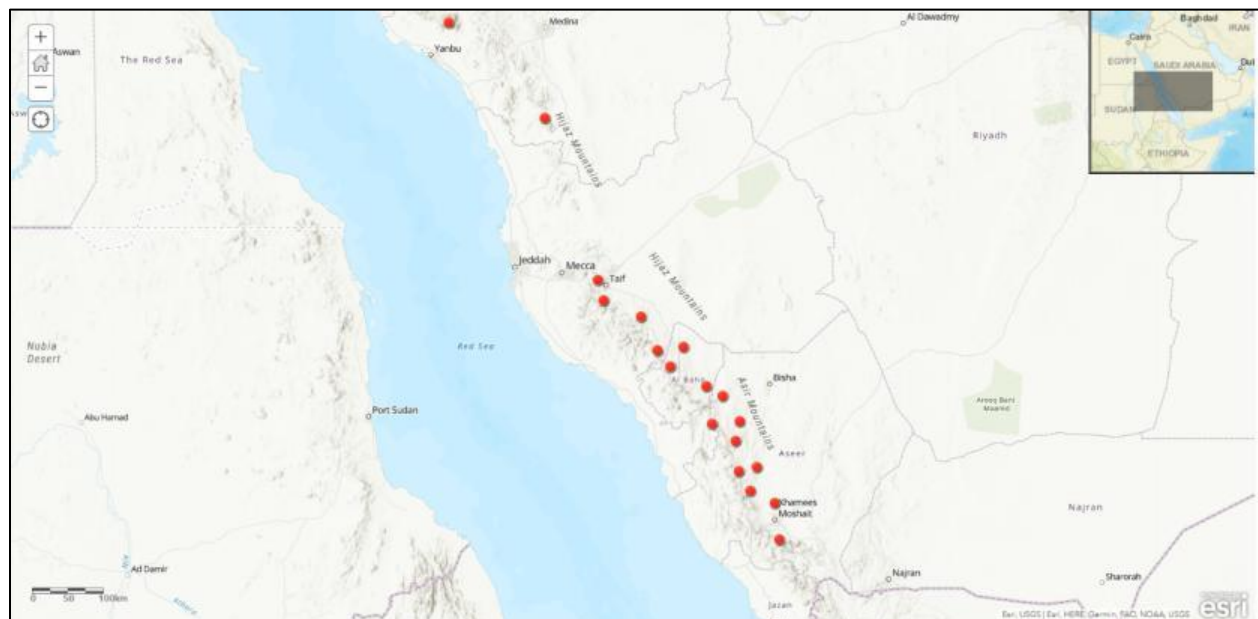
khalidbinsultanii for Prince Khalid bin Sultan bin Abdulaziz M. a former Saudi Deputy Minister of Defence.

Preliminary conservation status

Near Threatened (NT) has been assigned to *Ceropegia khalidbinsultanii* based on the species' EOO of 41,490 km² and AOO of 2,012 km² and the current threats of habitat transformation (roads and housing construction), populations' fragmentation and tourism.

Additional specimens examined

SAUDI ARABIA - Al-Taif • I.S. Collenette 815 (K!, herbarium specimen); Wadi Ammak near Al Hadda; 21°20.9808'N, 40°17.7485'E; alt. 2100 m; S.A. Alharbi S3a (UQU); Wadi Thee Gazal, Ash Shafa; 21°5.5702'N, 40°21.785'E; alt. 2057m; 23 Jan, 2011; S.A. Alharbi S4a (UQU); same data as for preceding; 1 Jan, 2011; S.A. Alharbi S6a (UQU); same data as for preceding; 10 Jan, 2011; S.A. Alharbi S7a (UQU); same data as for preceding; 9 Dec, 2010; S.A. Alharbi S8a (UQU); same data as for preceding; 19 Jan, 2011; S.A. Alharbi S16a (UQU); same data as for preceding; 8 Jan, 2011; S.A. Alharbi S16A (UQU); same data as for preceding; 30 Dec, 2010; S.A. Alharbi S13a (UQU); same data as for preceding; 9 Dec, 2010; S.A. Alharbi S14a (UQU); same data as for preceding; 17. Dec, 2010; S.A. Alharbi S00 (UQU); 9 Dec, 2010; S.A. Alharbi S10b (UQU); same data as for preceding; 21°5.4656'N, 40°21.7937'E; 9 Dec, 2010.



Map 2. Distribution of *Ceropegia khalidbinsultanii*

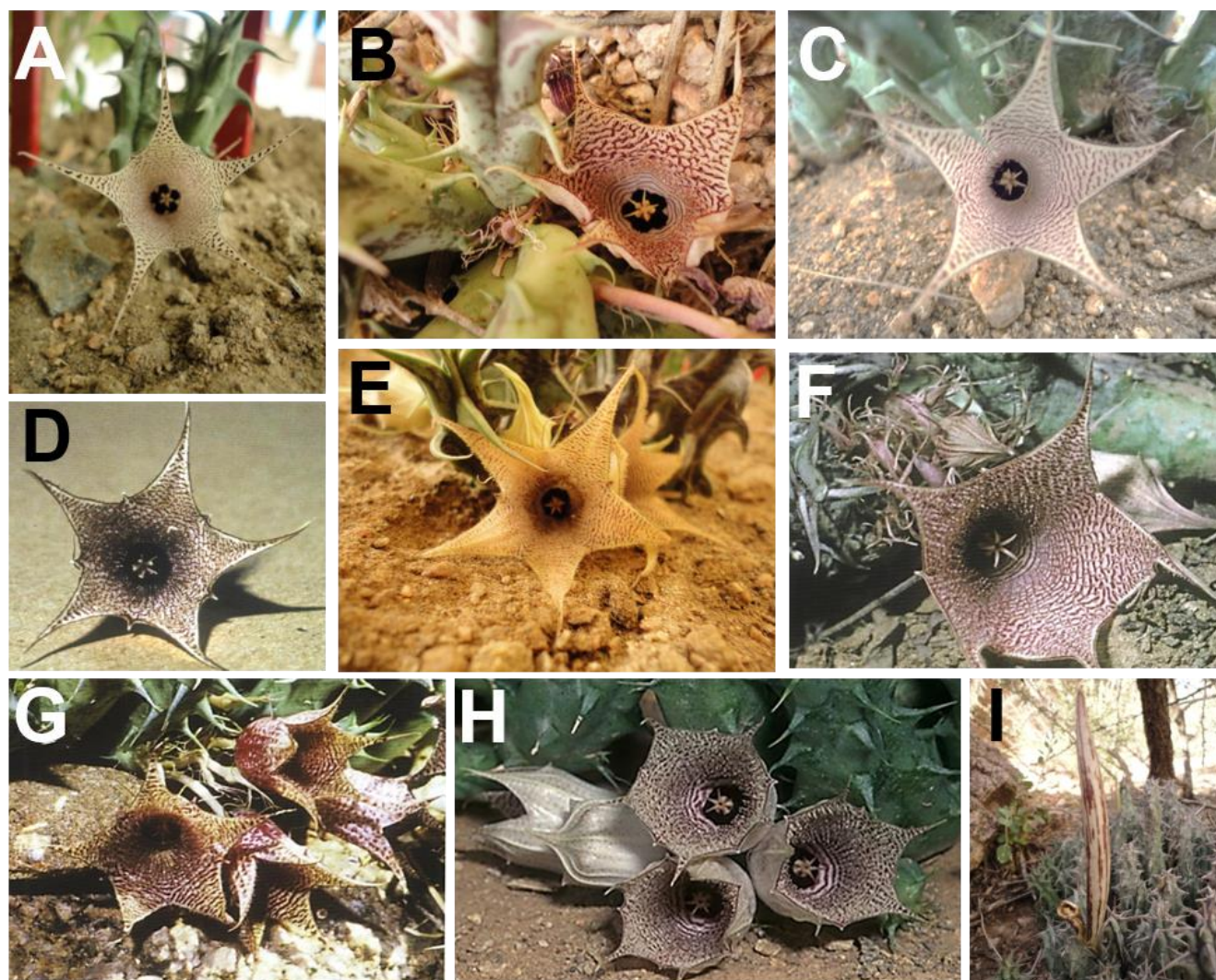


Figure 6. *Ceropegia khalidbinsultanii* **A** Alharbi S00 (*H. asirensis*) **B** Alharbi S10b (*H. asirensis*) **C** Alharbi S4a (*H. asirensis*) **D** Collonette 5944, Jabal Radhwa, (*H. radhwana*, **Type**) **E** Alharbi S16a (*H. asirensis*) **F** Collonette 1309, Al-Baha, (*H. asirensis*, **Type**) **G** Collonette 5970, Jabal Anagyan (*H. anagaynensis*, **Type**) **H** ex Tom McCoy KSA129 sub DP8384, 25 km SW of Khamis Mushayt, (*H. khalidbinsultanii*, **Type**). **I** follicles, Alharbi S14a. (**A,B,C,E, I**) photo by S.A. Alharbi from Wadi Thee Gazal, Ash Shafa; (**D,F,G**) reproduced from Plowes (2012)); (**H**) received from D. Plowes in 2011.

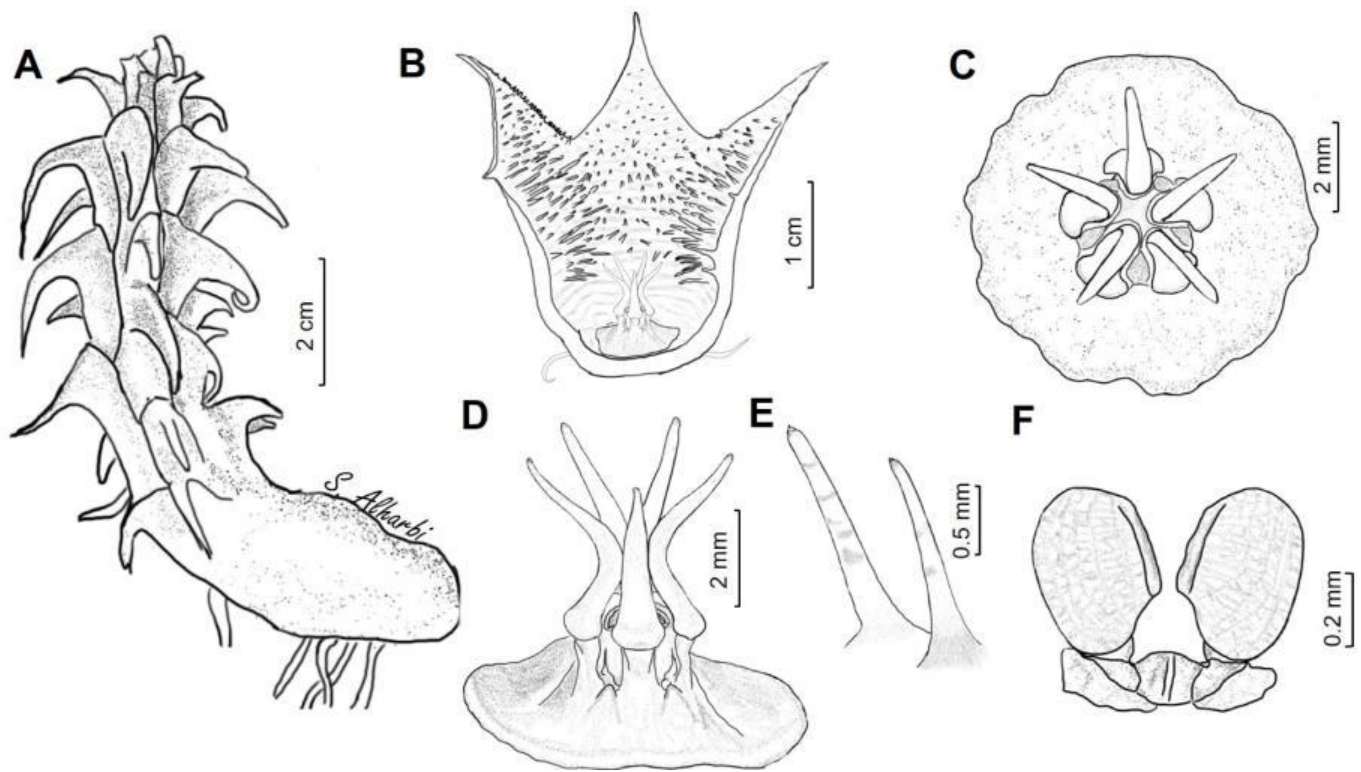


Figure 7. *Ceropegia khalidbinsultanii* **A** stem **B** side view of dissected flower **C** face view of gynostegium **D** side view of gynostegium **E** papillae inside corolla in mouth of tube **F** pollinarium. Drawn from S.A. Alharbi S4a, Wadi Thee Gazal, Ash Shafa.

Ceropegia laevis (J.R.I. Wood) Bruyns, S. African J. Bot. 112: 424 (2017).

<http://www.ipni.org/urn:lsid:ipni.org:names:77166440-1>

Figs 8, 9; Map 3

≡ *Huernia laevis* J.R.I. Wood, Kew Bull. 39: 128 (1984), Plate Ascl. 39, b.

Type

YEMEN, Jebel Marran, Khawlan As Sham, 1400 m, 31 Oct, 1979, *J.R.I. Wood* 3037 (holotype: K [46740.000])

Description

Dwarf succulent forming dense clump. Stems non-rhizomatous up to 80 mm long, erect, decumbent, grey-green mottled with purple or red; tubercles 3-5 mm long, 1 mm broad at base, conical, spreading, laterally flattened and joined towards base into 5 angles along stem, abruptly narrowing into fine spreading slender acuminate tooth. Inflorescences 1-2 per stem, each of 2-5 flowers developing in gradual succession on short peduncle with few narrow filiform bracts; pedicel 15 mm long, spreading and holding flower facing horizontally; flowers with no scent; sepals 15 mm long, 3 mm broad at base, narrowly ovate attenuate. Corolla 32 mm diam., broadly funnel-shaped, margin weakly bulging like an annulus; outside smooth, pale cream with 1 heavy (+ 2-4 lighter) raised longitudinal veins running down each lobe; inside shiny creamy- yellow, marked with shiny irregular broad maroon streaks and scrolls, smooth with few low conical papillae (wart-like) at corolla lobes apices each with minute apical bristle; tube 6 mm long, 10 mm broad at mouth, cupular; lobes 10 mm long, 14 mm broad at base, reflexed, deltoid-acuminate. Corona without basal stipe; outer lobes (discrete 5 lobes), 4 mm diam, subquadrate, emarginate to shallowly bifid, spreading on base of tube and fused to it towards base, blackish maroon; inner lobes 1 mm long, purple with cream at base, adpressed to backs of anthers and shorter than them, dorsiventrally flattened with ascending obtuse conspicuous gibbous at base, tapering to small smooth acute apex.

Distribution in Saudi Arabia

Jabal Al Qahar, 50 km NE of Baysh, Jazan, SW Saudi Arabia

General distribution

Probably endemic to SW Arabian Peninsula known so far from Saudi Arabia and Yemen

Habitat and ecology

Grow on limestone rocks among *Junipers* at elevations of 1828-2000 m. Flowering: mainly September- May

Preliminary conservation status

Ceropegia laevis should be considered as Nationally Endangered (EN) according to the IUCN Red List criteria. The species is known from only one location, its EOO and AOO (104.000 km²) would both qualify as Endangered, not part of protected area continuing decline is projected because of anthropogenic activities in the area.

Diagnosis

Ceropegia laevis can easily be distinguished from most other species of sect. *Huernia* in Saudi Arabia by the glabrous shiny yellow background corolla with an annulus like around tube mouth.

Etymology

laevis (Latin) smooth, flat; for the glabrous corolla (Eggli and Newton 2004).

Specimens examined

SAUDI ARABIA – Jazan • I.S. Collenette 8180 (K [fl in spirit: 57656.000]); Jabal Qahar; 17°42.0367'N, 42°51.1983'E; alt. 2000 m; 20 Apr, 1992.



Map 3. Distribution of *Ceropegia laevis* in Saudi Arabia

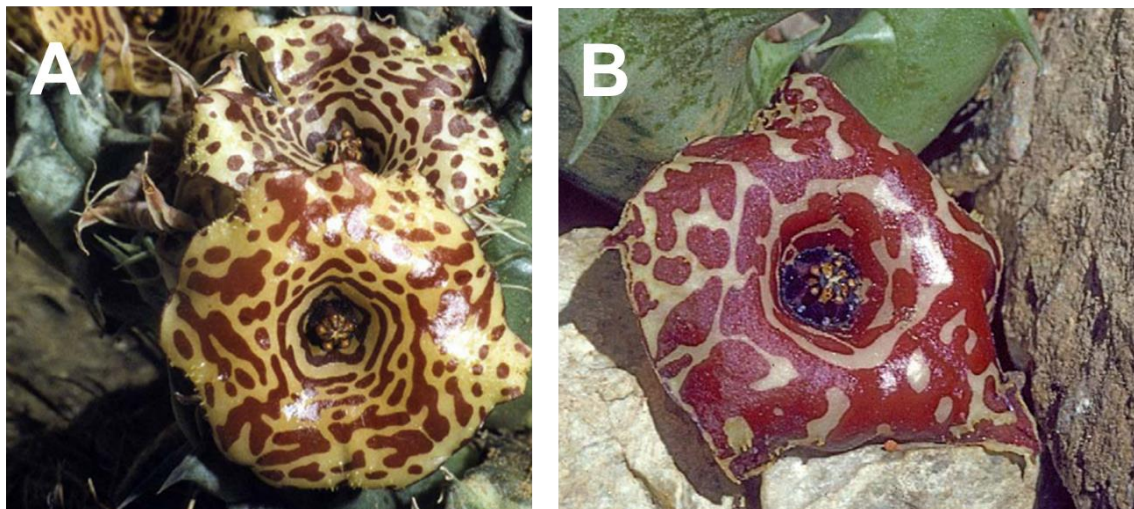


Figure 8. *Ceropegia laevis*, Jabal Qahar, 50 km NE of Baysh, Jazan, Saudi Arabia. **A** Collenette 8177 **B** ex S Collenette 8180 sub DP8296. Reproduced from Plowes (2014).

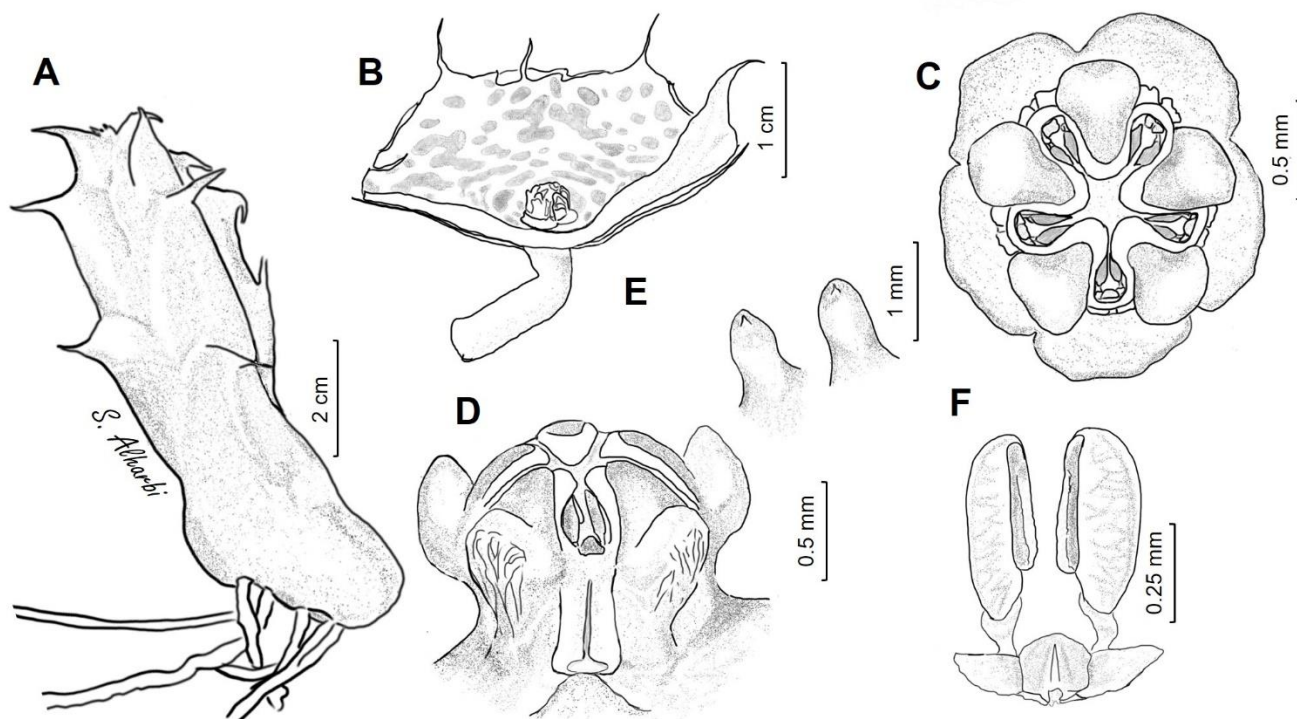


Figure 9. *Ceropegia laevis* **A** stem **B** side view of dissected flower **C** face view of gynostegium **D** side view of gynostegium **E** papillae inside corolla in lobe tip **F** pollinarium. Drawn from Collenette 8180, Jabal Qahar.

Ceropegia lodarensis (Lavranos) Bruyns, S. African J. Bot. 112: 424 (2017).

<http://www.ipni.org/urn:lsid:ipni.org:names:77166444-1>

Description

Dwarf succulent forming dense clump. Stems 30-100 mm long, non- rhizomatous, erect to decumbent, grey-green mottled with purple-red; tubercles 4-10 mm long (including leaf-rudiment), 1.5-5 mm broad at base, conical, spreading, laterally flattened and joined into 5 angles along stem, each tipped with a soft slender acuminate caducous leaf- rudiment. Inflorescence arising in lower half of stem, usually 1 per stem, each bearing 2-10 flowers developing in gradual succession from short peduncle sometimes 3 flowers developing simultaneously, bracts filiform without lateral teeth, flowers with no foetid odour, rarely with faint unpleasant smell; pedicel 8-20 mm long, 1- 2.5 mm thick, ascending holding flower facing upwards, tapering sometimes toward the point of flower attachment; sepals 8 -18 mm long, 1-2.5 mm broad at base, attenuate. Corolla 30–50 mm diam., campanulate; outside smooth, cream speckled with pale maroon spots uniformly scattered or concentrated on the upper half of corolla tube sometimes spots become darker especially on the upper half, with 1 heavy (+ 2-4 lighter) raised longitudinal veins running from lobes to base of tube; inside cream with irregular shaped short maroon lines and dashes changing to concentric broken lines in lower half of tube or uniformly coloured with purplish-red, sometimes deep coloured areas concentrated between the lobes or corolla entirely uniformly coloured with purplish-red; corolla covered except in lower third of tube with compressed conical papillae densely crowded and reach maximum size around mouth of tube (up to 3 mm long and 1.2 mm base width) each tipped by minute apical acuminata bristle; tube 7.5-15.5 mm long, 11-22 mm broad at mouth, pentagonal; lobes 9-22.8 mm long, 9-14.25 mm broad at base, spreading with recurved apex or sometimes reflexed, deltoid, caudate to acute or acuminate rarely attenuate usually concave or form channel at tip, intermediate lobes 1.5-4 mm long. Corona without basal stipe; outer lobes (5-10 mm diam.) spreading on base of tube and fused partially to it, discrete to 5 lobes with each lobe rectangular rarely subquadrate crenate, dentate, mucronate, emarginate or bifid blackish maroon; inner lobes 3-6 mm long, 1-1.5 mm at base, ivory white sometimes mottled with a few maroon spots at the tips or marked entirely with small purple spots adpressed to anthers in their lower half then rising up connivent and then diverging towards apices, dorsiventrally flattened around laterally broadened base becoming terete above and tapering gradually to a slender fine minutely scabrous or smooth apex, at base with slightly inflated transversal dorsal gibbosity with rounded to truncate end sometimes a conspicuous acute hump appear in the staminal tube under corona base, rarely a hook-like appendages grow from both sides of the base meet above the guardrails. Pollinia 0.7-0.8 mm long.

key to the varieties of *Ceropegia lodarensis*

1 Stem not stout, up to 100 mm; corolla up to 50 mm marked inside with irregular short maroon lines and dashes or rarely dotted; outer corona mostly distinct to five rectangular lobes.....2

+ Stem stout, up to 60 mm; corolla up to 30 mm marked inside with maroon rounded spots or dashes; outer corona disk or disc-like..... ***C. lodarensis* var. *rubrosticta*.**

2 Corolla tube interior with concentric broken lines or uniformly coloured with purplish-red, lobes marked with irregular shaped short maroon lines and dashes sometimes deep coloured areas concentrated between the lobes or corolla entirely uniformly coloured with purplish-red....
***C. lodarensis* var. *lodarensis*.**

+ Corolla tube interior with concentric short dashes, corolla lobes marked with small maroon dots..... ***C. lodarensis* var. *foetida*.**

Ceropegia lodarensis* (Lavranos) Bruyns **var. lodarensis*

Figs 10, 11; Map 4

≡ *Huernia lodarensis* Lavranos, J. S. African Bot. 30: 87 (1964). **Type:** YEMEN - Lodar (Lawdar) • J.J.Lavranos 1900 (holotype: K [fl in spirit: 24982.000]); 13°52.6751'N, 45°51.7598'E; alt. 900 m; 19 Aug, 1962.

= *Huernia collenetteae* Plowes, Asklepios 114: 8 (2012). **syn. nov.** **Type:** SAUDI ARABIA - Asir • I.S. Collenette 1176 (clonotype: SRGH [DP6868]); between Abha and Jabal Sawdah; 18°14.425'N, 42°25.2244'E; alt. 2650 m.

= *Huernia saudi-arabica* D.V.Field, Kew Bull. 35(4): 754 (1981). **Type:** SAUDI ARABIA - Asir • I.S. Collenette 549 (holotype: K! [herb. material: K000911103]); between Abha and Jabal Sawdah, 12 km NW Abha; 18°15.7389'N, 42°23.1535'E; alt. 2650 m.; 31 Mar, 1978.

Type

YEMEN - Lodar (Lawdar) • J.J.Lavranos 1900 (holotype: K [fl in spirit: 24982.000]); 13°52.6751'N, 45°51.7598'E; alt. 900 m; 19 Aug, 1962.

Description

Stems 30-90 mm long; tubercles 4-10 mm long (including leaf-rudiment), 1.5-5 mm broad at base. Inflorescence bearing 2-10 flowers developing in gradual succession from short peduncle sometimes 3 flowers developing simultaneously, flowers with no foetid odour, rarely with faint unpleasant smell; pedicel 8-20 mm long, 1- 2.5 mm thick, ascending holding flower facing upwards, tapering sometimes toward the point of flower attachment; sepals 8 -18 mm long, 1-2.5 mm broad at base, attenuate. Corolla 30–50 mm diam., campanulate; outside smooth, cream speckled with pale maroon spots uniformly scattered or concentrated on the upper half of corolla tube sometimes spots become darker especially on the upper half; inside cream with irregular shaped short maroon lines and dashes changing to concentric broken lines in lower half of tube or uniformly coloured with purplish-red, sometimes deep coloured areas concentrated between the lobes or corolla entirely uniformly coloured with purplish-red; papillae up to 3 mm long and 1.2 mm base width. tube 7.5-15.5 mm long, 11-22 mm broad at mouth, pentagonal; lobes 9-22.8 mm long, 9-14.25 mm broad at base, spreading to spreading with recurved apex or sometimes reflexed, deltoid, caudate to acute or acuminate, concave at tip, intermediate lobes 1.5-4 mm long. Outer corona lobes (5-10 mm diam.) discrete to 5 rectangular lobes; inner lobes 3-6 mm long, 1-1.5 mm at base.

Distribution in Saudi Arabia

Scattered over a wide area, extending from Al Habala in SW of the country to Al-Hadda in Al-Taif in the western region.

General distribution

Arabian Peninsula (Saudi Arabia and Yemen), Africa (Ethiopia)

Habitat and ecology

It occurs at 900-2650 m above sea level in granite outcrops mainly under shrubs.

Flowering: mostly Aug.-May

Diagnosis

Ceropegia lodarensis var. *lodarensis* is most similar to *C. khalidbinsultanii* but differs in having larger campanulate corolla with compressed conical papillae (up to 1.2 mm broad at base), sometimes uniformly coloured with purplish-red, flower with no bad or faint smell and has shorter stem tubercles.

Etymology

lodarensis for the occurrence at Lodar (Lawdar) in Yemen (Eggli and Newton 2004).

Preliminary conservation status

Ceropegia lodarensis var. *lodarensis* should be assessed as Near Threatened (NT) in Saudi Arabia due to species' AOO of 3,900 km² and EOO of 12,509.959 km² and the current threats of tourism, overgrazing, infrastructure and housing development.

Additional specimens examined

SAUDI ARABIA - Asir • I.S. Collenette 1280 (k [fl in spirit: 44272.000] & E); Al Habala, 50 km SE of Abha; 18°1.6787'N, 42°51.3655'E; alt. 2384 m.; 06 Apr, 1979.

SAUDI ARABIA - Al-Baha • I.S. Collenette 7785 (k [fl in spirit: 57339.000]); Jabal Shada, SW of Al Baha; 19°50.9947'N, 41°19.0693'E; alt. 1933 m.; 07 Apr, 1991; I.S. Collenette 8267 (K [fl in spirit: 59350.000]); same data as for preceding; 15 Sep, 1992.

SAUDI ARABIA - Al-Taif • I.S. Collenette 2227 (K [fl in spirit: 44371.000, 53692.000]); Al-Hadda; 21°20.8387'N, 40°17.152'E; alt. 2000 m.; 1981; I.S. Collenette 2633 (K [fl in spirit: 45473.000, 45894.000, herb. material sub DP6599 & sub Leach 17652]); SW of Al Hadda, off Taif to Abha road; alt. 2100 m.; 07 May, 1981; I.S. Collenette 5780 (K [fl in spirit: 35856.000]); Between Al Hadda and Harithi; 23 Mar, , 1986; S.A. Alharbi S1b (UQU); Wadi Thee Gazal, Ash Shafa; 21°5.4656'N, 40°21.7937'E; alt. 2057m; 29 Dec, 2010; S.A. Alharbi S2b (UQU); same data as for preceding; 09 Dec, 2010; S.A. Alharbi S3b (UQU); same data as for preceding; 23 Jan, 2011; S.A. Alharbi S4b (UQU); same

data as for preceding; 29 Dec, 2010; S.A. Alharbi S5b (UQU); same data as for preceding; 23 Nov, 2010; S.A. Alharbi S6b (UQU); same data as for preceding; 02 Oct, 2011; S.A. Alharbi S9b (UQU); same data as for preceding; 23 Nov, 2010; S.A. Alharbi S9a (UQU); same data as for preceding; 05 Jan, 2011; S.A. Alharbi S18a (UQU); same data as for preceding; 21°5.5702'N, 40°21.785'E; 17 Dec, 2010.

I.S. Collenette 1523 (E [fl in spirit]); A.J. Bntler AJB 13 (E [fl in spirit])



Map 4. Distribution of *Ceropogia lodarensis* var. *lodarensis* in Saudi Arabia

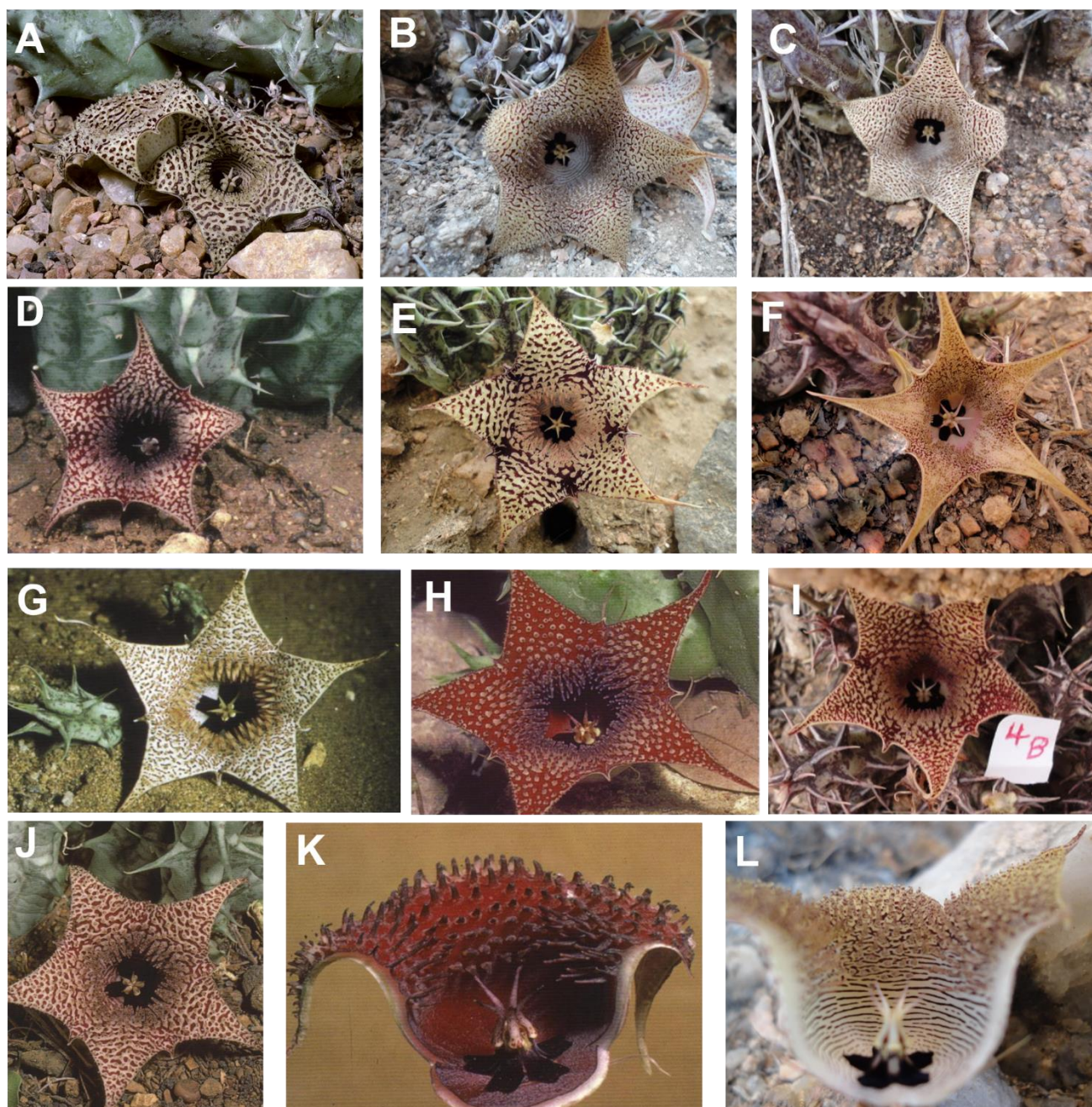


Figure 10. *Ceropegia lodarensis* var. *lodarensis* **A** ex J Lavranos 1789, sub DP3604, Yemen, (*H. lodarensis*, **Type**) **B** Alharbi S6B (*H. collenetteae*) **C** Alharbi S9B (*H. collenetteae*) **D** ex Collenette 549 sub DP6865, Jabal Al Sawdah, (*H. saudi-arabica*, **Type**) **E** Alharbi S2B (*H. collenetteae*) **F** Alharbi S18a (*H. collenetteae*) **G** Collenette 2227, Al-Hadda, (*H. collenetteae*) **H** ex Collenette 8232 sub DP8126, (*H. saudi-arabica*) **I** Alharbi S4B (*H. collenetteae*) **J** ex Collenette 1176 sub DP6868, Jabal Al Sawdah, (*H. collenetteae*, **Type**) **K** maroon uniform colour of corolla tube in ex Collenette sub DP6594, Abha, (*H. saudi-arabica*) **L** concentric broken maroon lines of corolla tube in Alharbi S6B (*H. collenetteae*). (**A**) reproduced from Plowes (2014); (**D**, **G**, **H**, **J**, **K**) reproduced from Plowes (2012); (**B**, **C**, **E**, **F**, **I**, **L**) photo by S.A. Alharbi from Wadi Thee Gazal, Ash Shafa.

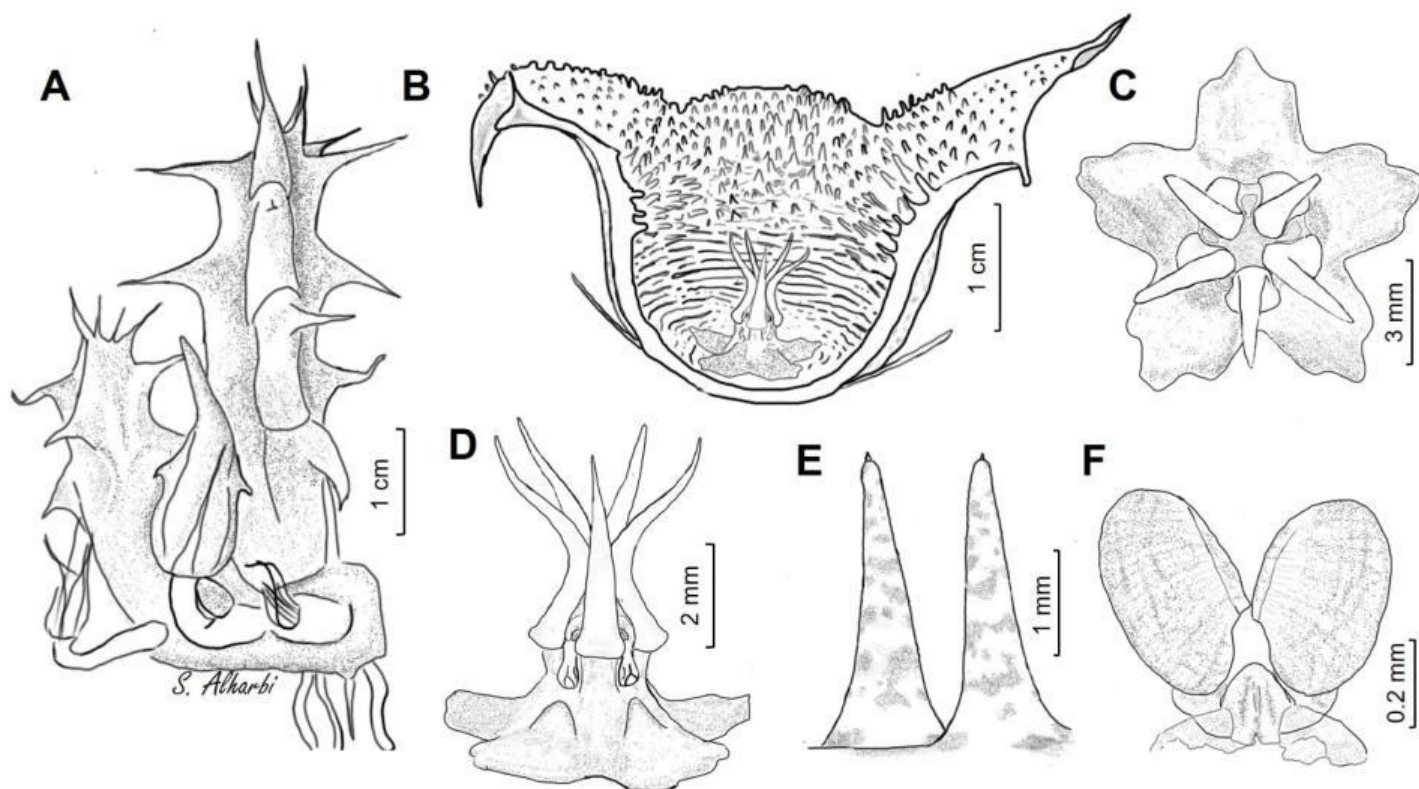


Figure 11. *Ceropegia lodarensis* var. *lodarensis* **A** stem **B** side view of dissected flower **C** face view of gynostegium **D** side view of gynostegium **E** papillae inside corolla in mouth of tube. **F** pollinarium. Drawn from (A) S.A. Alharbi S2B; (B, C, D, E, F) S.A. Alharbi S6B, Wadi Thee Gazal, Ash Shafa.

Ceropegia lodarensis* (Lavranos) Bruyns var. *foetida* (Plowes) S.A. Alharbi & R.N. Al-Qthanin, **comb. nov.*

Figs 12, 13; Map 5

≡ *Huernia foetida* Plowes, Asklepios 114: 9 (2012).

Type

SAUDI ARABIA- Jazan • I.S. Collenette 3743 (holotype: K! [fl in spirit: 38892.000]);
Jabal Fayfa, 100 km NE Jazan; 17°14.5296'N, 43°4.9368'E; alt. 1550 m.; 31 Jul, 1982.

Description

Stems up to 100 mm long; tubercles 7 mm long (including leaf-rudiment), 1.5 mm broad at base. Inflorescence bearing up to 4 flowers developing in gradual succession, flowers with very foetid odour; pedicel spreading and holding flower facing horizontally, tapering toward the point of flower attachment. Corolla 40 mm diam., campanulate; outside smooth, cream; inside cream with maroon dots changing to concentric short dashes in lower half of tube covered except in lower third of tube with compressed conical papillae densely crowded and reach maximum size around mouth of tube (up to 1 mm long and 0.5 mm broad at base). tube 11 mm long, 10 mm broad at mouth, pentagonal; lobes spreading, deltoid, attenuate with deep groove at tip, intermediate lobes 1 mm long. Outer corona lobes 8 mm diam. Five discrete rectangular lobes; inner lobes 3 mm long, 1 mm at base.

Distribution in Saudi Arabia

Rare, known so far from Jabal Fayfa, 100 km NE Jazan, SW the country.

General distribution

Probably endemic to SW Arabian Peninsula known so far from Saudi Arabia.

Habitat and ecology

Occur in granite outcrops at elevation of 1550 m.

Diagnosis

Clearly distinct by campanulate maroon doted corolla with very foetid odour.

Etymology

Foetida (Latin) smelly, for the strong, unpleasant smell of flowers.

Preliminary conservation status

Ceropegia lodarensis var. *foetida* is estimated to have an EOO of 80.173 km² (which would place the species in Critically Endangered CR) and AOO of 88 km² (which would

place it in EN). The size of its populations and current threats are not well-known, but populations in mountainous areas in Saudi Arabia are likely impacted by agriculture, overgrazing, development and tourism. Therefore, var. *foetida* should be considered Data Deficient (DD).



Map 5. Distribution of *Ceropogia lodarensis* var. *foetida*



Figure 12. *Ceropogia lodarensis* var. *foetida*, (*H. foetida*) Jabal Fayfa, **Type**. Reproduced from Plowes (2012).

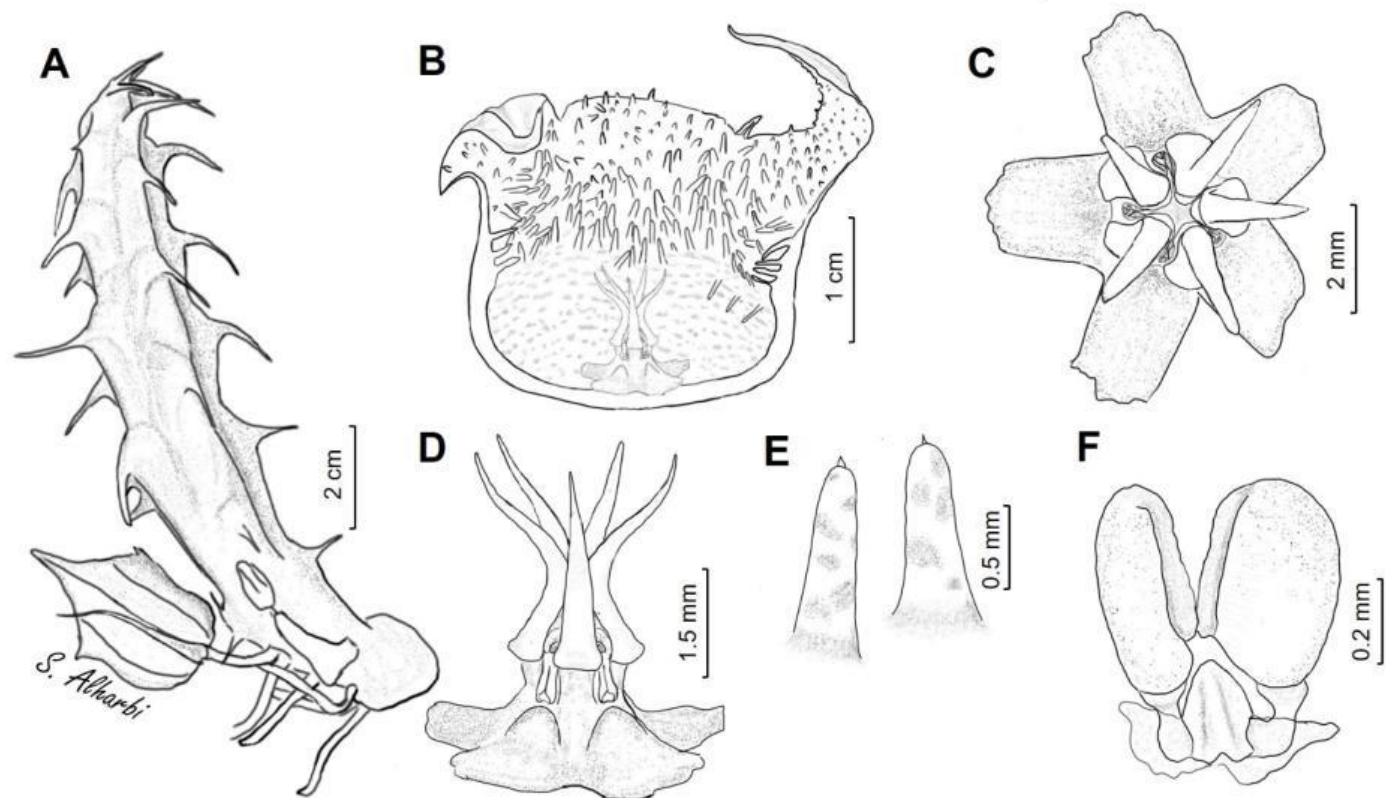


Figure 13. *Ceropegia lodarensis* var. *foetida* **A** stem **B** side view of dissected flower **C** face view of gynostegium **D** side view of gynostegium **E** papillae inside corolla in in mouth of tube. **F** pollinarium. Drawn from *Collenette* 3743, Jabal Fayfa.

Ceropegia lodarensis* (Lavranos) Bruyns var. *rubrosticta* (Plowes) S.A. Alharbi & R.N. Al-Qthanin, **comb. nov.*

Figs 14, 15; Map 6

≡ *Huernia rubrosticta* Plowes, *Asklepios* 114: 11 (2012).

Type

SAUDI ARABIA – Najran • I.S. Collenette 1482 (holotype: k! herb. material); Jabal Manfah, 24 km NE Najran; 17°36.9386'N, 44°12.3742'E; alt. 1700 m, 30 Apr, 1979.

Description

Stems 30-60 mm long, stout; tubercles 5.5-6 mm long (including leaf-rudiment), 2-3 mm broad at base. Inflorescence bearing 6 flowers developing in gradual succession from short peduncle, flowers with faint unpleasant smell; pedicel 11 mm long, 2 mm thick, ascending holding flower facing upwards, tapering sometimes towards the point of flower attachment; sepals 9.5 mm long, 2 mm broad at base, attenuate. Corolla 32 mm diam., campanulate; outside smooth, cream speckled with pale maroon spots on the upper half of corolla tube; inside cream with rounded maroon spots or dashes changing to concentric broken lines in lower half of tube; papillae up to 1.5 mm long and 0.75 mm broad at base; tube 10 mm long, 12 mm broad at mouth, pentagonal; lobes 8 mm long, 7.5 mm broad at base, spreading with recurved apex, deltoid, acute concave at tip, intermediate lobes 1.5 mm long. Outer corona lobes 5 mm diam. fused into disc or a slightly disc-like with short subquadrate crenate; inner lobes 3 mm long, 1 mm at base.

Distribution in Saudi Arabia

Rare, known only from Najran region, SW Saudi Arabia.

General distribution

Probably endemic to SW Arabian Peninsula known so far from Saudi Arabia

Habitat and ecology

Concentrated among rounded granite boulders at elevation of 1500-1700 m. above sea level. Flowering: March-April.

Diagnosis

The species is most similar to the Ethiopian endemic *Ceropegia boleana**, from which it can be discerned with flowers by the much campanulate corolla that are wider than the long, pentagonal tube, more conical papillae, and shorter inner corona (ca. 3 mm

compared to ca. 6 mm in *C. boleana*) and with plant habit and habitat that is erect to decumbent in granite rocks compared to *C. boleana* that is erect, pendulous or prostrate in basalt or sandstone.

It can be easily distinguished from other *C. Lodarensis* varieties proposed here with stout stems, flowers with more evenly rounded spots that are more red in colour, and with more slender papillae.

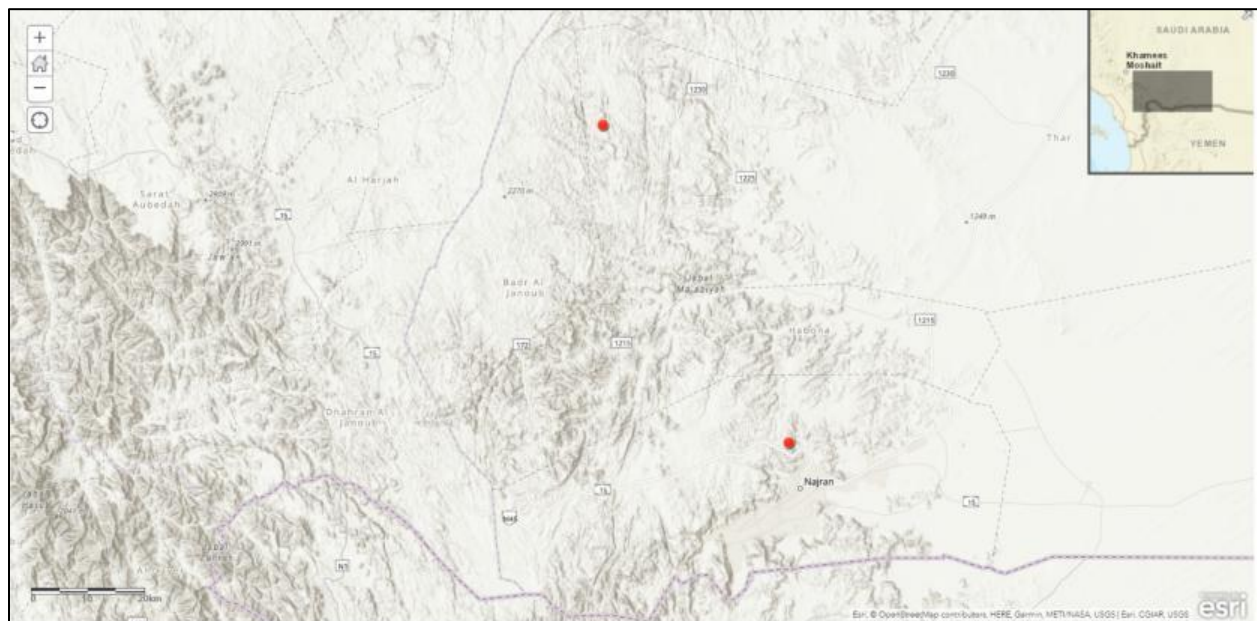
Ceropegia boleana* (M.G.Gilbert) S.A. Alharbi & R.N. Al-Qthanin **comb. nov.- *Huernia boleana* M.G.Gilbert, Cact. Succ. J. (Los Angeles) 47(1): 10 (1975).

Preliminary conservation status

Ceropegia lodarensis var. *rubrosticta* has an estimated EOO of 97.188 km² (which would place the species in CR) and AOO of 20 km² (which would place it in EN). The size of populations and current threats are little known. Therefore, *C. lodarensis* var. *rubrosticta* should be considered Data Deficient (DD).

Additional specimens examined

SAUDI ARABIA – Najran • I.S. Collenette 6059 (K [fl in spirit: 51184.000]); Al Jawshan, 70 km NW Najran; 18°8.4287'N, 43°51.2486'E; alt. 1520 m.; 07 Mar, 1987.



Map 6. Distribution of *Ceropegia lodarensis* var. *rubrosticta*

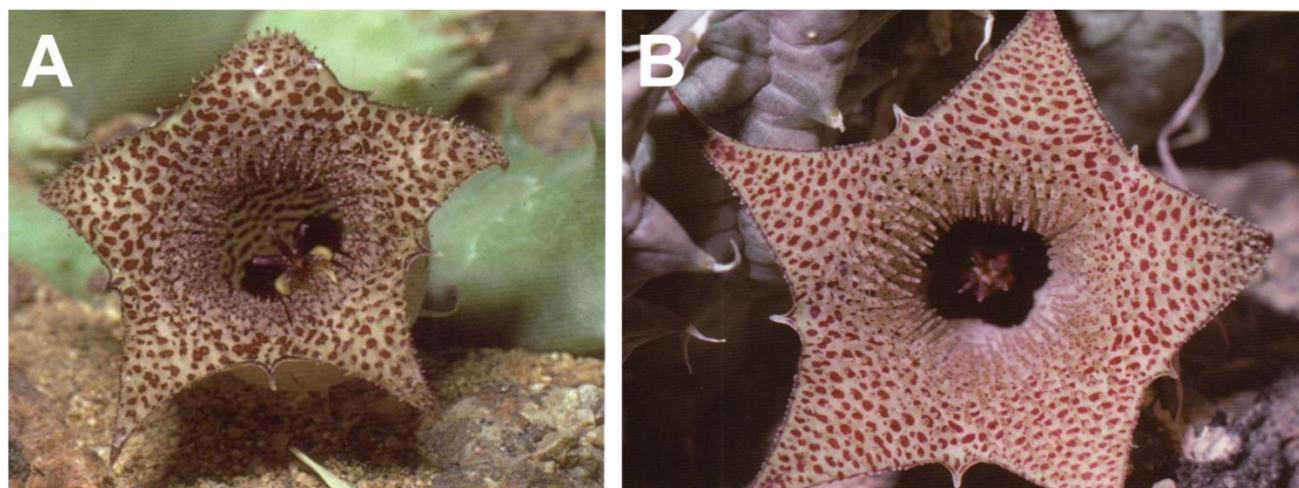


Figure 14. *Ceropogia lodarensis* var. *rubrosticta* (*H. rubrosticta*) **A** ex S Collenette s.n. sub DP7639, Al Jawshan, 70 km NW Najran (**Type**) **B** Collenette 1482, Jabal Manfah, 24 km NE Najran. Reproduced from Plowes (2012).

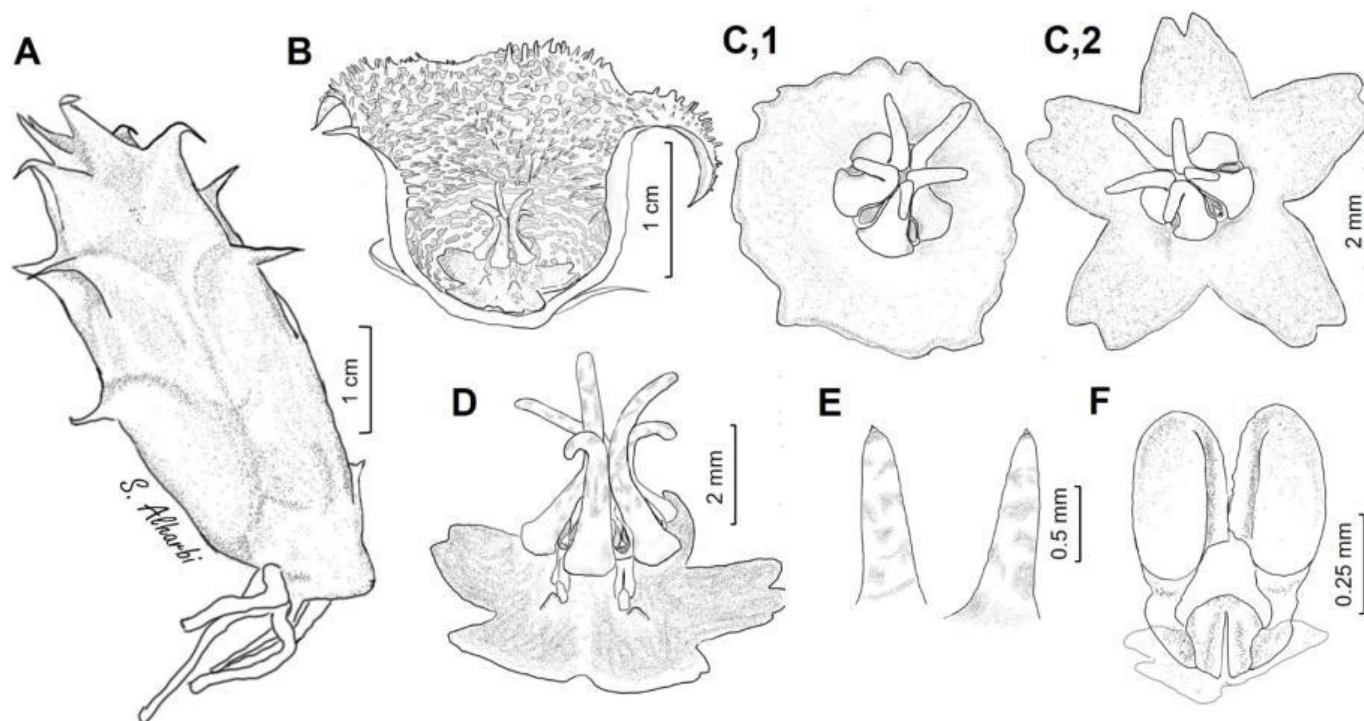


Figure 15. *Ceropogia lodarensis* var. *rubrosticta* **A** stem **B** side view of dissected flower **C** face view of gynostegium **D** side view of gynostegium **E** papillae inside corolla in mouth of tube. **F** pollinarium. Drawn from (**A**, **B2**, **C**) DP7639, Al Jawshan, 70 km NW Najran; (**B1**, **D**, **E**) Collenette 6059.

Funding

The authors have no funding to report.

Competing interests

The authors have declared that no competing interests exist.

Acknowledgements

We would like to thank the directors and members of staff of the Royal Botanic Gardens herbaria at Kew (K) and Edinburgh (E) for providing *Huernia* specimens available for this study and would like to express our gratitude to the International Asclepiad Society and the Cactus and Succulent Society of America for their kind permission to reproduce *Huernia* photographs from Asklepios 114 and Haseltonia 19, respectively.

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